Macquarie Island World Heritage Area Geoconservation Strategy

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Contents

1.0 Executive summary 3
2.0 Acknowledgments 4
3.0 List of acronyms and glossary 5
3.1 List of acronyms 5
3.2 Glossary 6
4.0 Introduction 7
5.0 Geodiversity of Macquarie Island 12
5.1 Introduction 12
5.2 Geological evolution 13
5.3 Rock associations, landforms and soils 13
6.0 Geoconservation 21
7.0 Management issues 22
7.1 Protection of WHA geoconservation values and geodiversity 22
7.2 Geo-interpretation 22
7.3 PWS geodiversity work 24
7.4 Landslip database 25
7.5 Climate change impacts 26
7.6 Illegal souvenir collecting of earth materials 27
7.7 Use of natural materials for building or track works 27
7.8 Coastal engineering works 28
7.9 Walking tracks 29
7.10 Restricted access areas 29
7.11 *Azorella* dieback 32
7.12 Biosecurity 33
7.13 Management of contaminated sites 34
7.14 Scientific sampling 34
7.15 Knowledge gaps 35
7.16 Environmental assessment 36
7.17 Removal of redundant scientific monitoring infrastructure 37
7.18 Rehabilitation 37
7.19 MIRAG 38
8.0 Recommendations 40
9.0 References 44
Appendix 1 Geoconservation extract from the Management Plan 47

List of maps

Map 1 Location of Macquarie Island 7
Map 2 Topography and general features of Macquarie Island – northern sheet 8
Map 3 Topography and general features of Macquarie Island – southern sheet 9
Map 4 Geological sketch map of Macquarie Island by Blake 12
Map 5 Simplified geology of Macquarie Island (north) 19
Map 6 Simplified geology of Macquarie Island (south) 20

List of figures

Figure 1 Idealised reconstruction of Macquarie Island oceanic crust 15

List of tables

Table 1	Rock associations of Macquarie Island	14
Table 2	Potential fields for proposed Landslip Database	25
Table 3	List of recommendations	41

List of photos

Photo 1	Pillow basalt south of Pyramid Peak	16
Photo 2	Layered troctolite at Elizabeth and Mary Point	16
Photo 3	Fault controlled lake. Unnamed lake south of Mt Blake	17
Photo 4	Raised coastal terrace on the west coast north of Bauer Bay (the Featherbed)	17
Photo 5	Wind eroded linear grooves on rock on escarpment edge above Bauer Bay	17
Photo 6	Patterned ground from freeze thaw cycles, plateau near North Mountain	17
Photo 7	Geology display board displayed in the stations mess during tourist visits	23
Photo 8	Cultural heritage interpretation panel at the historic digesters at the Isthmus	23
Photo 9	Rock collection on window sill of Green Gorge Hut	27
Photo 10	Start of the tourist boardwalk at Sandy Bay, on the banks of Finch Creek	29
Photo 11	Coastal “armouring” at the Isthmus in front of the BOM buildings	29
Photo 12	Section of Overland Track near Mt Jeffreys surfaced with locally quarried gravels	30
Photo 13	Rocks placed as water bars on Link Track	30
Photo 14	Boulders that are part of a significant raised beach geoconservation site adjacent to the Island Lake Track	31
Photo 15	Reroute around a slump on Overland Track near Sawyer Valley	31
Photo 16	Terraces eastern slopes of Mt Blake	33
Photo 17	*Azorella* dieback on terracing on the north east slopes of Mt Eitel	33
Photo 18	Drill hole with large eye bolt supporting a steel ladder in Gadget Gully	37
Photo 19	Erosion study site with redundant markers and erosion monitoring pins	37
Photo 20	Stored material on partly rehabilitated old helipads on the Isthmus	38

1.0 Executive summary

Macquarie Island is a small subantarctic island approximately 1500 kilometres south east of Hobart. It is a World Heritage Area property listed primarily for its unique geodiversity values, being the only island in the world composed entirely of oceanic crust and rocks from the mantle - deep below the earth's surface. It is part of the State of Tasmania and managed by the Tasmania Parks and Wildlife Service (PWS).

The *Macquarie Island Nature Reserve and World Heritage Area Management Plan 2006* fully acknowledges the island's geoconservation significance. It lists a number of objectives, policies and actions that relate directly to conserving and protecting geoconservation values. One of the actions is to prepare a geoconservation management strategy for the island and produce an inventory of significant geoconservation sites. This document addresses that action.

The aim of the Macquarie Island Geoconservation Strategy is to conserve the World Heritage geoconservation values for which the area was listed and to guide management and research activities on the island.

The strategy provides details of the island's unique geodiversity and geoconservation values; discusses management issues that relate to the island's geodiversity; and provides recommendations for conserving the significant geoconservation values.

In summary, the main recommendations are that:

- The protection of the Macquarie Island World Heritage geoconservation values remain a primary objective of the management of the island.
- PWS endorse this strategy in managing the geodiversity values of Macquarie Island.
- The strategy is used to inform the review of the Macquarie Island Management Plan 2006.
- Geodiversity values are fully considered as part of any management, operational or research actions undertaken or in the development of any polices that cover the island.
- Relevant earth science research on the island is facilitated.
- The interpretation of geodiversity values is given greater prominence in interpreting the natural values of the island.
- *A MIRAG working sub group is established to provide structured input into management planning and activities undertaken on the island.*
- Sites listed in the inventory of significant geoconservation sites on Macquarie Island are considered for listing on the Tasmanian Geoconservation Database.

2.0 Acknowledgments

Peter Voller and Alistair Scott from DPIPWE, SLB Branch Manager and RMC General Manager respectively, are acknowledged for appreciating the importance of Macquarie Island's geodiversity and approving my extended trip to the island to amongst other tasks undertake field work as part of the preparation of the strategy. Thanks also to Geoconservation Section staff members; Jason Bradbury, Kath Storey, Rolan Eberhard and Kathy Noble who during my absence took on additional tasks to maintain the section's functionality.

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DPIPWE staff that provided useful information to me prior to my visit to the island included, Mike Pemberton, Grant Dixon, Noel Carmichael, Jennie Whinam and Micah Visoiu. John Everard from Mineral Resources Tasmania and Patricia Selkirk from Macquarie University both provided very useful information and comments on a preliminary inventory of geoconservation sites.

The AAD provided logistical support for the trip to the island and whilst on the island.

The 2013/14 ANARE expeditioners, including members of the MIPEP team are all thanked for making my stay on the island so memorable. In particular the two PWS Rangers on the island, Chris Howard and Kris Carlyon and the MIPEP manager Keith Springer are thanked for the many useful discussions on the island's conservation.

Finally Peter Voller, Mike Pemberton, Jenny Scott, Chris Howard, Kris Carlyon and Keith Springer are also thanked for providing useful comments on earlier drafts of this document.

3.0 List of acronyms and glossary

3.1 List of acronyms

AAD	Australian Antarctic Division
ANARE	Australian National Antarctic Research Expedition
ANARE expeditioner	Person working on the island, including those from outside the AAD e.g. PWS or research institution personnel
BCB	Biodiversity Conservation Branch (a branch within RMC)
BOM	Bureau of Metrology
DPIPWE	Department of Primary Industries Parks Water and Environment
LARC	Light amphibious resupply craft
MIPEP	Macquarie Island Pest Eradication Program
MIRAG	Macquarie Island Research Advisory Group
PWS	Parks and Wildlife Service
RMC	Resource Management Conservation Division (a division of DPIPWE)
RAA	Reserve Activity Assessment
Ramsar	City in Iran where the convention on wetlands was signed in 1971, thus the conventions short title “Ramsar convention on wetlands”
RIC	Ranger in Charge
RTA	Return to Australia
SLB	Sustainable Landscapes Branch (a branch within RMC)
SMA	Special Management Area
TASMARC	Tasmanian Shoreline Monitoring and Archiving project
TGD	Tasmanian Geoconservation Database
TGDRG	Tasmanian Geoconservation Database Reference Group
UTas	University of Tasmania
WHA	World Heritage Area
WHS	Work Health and Safety

3.1 Glossary

The following definitions are from the Dictionary of Earth Sciences (Allaby 2008).

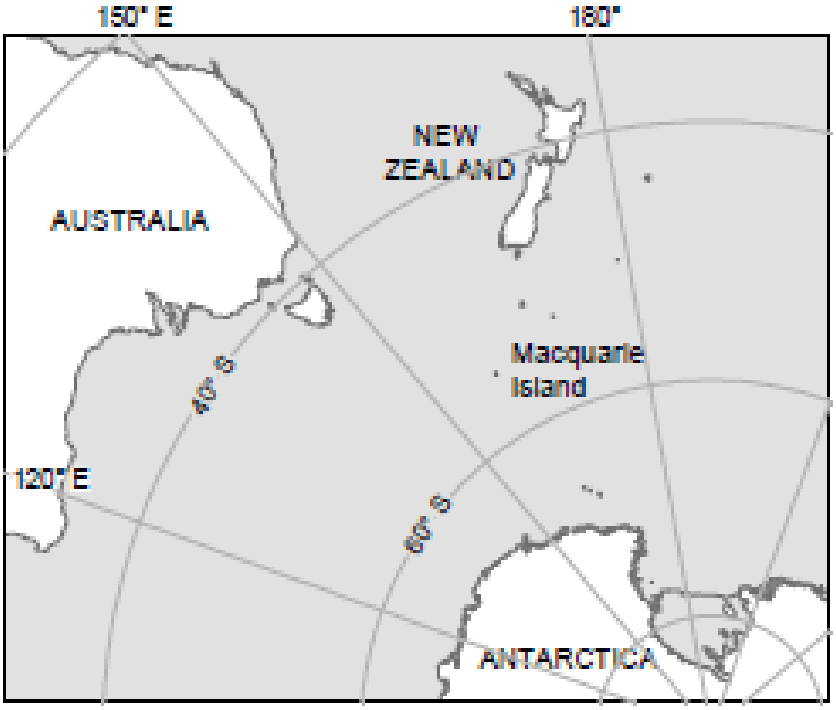
dyke	Discordant, or cross cutting, tabular intrusion.
lithosphere	The upper (oceanic and continental) layer of the solid Earth, comprising all crustal rocks and the brittle part of the uppermost mantle.
mantle	Zone lying between the earth's crust and core, approximately 2300 km thick.
mid-ocean ridge	A long, linear, elevated volcanic structure often lying along the middle of the ocean floor.
obduction	The lateral, subhorizontal displacement of a lithospheric plate on to a continental margin at a destructive plate boundary. It is the opposite of subduction.
oceanic crust	The oceanic rocks which form 65% of the Earth's surface, and are the upper part of the oceanic lithosphere, overlying the Mohorovčić seismic discontinuity.
ophiolite	Sequence of rocks, consisting of deep sea sediments lying above basaltic pillow lavas, dykes, gabbro and ultramafic peridotite.
periglacial	Any environment where the action of freezing and thawing is currently, or was during the Pleistocene, the dominant surface process.
solifluction	Dowhill movement of regolith that has been saturated with water.
strike-slip plate boundary	A fault in which the major displacement is horizontal and parallel to the strike of a vertical or subvertical fault plane**.**
transpression	A tectonic regime which combines both transcurrent strike-slip movement with oblique compression.
ventifacts	A pebble that has been faceted by the abrasive action of wind-blown sand and dust.

