Helictite, (2021) 46**:** 47-64

Investigation into the geoconservation significance of the Lost World boulder caves, Mt Arthur, Tasmania

Sarah McNab[1]

[1] Mundaring, Western Australia. sarah.mcnab@hotmail.com

Abstract

This report outlines the geoconservation significance of the Lost World boulder caves of Mount Arthur in Wellington Park, Southern Tasmania. The study carried out an investigation into the geo-diversity and the geoconservation significance of the site, analysed current and possible future threats to the site, and also recommended some potential management approaches for the site. It is hoped that this study will motivate further research into the role of these caves as a unique habitat, whilst also prompting the application of more targeted environmental management approaches to the area.

1.0 Introduction

Geological and geomorphological conservation, or geoconservation, is the effort to manage change in geodiversity - the diversity found within abiotic nature. Although geoconservation has been recognised as being of some importance for over 100 years, there has always been an imbalance between the biotic and abiotic elements of nature when it comes to conservation policy and practice (Gray 2004). Conservation of geodiversity is in itself important, as many of the processes that formed the present landscapes are now inactive. Once disturbed, these sites may never recover (Pemberton 2007).

Geomorphology controls physical conditions, which in turn control biodiversity. Management of biodiversity is therefore highly dependent upon management of the landscape on which it resides. The emergence of the geoconservation concept in recent decades has prompted many environmental management bodies to focus increased attention on research into the geological and geomorphological aspects of the sites that they are managing, thus adopting a 'total ecosystem perspective' (NRM South 2003; Pemberton 2007).

1.1 Site Description

1.1.1 Location and access

The study site is situated approximately 9 km directly west of the city of Hobart on Mount Arthur and is easily accessible from The Big Bend on Pinnacle Road via the Lost World walking track (see Figure 1).

The walking track leads to a spectacular lookout at the top of a natural amphitheatre formed by dolerite cliffs. At the base of this escarpment lies an extensive boulder field which can be accessed via a rough track created by rock climbers that leads down the northern margin of the cliffs. There is also a less complexly developed boulder field situated above the cliff line (see Figure 2). Numerous caves are present in the boulder fields, with many chambers connected by easily accessible passages.

The Lost World lies within Wellington Park, which is reserved under the *Wellington Park Act 1993*. It is not officially classified as a national park under Tasmanian legislation, though the applicable regulations are virtually identical. The reserve is managed by the Wellington Park Management Trust and local city councils, one aim of management being preservation (Wellington Park Management Trust 2010).

1.1.2 Previous studies

Although the site is readily accessible and lies within the Wellington Park, there has been very little investigation or detailed recording of its features.

Skinner (1973) appears to be the only person to previously attempt to document any of the caves in detail, surveying three: "Lost World Grotto" (305 m long), the 360 m "Dolerite Delight" (which he suggested might be joined) and "Campers Cavern" (135 m), and referring to a fourth as "only about 100 metres long". Skinner noted the existence of *Hickmania,* another (unidentified) spider and a cave cricket he thought was of the genus *Parvotettix.* Unfortunately, lack of locational details has not,

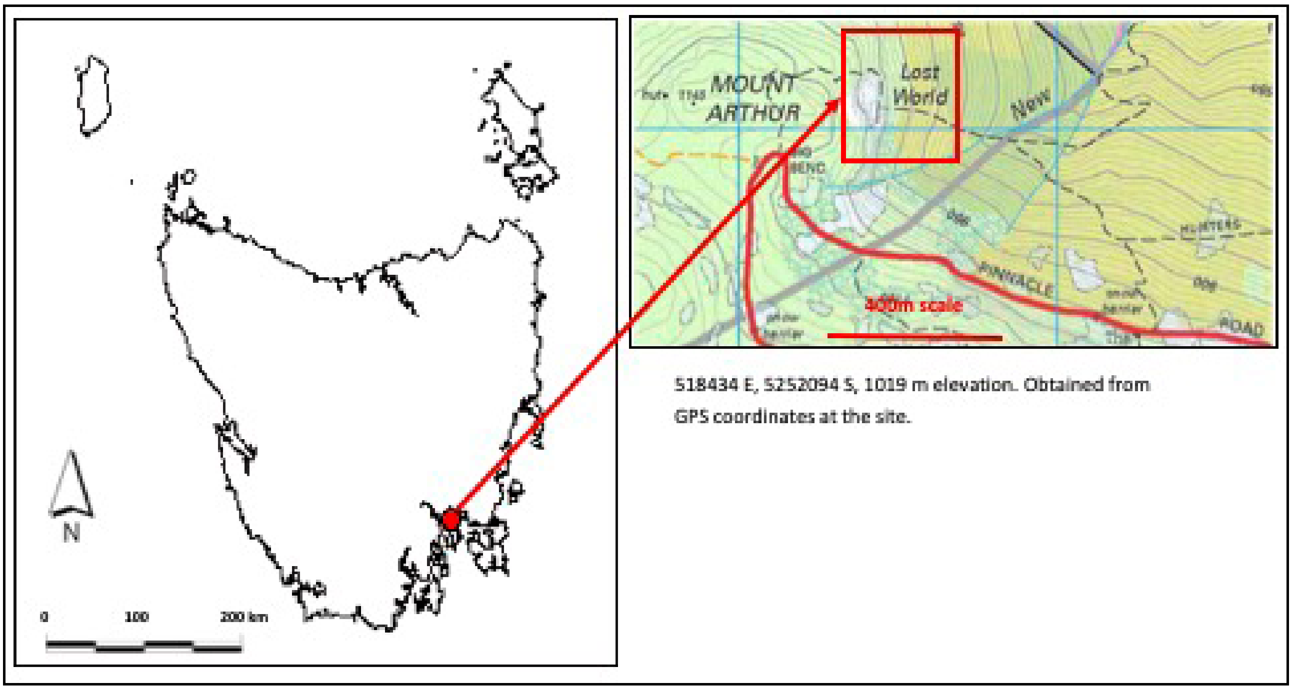


Figure 1. Map of Tasmania, showing the approximate position of the study site, together with an enlarged (1:25000) topographic map with coordinates and elevation. Topographic map obtained from LISTmap version 1.2, Department of Primary Industries, Parks, Water & Environment, accessed 19th March 2010 <www.thelist.tas.gov.au/listmap>.

to date, facilitated identification of these particular caves. They may, in part, overlap the caves described here.

Banks (1981, quoted in Dixon 1995) attributed the lack of major disruption among the fallen columns to "paucity of fractures across the columns, to lowness of the cliff in the early stage of its development during the Last Ice Age and to a cushioning effect of a thick bed of snow in the hollow adjacent to the cliffs supporting and slowly lowering the columns after they were wedged out."

Kiernan noted the existence of this substantial system of talus (boulder) caves in discussing talus, joint and fault caves in Tasmania (Kiernan 1982).

Bradbury included 'Lost World boulder caves' in his inventory of sites of geoconservation significance in Tasmania. He regarded them as 'Outstanding for Tasmania' (Bradbury 1995, p. 27).

In 1995, Dixon included the 'Lost World dolerite boulder cave complex' among 'Additional features of geoconservation significance which should be considered for National Estate listing'. He considered the cave complex might be significant at the national level, given the lithology and form.