4.0 Introduction

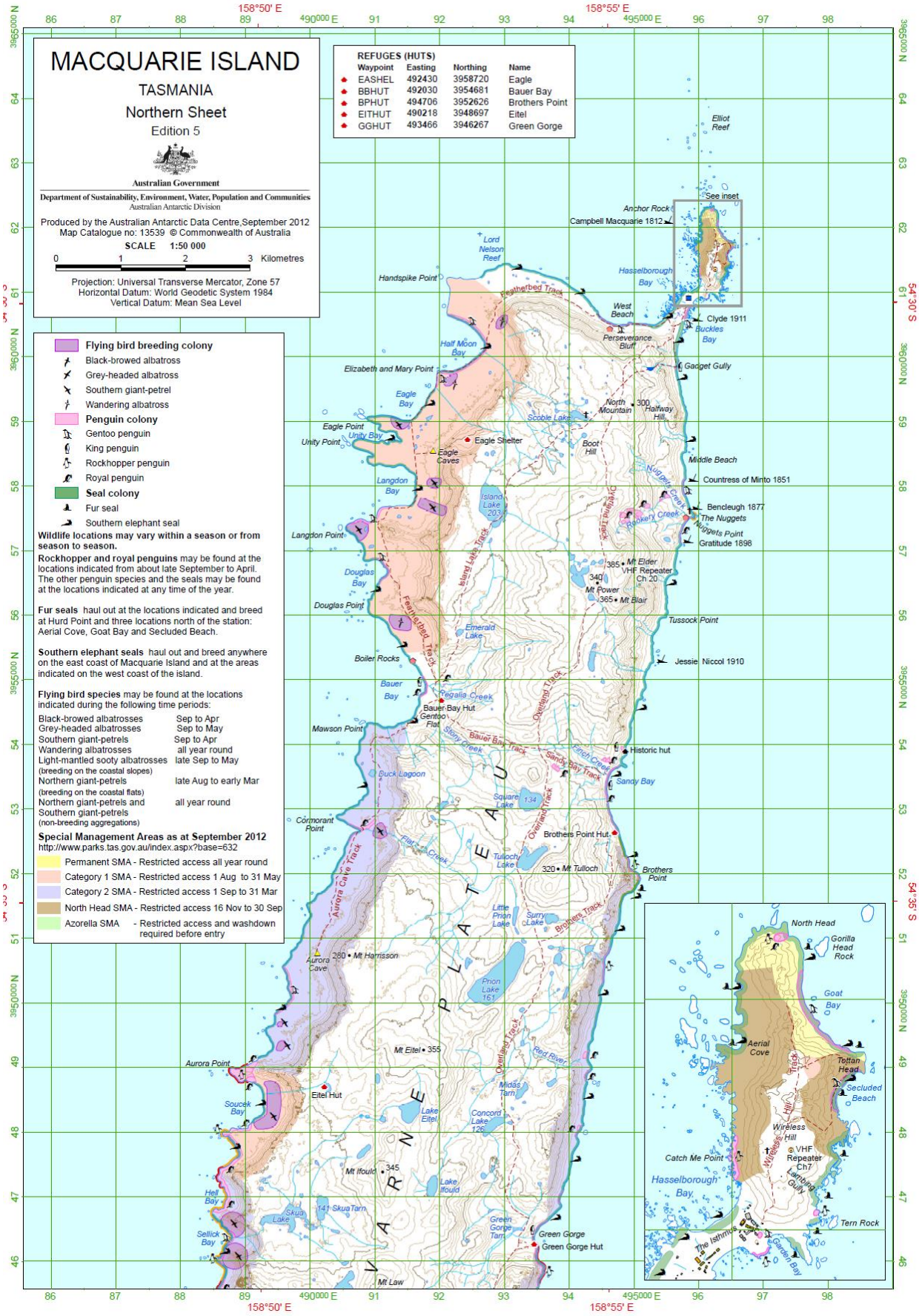
Macquarie Island is a small subantarctic island approximately half way between Australia and Antarctica. It is part of the State of Tasmania and managed by the Tasmania Parks and Wildlife Service (PWS). It is a World Heritage Area (WHA) property listed primarily for its unique geodiversity values, being the only sub-aerial exposure of oceanic crust on Earth that is still within an ocean basin and unaffected by obduction. Due to faulting, all levels of oceanic crust from surface to mantle lithosphere inclusive are well exposed. It lies on Macquarie Ridge, which is a uniquely transpressional oceanic plate boundary. Huge numbers of wildlife, in particular seals, penguins and seabirds, either live on the island or visit the island seasonally to breed and moult.

Details of the location, history, climate, oceanography, geodiversity, limnology, vegetation and fauna can be found in the *Macquarie Island Nature Reserve and World Heritage Area Management Plan 2006* (PWS 2006).

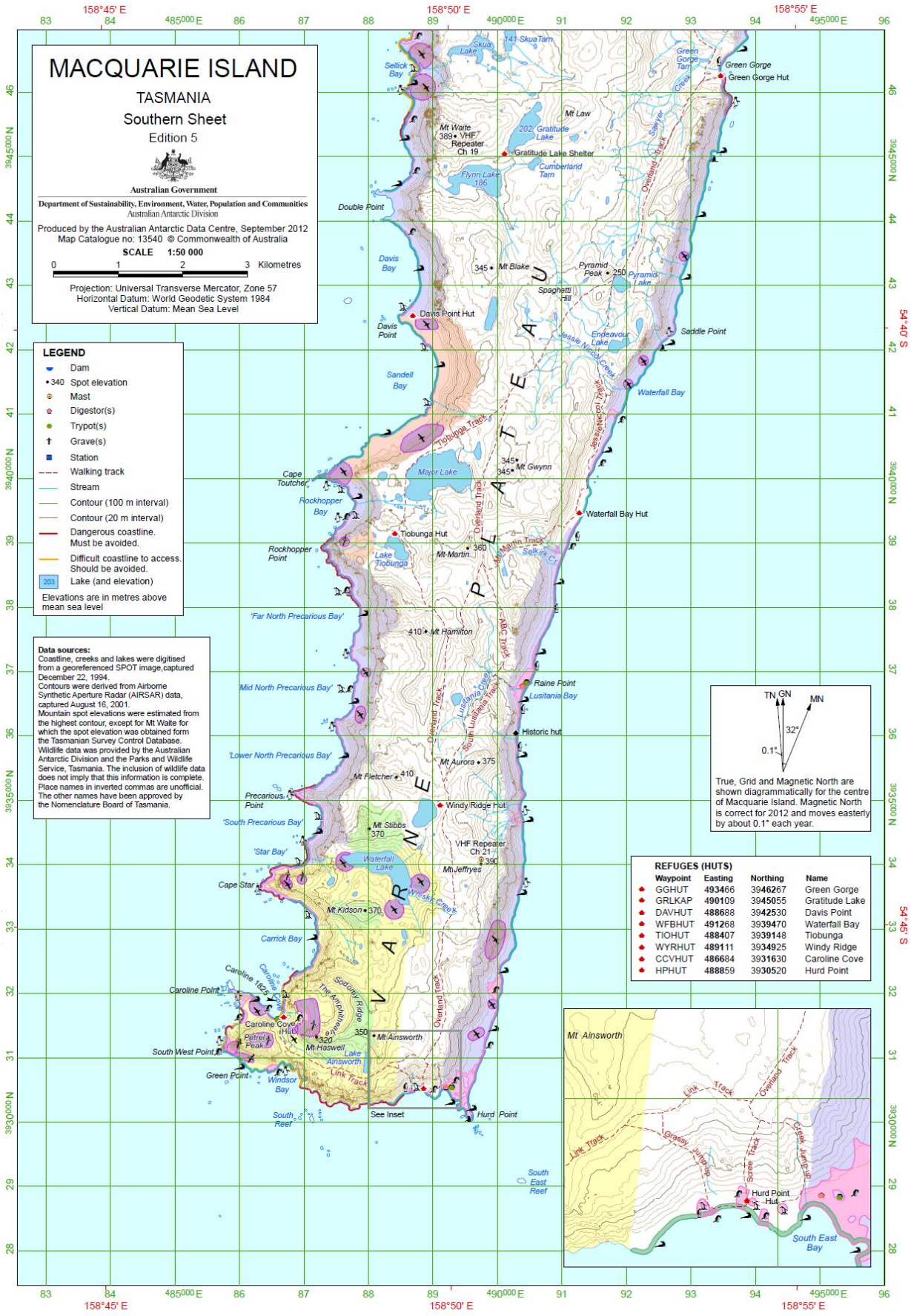
Macquarie Island is located some 1500 kilometres to the south east of Tasmania in the Southern Ocean at a longitude of approximately 158°55' east and latitude of 54°30' south (Map 1). The main island is approximately 34 kilometres long and 5.5 kilometres wide at its broadest point. Two small groups of islands, Judge and Clerk Islets and Bishop and Clerk Islets lie approximately 11 kilometres to the north and 37 kilometres to the south respectively. The main island has steep coastal slopes rising to an undulating plateau between 200 and 300 metres above sea level and containing a number of lakes. The highest peaks are over 400 metres. The island's topography is shown in Maps 2 and 3. The island lies in the path of strong westerlies and the influence of the Antarctic circumpolar current. It experiences a cool, wet and windy climate.



Map 1. Location of Macquarie Island (map courtesy AAD data centre).



Map 2. Topography and general features of Macquarie Island – northern sheet. Map courtesy AAD Data Centre.



Map 3. Topography and general features of Macquarie Island – southern sheet. Map courtesy AAD Data Centre.

After its discovery in 1810 by sealers, the island's abundant wildlife was exploited for commercial gain, initially heavily, then intermittently until 1919 (Cumpston 1968). The island was proclaimed a wildlife sanctuary in 1933, re-proclaimed the Macquarie Island Wildlife Reserve in 1972 and in 1977 was declared a Biosphere Reserve (PWS 2006). In 1997 the island was listed on the World Heritage Area list and it was only then that the island's unique geodiversity was formally recognised.

The nomination for World Heritage listing focused on the island's geology and particularly on the sequences from the oceanic lithosphere including the oceanic crust and upper mantle. These elements of the island's geoconservation significance are summarised below (Department of the Environment, Sport and Territories 1996):

- It is the only known locality in the world where oceanic lithosphere formed at a normal mid-ocean spreading ridge environment is being exposed above sea-level within a major ocean basin.
- It provides a unique example of ocean crust uplifted as a result of transpression at a strike-slip plate boundary in an oceanic setting.
- The exposed rock sequence provides a uniquely complete section through the Earth's oceanic crust to upper mantle rocks.
- The geological evolution of Macquarie Island began 10 million years ago and continues today with the island experiencing earthquakes and a rapid rate of uplift, all of which are related to active geological processes along the boundary between two plates.
- The island is unique in that its present geomorphology shows features of the marine erosion (raised beaches and benches) that have progressively affected its whole surface during uplift. This unique feature complements, and is a consequence of, its unique geological attribute of being uplifted sea-floor.
- It, therefore, has outstanding universal value in that it provides a unique opportunity to study, in detail, geological features and processes of oceanic crust formation and plate boundary dynamics above sea-level.

Chapter 5 of this strategy provides more details on the island's geodiversity. The Management Plan for the island (PWS 2006) fully acknowledges the island's geoconservation significance. It lists a number of objectives, policies and actions that relate directly to conserving and protecting geoconservation values. These are reproduced in Appendix 1. One of the listed actions in the plan is to prepare a geoconservation management strategy for the island and produce an inventory of significant geoconservation sites. This document addresses that action.

The aim of the Macquarie Island Geoconservation Strategy is to conserve the World Heritage geoconservation values for which the area was listed and to guide management and research activities on the island. The strategy's aim is in line with the Tasmanian Governments Natural Heritage Strategy (DPIPWE 2013) that provides a long term plan for conserving Tasmania's rich and diverse natural heritage.

A substantial amount of geoscientific work has been conducted on the island over many decades. However, most earth scientists that have visited the island do so to look at specific aspects of the island's geodiversity undertaking targeted research and not to address geoconservation issues explicitly. Exceptions to this have included Michael Pemberton who provided substantial input into both the WHA nomination and the Management Plan and two general publications on Macquarie Island (Pemberton *et al.* 1999 and DPIWE 2001). Michael Comfort and Paul Donaldson (Comfort and Donaldson 2011) and Ian Houshold (Houshold and Dyring 2007) also undertook preliminary geoconservation work on the island. All of these researchers were members of the DPIPWE's Geoconservation Section (or equivalents under previous Departmental structures) and were restricted to short visits (less than a week) to the island during resupply voyages. In 2013 an opportunity arose for a Geoconservation Section staff member to spend some three and a half months on the island over the 2013/14 summer to undertake a number of management related tasks on the island including conducting field work for the compilation of this strategy.

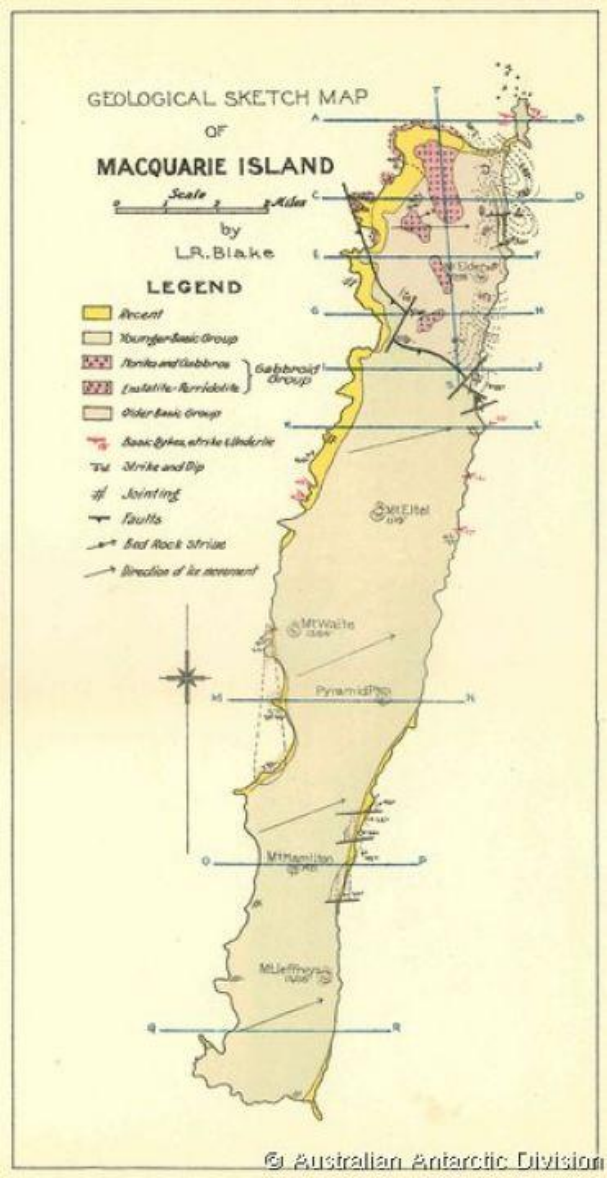
The strategy has been developed by reference to the substantial volume of published earth science literature that exists for the island, discussions with earth scientists who have worked on the island and finally by field work documenting a number of the significant geoconservation sites. Discussions with PWS and other DPIPWE staff on the island's management were undertaken. The author also discussed geo-interpretation and geo knowledge with fellow ANARE expeditioners and groups of tourists visiting the island as part of commercial subantarctic cruises.

The following chapters outline: a general description of the island's geodiversity (Chapter 5); a discussion on geoconservation relating to the island (Chapter 6); management issues (Chapter 7) and strategy recommendations (Chapter 8). Future earth science work on the island will shed new light on our understanding of the island's geodiversity. Information from such studies needs to be incorporated into updates of the strategy and in particular the inventory of significant sites must be seen as a living document incorporating new findings. The Management Plan for the island is due for review and the contents of this strategy should be considered in undertaking the Management Plan review.

5.0 Geodiversity of Macquarie Island

5.1 Introduction

Although Macquarie Island was first discovered in 1810, it was not till a century later that the first geologist undertook the initial systematic geological studies on the island. Blake, a geologist with the Australasian Antarctic Expedition, spent more than two years on the island from 1911 to 1914 and he produced the first geological map (Mawson 1943) (Map 4).



Map 4. Geological sketch map of Macquarie Island by Blake (Mawson 1943). Map courtesy AAD Data Centre.

Since Blake's visit, and from the time ANARE established a permanent station on Macquarie Island in 1948, there has been a considerable number of geological and geomorphological and some soil studies conducted on the island with a substantial volume of scientific literature produced on the island's geodiversity. Through this body of research, it became evident that the island's geodiversity was unique and it was listed as a World Heritage Area in 1997 principally for its geology and geomorphology. Unlike other subantarctic islands, Macquarie Island is entirely oceanic in origin. It is the only known locality in the world where oceanic lithosphere formed at a mid-ocean spreading ridge environment is exposed above sea-level within a major ocean basin.

The island's geodiversity has been summarised in a number of publications including Selkirk *et al.* (1990), Department of Environment, Sport and Territories (1996), Pemberton *et al*. (1999), PWS (2006), Goscombe and Everard (in prep).

Goscombe and Everard undertook a detailed geological survey of Macquarie Island for Mineral Resources of Tasmania (MRT) from 1994-96 producing a series of 1:10000 geological maps (Goscombe and Everard 1998). Simplified versions of these are reproduced here as Maps 5 and 6. This was the first detailed systematic mapping of the island. Previous workers (Varne *et al.* 1969, Griffin and Varne 1980, Griffin 1982, Christodoulou *et al.* 1984 and Blake in Mawson 1943) had established the broad distribution of rock types by reconnaissance mapping. An accompanying Geological Survey of Tasmania Report was drafted (Goscombe and Everard in prep.) and much of the description of the island's geology presented below comes from this.

5.2 Geological evolution

Macquarie Island is totally oceanic in origin, all rock units having formed on or beneath the ocean floor. It is estimated that between 30 million and 11 million years ago Macquarie Island first evolved in the Southern Ocean as a spreading ridge. These can run for thousands of kilometres along the bottom of the large ocean basins and in these locations basalt magma from deep within the earth flows up to the ocean floor and out through long fissures or volcanic vents forming new oceanic crust.

The southern parts of Macquarie Island are dominated by basalt which cooled below two and a half kilometres of water, producing spectacular features such as pillow lavas (Photo 1). Their skins cool very rapidly on coming into contact with sea water, imploding to form round to oval shaped pillows. Evidence for this includes a glassy external margin on the pillows which indicate rapid cooling and very little time for any crystal development.

About 10 million years ago the spreading stopped. Instead of moving apart, areas on either side started to squeeze together forcing the oceanic crust and parts of the upper mantle, upwards. There was a major reversal in geological processes and Macquarie Island started its two and a half kilometre journey to emerge above the sea surface about 600 to 700 thousand years ago.

5.3 Rock associations, landforms and soils

The detailed geological mapping of Macquarie Island (Goscombe and Everard 2001) identified eight rock associations and has enabled reconstruction of the oceanic crust at the time of formation. Table 1 lists the eight rock associations, and Figure 1 shows an idealised schematic section of Macquarie Island oceanic crust (Goscombe and Everard 1999).

Various types of basalt dominate the upper parts (500-1200 metres) of the stratigraphy of Macquarie Island. These were extruded onto the ocean floor and solidified at depths of around two and a half kilometres over a period of about 20 million years. Basalt is the most common rock type found on ocean floors where it accumulates with very fine sediment (or oozes) which have settled out of the water column. Examples of basaltic rocks dominate the central and southern portions of the island.

These extrusive rocks are juxtaposed through tectonic activity (faulting) with intrusive rocks from deeper in the lithosphere such as dolerite, gabbro, troctolite (Photo 2) and dunite with the lowest intrusives being the upper mantle harzburgite association which together represent a depth of about 2500 metres into the oceanic crust.

Table 1. Rock associations on Macquarie Island listed in descending order to deeper crustal levels adapted from (Goscombe and Everard in prep.).

Extrusive basalts and sediment association
Pillow basalts
Massive tabular basalt flows
Hornblende-phyric basalt
Picrite bodies
Hyaloclastite
Volcanoclastic breccias
Block breccias with sediment matrix
Sedimentary rocks
Sheeted dolerite dyke association
Mid crustal sheeted dolerite dykes proper
Lateral transition between gabbro and sheeted dyke associations
Microgabbro transition
Massive coarse gabbro association
Gabbro
Layered gabbro
Microgabbro dykes
Ultra mafic screens
Xenoliths
Troctolite association
Troctolite
Gabbro units
Plagioclase-wehrlite units
Mixed plagioclase-wherlite/dunite association
Plagioclase-wehrlite
Dunite and plagioclase-dunite
Troctolite and gabbro screens
Igneous veins
Mixed dunite/harzburgite association
Dunite and plagioclase-dunite
Plagioclase-wehrlite
Igneous veins
Harzburgite association
Harzburgite
Dunite units
Other ultra-mafic units
Gabbro dykes, pegmatites and veins
Troctolite vein
Plagioclasse-wehrlite veins
Phlogopite-felsdpar pegmatite veins
Hornblende-feldspar veins

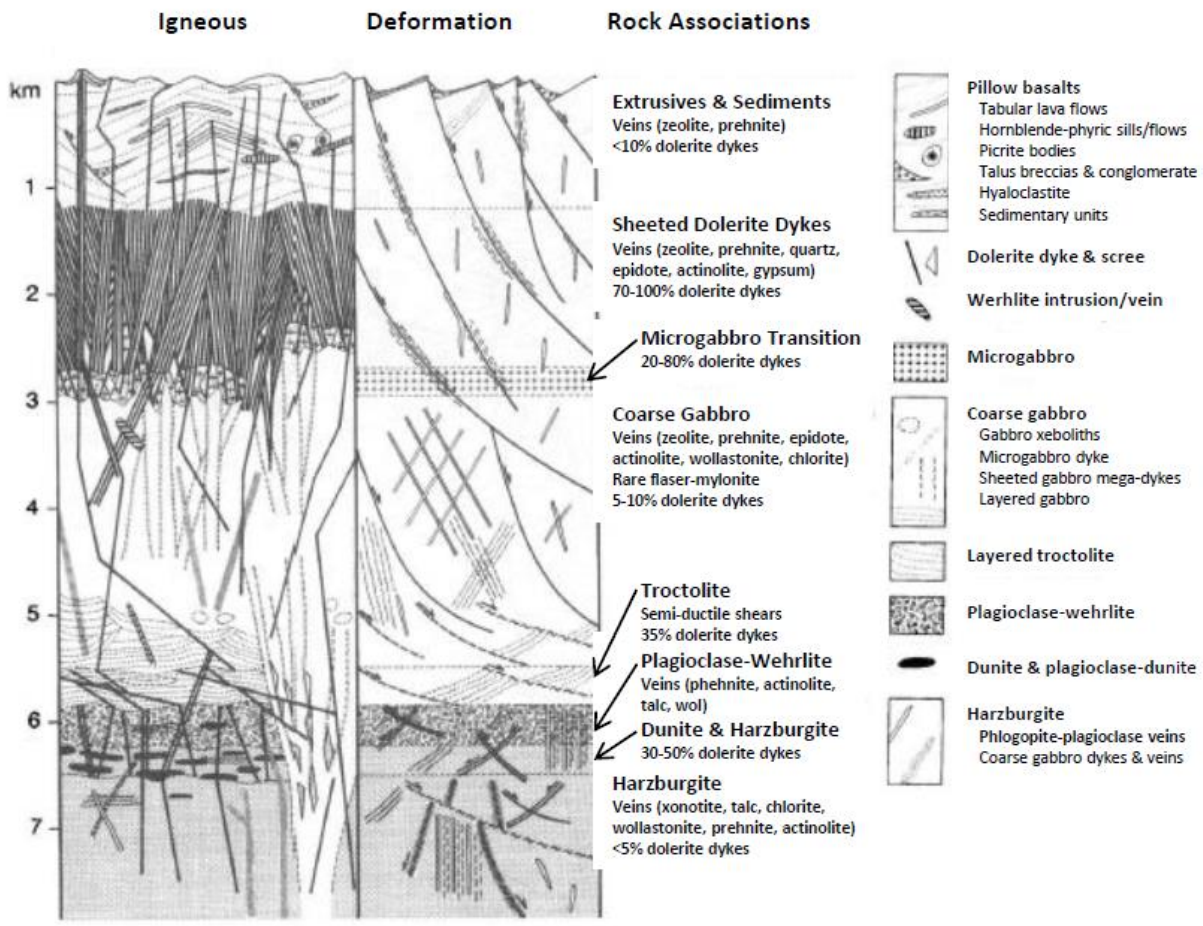


Figure 1. Idealised reconstruction of Macquarie Island oceanic crust in a hypothetical state, with all extensional deformation such as growth faults and differential block uplift removed. Deformational features associated with the spreading axis environment are represented on the right. Thickness of rock associations are based on maximum exposed thicknesses preserved on Macquarie Island, except for coarse gabbro and extrusives that are based on average known thicknesses in oceanic crust and ophiolites. Goscombe and Everard (1999).

The current landscape of Macquarie Island has resulted from the interplay of faulting, uplift, sea-level changes, erosion and periglacial processes (Selkirk *et al*. 1990). All of those processes remain active on the island today.

Tectonic activity associated with the uplift of Macquarie Island has been fundamental in creating lake basins, channeling streams and producing numerous fault scarps (Selkirk-Bell 2000). Essentially all lakes on the plateau are either influenced in shape by faults (Photo 3) or they exist because drainage has been blocked by neo-tectonic (recent) fault activity (Goscombe and Everard in prep.). The region remains seismically active (Jones and McCue 1988).

There are numerous palaeo-beach deposits and palaeo-beach terraces (Photo 4) at altitudes from 6 to 270 metres above sea level (Adamson *et al*. 1996, Ledingham and Peterson 1984). Work on these features helped in formulating the theory of island uplift and helped show that the island had not been glaciated. The prominent palaeo-beach terrace, up to 700 metres wide, that occurs on the west coast as far south as Sellick Bay and less prominent on parts of the east coast has been dated at 6000 to 8000 years old (Selkirk *et al*. 1990).

Photo 1. An example of pillow basalt south of Pyramid Peak. This is the dominant rock type on the island. (pillows approximately one metre in diameter).

Photo 2. Layered troctolite at Elizabeth and Mary Point (note GPS for scale).

This terrace formed when uplift of the island was at approximately the same rate as sea level rise, leading to a protracted period of sea erosion at the same structural level. It shows that differential uplift of different blocks occurred on the island with no such terrace south of the major Sellick Bay Fault from Sellick Bay to Lusitania Bay (Goscombe and Everard in prep.). The topography south of this fault also appears more recent and rugged and less rounded by erosion compared to the northern parts of the island, suggesting it was exposed above sea level more recently in comparison to the rest of the island. Uplift rates for the island have been estimated based on the raised beach features and range from 0.8 to 6 mm per year (Adamson *et al*. 1996). The latest average rate of 0.8 mm per year is considered the most reliable and gives an estimate for the emergence of the top of the island from the ocean at 600000 to 700000 years ago, making it geologically a young island.

Since its emergence above sea level, Macquarie Island has been subject to wind, water and marine erosion processes that still operte today on this tiny projection into the Southern Ocean. The more scalloped western coastline of the island reflects the differential erosional energy between the two coasts that is also reflected in the difference in width of the coastal terrace on the west (400 - 700 metres) and east coast (0 – 100 metres).

Wind polished rocks and ventifacts (Photo 5) are found on the west coast and western edge of the escarpment demonstrating the erosive force of the winds that have impacted Macquarie Island (Adamson *et al*. 1988). Most west coast beaches except Bauer Bay are devoid of sand, it having been blown up onto the escarpment and deposited as aeolian deposits (Goscombe and Everard in prep.). There are a number of sandy beaches on the east coast including the Isthmus, Sandy Bay, north and south of Nuggets Point and Green Gorge. Many bays on the west coast are filled with mega-boulders up to 2 – 20 metres across. These deposits are escarpment talus that has been moved into close packing arrangements by extremely high energy seas.

Photo 3. Fault controlled lake with the fault defining right hand margin of lake. Unnamed lake south of Mt Blake.

Photo 4. Raised coastal terrace on the west coast north of Bauer Bay (the Featherbed).

Photo 5. Wind eroded linear grooves on rock on escarpment edge above Bauer Bay (lichen suggests these are now inactive).

Photo 6. Patterned ground from freeze thaw cycles, plateau near North Mountain. (Note GPS for scale).