Leaman (1999) was impressed by the site, suggesting its "tumble of dolerite columns" were the result of ice activity and, possibly, seismic activity. He described the "extensive caverns beneath the jumble" as being due to "removal of much of the debris which can accumulate between boulders" but refrained from further comment, except to warn "this is a dangerous and awesome place".[1]

The geomorphology of the study site is strongly controlled by the geology of Wellington Range, which is comprised primarily of dolerite emplaced during the Jurassic period approximately 170 Ma BP (Seymour and others 2007). This dolerite is an intrusive igneous rock found extensively throughout Tasmania. It originally intruded the surrounding host rock as a magma at a temperature of approximately 1100°C. As it cooled and crystallised, the rock contracted, causing jointing within the body of rock and forming the polygonal columns that are exposed in several places on Mount Wellington and Mount Arthur. The boulder deposits situated at the base of the dolerite cliffs of the study site represent a landscape created by slope failure and mass wasting. Figure 2 shows the strong trend in the orientation of the collapsed dolerite columns, suggesting a mass wasting event that caused simultaneous toppling of the weathered columns away from the cliff. This

1 Editorial addition: Lost World Boulder Caves has been listed as a geoconservation site in the Tasmanian Geoconservation Database (accessed through https://www.naturalvaluesatlas.tas.gov.au/#GeositePage:2224) where it is stated that there are passages in excess of 300 m length and 40 m depth. The (official) Statement of Significance for this site is: "Notable example of type, the most extensive network of boulder caves known in Tasmania" (the listing originated in March 1995; accessed 26 June 2021)

event has preserved cracks and crevasses within and between these dolerite columns which now present as boulder caves.

Boulder caves may incorporate morphologies resembling karst, and may even have a predominance of subsurface drainage through conduit-type voids, but they differ from karst caves by lacking long-term evolution by solution and physical erosion.

1.2 Aims

The aim of this report is to assess the geoconservation significance of the Lost World boulder caves. The caves are the most extensive of their type known in Tasmania (Wellington Park Management Trust 2005), and as such have considerable potential geoconservation significance. By investigating the physical conditions of these caves, their role as a special habitat can be better understood. This study will broadly document the geodiversity and biodiversity of the cave systems. These data will provide greater understanding of potential threats to the site, allowing a targeted management plan to be utilised to protect these unusual karst-like systems.

1.3 Methods

1.3.1 Cave mapping

A limited but concise cave mapping exercise was carried out in one of the largest cave systems within the boulder field at the base of the cliffs (see Figure 2). These particular caves were chosen for their ease of access, representative morphology and large extent. Three people were required in the cave system at all times to carry out the mapping exercise; two people acted as surveyors, and the third person acted as the sketcher. Surveyors carried a laser range finder to obtain accurate distance measurements, and a clinometer to measure slope angles. The mapping exercise encompassed cavern and passage morphology, as well as noting signs of anthropogenic disturbance. Cave surveying and sketching was conducted in a manner that conforms to the Australian Speleological Federation's Cave Survey and Map Standards (Grimes 1997).

1.3.2 Identification of geodiversity values

Identification of geodiversity values was achieved with the use of a table adapted from Gray (2004, pp. 131-132), which lists a summary of common geodiversity values and examples of each. The table was modified to suit the site being surveyed, and a copy given to each volunteer who visited the site during data collection field trips. Each volunteer attempted to identify as many values as possible whilst at the site. Their responses to the values listed were compiled, and are summarised in section 4.1. This was a valuable exercise as it encompasses the views and opinions of people from different backgrounds and with differing attitudes towards the subject of the study. Whilst the study would have ideally included more people, the opinions given by the available volunteers are believed to be sufficient.

Figure 2. Photos of the study site. The photo on the left shows the two scree deposits surveyed, separated by jointed dolerite cliffs. The photo on the right, taken from the top of the cliff line, shows a strong trend in the orientation of the collapsed dolerite columns. Scale bars shown are approximate.

1.3.3 Analysis of threats

Analysis of current and future threats to the study site was carried out with reference to Murray Gray's text *Geodiversity: valuing and conserving abiotic nature* (2004). Gray dedicates an entire chapter to common threats that geodiversity faces. A brief insight into current threats was achieved through observation of current physical conditions at the site, such as signs of anthropogenic disturbance.

1.4 Limitations and challenges

This investigation was highly dependent upon volunteer availability and weather conditions. For safety reasons, at least five people were required at the site during data collection field trips. This allowed the three people required for mapping to enter the caves, with at least two people remaining on the surface to carry out extra data collection and to act as a safety presence in the event of an accident or emergency. Weather conditions were another limiting factor during this study, as they impact significantly on the safety of the study site. Mount Wellington commonly experiences sudden changes in weather conditions, with field trips being postponed due to rain and fog on several occasions. Slippery conditions caused by rain or snow proved to be dangerous, as considerable rock-hopping was required along the access route.

The most significant challenge when conducting this study was the lack of both theoretical and empirical knowledge regarding the site. Apart from the brief listings and survey mentioned in section 1.1.2, the Lost World has never been comprehensively documented, so there was little opportunity to consult literature during planning stages or prior to data collection. The most appropriate literature offered insights into comparable environments, but nothing provided preparation for the overwhelming amount of information potentially available for collection at this very complex study site. It was easy to become 'bogged down' in excessive data collection. As such, compilation of this report became focussed upon giving a broad overview of the site, leaving scope for more specialised, targeted studies in the future.

2.0 Cave Environments

Caves are complicated landforms both structurally and environmentally. Environments outside and inside the cave are highly differentiated due to their structural complexity (Russell and MacLean 2008). This section will outline the geodiversity of the Lost World by describing the geomorphology of the site, as well as suggesting several possible formation scenarios.

2.1 Cave morphology

There are two primary boulder fields at the study site. While caves within each deposit show many similar characteristics, there are significant structural differences between the two boulder deposits. This is primarily caused by their different modes of formation (see section 2.2).

2.1.1 Cave systems above the cliff line

The boulder field situated above the cliff line consists of dolerite blocks up to approximately 5 m in size, with the majority being 1 - 2 m in size. This deposit shows signs of long-term stability, with all block faces observed being both chemically and physically weathered (though not extensively), and most blocks being covered with lichens and mosses. Boulder caves in these deposits are abundant, but lack both the vertical and lateral extent, and the structural integrity of those in the boulder deposit at the base of the escarpment. The structure of these caves is controlled by the various and chaotic orientations of the blocks within the deposit, and hence of the resulting interstices between these blocks. With no preferred orientation of the blocks within this deposit, the caves can be very difficult to navigate. Caves also showed a far greater tendency to be isolated from each other above the cliff line than those in the amphitheatre where more consistent block orientations allowed greater continuity of interstitial space.

The cave systems above the cliff line are well ventilated and contain a significant diversity of cave fauna (see section 3.1). Despite a short-term lack of rain preceding the first data collection field trip (conducted in March), the caves in this area appear consistently damp and humid. Moss is present on many moist boulder faces, and mud is common at the base of the caves. This suggests that these cave systems are likely to provide a damp environment even throughout the drier months of the year, whilst also discounting the possibility of a significant drainage system with high volumes of water flow, as this would have washed away the mud.

2.1.2 Cave systems below the cliff line

In contrast to the deposits above the cliff line, those situated at the base of the escarpment contain dolerite blocks up to 20 m in size, and possibly even larger. The morphology of this deposit is primarily controlled by the form of the polygonal dolerite columns of the cliff, as it has obviously been created during a toppling process in which the columns toppled simultaneously, thereby providing lateral support to one another that allowed the columnar form of adjacent columns to be retained (see Figure 2). This deposit shows the same signs of long-term stability as discussed in section 2.1.1, with the addition of trees growing from the interstices between rock masses. Boulder caves within this deposit are very well developed, with significant lateral and vertical extent, as well as considerable connectivity between caverns. The morphology here begins to resemble that of fissure caves, with parallel walls and narrow passages (Striebel 2008), as a result of the strong structural alignment of the dolerite columns. The structural integrity of these caves is robust due to the structural control of the collapsed columns.