Twelve palaeo-lake deposits of laminated silt and thin layers of fibrous organic material have been located on Macquarie Island (Goscombe and Everard in prep.). These deposits formed in lakes on the plateau that were subsequently drained as a result of escarpment retreat and erosion back to the lake margin. Most lakes were drained between 6000 and 16000 years ago, at a time when sea level was rising faster than the uplift of the island. This sea erosion and escarpment retreat was substantial, leading to drainage of many palaeo-lakes (Selkirk *et al*. 1988).

Goscombe and Everard (in prep) identified two broad types of mass wasting slope deposits; scree slopes and alluvial fans. Scree slopes occur on the escarpment face around the entire island at the base of cliffs and gullies. Scree slopes are of 34-40° in contrast to alluvial fans with slopes of 7-30°. Alluvial fans often grade into scree inland against the escarpment. Both deposits are formed by rapid erosion and retreat of the escarpment face. This erosion is significant in many parts of the east coast because of recent undercutting by wave action and on the west coast because many slopes are steep due to earlier wave action and bare due to the steep slopes.

Periglacial features on the island are prevalent on the plateau with widespread terraces and patterned ground. On bare ground stone sorting resulting from frost action is common (Selkirk *et al.* 1990). Stone

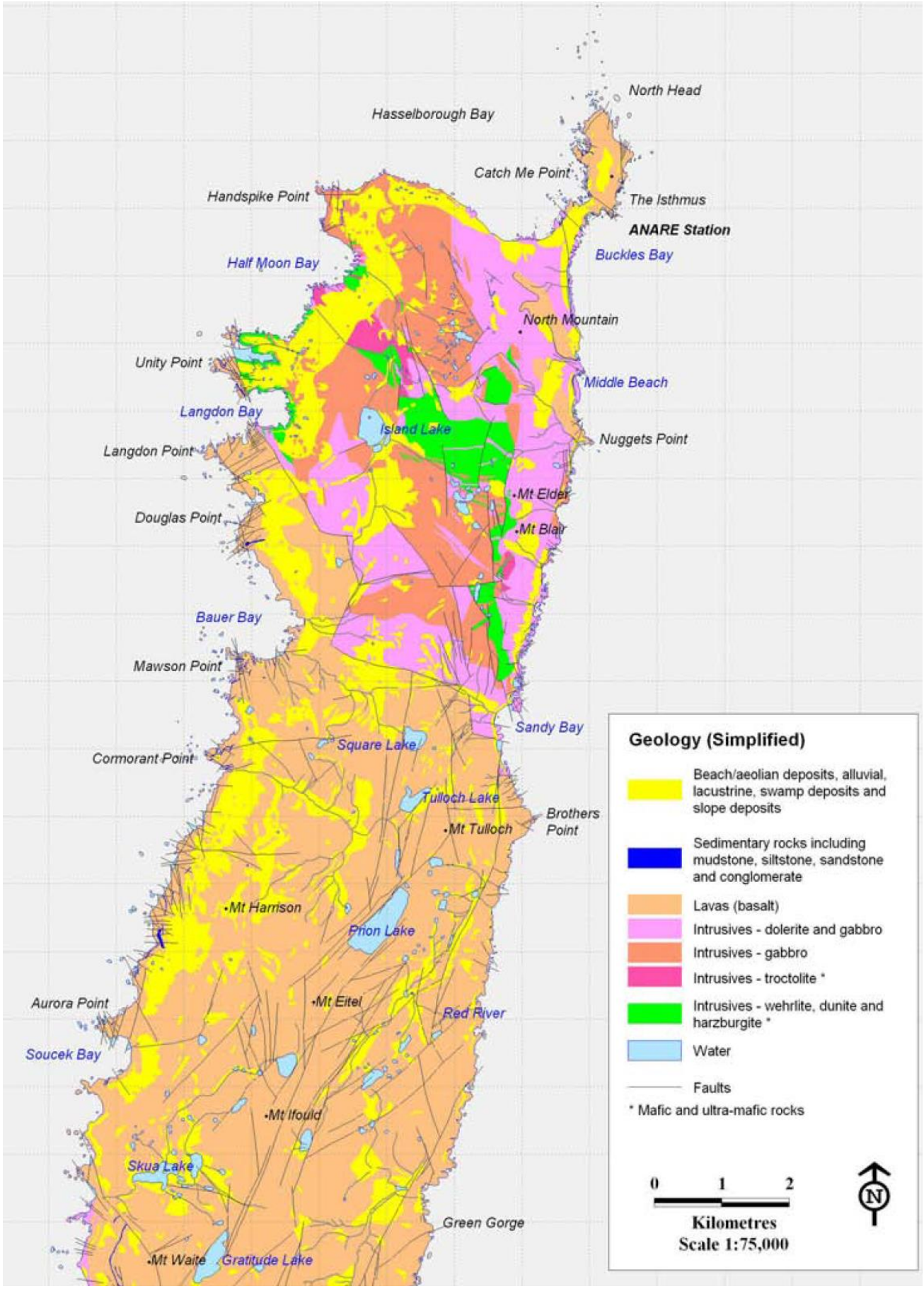
stripes, small stone polygons (Photo 6) and sorted downslope movement of gravel all occur. Stone stripes run downslope on surfaces sloping 2° to 20° with parallel lines of gravel separated by finer material forming mounds 2-3 cm high and 10-25 cm wide (Löffler *et al*. 1983 and Peterson *et al*. 1983).

Taylor (1955a) first described the prominent terraces on the island. He noted leeward terraces on east facing slopes where vegetation forms the risers and the gravel forms the treads and the less regularly formed windward terraces on west facing slopes with soil and gravel rises and vegetated treads. Löffler *et al*. (1983) considered the leeward terraces as relict solifluction landforms developed during a former more severe climate. Recent work by Selkirk-Bell and Selkirk (2013) has shed new light on the processes forming the terraces concluding that the terrace form is the result of the complex interaction of slope, aspect, gravel and vegetation with the prevailing climatic conditions.

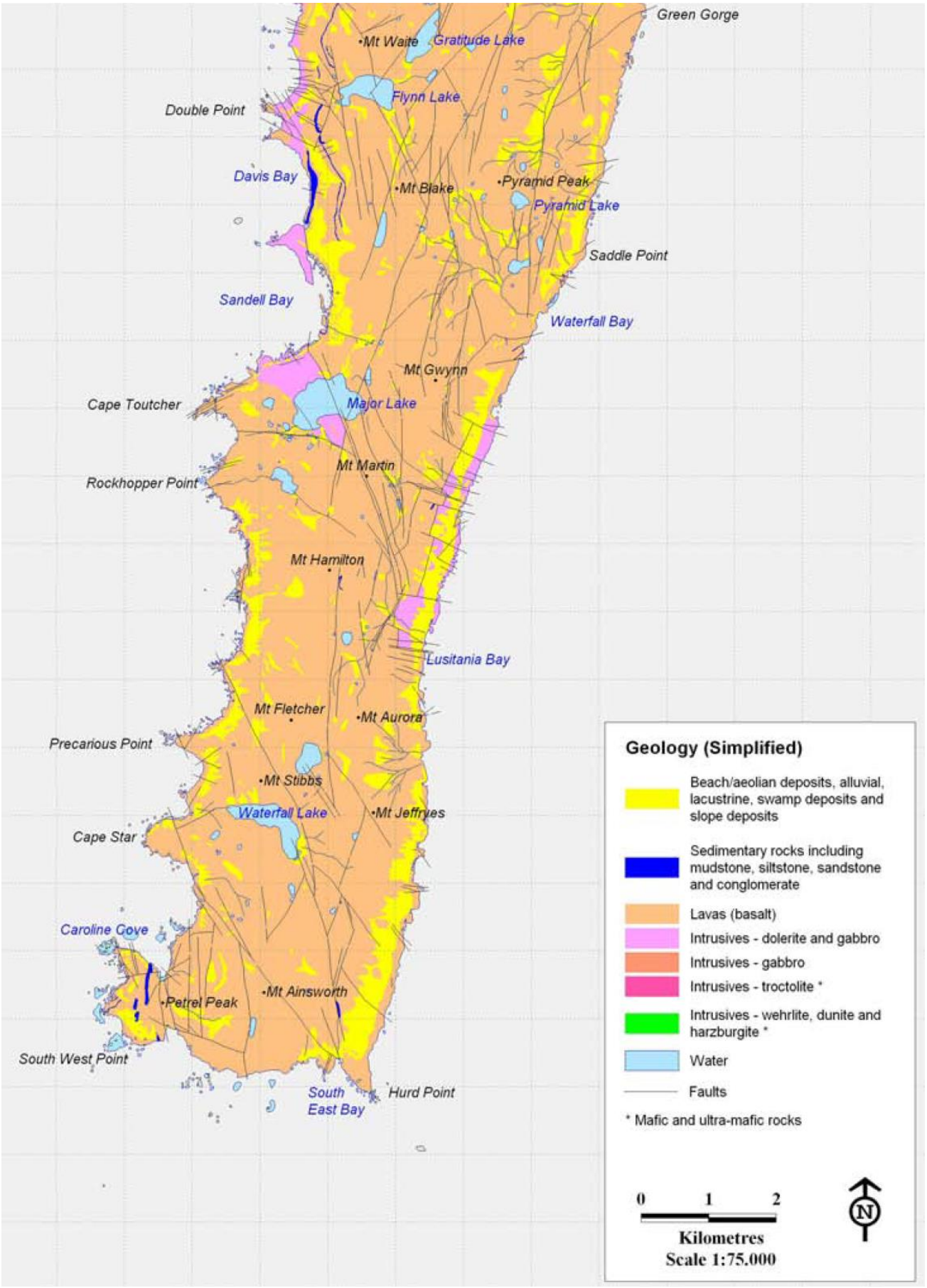
Soils on the island have been described by Taylor (1955b) and fall into three broad types: high moor peat, mire peat and gravely loam material. In general Taylor found where wind velocities were not very high and the rate of plant growth is not slowed down a peat soil is formed. The type of peat formed varies with the absence or presence of a permanent water table in the peat profile. Where wind velocity is very high and the plant growth rate retarded, then dry tundra soils are formed. The effect of organic matter generally masks the effect of parent material except for soils formed on transported material such as wind deposited sands.

Lowland peat bogs may be as deep as six metres and are thought to have formed over the last 5000 to 10000 years (Rich 1996 and Selkirk *et al.* 1990). Excellent examples, known as 'featherbeds', occur at Handspike Point. This would suggest a very fast rate of organic accumulation or slow rate of decomposition in comparison to peats in other parts of the world. Rates are never constant (Selkirk-Bell 2000), but on average it appears as if the lowland bogs on Macquarie have developed at about ten times the rate of many other peatland areas in the world. This may be because of peculiar nutrient conditions but is more likely to be a result of slow rates of decomposition.

The description of the island's geodiversity given here is by no means complete and readers are referred to the noted references for additional information and detail. Significant geoconservation features are listed and described in an inventory (DPIPWE *in prep*.) that provides details on some of the more significant features present on the island.



Map 5. Simplified geology of Macquarie Island (north), after Goscombe and Everard (1998).



Map 6. Simplified geology of Macquarie Island (south), after Goscombe and Everard (1998).

6.0 Geoconservation

Geoconservation is a relatively recent field in the earth sciences and conservation area (Gray 2004). Sharples (2002) defined the terms geoconservation and geodiversity as follows:

- *Geoconservation* is the identification and conservation of geodiversity for its intrinsic, ecological or heritage values.
- *Geodiversity* is 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.

These definitions have been adopted in Tasmania and the concepts of geoconservation and geodiversity are considered integral to nature conservation by Tasmanian land management authorities and are fully incorporated in to the Macquarie Island Management Plan (PWS 2006).

Given the important geoconservation values of the island are recognized as being of outstanding universal value, warranting inclusion on the World Heritage List, the management plan listed as a specific action *to prepare a geoconservation management strategy that identifies sites of geoconservation significance, maps locations accurately and provides management recommendations* (Section 5.2 of the Plan). This document addresses the requirement of a Geoconservation Strategy while a draft inventory of significant Macquarie Island geoconservation sites with location and management recommendations specified is being prepared separately (DPIPWE *in prep*.).

The Tasmanian Geoconservation Database (TGD) is a management tool that has been developed to assist in the management of Tasmania's significant geoconservation features (Comfort and Eberhard 2011). Currently there are two Macquarie Island sites listed on the database. These are the *Macquarie Island Oceanic Lithosphere* (that encapsulates the whole island) and *Macquarie Island Relict Sea Caves* sites. The geological component of the lithosphere site was assigned a global significance on the database.

It is recommended that all sites listed in the inventory (DPIPWE *in prep*.) be considered for potential listing on the TGD to gain formal recognition of the sites and put them in context with other sites across Tasmania. TGD site information is publically available through the DPIPWE's Natural Values Atlas (www.naturalvaluesatlas.tas.gov.au). To be considered for listing on the TGD individual sites must firstly be nominated and are then reviewed by the Tasmanian Geoconservation Database Reference Group (TGDRG).

7.0 Management issues

The management of Macquarie Island rests with the Tasmania Parks and Wildlife Service and is guided by the *Macquarie Island Nature Reserve and World Heritage Area Management Plan 2006* (PWS 2006) and requirements of the World Heritage Convention. The plan provides objectives, policies and actions for the conservation and protection of reserve values including geoconservation. The objectives, policies and actions relating to geoconservation as listed in the Plan (Appendix 1) are endorsed by this strategy. A number of additional management issues relating to geoconservation and geodiversity are discussed in the sections below and provide more detail than the Management Plan structure allows. They are all compatible with the current Management Plan. Recommendations that relate directly to the island's geodiversity arising from these issues and additional recommendations from other parts of the strategy are summarised in Chapter 8 of the strategy.