The cave systems at the base of the escarpment have multiple entrances, and are very well ventilated. A significant diversity of cave fauna occurs in these systems (see section 3.1), which are very damp and humid. The floors of most passages in these systems consist of mud and gravel (see Figure 3), while the floors of caverns are typically covered in rock piles and large boulders. Very little organic matter is present within the caves.

Figure 3. Narrow passage, showing the entrance of a near-vertical shaft to a lower level, and the typical vertical walls controlled by the structure of the toppled boulders. This image also tries to show the damp, muddy floors that contain high amounts of gravel and cobblestones.

Cracks and crevasses between the dolerite blocks are controlled by the orientation of the collapsed columns. The largest caverns within this boulder field occur where a column has fallen onto uneven ground and formed a void, or where larger blocks have fallen subsequent to the columns. Most passages between caverns are controlled by the structural planes of the columnar jointing (east-west), or by the strike of the cracks within the columns, which is perpendicular to the orientation of the columnar jointing (north-south). Caverns are up to 6 m in height, ranging from a few metres in width and/or length to over 30 m. Passages are typically 1- 2 m wide, with vertical walls and a planar roof (see Figure 3).

The cave systems surveyed and mapped for this report, informally named ‘Multistorey Cave’ and ‘Lost World Labyrinth’, have several levels that are controlled by the way in which the columns fell. The maps (Figures 4, 5 and 6), provide an insight into two of the largest and most easily accessible cave systems at the study site. These cave systems are highly representative of the area, displaying most of the geodiversity values discussed in this report.

2.2 Cave formation scenarios

The chaotic arrangement of the boulder deposit above the cliff line suggests a gravity-driven mass movement event, with the boulders originating from upslope (allochthonous). The structural trends of the caves below the escarpment suggest a more complex origin, formed by toppling from the adjacent cliff face (autochthonous). While the scope of this project did not allow for thorough investigation into the exact mode of formation of these caves, literature review has revealed some possible scenarios that may suit the site. The first scenario, inspired by Colhoun’s research into periglacial landforms and deposits in Tasmania (2002), involves *in situ* frost and ice wedging of the dolerite columns on the cliff face. This process involves continual expansion and contraction of water trapped between the joints in the rock as it freezes and thaws in this elevated environment. Freeze/thaw cycles do not account for the seemingly simultaneous collapse of the columns though, so may only be considered a contributing factor, rather than the primary cause, of the cave formation.

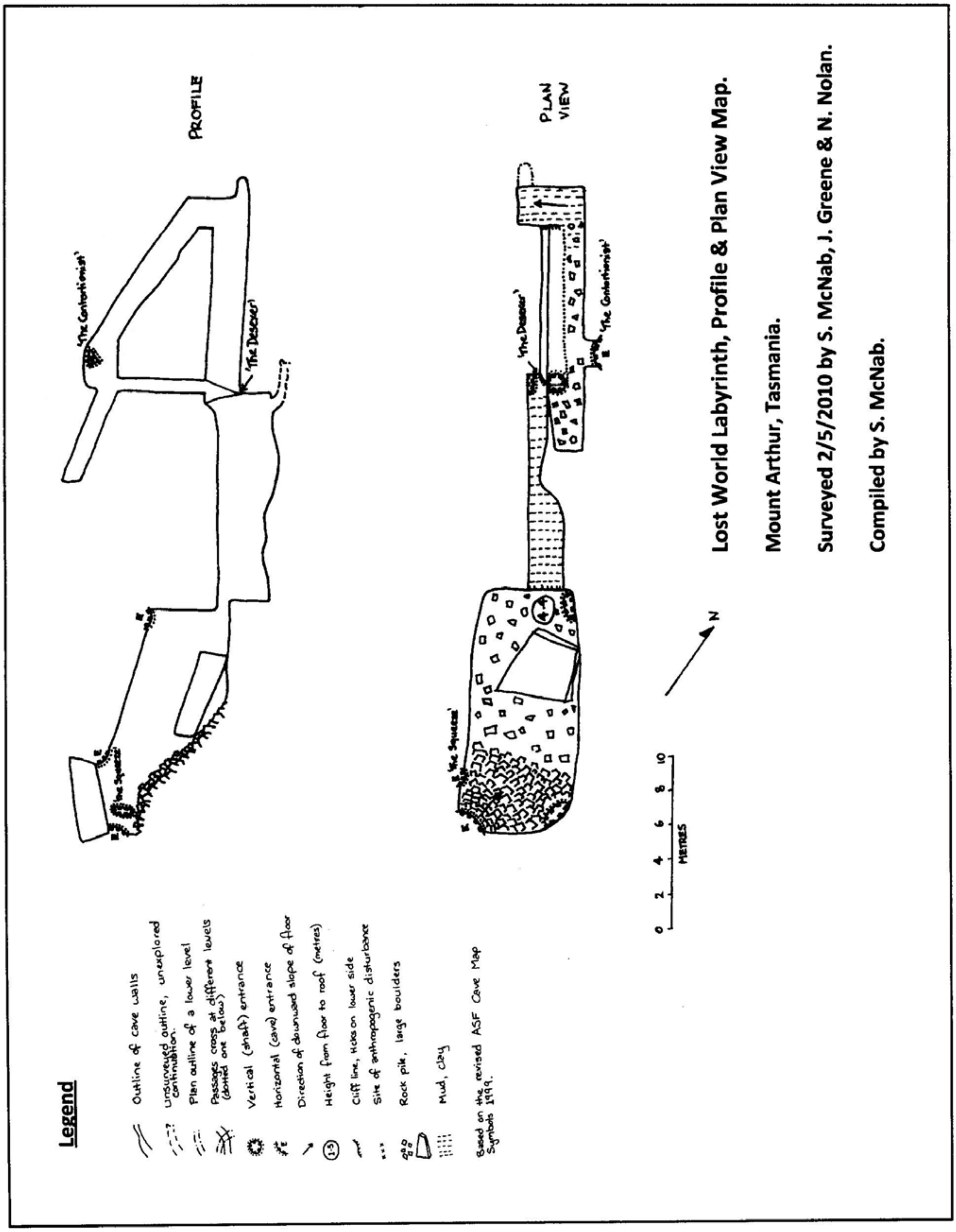
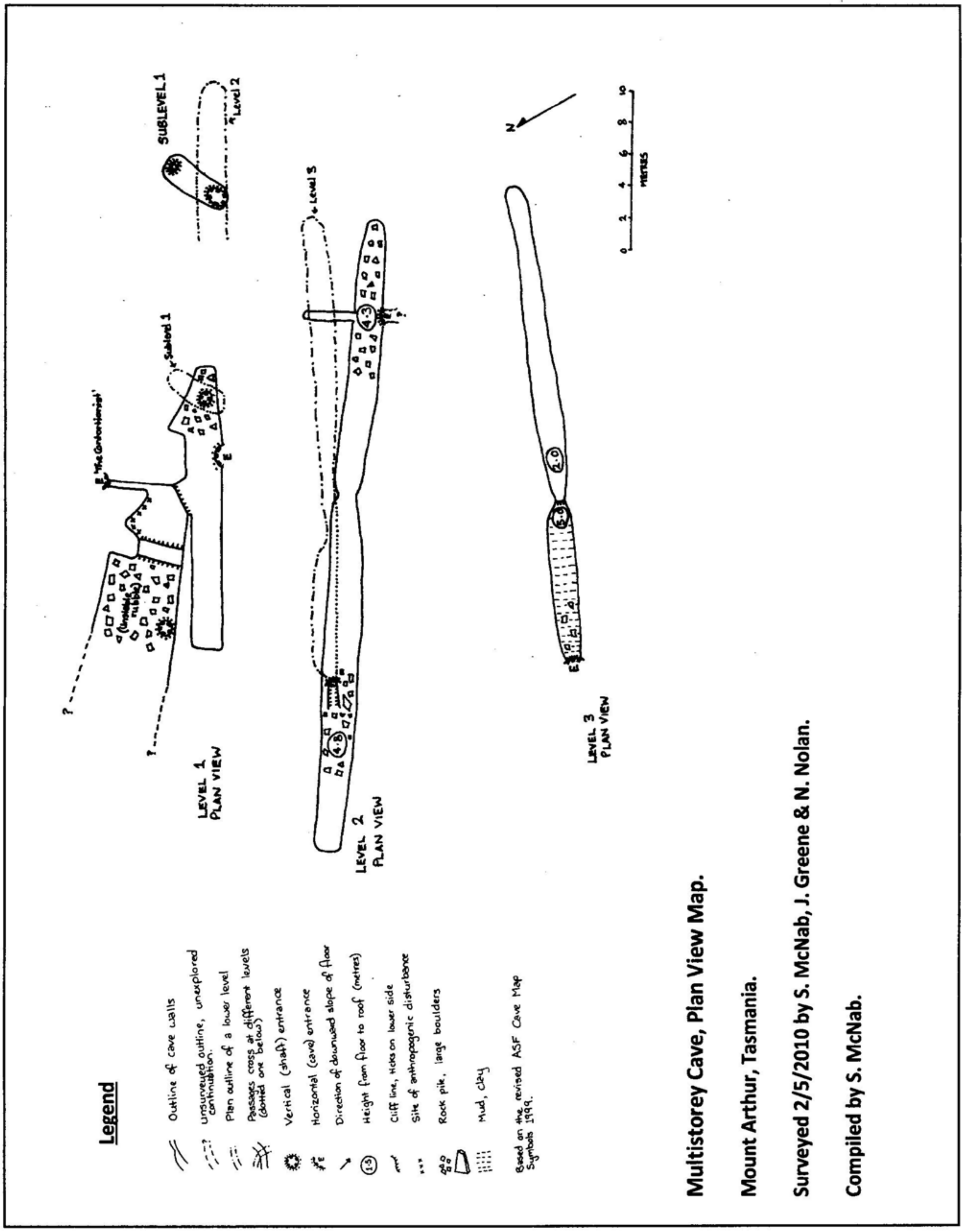


Figure 4. Plan and profile / longitudinal section of Lost World Labyrinth, Mount Arthur.

Figure 5. Plans showing three levels in Multistorey Cave, Mount Arthur.



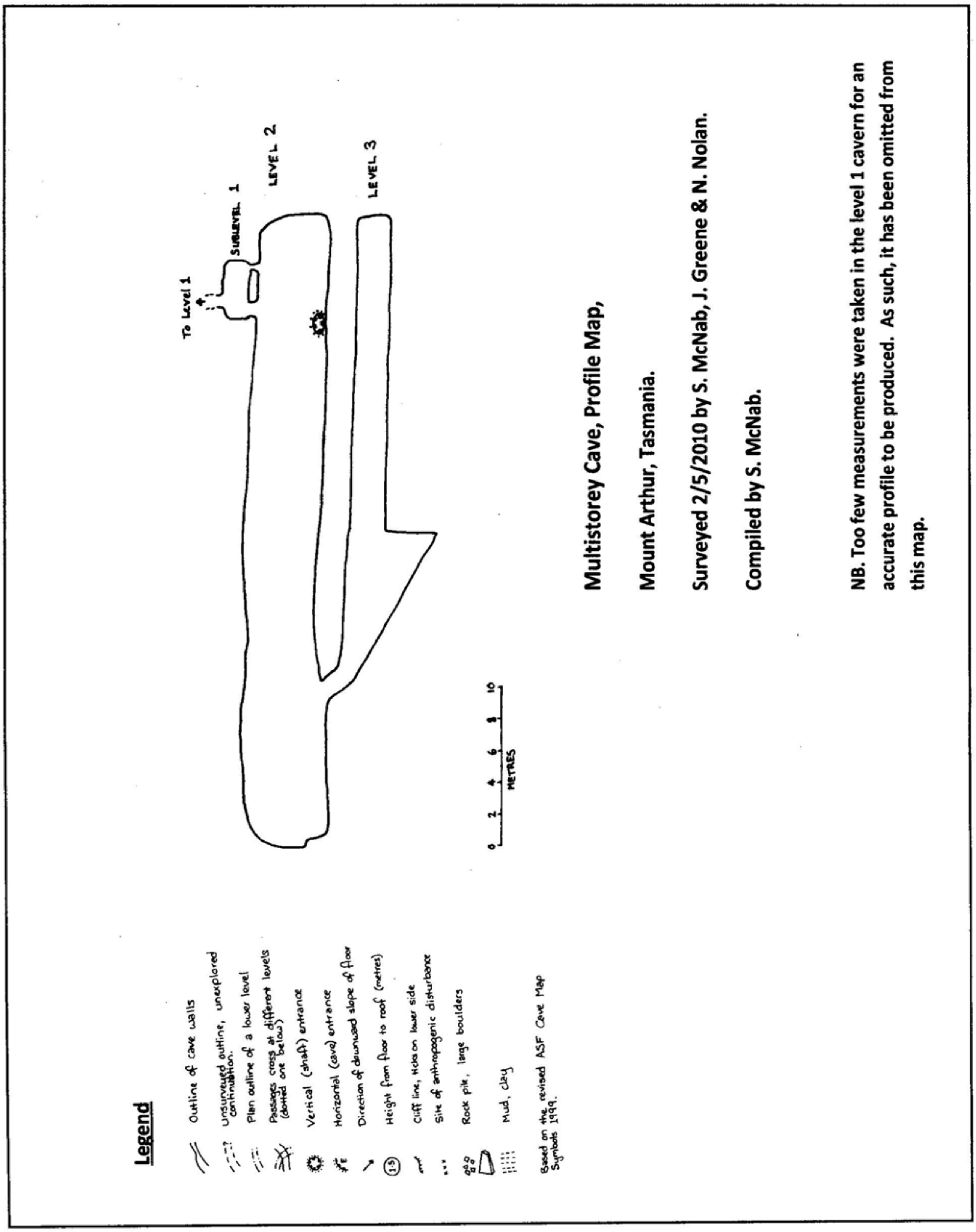


Figure 6. Profile / longitudinal section of Levels 2 and 3 of Multistorey Cave, Mount Arthur.

The second scenario is partially based on the proposed origin of the extensive talus caves of Sweden, described by Sjoberg (1986). Sjoberg describes talus (or boulders) on collapsed mountain slopes creating "more or less vertical caves with big grottos connected by narrow passages" (1986, p. 396), concluding that the stacking of the boulders is evidence of momentary collapse caused by a neotectonic event. A similar earthquake event is not impossible at the study site, given the fault-bound geological setting of Mount Wellington (Stacey & Berry 2004), and may have caused the cliff face (already weakened by jointing within the rock) to collapse in a single event to form much of the boulder field at its base.