7.1 Protection of WHA geoconservation values and geodiversity

The protection of World Heritage geoconservation values and the island's geodiversity are primary objectives of the Management Plan in relation to geodiversity. They are seen as fundamental considerations in the management of the island and underpin considerations of the following management issues.

Recommendation

- *That a primary objective of the management of Macquarie Island remains protection of World Heritage geoconservation values.*

7.2 Geo-interpretation

As noted throughout the strategy, the geodiversity of Macquarie Island is unique and of outstanding World Heritage value. While the abundant wildlife is obvious to most visitors and ANARE expeditioners, the geodiversity values are not necessarily so apparent and good interpretation is important to present these values. This is a key objective outlined in the Management Plan: *maintain a high standard of geo-interpretation for visitors including up to date booklets and other interpretative material as required* (Management Plan Section 5.2).

DPIPWE has produced a number of publications that clearly explain and illustrate the island's geodiversity and the associated World Heritage values. *Macquarie Island a new arrival - the geological development of a young island* (Pemberton *et al.* 1999) is a short booklet produced by PWS that deals exclusively with the island's geodiversity while the more glossy publication *Macquarie Island* (DPIPWE 2012) covers not only the geology but also climate, vegetation and wildlife of the island. This second publication is provided by PWS to all tourists and ANARE expeditioners to the island. It provides a very good description of the island's geology and geomorphological processes and associated World Heritage values. The PWS website (www.parks.tas.gov.au) has a section that covers Macquarie Island with separate geoheritage pages. A number of other general publications on Macquarie Island also include good information on the geodiversity, for example *Subantarctic wilderness: Macquarie Island* (Terauds and Stewart 2008) and surprisingly a children's book *One Small Island - the story of Macquarie Island* (Lester and Tulloch 2011).

Despite the ready availability of good information on geodiversity many expeditioners and visitors to the island do not appear to have much prior knowledge of the island's geodiversity. In addition to the printed material that visitors receive prior to landing, most visiting tourist ships also give short presentations to their passengers including some very basic facts about the island's geology. Sometimes this is done by the PWS Ranger in Charge (RIC) from the island. ANARE expeditioners also receive, as part of their pre departure training in Hobart, a short presentation from PWS outlining the natural values of the island. The information presented on the island's geodiversity is generally very brief in these presentations.

PWS utilises volunteer guides from ANARE expeditioners on the island to assist in showing visiting tourists around parts of the island (The Isthmus and Sandy Bay). PWS provides some basic training and briefing notes to the volunteer guides. These notes currently include only one short paragraph that relates to the island's geodiversity (see below).

> Extract from PWS notes to volunteer guides:
> *Why is the island a World Heritage Area?*
> *For the geology: whereas most of the earth's terrestrial land is made up of either layers of sediment, or lava that has come from deep below the earth's surface, Macca* [sic] *is a piece of the ocean floor/earth's mantle exposed above sea level. It is the only place in the southern hemisphere where the oceanic crust is above sea level.*

There is more interpretation on the island's unique geodiversity that could be done to the benefit of both tourists and ANARE expeditioners. An outdated display board (Photo 7) that comprises rock samples and a geology map of the island is bought into the station mess (where tourists spend time having a hot drink during their visits to the station) and is currently the only geo interpretative panel available for tourists or expeditioners on the island.

Photo 7. Geology display board displayed in the stations mess during tourist visits.

Photo 8. Cultural heritage interpretation panel at the Isthmus digesters.

The practice of supplying to tourists and ANARE expeditioners, a copy of the informative publication *Macquarie Island* (DPIPWE 2012) should continue as it provides an excellent introduction, among other topics, to the island's geodiversity. It is also recommended that the training and briefing notes to the

volunteer tourist guides for the tourist visits be revised to include more geodiversity information. The briefing notes should outline specific locations around the station useful for interpreting some of the island's geodiversity. The Razorback lookout lends itself as an ideal location to introduce visitors to the island's geodiversity with a number of features clearly visible from there such as the coastal terraces and the featherbeds, the Isthmus, coastal escarpments and North Head. It is also some distance away from wildlife, such as seals and penguins, and therefore has less biological focus. A good example of pillow lava exists along Hasselborough Bay which should be pointed out as groups walk along the beach towards the station. There is also potential for geo interpretation around Sandy Bay and although the Royal and King Penguin colonies potentially attract visitors interest, there are a number of geo themes that could also be interpreted perhaps with information boards on the boardwalk.

It is recommended that a geodiversity focused interpretive panel, similar to the ones located at the historic digesters on the Isthmus (Photo 8), be designed and in the first place be mounted at the Razorback lookout. The panel, like others, could be temporarily installed during the tourist season to prolong its life in the harsh environment. It is also recommended that a contemporary display board be provided for permanent installation in the station mess so that it can be viewed at leisure and out of the weather by visitors and ANARE expeditioners alike. (Given space restrictions consideration of mounting the display on the mess porch could be considered.) Apart from the above mentioned interpretative material no additional infrastructure is recommended at this stage to assist in geo-interpretation on the island as there are adequate opportunities to interpret the island's geodiversity values at areas currently visited by tourists and served by existing tracks and boardwalks.

Recommendations

- *Interpretation should emphasise that the geodiversity of the island is of world heritage significance.*
- *Copies of the informative publication Macquarie Island (DPIPWE 2012) continue to be provided to all tourists and ANARE expeditioners that visit the island;*
- *Improved training and briefing notes for volunteer tourist guides to include more geodiversity information including reference to specific geo site localities be developed by PWS in consultation with the Geoconservation Section of DPIPWE;*
- *A geodiversity focused interpretive panel be designed and installed at the Razorback lookout;*
- *A contemporary display board covering the island's geoconservation values is designed for permanent installation in the station mess;*
- *Investigate opportunities for on-line media interpretations of the islands geodiversity and geoconservation values.*

7.3 PWS geodiversity work

Given the significance of the Reserve's geoconservation World Heritage values it is important that adequate PWS time is allocated to geoconservation work related tasks. There are a number of geodiversity based tasks that the PWS Rangers stationed on the island presently undertake and others that they could become involved in for the benefit of geoconservation on the island. These tasks are outlined below. With competing demands for Ranger's time, these tasks need to be considered as part of the overall annual work program. RMC Geoconservation staff are available to provide input into the planning of the works program through the Macquarie Island Executive Officer.

The following recommendations are suggested as various tasks for inclusion in the annual PWS work program planning for Macquarie Island. Some tasks, for example geo-interpretation, are likely to involve agency staff not physically stationed on the island. Note that a review of the current long term photo monitoring program needs to be undertaken in consultation with DPIPWE and PWS staff to determine future direction of this long term data set.

Recommendations

- *Enhancing geo-interpretation opportunities to visitors and ANARE expeditioners;*
- *Following a review of the current photo monitoring program, continue involvement in taking the photo series for the long term photo monitoring program on erosion and vegetation change (post rabbit eradication monitoring must include soil erosion measures as well as vegetation indicators);*
- *Converting the existing Geoheritage Database into a Landslip Database and maintaining and contributing to the database to record details of landslip events on the island (see Section 7.4 below);*
- *Undertaking periodic erosion monitoring (for sites re-established in 2014) as part of a scheduled monitoring program and research strategy;*
- *Administering and monitoring permit condition compliance for scientific work, and supporting earth science research on the island;*
- *Ensure AAD activities on the island that have the potential to impact on geoconservation values comply with any relevant permit conditions or provisions under the Nature Conservation Act 2002, the National Parks and Reserves Management Act 2002, the island's Management Plan 2006 and this strategy;*
- *PWS consult with RMC Geoconservation staff in planning the annual PWS island works program to ensure that key geoconservation tasks are included and adequate staff time and resources provided.*

7.4 Landslip database

A *Geoheritage Database* [sic] exists that records occurrences of landslips and to date has been irregularly maintained. With rabbits now eradicated from the island (PWS 2014) it is recommended that records of the frequency and size of landslips and their development (e.g. continuing to be active or stabilising with vegetation re-establishing etc.) be recorded over time to try and obtain a measure of landslip occurrence in the absence of rabbits.

It is recommended that the *Geoheritage Database* be renamed and reactivated to record observations on landslips on the island. The database should simply be referred to as the *Landslip Database*. Simple observational data, listed under the fields as noted in Table 2 should be collected from any *ad hoc* observations from PWS staff while undertaking fieldwork on the island. Observations from other ANARE expeditioners should also be encouraged.

Table 2. Potential fields for proposed Landslip Database.

Database field	Notes
Site number	Unique number
General location	Meaningful simple description
GPS grid reference	Full AGM 6 and 7 digit grid reference
Date landslip observed	Date current observations made
Estimated date landslip occurred	Note this may be different from above field
Landslip size: length, width, slope	Approximate dimensions in metres and estimate of slope in degrees, height of headwall
Trajectory of landslip	An assessment if it is active or stabilising
Photo details	Location where photos are taken from and photo ID number linked to site number
Additional notes	Soil depth, vegetation type, weather conditions etc.

Recommendation

- *That the Landslip database be re-established and regularly updated with current landslip activity on the island.*

7.5 Climate change impacts

Macquarie Island has experienced a marked shift in its climate since 1970, with increasing precipitation and changed patterns, accompanied by a steady increase in mean wind speed and changes in wind direction associated with increased cyclonic activity (Adams 2009). These changes have the potential to impact on the island's geodiversity through changes to rates and magnitude of erosion and deposition and hydrological processes.

Changes in precipitation entail heavier rain events, particularly over winter, increasing potential for erosion both through surface flow and subsurface flow. In 2013 a number of landslips across the island were observed following a heavy rain event (Chris Howard pers. comm.) and in 2000 four landslips that clipped the old Caroline Cove hut appeared to be triggered by a heavy rain event (Keith Springer pers. comm.) and it is possible that this type of event could become more common in the future. Vegetation regrowth, following the eradication of rabbits may in the medium term reduce this potential impact, especially on the steep coastal slopes with tall *Poa* tussock and Macquarie Island cabbage (*Stilbocarpa polaris*) reestablishing, providing greater vegetation intercept for rain droplets, increased water uptake through transpiration and increasing mechanical strength of soil through root growth. For large eroded bare areas on the island, where re-vegetation is impeded by factors such as frost heave, fluvial and wind erosion, the increase in rainfall and more intense rain events, is likely to lead to an increase in erosion and further impede revegetation. A lack of a detailed understanding of hydrological processes on the island (Scott 2010) limits the ability to predict potential impacts of changes in rainfall patterns (see Section 7.15).

Changes in wind regimes can also potentially impact directly on erosion processes currently active on the island. When combined with changes to rainfall patterns, where soil drying is more likely between rain events, soil particles will be more easily transported by aeolian processes. In areas where *Azorella macquariensis* is suffering dieback increasing winds could have large impacts on areas of fjaeldmark through increased wind erosion (see Section 7.11).

Presently climate and weather data for the island are collected on the Isthmus close to sea level. Conditions on the plateau vary considerably from this and it is important that weather data be collected from other parts of the island to help understand potential impacts on the island's environment including geodiversity. Prior to the MIPEP commencing, weather data was collected from a site near Windy Ridge Hut for a number of years (Keith Springer pers. comm.) though there is a question on the reliability of the data (Noel Carmichael pers. comm.). It is suggested if the data is determined to be reliable enough to be useful that it then be made more available. Weather data was also collected from Mt Elder (Tweedie 2000) and there is a current proposal to establish a remote weather station at Mt Elder as part of a PhD program (Nick Fitzgerald pers. comm.) and this is supported. Over time additional automatic weather stations in other parts of the island should be considered to better document the variability across the island.

Watson *et al*. (2010) give an estimate of the absolute sea level change over the twentieth century of +2.0 mm yr^{-1} (± 0.8) at Macquarie Island concluding that this is consistent with the upper bound of the global average rate of absolute sea level rise over the same period. Accelerated sea level rise may have significant effects on the island with natural values and built infrastructure potentially impacted. A policy of non-intervention should be adopted. PWS have a photo monitoring program at the Isthmus that over time could be used to assess changes to the shoreline in the face of climate change. A proposal to establish surveyed shoreline transects is currently under consideration by PWS (Chris Howard pers. comm.). If the program proceeds, it should be established following TASMARC methodology (Tasmanian Shoreline Monitoring and Archiving project). This is described in Sharples (2010) and on the TASMARC website (www.tasmarc.info).

Recommendation

- *That additional weather monitoring stations be located on the island to provide increased information on climatic and climate change impacts on geodiversity and biodiversity. The stations should include measurements of soil temperature and moisture.*

7.6 Illegal souvenir collecting of earth materials

Given the uniqueness of the rocks on the island, and their often highly polished nature due to the high energy coastal processes and winds, there is a tendency by some visitors or expeditioners to collect rocks from the island. Interesting rocks are also at times collected and placed in field huts (Photo 9). Under the *Nature Conservation Act 2002,* collecting earth materials without a permit is illegal. Rocks should be left in situ and not moved around the island as in the case of displaying rocks in field huts. Some Station Leaders have in the past enforced this and had a 'clean windowsill' policy on station where rooms were not to be adorned with natural memorabilia picked up from the island (Keith Springer pers. comm.).