The final scenario, suggested initially by Kevin Kiernan (pers. comm.) and developed with reference to Caine (1982, 1983) and Smith (2007), involves basal slipping of the dolerite on the lubricating sedimentary rocks below it. Smith describes caves on Pilchers Mountain in NSW that formed from massive sandstone block separation aided by "the presence of underlying shale and coal bands which acted as slip planes when lubricated by groundwater" (2007, p. 15). Colhoun (2002) explains that the rock unit underlying the dolerite sill on Mount Wellington is composed of weak sandstones and mudstones that are conducive to slope failure. Considering the damp environment of Wellington Range, a scenario similar to that proposed by Smith (2007) is plausible.

3.0 Biodiversity

Subterranean habitats are characterised by complete darkness in most cases, resulting in the absence of green plant life (Eberhard and others 1991). The extent of microclimatic variation is controlled by a combination of cave structure and the physical conditions within the caves. Multiple entrance caves, such as those of the Lost World area, have highly variable microclimatic conditions due to increased ventilation, allowing constant exchanges with the outside environment (Russell and Maclean 2008). Sources of nutrition are scarce, meaning that only highly specialised species are able to survive in subterranean environments (Eberhard and others 1991).

Cave ecosystems are generally small, highly specialised, and relatively isolated, resulting in an island-like geographic range of cave-dwelling species (Eberhard and others 1991). This attribute lends itself to endemism, which is a significant factor in the conservation of cave biology. The functional role of caves as an ecosystem is an important value of geodiversity, and this section will briefly outline the biodiversity observed at the Lost World that may increase the geoconservation significance of the site.

3.1 Fauna

The classification of cave-dwelling fauna, or cavernicoles, is based on their association with various zones within the cave (Doran and others 1997):

- *Troglobites* are adapted to subterranean environments, and cannot survive outside them.
- *Troglophiles* typically live and breed within the cave environment, but are not confined to it.
- *Trogloxenes* regularly inhabit caves for shelter, generally staying close to the entrance as they require access to the surface to feed.
- *Accidentals* are surface-dwelling animals that cannot survive in a subterranean environment, but unintentionally find themselves trapped within a cave system.

Cavernicoles observed at the Lost World consisted only of invertebrates. The scope of this investigation did not allow for further research into evidence of vertebrates.

3.1.1 Invertebrates

The most abundant cavernicole observed within caves at the Lost World is a large arachnid, confirmed by Niall Doran (pers. comm.) to be the Tasmanian Cave Spider (Figures 7 and 8). *Hickmania troglodytes* is a troglophile (Doran and others 1997, 1999), primarily residing in the entrance and twilight zones, and is known to inhabit caves on Mount Wellington (Eberhard and others 1991). *H. troglodytes* is the largest spider in Tasmania, and is endemic to the state. The species displays physical traits of both primitive and advanced spider groups, and as such is considered to be highly significant in evolutionary terms. Doran and others (1999) also recognised the species as being ecologically important as a top-level cave predator, and zoogeographically important, as it has been discovered that its closest relatives are found in South America. This spider is the only known species in the *Hickmania* genus (Doran and others 1997).

Figure 7. *Hickmania troglodytes*, found in the twilight zone of Multistorey Cave. Maximum leg span of approximately 15 cm.

Figure 8. *Hickmania troglodytes*, found in the twilight zone of a talus cave above the cliff line, with a maximum leg span of approximately 18 cm.

H. troglodytes is particularly susceptible to any alterations in the availability of food. As these spiders feed primarily on crickets of the genus *Micropathus*, which are also found in the Lost World boulder caves, food availability is highly dependent upon events outside the cave, as that is where *Micropathus* feeds (Doran and others 1997, 1999). External conditions and disturbances can therefore indirectly affect the survival of the Tasmanian Cave Spider.

Cave crickets are widespread in Tasmanian caves, with the *Micropathus* genus most common in the western and southern parts of the state that receive more rainfall. Most cave crickets are omnivorous, sourcing their food from outside the cave system. *Micropathus* is endemic to Tasmania (Eberhard and others 1991). *Micropathus tasmaniensis* was recorded from a "fissure cave in dolerite, Mt. Arthur" (Richards 1968); it was collected in August 1967 by A. Goede. Niall Doran (pers. comm.) believes the cricket shown in Figure 9, observed by us in several caves at the Lost World, to be a species of the *Micropathus* genus. This appears to be a reasonable assumption, given earlier records and the presence of *H. troglodytes*, whose primary food source is *Micropathus* spp.

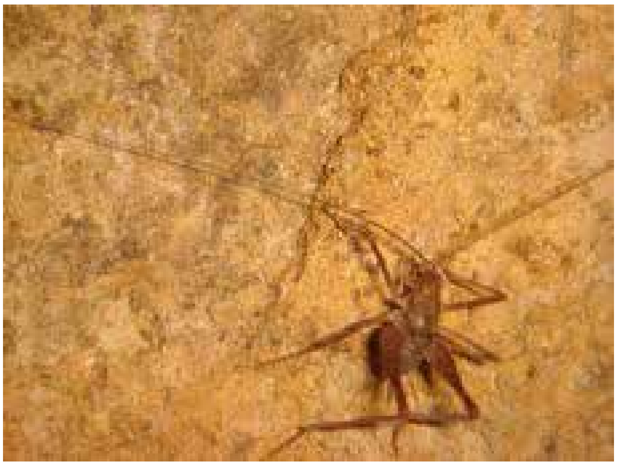


Figure 9. Unidentified specimen of the *Micropathus* genus, found in the twilight zone of Multistorey Cave.

Tasmanian glowworms are the larval stage of the fungus gnat *Arachnocampa tasmaniensis*, which is endemic to Tasmania (Driessen 2009, 2010; Eberhard and others 1991). Larvae hatch in spring and summer, emitting bright blue light and producing silk threads covered with droplets of sticky mucus to catch their prey (Driessen 2009, 2010). *A. tasmaniensis* is not confined to cave systems, but also occurs in moist and sheltered surface habitats such as forests. The species is most commonly found near the entrances to stream caves (Eberhard and others 1991), which is why it was a surprise to observe them in one of the caves above the cliff line at the Lost World (see Figures 10 and 11). Situated on the base of a damp boulder approximately 10 m below the surface in the twilight zone, the glowworms are luminous, and their silk threads are easily observable. The presence of *A. tasmaniensis* at the study site makes preservation of the surrounding forest essential, because it provides additional refuge and allows continuous colonisation of the caves (Eberhard and others 1991).

3.2 Flora

Photosynthesis depends upon the presence of light, so the absence of light within cave systems means that the vast majority of plant species are not able to survive in this environment. While there are consequently no plant species entirely unique to the subterranean environment, some surface-dwelling plant types are able to adapt to living in

Figures 10 & 11. *Arachnocampa tasmaniensis* colony found in the twilight zone of a boulder cave above the cliff line.

Figure 12. Shaft-type cave entrance, characterised by a depression in the boulder field, and colonised by a variety of plant species. High moisture levels and ample shade provide favourable conditions for fern species, which are the dominant plant type in these environments at the Lost World.

a cave system. Common subterranean plant types include fungi, cyanophyceae and algae, as well as mosses, liverworts and ferns typical at the entrances of caves (Vandel 1965). While mosses and lichens are common around the entrances, the only plant type present within the deeper reaches of the cave systems at the Lost World is algae. Algal growths are common on consistently damp cave walls in the twilight zone, and present in caves both above and below the cliff line at the study site, though not in significant amounts in the deeper reaches experiencing total darkness.

The role of the Lost World boulder deposits as a habitat for woody shrubs and several tree species is a research topic beyond the scope of this report, however the high moisture levels held by these deposits may prove to play a significant role in the distribution of several plant species. Many eucalypt and myrtle species are concentrated in damp depressions throughout the boulder fields, with the entrances to caves providing a moist environment inhabited by a vast diversity of species, particularly ferns (see Figure 12). Myrtle clusters are concentrated along the base of the cliff line, while eucalypts are more evenly spread out in the landscape. These trends could prove to be significant. Further research is required in· this area.

4.0 Geodiversity and Geoconservation

4.1 Geodiversity values

Geodiversity can be valued in a number of ways, from encompassing an entire community's attitude, to being valued by a single individual. Gray (2004) describes geodiversity as being valued intrinsically, culturally, aesthetically, economically, functionally and educationally. Table 1 outlines the values that I believe to be applicable to the Lost World boulder caves, and those identified by study volunteers.

As with any landscape, the Lost World should be valued for its integrity and right to existence. The geological processes involved in the formation of this landscape are no longer active as Tasmania has become a relatively tectonically and geologically stable land mass. The physical processes that contributed to the morphology of the landscape, such as gravity-driven mass wasting and slope failure, are still active. However, this study indicates that the landscape shows signs of long-term stability, hence if it were to be artificially altered or damaged in any way, recovery over a human time scale is likely to be unattainable.

Table 1. A summary of geodiversity values that are applicable to the study site, and a brief explanation of each. Adapted from Gray (2004, pp. 131-132).

Value Type	Specific Value	Explanation of Value
Intrinsic Value	- Intrinsic and existence value	The landscape has integrity in its own right (NRM South 2003a,b). If disturbed, recovery may be unattainable due to the time scale of the natural processes that maintain the landscape, and the sensitivity of the geosystem and ecosystem as a whole.
Cultural Value	- Spiritual	While the exact link of the study site with Tasmania's Aboriginal cultures is unknown, their spiritual beliefs and understandings create an important connection to the land that must be considered when assessing the geodiversity of this site. This is outside the scope of this project.
	- Sense of place	Local landscapes are an important aspect of contemporary communities, playing a significant role in our sense of place and in our health (NRM South 2003a). Individuals' attachments to the landscape stem from interrelationships between aesthetic values, cultural values, intrinsic values, and functional values. Areas where the landscape is being heavily degraded have an ill effect on the health of some residents, and can cause anxiety amongst communities that leads to a loss of sense of place (NRM South 2003a; Gray 2004)
Aesthetic Value	- Local landscape	Local landscapes often have high visual appeal. Simply referred to as "The Mountain" by most residents, Mt Wellington (and by association Mt Arthur) is one of the most prominent and aesthetically pleasing features of Hobart's landscape.
	- Geotourism	Recreational activities, such as caving and climbing, are highly valued on natural landscapes in Tasmania. Leisure activities can be strongly linked to geotourism, as well as contributing to a sense of place for many locals (Gray 2004).
	- Leisure activities	Recreational activities, such as caving and climbing, are highly valued on natural landscapes in Tasmania. Leisure activities can be strongly linked to geotourism, as well as contributing to a sense of place for many locals (Gray 2004).
Functional Value	- Geosystem functions	Physical systems in dynamic equilibrium, such as that at the Lost World, are extremely important for the continuing function of environmental systems (Gray 2004). It is essential for the health of the ecosystems reliant upon these landscapes that the Integrity of the natural landforms and processes is maintained on all scales.
	- Ecosystem functions	The physical landscape provides the template on which ecosystems reside and function (Gray 2004; Pemberton 2007). The link between geodiverslty and biodiversity is finally being recognised (Pemberton 2007), which means that the role of the physical landscape in the continuing function of ecosystems is achieving a high level of value.

Value Type	Specific Value	Explanation of Value
Research and Education Value	- Earth history and processes	Geological and geomorphological features have allowed scientists to reconstruct much of the planet's history, including the changing geography of land masses (Gray 2004). Dynamic sites such as the Lost World are also important for research into on-going processes, and understanding how they may change in the future.
	- Environmental monitoring	Current and potential future human impacts on the use of landscapes can be ascertained through environmental monitoring (Gray 2004), which allows for the production of a targeted conservation management plan.
	- Education & training	The role of geological and geomorphological landscapes in education of children and the training of future geologists, geomorphologists and pedologists is invaluable. Sites that can be used to demonstrate principles, as well as past and current processes, are essential in order for this to be achieved, and are highly valued as a result (Gray 2004; Pemberton 2007).

The community of Hobart associates a strong sense of place with the landscape of Mount Wellington, and by association, Mount Arthur. The aesthetically pleasing nature of this dominant feature in the local landscape adds to this sense of place. Many individuals experience an emotional attachment to their local landscape, enhanced by interrelationships between aesthetic values, cultural values, intrinsic values and functional values (NRM South 2003a). While the average annual number of visitors to the site is difficult to determine, rock climbing is known to be popular in the area, and anthropogenic disturbance indicates that the caves have been explored in the past. Caving would likely be a popular leisure activity, with the potential for a geotourism venture in the future. Degradation of this landscape would not only impact upon such future economic opportunities, but would also adversely affect many peoples' sense of place, as suggested by NRM South (2003a).

The functional value of the Lost World boulder caves is immeasurable. As the largest group of boulder caves known in Tasmania (Wellington Park Management Trust 2005)[2], these caves host a fragile ecosystem that is highly sensitive to change, and they provide a habitat for several species endemic to the state. This functional value gives rise to research and education opportunities. Despite its small area, the potential for significant scientific discovery at such a site is immense. Environmental monitoring is also important, both to maintain the integrity of the landforms and processes at all scales, and to ensure the continued success of the diverse ecosystem that the caves sustain.

4.2 Threats to geodiversity

Many people would consider geodiversity as being robust and unthreatened, not needing any form of management (Gray 2004; Pemberton 2007). However, as many geomorphological features were created by relict processes, their capacity to recover from disturbance is severely limited, and in some cases extinguished (Pemberton 2007). Some systems are able to repair themselves more readily and at a faster rate than others, which is a factor that must be carefully considered when planning management strategies for sites being threatened. NRM South believe that "some geological sites, for example Mt Wellington, are robust and do not need active management while others, like the karst around Hastings, and many of the sand dunes on the south-east coast need careful management and protection" (2003a, p. 5). Such a belief involves the ill-informed assumption that Mount Wellington is a homogeneous geosystem. This is clearly not the case. Stringent environmental monitoring and targeted management plans are required to maintain the geodiversity of the Lost World.

Direct anthropogenic threats are already having an effect on the boulder caves at the study site. In one of the more easily accessible caverns, graffiti has been carved into several of the walls (see Figures 13 and 14). A lack of public information

2 The current (2021) Geodiversity webpage (https://www.wellingtonpark.org.au/geodiversity/) refers to: "the Lost World boulder cave system (including the longest non-carbonate terrestrial caves known in Tasmania) –Eds.

Figures 13 & 14. Photos showing the excessive amount of graffiti in one of the main entrance caverns of Multistorey Cave (exact position indicated on the map in Figure 5).

and inadequate conservation measures will allow such damage to continue. These disturbances not only affect the aesthetic and intrinsic value of the site, but also threaten the cave environment and the biodiversity sustained within the system. Doran and others (1999) explain that *H. troglodytes* is prone to deserting webs and even egg sacs if disturbed too frequently, and such a state of agitation is detrimental due to the amount of energy it requires in view of the scarcity of food sources. This may account for their rarity in caves developed for tourism (Doran and others 1997).