Recommendation

- *That provisions of the Nature Conservation Act 2002 are actively enforced on Macquarie Island to prevent the illegal relocation or collection of rocks and to reiterate how special the island's rocks are.*

Photo 9. Rock collection on window sill of Green Gorge Hut (March 2014).

7.7 Use of natural materials for building or track works

Due to the expense and logistical issues involved in transporting materials to the island, and on the island itself it has been common practice to utilise some earth materials sourced on the island for limited building purposes and track works. The use of such materials is essentially a form of quarrying from a non renewable resource within a World Heritage Area. It can be argued that using local material is a good practice in that it maintains the overall integrity of the island instead of shipping in foreign gravel or sand. It does not appear that this issue is specifically covered by the current Management Plan and it is recommended that a policy be developed that covers the use of natural materials on the island. The use of earth materials sourced from the island must be fully justified and the potential impact on geoconservation values fully assessed prior to any excavations occurring. The policy should outline the approval process and provide guidelines covering the extraction of material. Guidelines need to specify the type of material that is available for use, the volume and the location from where it can be sourced and the extraction method to be used. Beach sand and some cobbles are commonly required for works around the station that involve maintaining the vehicle tracks and sand for concreting and fill. Typically this has been sourced from the beach on Buckles Bay north of Gadget Gully. A major rebuilding of AAD infrastructure at the Isthmus as buildings are replaced has begun and the demand for rock or sand may increase. A policy should be in place and considered as part of the planning stage for any new infrastructure works. The policy needs to be developed in consultation with the PWS and the AAD and linked with appropriate Management Plan zones. The policy also needs to cover

protocols that assist the PWS RIC with on ground management for 'small task' minor extraction of gravel etc. Some local material has been used for minor walking track works and this is further discussed under Section 7.9 of this strategy.

Recommendations

- *That the current Management Plan be augmented with a policy that covers the use and extraction of natural materials on the island. Until this has been done any excavations etc. should be covered through the RAA process and the following guidelines should be used;*
- *Any use of sand, gravel or other earth resources should be carefully planned and all options should be considered to avoid or limit the amount used;*
- *Where sand is quarried it should be removed as a thin layer across an active beach area rather than a hole in an inactive area;*
- *No pebbles or cobbles to be removed from palaeo shoreline deposits;*
- *Bedrock in the intrusive igneous rocks adjacent to and south of Hasselborough Bay should not be excavated.*

7.8 Coastal engineering works

As noted in Section 7.5, a general policy of non-intervention should be adopted in dealing with potential sea level rise impacts related to climate change. Coastal engineering works have the potential to impact natural values by interfering with natural coastal processes and thus are in conflict with the geoconservation objective of *Maintain natural rates and magnitudes of change in earth processes* (Management Plan Section 5.2). To date, there have only been minor coastal engineering works undertaken on the island, however given the amount of built infrastructure on the Isthmus and the potential for coastal erosion and flooding there may be future pressure for more extensive works. Any proposed coastal works must be clearly justified, limited in extent and expertise in coastal engineering consulted as part of the assessment process. Examples of potential coastal works currently under consideration include remediation works on the start of the tourist boardwalk at Sandy Bay (Photo 10) where the current structure is slumping and potential works to improve the launching area for Work Health and Safety (WHS) reasons on Buckles Bay where zodiacs and LARCs land.

A small section of old coastal hardening on the Isthmus in front of the Bureau of Metrology (BOM) buildings shows signs of failure and ineffectiveness (Photo 11). There have been calls to remove the concrete blocks to restore the natural view fields. Recently steel reinforcing projecting from the blocks was cut off and removed as it was considered a hazard to wildlife, a WHS issue to expeditioners and was also aesthetically intrusive (Clive Strauss pers. comm.).

Recommendations

- *In general, a non-intervention approach to the potential impacts of climate change induced sea level rise be adopted;*
- *That an assessment be made of the current coastal hardening at the Isthmus and if it can be removed without further damage to the coastline that the blocks be removed. Advice from a coastal engineer should be sought before any works to remove the blocks are undertaken;*
- *Advice from a coastal engineer should be sought before any further coastal engineering works are considered.*

Photo 10. Start of the tourist boardwalk at Sandy Bay, on the banks of Finch Creek.

Photo 11. Coastal "armouring" at the Isthmus in front of the BOM buildings.

7.9 Walking tracks

There is an extensive network of walking tracks and routes across Macquarie Island (Maps 2 and 3). Limited track hardening works have been undertaken. Most tracks are well marked with painted timber marker posts. A walking track strategy was completed in 2001 for PWS (Dixon 2001) with a prioritised track management program. The strategy was only partially implemented (tourist tracks essentially) and then somewhat overtaken by events with the higher level of island-wide trampling during the MIPEP period. Degradation associated with walking tracks and access routes has the potential to degrade geoconservation values of the island, though degradation is often localised and at least in coastal environments can be considered insignificant by comparison with areas trampled by seals and penguins (Scott and Kirkpatrick 1994). Scott and Kirkpatrick (1994) however also point out that the effects of human trampling are more apparent and of greater concern on the upland plateau, steep coastal slopes and higher parts of the coastal terrace. On the significant periglacial terraces, walking tracks can and do directly impact the vegetated risers and can lead to degradation through the breakdown of the treads in a similar way as described in Section 7.11 with *Azorella* dieback. Many of the issues identified by Dixon in 2001 remain current and it is timely for PWS to revisit the strategy to direct future track management. There are a number of issues relating to walking tracks that potentially impact on geodiversity values and these should be considered in a review of the strategy. These include the following and are further discussed below.

- Use of local materials for track works
- Considerations in rerouting tracks
- Informal access routes as part of scientific research programs
- Reduced usage following the end of MIPEP
- Track marking

There has been limited use of local materials for track hardening or erosion control structures (e.g. water bars) on walking tracks on Macquarie Island. Photo 12 shows a section of the Overland Track surfaced with locally quarried gravel and Photo 13 rock water bars on the Link Track. Dixon (2001) recommended that the use of locally sourced rocks should be considered wherever possible for track surfacing, noting that if installed properly rock work is stable, robust, relatively maintenance free and much more aesthetically pleasing than wooden structures. However, he also noted that on Macquarie Island rock use is likely to be limited by the lack of locally available material and practical considerations such as weather conditions may preclude flying multiple loads of suitable material from elsewhere on the island. If rock, or gravel is to be considered for track work then a careful assessment of where the material is to be sourced from must be undertaken. This even holds true when sourcing individual rocks for steps or water bars to ensure that in

removing rocks geoconservation values are not impacted (e.g. removing significant boulders from a raised beach, Photo 14 or using rare rock types such as hyaloclastites) or that erosion is not initiated where rocks are sourced from. Use of such materials must be considered as quarrying, though on a small scale, and an assessment made as to the relative benefit of using local rocks. Such works should be confined to track sections that are unlikely to be rerouted or superseded and placed where there is confidence that users will stick to the hardened track surface and not replicate trampling damage adjacent to the track.

Photo 12. Section of Overland Track near Mt Jeffreys surfaced with locally quarried gravels.

Photo 13. Rocks placed as water bars on the Link Track.

Minor track reroutes on Macquarie Island are fairly common and are often simply achieved by moving marker posts to direct foot traffic to a new route. Rerouting can be effective in preventing muddy sections of track developing or avoiding seasonal occurrences of wildlife. However, rerouting can also simply replicate track degradation problems and an assessment must be made to minimise overall environmental impacts. If a track is left too long before rerouting then it may not recover and it is perhaps arguably better to concentrate the damage to one path rather than ending up with multiple parallel degraded paths. For example rerouting to avoid slumping should be done a reasonable distance from the slump so as not to simply enlarge the slump being bypassed (e.g. Photo 15). When rerouting above a slip care needs to be taken to avoid directing additional water towards the slip area and when rerouting below, toe stability of the slump requires consideration.

Photo 14. Boulders that are part of a significant raised beach geoconservation site adjacent to the Island Lake Track. Removal for track work would devalue the significance of the geoconservation site.

Photo 15. Reroute around a slump on the Overland Track near Sawyer Valley. The reroute is now adding to instability of the site with the original slump being enlarged.

As Dixon (2001) noted, pads and subsequent track degradation problems can arise where researchers routinely use a specific route to access research sites with subsequent potential impacts on geodiversity where significant erosion results, as was the case on North Head during a seal monitoring project (Scott and Kirkpatrick 1994). As Dixon recommended, in assessing any research projects, an assessment should be made of potential trampling damage as part of the overall project assessment.

During the MIPEP program there was a much greater use of the walking track network by the team of 12 or so hunters and dog handlers over nearly three years, with usage based all year round and not confined to summer as is the case largely with summer based science programs. It would be appropriate to leave the decision on some track hardening or rerouting for a season or two to see if the reduced usage of some of the degraded areas enables self-repair. This has been recommended to PWS in the case of the access track to Caroline Cove where a RAA had been prepared for a reroute. With the Caroline Cove hut no longer in use there may not be justification for a marked route to the cove given it is in a permanent SMA.

The primary objective in managing walking tracks should be for environmental reasons and not for walker comfort *per se*. It is acknowledged however that much track work done for environmental reasons will inevitably increase walker comfort.

It was observed that a substantial amount of PWS staff time is currently taken up in replacing and maintaining timber track markers due to the weathering of the paint in the harsh climate. Both Dixon (2001) and the Management Plan (PWS 2006) recommend that an alternative to painted timber stakes be investigated to provide longer lived track markers. This recommendation is supported and though not having a direct bearing on geoconservation values it would free up PWS staff time, some that could be available for other conservation works including geoconservation.

Recommendations

- *That the 2001 Walking Strategy be reviewed to guide current Walking Track management on the island;*
- *Walking track management and hardening should primarily be undertaken to protect the environment rather than provide for walker comfort;*
- *Any proposed use of local materials for track works is fully assessed prior to its use with special reference to potential impact on geoconservation values;*
- *Track reroutes, are fully assessed and considered before implementing;*

- *The assessment of any research projects must include an assessment of potential trampling damage as part of the overall project assessment;*
- *Short term track management decisions need to consider the significant change in walking track usage following the end of MIPEP;*
- *A less labour intensive solution to track marking is investigated and introduced.*

7.10 Restricted access areas

Currently there are a number of Special Management Areas (SMAs) that limit access to parts of the island, either seasonally or permanently, to protect specific biodiversity values (Maps 2 and 3). All are associated with the location of breeding seabirds or *Azorella* dieback. In addition, ANARE expeditioners are restricted to the formal track network and not permitted to walk off track unless a special access permit has been granted or they are part of an authorised activity where a revised or temporary access authority is issued. These measures are supported in that they also reduce potential trampling damage or erosion in untracked areas. Two tracks, the Featherbed Track and the Aurora Cave Track that traverse parts of the sensitive featherbeds on the west coast are closed seasonally through SMAs for nesting seabirds. This seasonal closure potentially also protects the featherbed, a geoconservation feature, from excess trampling pressure.

Consideration should be given to declaring SMAs to protect specific geoconservation values if they are considered to be under threat from visitation. A number of relict sea caves on the island contain a variety of sensitive features, including relict sediments, speleothems, subfossil bones and historical artifacts. The management notes from the TGD listing of these sites state that: *visitation should be discouraged*. The caves should be assessed and managed in accordance with the PWS Cave Access Policy and if necessary a SMA declared to further protect the caves and the features contained within them.

Recommendations

- *That consideration is given for declaring SMAs to protect specific geoconservation values if they are considered to be under threat from visitation;*
- *That relict sea caves on the island should be assessed and managed in accordance with the PWS Cave Access Policy and if necessary an appropriate SMA be declared.*

7.11 Azorella dieback

The endemic cushion plant *Azorella macquariensis* is currently suffering a catastrophic decline on Macquarie Island (Threatened Species Section 2012). *A macquariensis* is a major structural component of fjaeldmark, and its loss will cause severe modification to the ecosystem and is likely to lead to major erosion problems and decline of associated species (Threatened Species Section 2012). Whinam *et al*. (2014) noted that the dieback may be linked to climate change. *A macquariensis* is also a key component in the periglacial terraces (Selkirk 1998) that are widespread on the island and are a key geoconservation feature (Photo 16). The decline of the cushions (Photo 17) could potentially alter the condition and the form of these features (Selkirk -Bell and Selkirk 2013).

Recommendation

- *That research into the* Azorella *dieback and its impact considers potential impacts on geodiversity as well as the associated plant communities.*

Photo 16. Terraces, eastern slopes of Mt Bake.

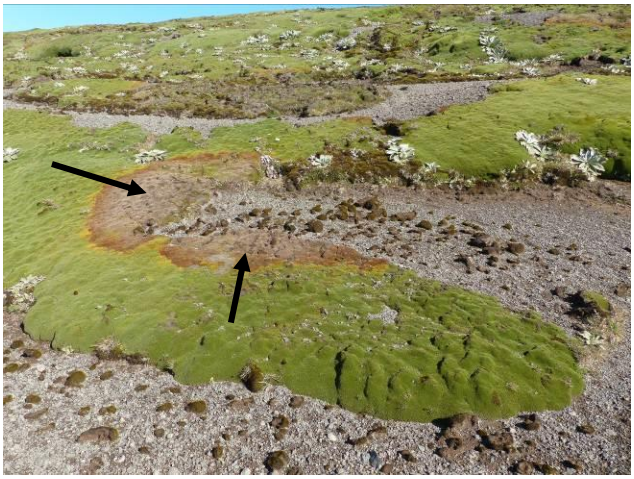


Photo 17. *Azorella* dieback (arrowed) on terracing on the north east slopes of Mt Eitel.

7.12 Biosecurity

Significant effort and resources have gone into eradicating a number of alien species from the island with perhaps the removal of rabbits having the most direct benefit to the island's geodiversity (PWS 2007). A key component in the management of the island is to prevent the reintroduction of eradicated species or new incursions of other alien species through thorough biosecurity measures. Although rabbits are unlikely to be under threat of reintroduction, other alien species if they were to establish on the island may have detrimental impacts to the island's natural values including geodiversity. This could include various plant species, soil microbes or invertebrates. Alien plant species have the potential to alter natural rates of erosion, and/or interfere with sediment movement, while soil microbes and invertebrates could change the native soil biota with subsequent changes to the island's geodiversity. Strong biosecurity measures are supported not only for the obvious biodiversity reasons but also to protect the island's geodiversity. Of particular concern is the possibility of introducing alien species through scientific equipment, specifically soil sampling equipment such as corers. As noted under the scientific collecting section (Section 7.14) all sampling equipment must be thoroughly cleaned and sterilised prior to being bought to the island.

With cats and rabbits now removed from the island, there has been some consideration to introduce the Reischek's parakeet (*Cyanoramphus hochstetteri*) and the Buff-banded rail (*Gallirallus philippensis*) that are very closely related to the extinct Macquarie Island parakeet (*Cyanoramphus erythrotis*) and the extinct endemic *Gallirallus philippensis macquariensis* (Chris Howard pers. comm.). This could potentially aid vegetation seed dispersal on the island, provide localised soil disturbance essential for some plant species and be another step in complete restoration of the island and its biota to a pre human condition. Potential impacts, both positive and negative, on the island's geodiversity must be fully considered in assessing any such introductions.

Recommendations

- *That high standards of biosecurity be rigorously maintained for the Island;*
- *That any introduction or reintroduction of biota to the Island be comprehensively assessed and the potential impact on the island's geodiversity, in particular the soil, be included in any conservation assessment.*

7.13 Management of contaminated sites

There are a number of known contaminated sites on the island impacting on the island's geodiversity and other values. The sites are confined to areas around the Isthmus and relate to earlier activities associated with the operation of the ANARE base. Sites have been surveyed (Deprez *et al*. 1994) and comprise wastes associated with an old, now disused tip site and a number of hydrocarbon spills.

Some material from the tip site has been removed and returned to Australia (RTA) although a substantial amount of waste material remains buried on site. The tip site is located on Hasselborough Bay and is subject to disturbance during high seas and storm events. Wildlife access the site and elephant seals have been known to expose buried rubbish. Rubbish that is exposed and that can be easily removed is periodically taken from the site (primarily to avoid injury to wildlife) and RTA'd. Station earth moving machinery using beach materials obtained onsite is used to cover any larger exposed rubbish. This was most recently done in 2013 (Clive Strauss pers. comm.). Most waste at the tip site is considered hard waste although there are some contaminants such as old batteries present and Deprez *et al.* (1994) found some elevated metal levels in the sampling they undertook. Deprez *et al.* (1994) classified the site as "Possibly contaminated" and recommended a rehabilitation plan be implemented and repeat sampling post rehabilitation be undertaken.

Three plumes of diesel-range product have been identified as requiring remediation. These plumes are located at the Fuel Farm, the Main Powerhouse, and in an area to the north-east of the Main Powerhouse. Active works are currently being undertaken in treating these sites (AAD 2013) using a system of nutrient enhancement and aeration. In addition to the three plumes, other areas of hydrocarbon contamination exist and there is potential for more than those currently documented. For example during construction over the 2013/14 summer of a new helicopter hangar on the Isthmus, contaminated soil containing hydrocarbons was exposed highlighting the issue.

The remediation work conducted to date has clearly shown that treating contaminated soils is a difficult and expensive task. Preventing future oil spills by ensuring that, existing infrastructure (e.g. bunding) and operating procedures are effective in minimising the risk of spills, must be given the greatest priority.

Recommendations

- *Critical fuel infrastructure is maintained and safe operating procedures adopted to minimise risk of future fuel spills and that remediation works at the Fuel Farm and Main Powerhouse continue with agreed to end point targets established;*
- *The tip site is regularly monitored, loose exposed material removed and if necessary careful use of machinery employed to cover recently exposed larger rubbish where it is in danger of moving offsite or poses a risk to the natural environment;.*
- *The PWS RIC must be consulted before any works are conducted on the tip site;*
- *Guidelines be developed and adopted to manage any further hydrocarbon contaminated soils that become exposed during construction activities or via erosion.*

7.14 Scientific sampling

Sampling as part of scientific research has the potential to irreversibly damage significant geoconservation values on the island. Given the geological time scale, earth resources on the island must be considered as essentially non-renewable and any approved collecting for scientific (or other reasons) must be fully assessed prior to making a decision on whether to grant approval as outlined in the Management Plan Section 6.8. This is currently done by RMC Geoconservation staff in consultation with other MIRAG members. The Management Plan provides some guidelines on assessing research applications. To aid those applying for research permits it could be beneficial to develop a document that provides greater guidelines

for sampling principles and general conditions that apply to scientific sampling of earth materials on the island. Sampling guiding principles should include but not be limited to:

- Any sampling of earth materials from Macquarie Island must have strong justification;
- Use of previously sampled and curated material from the island should be encouraged and where there are existing collections there must be demonstrable justification for any further sampling;
- Sampling must be kept to the minimum amount required to undertake the specified research;
- Sampling must be done in a way that minimises impact on the island's geodiversity;
- Drilling or coring of bedrock or any rock outcrop would only be approved in exceptional cases;
- Appropriate collected material must be lodged and curated with an institution where it is available to other researchers;
- Details of the material collected and locations must be lodged with DPIPWE;
- Research results must be made available through published scientific papers or other reports lodged to DPIPWE and made available to other researchers.

There have been significant breaches of scientific collecting permit conditions relating to earth materials in the past (Michael Pemberton pers. comm.). To minimise occurrence of such breaches and potential adverse impacts on the island's geoconservation, permit conditions should be clearly written, and as is current practice the PWS RIC on Macquarie Island go through with individual researchers the permit conditions on their arrival on the island and prior to conducting any sampling. As prescribed in the management plan breaches of permit conditions may attract penalties and affect the issue of further permits.

Recommendations

- *Scientific sampling guidelines for earth materials from Macquarie Island are developed;*
- *Continue the practice of PWS RIC going through permit conditions individually with researchers prior to fieldwork being conducted and enforce permit conditions.*

7.15 Knowledge gaps

In compiling this geoconservation strategy and the inventory of significant sites (DPIPWE *in prep*.) it has become apparent that despite the substantial body of earth science research that has been conducted on the island there are a number of important areas where there are gaps in the earth science knowledge. The two main areas identified as requiring further work are in the areas of soils and hydrology. The only comprehensive soil survey of the island was completed nearly sixty years ago (Taylor 1955b) and a current systematic survey of the island's soils is well overdue. It is likely such a survey would reveal important information on the island's soils, and extensive peatlands, and would be of importance in adding to the geoconservation inventory and could assist in helping to understand the current *Azorella macquariensis* dieback. There is also a knowledge gap around hydrological processes on the island. Scott (2010) in preparing an ecological character description for a proposed Macquarie Island Ramsar site, listed a number of aspects of hydrology as high priorities for research including all aspects of surface and subsurface flow, soil hydrology and the hydrology of coastal mires especially the north west featherbed. Projected climate change impacts for the island (Adams 2009) also highlight the need for research into the hydrological processes on the island. Scott (2010) further noted that rates of geomorphic processes in peatlands and updated information on peat soil properties, dynamics and classification were high research priorities.

Other areas that would benefit from targeted earth science research on the island include the sea caves and periglacial terraces. Considerable potential exists in relict sea caves (Harris *et al.* 2010) to assist in interpreting the evolution of the landscape. The caves, and the potentially dateable sediments they contain (although mid to upper layers have been heavily disturbed by rabbits in the past 130 years) are important in interpreting the landscape evolution of the island and providing evidence of the relationship between tectonic uplift and paleo sea levels. Work has been completed on the extensive periglacial terraces on the island (Taylor 1955a, Löffler *et al.* 1983, Peterson *et al.* 1983, Selkirk *et al.* 1988, Selkirk *et al*. 1990, Selkirk

1998, Selkirk-Bell and Selkirk 2013) but a comprehensive island wide survey mapping and classification program would be useful in further documenting these significant geoconservation features.

A key document consulted in preparation of the Strategy was a draft of the Tasmanian Geological Survey Report: *Field relationships in oceanic crust, Macquarie Island. Part 1 – Igneous field relationships, rock-types and crustal reconstruction* (Goscombe and Everard in prep.). This document should accompany the excellent geological maps produced by MRT, however it has not been finalised and remains in a draft form only and not widely available. Much of the information in the draft Tasmanian Geological Survey Report is covered in Goscombe and Everard (2001) though useful material on the island's geomorphology in the draft report has not been included. It is recommended that MRT be encouraged to have the Geological Survey Report finalised and published. Although still of a technical nature it would suit a broader audience, including interested members of the public, than the 2001 paper.

In determining future research priorities for the island it is important that both AAD and DPIPWE promote the importance of research aimed at further understanding and documenting the significance of the World Heritage geoconservation values of the island.

Recommendations

- *Encourage research into the island's soils, hydrology, periglacial terraces and dating of cave deposits;*
- *Encourage MRT to have the Tasmanian Geological Survey Report accompanying the geological maps for Macquarie Island finalised and published.*

7.16 Environmental assessment

Section 6.3 of the Management Plan (PWS 2006) provides objectives and policies for environmental impact assessment of proposed activities or developments. Under the general policies specific references are made to take account of disturbances to wildlife or vegetation. No specific mention of geodiversity values is made in this part of the plan and it is recommended that a reference to potential impacts to geodiversity be included in the review of the Management Plan. It is also recommended that the plan review include a section on the use of natural materials, for example rock, sand or gravel, to provide clarity and limits on the use of such materials and their potential impact on the geodiversity values of the island (see also Sections 7.7 and 7.9 above).

The policy of requiring the RAA process to apply to proposals that involve landscape modification, research, management or maintenance work involving any ground-breaking, structural disturbance, or environmental manipulation of any kind is supported. It is important that potential impacts of proposals on the island's geodiversity are fully considered and assessed. Impacts to the island's geodiversity are generally irreversible and permanent in nature with geodiversity resources essentially non-renewable. Activities causing permanent degradation can be quite small scale, for instance a drill hole in bedrock will be permanent and the decision to drill into bedrock must not be taken lightly and any such proposals fully assessed with alternatives considered. The longevity and likelihood that infrastructure will not be superseded must be considered as full rehabilitation following such activities is not possible. Photo 18 shows an example of a drill hole and eye bolt mounted in Gadget Gully.

Recommendations

- *As part of all environmental assessments potential impacts on the island's geodiversity be fully assessed;*
- *In reviewing the current Management Plan, specific mention to geodiversity values is made within the environmental assessment section and should include a policy on disturbance to the island's geodiversity;*

- *That the Management Plan review also include a section on the use of natural materials for example rock, sand or gravel.*

Photo 18. Drill hole with large eye bolt supporting a steel ladder in Gadget Gully.

Photo 19. Erosion study site on the plateau east of Bauer Bay with redundant markers and erosion monitoring pins.

7.17 Removal of redundant scientific monitoring infrastructure

Substantial research has been undertaken on Macquarie Island (PWS 2006) and as part of some of these studies limited infrastructure has been installed. The majority of this is in the form of marker posts or fenced exclosures. Many of these are now redundant to the research and where this is the case then they should be removed so as not to adversely impact on the sites aesthetically. The erosion monitoring established east of Bauer Bay on the plateau by Selkirk and Saffigna (1999) is an example of an earth science study where erosion pins etc. are no longer functional (Photo 19). Many examples of exclosures dating from pre rabbit eradication studies exist across the island and should be considered for removal after consultation with researchers.

Recommendation

- *Redundant scientific monitoring infrastructure is removed from the field after consultation with researchers.*
- *A requirement for the removal of any scientific infrastructure when projects are completed should be included in approvals for research.*

7.18 Rehabilitation

Despite its World Heritage listing, Macquarie Island contains substantial and widespread areas of degraded land. The majority of this is the result of extensive past browsing and subsequent erosion and vegetation modification from the introduction of rabbits. On the Isthmus (Map 2) the AAD station and associated infrastructure by its very nature has degraded the natural landscape and there are other localised human impacts across the island associated with walking tracks and field huts. The Management Plan outlines rehabilitation objectives, policies and actions (Section 5.4). To date there has been very limited active rehabilitation works undertaken and this is not expected to change. Where land is degraded by human actions natural rehabilitation can be quite successful in restoring areas particularly in the coastal environment such as on the Isthmus. However such rehabilitation will not be effective if machinery access is still permitted. An example of this is at the three temporary helicopter pads located south of the fuel farm established as part of MIPEP. Under the eradication program these were to be rehabilitated once baiting

was completed. The areas were allowed to partly rehabilitate but are now currently being used to store station materials (Photo 20) setting back the rehabilitation process. It is important that areas targeted for rehabilitation are not subsequently disturbed but are given every chance for natural rehabilitation to proceed unhindered. Avoiding or minimising disturbance to the natural environment should be the key objective in undertaking any works on the island to reduce the need for rehabilitation in the first instance.