While it may not necessarily directly impact the Lost World boulder caves, the threat of climate change has implications for the future of the subterranean environment and biodiversity sustained within this system. The role of the caves as a habitat during climate change would make an interesting research topic; however, a changing environment would put the survival of several species inhabiting these caves at risk. Doran and others (1999, p. 259) found that "*H. troglodytes* is itself very intolerant of desiccating conditions and high temperatures". In addition to temperature variations, the availability of water in all forms is important for the maintenance of this ecosystem. Glowworms are apt to shrivel up and die if there is a significant reduction in humidity and moisture availability (Driessen 2009).

Indirect threats to the entire catchment area have profound implications for the geosystem and ecosystem functions of the Lost World boulder caves. Caves are entirety dependent upon outside sources for energy input, and as such are vulnerable to external events, even if they occur at some distance from the cave system (Doran and others 1997). Land clearing, though unlikely within the boundaries of Wellington Park, would adversely affect each of the invertebrate species described in section 3.1.1. Cave crickets rely on forests outside of the cave system for their food supply, and they in turn are the primary food for *H. troglodytes*. Additionally, glowworm colonies often live in the surrounding forests as well as inside cave systems. The preservation of these forests is essential, as they provide a refuge for glowworm populations, and allow continuous colonisation of the caves (Eberhard and others 1991). Forestry and road-building in the catchment area of the Waitomo Caves in New Zealand was proved to cause a decline in the resident glowworm population, which was further exacerbated by changes to the cave entrance to suit the ever-increasing number of tourists entering those caves (Eberhard and others 1991; Driessen 2009, 2010).

Future proposals to expand the geotourism industry must not be overlooked either. Caves effectively have no carrying capacity, and visitors contribute extra fluxes of energy and mass into low energy systems that may not be able to sustain such conditions (Russell and MacLean 2008). Caves such as these would require modifications for ease of access, which would also alter the input of energy and mass. While the structural integrity of these caves suggest that this is a more robust site than many karstic tourist caves, the geosystem as a whole would be put under enormous pressure if these caves were to become a popular tourist destination.

4.3 Geoconservation significance

The intention of this report is to build a case for the geoconservation significance of the Lost World boulder caves by outlining the geodiversity of this site and the threats to that geodiversity. The appropriate human response to threats regarding features that hold some form of value is conservation (Gray 2004). The Lost World boulder caves deserve significant geoconservation measures due to the following reasons, which have hopefully been made clear throughout this report:

- The inability of this system to recover from disturbance as a result of the time scale and complexity of the processes that created it.
- The intimate link between geodiversity and biodiversity at the site.
- Both direct and indirect threats that are already affecting the integrity of the site.

Being situated within Wellington Park, the Lost World already receives some level of conservation afforded by management by the Wellington Park Management Trust. However, as pointed out by Doran and others, "where caves do fall in large reserves, this has mostly occurred as a by-product of protecting other faunal or natural values in the area" (1999, p.261). This is almost certainly the case for this site. The Lost World boulder caves lie within the boundaries of both Tasmanian Geoconservation Database listed 'Wellington Range Periglacial Terrain' (DER18, sensitivity 2) and 'Lost World Boulder Caves' (DERl5, sensitivity 8). These regions are considered to be significant only at the state level, according to the database, and the boulder caves are considered to be 'robust' with a sensitivity of 8 (DPIPWE 2009)[3]. While this may be true structurally speaking, it has obviously not taken account of all aspects of geodiversity, such as ecosystem function, that suggest it is a fragile site and must be afforded active protection.

3 This page has been modified since the original investigation; its replacement appears to be: https://dpipwe.tas.gov.au/conservation/geoconservation/tasmanian-geoconservation-database/geoconservation-sites-listing-process.

5.0 Recommendations

Based upon the findings of this investigation, my initial recommendation is that more research be conducted at the study site. A lack of scientific publications suggests that the scientific community is largely unaware of the geodiversity of this site, and of its geoconservation significance. This report has only provided a broad overview of the site, but the discoveries made thus far encourage further, more specialised studies.

In order to monitor and maintain the Lost World boulder caves, a management plan targeted specifically at the study site must be adopted. In terms of geodiversity, there are no comparable sites in Tasmania that have been the subject of a unique management plan. While other boulder caves throughout the world have been documented and studied (Smith 2007; Sjöberg 1986; Striebel 2008; Kastning 2009), none of these authors have outlined suitable, comprehensive management plans. Management of the site should have a holistic approach, encompassing protection of the abiotic components, so as to save them from further vandalism, as well as management and monitoring of the biotic components. An appropriate starting point for the planning of such an approach would be to consider the analogy with karst landscapes and their management strategies. The management of sensitive karst landscapes is well-documented, and could serve as the basis on which management of this boulder cave system is planned.

In accordance with the holistic management approach, conservation of these caves is essential. While the abiotic structures themselves are robust and show signs of long-term stability, the ecosystem they support is fragile and sensitive to disturbance. Legislation to protect geological and geomorphological sites does exist (NRM South 2003a), but the inclusion of these specific landforms within the partially protected Wellington Park is likely to be incidental. While Doran and others (1999) stress the importance of conservation of the cave's catchment as a whole, the Lost World boulder caves do not appear to have an integrated hydrological system. Nevertheless, as water is likely to feed in from multiple sources, the environs need to be protected from polluting materials and disturbing activities. Further, as Section 4.2 outlines, conservation of the surrounding forested area is essential for the survival of the cave fauna.

6.0 Conclusions

In terms of conservation management, there has always been a strong imbalance between the biotic and abiotic elements of nature. However, the growing recognition of the importance of geoconservation is prompting a more holistic approach to modern environmental management. The Lost World boulder caves, although recognised to be the most extensive cave system of this type known in Tasmania, have received scant attention in scientific literature.

The two boulder deposits surveyed show many structural differences, however the cave systems in both play host to similar faunal assemblages. Caves above the cliff line are characterised by chaotic boulder alignments, are less extensive and tend to be isolated. The environment within the caves is very damp, and hosts *H. troglodytes*, a species of the *Micropathus* genus, and a colony of *A. tasmaniensis* still in its larval stage. These caves likely formed from a gravity-driven mass wasting event.

Cave systems below the cliff line are structurally controlled by toppled dolerite columns, and show significantly more connectivity and extent than those above the cliff line. This damp environment also supports the existence of *H. troglodytes* and the *Micropathus* genus, but the presence of glowworms has not been observed in these caves during this study. Several theories have been proposed in this report and elsewhere for the formation of these caves, however further research would be required before a firm conclusion could be made.

The Lost World boulder caves are valued intrinsically, culturally, aesthetically, functionally and for their research and education potential. The boulder caves hold considerable geoconservation significance, and if damaged or disturbed, may not be able to recover. These cave systems host a fragile ecosystem that is sensitive to disturbance, in many ways similar to that of a conventional karst. Human presence is already impacting upon the integrity of the caves, with graffiti observed in one of the surveyed caverns.

Based on the findings of this report, further research must be conducted into this unique system. The development and implementation of a targeted management plan is essential to prevent further damage to this environment, and must adopt an approach that recognises the importance of incorporating both the biotic and abiotic components of the landscape. While the caves are situated within the boundaries of Wellington Park, more specific conservation measures must be adopted so that these unique caves are preserved well into the future.