Recommendation

- *Areas identified for natural rehabilitation should be clearly marked or documented in order to prevent mechanical or human access that may retard the rehabilitation process.*

Photo 20. Stored material on partly rehabilitated old helipads on the Isthmus.

7.19 MIRAG

The Macquarie Island Research Advisory Group (MIRAG) is a multi-disciplinary review committee that advises on proposals for scientific and monitoring programs to be conducted on the island (PWS 2006). The membership is currently comprised of representatives from RMC, PWS, AAD and UTas. Given the island's significant World Heritage geodiversity values it is essential that geoconservation representation is maintained on the group. Currently this is the Section Leader of the Geoconservation Section of RMC, DPIPWE. As is current practice, impacts of proposed research programs on all natural values, including geodiversity must be assessed by MIRAG and this should continue.

The role of MIRAG could be expanded to be more proactive in promoting appropriate research on the island rather than just reviewing research proposals received by the group however this can only be achieved in cooperation with the AAD. The section on knowledge gaps of this strategy (Section 7.15) highlights some research priorities from a geoconservation perspective and it is clear that other disciplines have significant knowledge gaps as well, that could be proactively managed.

Given the current work load of PWS Rangers stationed on the island, work tasks, including research and monitoring activities need to be prioritised and this is currently done as part of the development of an annual PWS works program (see also Section 7.3), which is largely driven by the PWS Macquarie Island Executive Officer. It is suggested that a MIRAG working sub group be formed that can meet more regularly than MIRAG to provide structured input into management planning and activities undertaken on the island. Such a group would need to be multi-disciplinary and should include representation from the geodiversity, biodiversity and Parks management areas and would provide specific advice on impacts to the natural values of the island. This group could assist in developing priorities across the agency, identify research gaps and provide input into MIRAG.

Any AAD planning for future infrastructure needs at the ANARE base, including upgrading/replacement of existing buildings (which is currently underway), should also involve PWS as the land managers in the early stages to ensure that impacts on the natural and heritage values of the Island are considered early on in the planning process.

Recommendations

- *Geoconservation expertise continue to be represented on MIRAG;*
- *MIRAG be proactive in promoting and encouraging appropriate research;*
- *Consideration be given to establishing a MIRAG working sub group to provide structured input into management planning and activities undertaken on the island.*

8.0 Recommendations

Previous chapters of this strategy have included a number of recommendations aimed at conserving the significant geoconservation values of Macquarie Island. They are collated and summarised in this chapter grouped under general headings. The majority of recommendations relate to PWS as the land managers, though a number relate to other groups such as RMC, MIRAG and the AAD. Many of the actions identified in the recommendations are currently being employed in the island's management while some recommendations will require a change in management practice or the development of additional polices or guidelines.

The major recommendations made in this strategy can be summarised as:

- The protection of the Macquarie Island World Heritage geoconservation values remain a primary objective of the management of the island.
- PWS adopt this strategy in managing the geodiversity values of Macquarie Island.
- The strategy is used to inform the review of the Macquarie Island Management Plan.
- Geodiversity values are fully considered as part of planning and executing any management, operational or research actions undertaken and in the development of any polices that cover the island.
- Relevant earth science research on the island is continued to be facilitated.
- The interpretation of geodiversity values is given greater prominence in interpreting the natural values of the island.
- *A MIRAG working sub group is established to provide structured input into management planning and activities undertaken on the island.*
- Sites listed in the inventory of significant geoconservation sites (DPIPWE *in prep*.) are considered for listing on the Tasmanian Geoconservation Database.

In considering these recommendations PWS should work closely with the Geoconservation Section of RMC to maximise the conservation outputs for Macquarie Island's geodiversity given the limited resources available. Specific recommendations are listed in Table 3 and for reference purposes have been numbered sequentially. The recommendations have been grouped under the following general headings:

- Adoption of the Geoconservation Strategy and protection of WHA geoconservation values and geodiversity.
- Geo-interpretation.
- Research and monitoring.
- Land management activities.
- Environmental assessment.
- MIRAG.

Table 3. List of recommendations, grouped under general themes. The third column lists key agency or agencies responsible for the specific recommendation, while the fourth column gives a priority ranking for each recommendation. High (H), Medium (M) and Low (L).

Adoption of the Geoconservation Strategy and protection of WHA geoconservation values and geodiversity			
8.1	PWS adopt this strategy in managing the geodiversity values of Macquarie Island.	PWS	H
8.2	The protection of the Macquarie Island World Heritage geoconservation values remain a primary objective of the management of the island.	PWS	H
8.3	The strategy is used to inform the review of the Macquarie Island Management Plan.	PWS	H
8.4	Sites listed in the Macquarie Island inventory of significant geoconservation sites are considered for listing on the TGD.	RMC	H
Geo-interpretation			
8.4	Interpretation should emphasise that the geodiversity of the island is of world heritage significance.	PWS	H
8.5	Copies of the publication Macquarie Island (DPIPWE 2012) continue to be provided to all tourists and ANARE expeditioners that visit the island.	PWS	H
8.6	Improved training and briefing notes be developed for volunteer tourist guides to include more geodiversity information.	PWS, RMC	H
8.7	A geodiversity focused interpretive panel be designed and installed at the Razorback lookout.	PWS, RMC	M
8.8	A contemporary display board covering the island's geoconservation values is designed for permanent installation in the station mess.	PWS, RMC	M
8.9	Opportunities for on-line media interpretations of the islands geodiversity and geoconservation values are investigated.	PWS	M
Research and monitoring			
8.10	A landslip database be established and regularly updated recording current landslip activity on the island.	PWS, RMC	M
8.11	Refine the current photo monitoring program for the long term photo monitoring of erosion and vegetation change.	PWS, RMC, UTas	M
8.12	Undertake periodic erosion monitoring (for sites re-established in 2014) as part of a scheduled monitoring program.	PWS, RMC	H
8.13	Additional weather monitoring stations be located on the island to collect weather data for analysis and interpretation to provide increased information on climatic and climate change impacts on geodiversity and biodiversity.	PWS, RMC, Utas	M
8.14	Research into the *Azorella* dieback and its effect considers potential impacts on geodiversity as well as the associated plant communities.	RMC	M
8.15	Scientific sampling guidelines for earth materials from Macquarie Island be developed.	PWS, RMC	M

8.16	Administer and monitor permit condition compliance for earth science scientific research work on the island and support the continued practice of the PWS RIC going through permit conditions individually with researchers prior to fieldwork being conducted.	PWS, RMC	H
8.17	Geoconservation expertise continues to be represented on MIRAG.	MIRAG	H
8.18	Earth science research consistent with and contributing to management of the island's values is supported and in particular research into the island's soils, hydrology, periglacial terraces and dating of cave deposits be encouraged. MIRAG be proactive in promoting and encouraging appropriate research.	RMC, MIRAG	H
8.19	MRT be encouraged to have the Tasmanian Geological Survey Report accompanying the geological maps for Macquarie Island finalised and published.	RMC, MRT	M
8.20	The assessment of any research projects to include an assessment of potential trampling damage as part of the overall project assessment.	PWS, RMC	H
8.21	A requirement for the removal of any scientific infrastructure when projects are completed should be included in approvals for research, and if warranted a bond set to cover the cost to remove.	PWS, RMC	M
Land management activities			
8.22	Provisions of the Nature Conservation Act 2002 are actively enforced on Macquarie Island to prevent the illegal relocation or collection of rocks.	PWS	H
8.23	An assessment by a coastal engineer be made of the current coastal hardening at the Isthmus and if it can be removed without further damage to the coastline that the blocks be removed.	PWS, AAD	H
8.24	Advice from a coastal engineer be sought before any new coastal engineering works are considered on the island.	PWS, AAD	H
8.25	High standards of biosecurity be rigorously maintained for the Island.	PWS, AAD	H
8.26	Any proposed introduction of biota to the Island be comprehensively assessed and the potential impact on the island's geodiversity, in particular the soil, be included in any assessment.	PWS, RMC	H
8.27	Redundant scientific monitoring infrastructure be removed from the island after consultation with researchers.	PWS	M
8.28	Areas identified for natural rehabilitation should be clearly marked or documented in order to prevent mechanical or human access that may retard the rehabilitation process.	PWS, AAD	H
8.29	The current Management Plan be augmented with a policy that covers the use and extraction of natural materials on the island. Until this has been done any excavations or quarrying of material should be covered through the RAA process and guidelines as noted in 7.7 be followed.	PWS, RMC	M
8.30	That consideration is given for declaring SMAs to protect specific geoconservation values if they are considered to be under threat from visitation	PWS	M
8.31	Critical fuel infrastructure is maintained and safe operating procedures adopted to minimise risk of future fuel spills and that remediation works at the Fuel Farm and Main Powerhouse continue with agreed to end point targets established.	AAD, DPIPWE	M
8.32	The old tip site is regularly monitored with the PWS RIC consulted prior to any works being conducted to remove or bury loose or exposed material.	PWS	M

8.33	Guidelines be developed and adopted to manage any further hydrocarbon contaminated soils that become exposed during construction activities or via erosion.	AAD, DPIPWE	M
8.34	The 2001 Walking Strategy be reviewed to guide current Walking Track management on the island.	PWS	M
8.35	Walking track management and hardening should primarily be undertaken to protect the environment rather than provide for walker comfort.	PWS	H
8.36	Any use of local materials for track works is fully assessed prior to its use with special reference to potential impact on geoconservation values.	PWS	H
8.37	Track reroutes, are fully assessed and considered before implementing.	PWS	H
8.38	Short term track management decisions need to consider the significant change in walking track usage following the end of MIPEP.	PWS	M
8.39	A more permanent and less labour intensive solution to track marking is investigated and introduced.	PWS	M
Environmental assessment			
8.40	Potential impacts on the island's geodiversity be fully assessed and part of all environmental assessments.	PWS, AAD	H
8.41	In reviewing the current Management Plan, specific mention to geodiversity values is made within the environmental assessment section and should include a policy on disturbance to the island's geodiversity.	PWS	M
8.42	The Management Plan review to include a section on the use of natural materials for example rock, sand or gravel.	PWS, RMC	M
8.43	Ensure AAD activities on the island that have the potential to impact on geoconservation values comply with any relevant permit conditions or provisions under the Nature Conservation Act 2002, the National Parks and Reserves Management Act 2002, the Macquarie Island Nature Reserve and World Heritage Area Management Plan 2006 and this strategy.	PWS, AAD	H
MIRAG			
8.44	A MIRAG working sub group is established to provide structured input into management planning and activities undertaken on the island.	PWS, RMC	H

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Appendix 1 Geoconservation extract from Management Plan

The following is section 5.2 from the *Macquarie Island Nature Reserve and World Heritage Area Management Plan 2006* and lists the objectives, policies and actions relating directly to geoconservation.

Geoconservation

Macquarie Island is a geological wonder of World Heritage value (see Section 3.6). The rocks provide the foundation for the development of the landforms, soils, plants and animals that, as a whole, create one of the truly remarkable places on Earth. It exemplifies the importance of appreciating the entire environment when considering conservation and protection of its values. The diversity of earth features or geodiversity and therefore biodiversity makes Macquarie Island an island of unique natural diversity. It is a site of global geoconservation significance.

Objectives –Geoconservation

The objectives for geoconservation in the reserve are to:

- protect WHA geoconservation values;
- protect, maintain and monitor geodiversity;
- protect, maintain and monitor sites of geoconservation significance;
- maintain natural rates and magnitudes of change in earth processes;
- avoid harmful impacts on geoconservation values;
- encourage geoscientific research that is consistent with the values for which the area was nominated for World Heritage listing; and
- maintain a high standard of geointerpretation for visitors including up-to-date booklets and other interpretive material as required.

Policies

- Potential adverse impacts on geodiversity and earth processes will be assessed when planning any development or action, including land rehabilitation and stabilisation (see Section 6.3).
- Management practices and development will avoid or otherwise minimise impacts on the integrity of sites of geoconservation significance.
- Scientific research will be conducted in a way that avoids adverse impacts on geodiversity, sites of geoconservation significance or the aesthetics of significant exposures. Geoscientific research must be consistent with the World Heritage values for which the area was nominated and must be justified in this context.
- The use of coring devices and other mechanical sampling devices for geoscientific research will not be permitted unless special permission is provided. Any approval will be controlled and monitored. Similar conditions will apply to the use of explosives for geoscientific or management purposes.
- All scientific applications for research, including geoscientific research, must be assessed and approved as set out in Section 6.8 of this plan.

Actions

- Prepare a geoconservation management strategy that identifies sites of geoconservation significance, maps locations accurately and provides management recommendations.
- Ensure that scientific collection permits have appropriate conditions to avoid or minimise impacts of collecting on geological outcrops and other geological, geomorphological or soil features.
- Closely assess, scrutinise and monitor scientific permits in order to ensure impacts on geodiversity and World Heritage values are avoided.
- Assess and, if appropriate, monitor human impacts on soils and landforms.
- Assess and, if appropriate, monitor the impacts of global climate change on coastal and periglacial features and landforms.

- Ensure that high-quality interpretation of the World Heritage values of the reserve is provided to Australian Antarctic Program (AAP) personnel and visitors.