"Everything we have, we inherited from the past, and everything we use or lose deprives future generations of it. That, in a nutshell, is the case for valuing and conserving abiotic nature." - Murray Gray (2004, p. 368).

7.0 Acknowledgements

I would like to express my thanks to Kevin Kiernan, who supervised my project, offering opinions, suggesting theories and inspiring enthusiasm for the subject. I would also like to thank Rolan Eberhard for his encouragement, interest and references, and to Niall Doran, for his expert opinion on the Tasmanian Cave Spider. But most of all, I must thank my friends and project volunteers: Joshua Greene, Jarod Harris, Megan Abbott, Nicholas Nolan and Geoff Lewis. They provided shoulders to stand on, inspired ideas when I needed them most, and remained enthusiastic, even when it snowed on us.

8.0 References

Banks, M.R. 1981 The rocks of Mt Wellington [in] *A climber's guide to the Organ Pipes, Mt Wellington*. Climbers Club of Tasmania, pp. 20-24.

Bradbury, Jason 1995 *Continuation of Preliminary Inventory of Sites of Geoconservation Significance in Tasmania: Central, northern and western Tasmania*. Earth science section, Parks and Wildlife Service, Hobart.

Caine, N. 1982 Toppling failures from alpine cliffs on Ben Lomond, Tasmania. *Earth Surface Processes and Landforms* 7: 133-152.

Caine, N. 1983 *The Mountains of Northeastern Tasmania*. Balkema, Rotterdam

Colhoun, E.A. 2002 Periglacial landforms and deposits of Tasmania. *South African Journal of Science*, 98: 55-63.

Dixon, Grant 1995 *Aspects of Geoconservation in Tasmania; a preliminary review of significant earth features.* A report for the Parks and Wildlife Service, Tasmania and the Australian Heritage Commission, p. 90.

Doran, N.E., Eberhard, S.M., Richardson, A.M.M. and Swain, R. 1997 Invertebrate biodiversity and conservation in Tasmanian caves. *Memoirs of the Museum of Victoria*, 56(2): 649-653.

Doran, N.E., Kiernan, K., Swain, R. and Richardson, A.M.M. 1999 *Hickmania troglodytes*, the Tasmanian Cave Spider, and its potential role in cave management. *Journal of Insect Conservation*, 3: 257-262.

DPIPWE 2009 Significance of listed Geoconservation Sites & Listing Process, Department of Primary Industries, Parks, Water and Environment, viewed 21st May 2010 http://www.dpiw.tas.gov.au/lnter.nsf/WebPages/UEM-74KVWV?open In 2021 see: https://dpipwe.tas.gov.au/conservation/geoconservation/tasmanian-geoconservation-database/geoconservation-sites-listing-process.

Driessen, M.M. 2009 Baseline monitoring of the Tasmanian Glow-worm and other cave fauna: Exit Cave and Mystery Creek Cave – Tasmania. *Nature Conservation Report* 09/02, Department of Primary Industries and Water, Tasmania.

Driessen, M.M. 2010 Enhancing conservation of the Tasmanian glowworm, *Arachnocampa tasmaniensis* Ferguson (Diptera: Keroplatidae) by monitoring seasonal changes in light displays and life changes. *Journal of Insect Conservation*, 14: 65-75.

Eberhard, S.M., Richardson, A.M.M. and Swain, R. 1991 *The Invertebrate Cave Fauna of Tasmania*. Zoology Department, University of Tasmania.

Gray, M. 2004 *Geodiversity: valuing and conserving abiotic nature*. John Wiley & Sons, West Sussex, England.

Grimes, K. 1997 *Australian Speleological Federation Cave Survey and Map Standards*. Australian Speleological Federation, viewed 12th March 2010 <http://www.caves.org.au/m_std-surv.html>.

Kastning, E.H. 2009 Morphogenesis of Boulder Caves in the Northeastern United States (Paper no. 42- 5). 44th Annual Meeting of the Northeastern Section, Geological Society of America.

Kiernan, Kevin 1982 Mechanically shaped pseudokarst: Talus, joint and fault caves and their potential in Tasmania. *J. Syd. Speleol. Soc.*, 26(3):41-51.

Leaman, David 1999 *Walk into History in Southern Tasmania*. Leaman Geophysics, Hobart. pp. 50-52.

NRM South 2003a *Managing Landscapes and Cultural Values: Discussion Paper*. The Southern Natural Resource Management Regional Committee, Hobart, Tasmania.

NRM South 2003b *Regional NRM Strategy Development: Geoconservation and Geodiversity, Rocks, Karsts, Coasts and Rivers - Southern Region*. The Southern Natural Resource Management Regional Committee, Hobart, Tasmania.

Pemberton, M. 2007 *A Brief Consideration of Geodiversity and Geoconservation*. Department of Primary Industries and Water, Tasmania. http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=FA706168BEC5DD2F440B6B81AA95EB61?doi=10.1.1.554.610&rep=rep1&type=pdf

Richards, A.M. 1968 The Rhaphidophoridae (Orthoptera) of Australia. Part 6. Two new species from northern Tasmania. *Pacific Insects*, 10(1): 167-176.

Russell, M.J. and MacLean, V.L. 2008 Management issues in a Tasmanian tourist cave: Potential microclimatic impacts of cave modifications. *Journal of Environmental Management*, 87: 474-483.

Seymour, D.B., Green, G.R. and Calver, C.R. 2007 The Geology and Mineral Deposits of Tasmania: a summary. *Geological Survey Bulletin* 72, Mineral Resources Tasmania, Rosny Park.

Sjöberg, R. 1986 Caves indicating neotectonic activity in Sweden. *Geografiska Annaler, Series A, Physical Geography,* 68(4): 393-398.

Skinner, Andrew 1999 The Lost World, Mt Wellington 6/12/73. *Speleo Spiel,* 86: 8-10.

Smith, G.K. 2007 Tectonic and Talus Caves at Pilchers Mountain, New South Wales. *Helictite*, 40(1): 11- 20.

Stacey, A.R. and Berry, R.F. 2004 The structural history of Tasmania: a review for petroleum explorers. PESA Eastern Australasian Basins Symposium II: 19-22 September, Adelaide.

Striebel, T. 2008 Granite Caves in the Fichtelgebirge Mountains, Germany. *Proceedings of the International Conference on Granite Caves,* *September 17-22*. Institute Universitario de Geologica - Clube Espeleolóxico Maúxo, A Coruña, Spain.

Vandel, A. 1965 *Biospeleology: The Biology of Cavernicolous Animals*. Pergamon Press, London.

Wellington Park Management Trust 2005 *Potential Research Opportunities in Wellington Park: Adapted from the Wellington Park Management Plan 2005, Appendix E.* viewed 2nd March 2010 <http://www.wellingtonpark.tas.gov.au/pdf/researchOpportunities.pdf>. Subsequently replaced by: /www.wellingtonpark.org.au/assets/Research_Opportunities_in_Wellington_Park_update_2020.pdf (viewed 26 June 2021).

Wellington Park Management Trust 2010 Legislation, viewed 24th April 2010 <http://www.wellingtonpark.org.au/legislation/>.

[Editorial Note: This paper originated as part of geomorphology coursework and fieldwork towards a Bachelor of Science degree at the University of Tasmania in 2010. Because of the potential interest in the subject features and the relative lack of documentation of these caves the editors have been pleased to accept this paper for publication in *Helictite*. Some updating and minor text changes have been deemed necessary.]