

# DWLBC REPORT

Prioritising rock-holes of  
Aboriginal and ecological  
significance in the  
Gawler Ranges

**2009/08**



**Government of South Australia**

Department of Water, Land and  
Biodiversity Conservation



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# **Prioritising rock-holes of Aboriginal and ecological significance in the Gawler Ranges**

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# FOREWORD



South Australia's unique and precious natural resources are fundamental to the economic and social wellbeing of the State. It is critical that these resources are managed in a sustainable manner to safeguard them both for current users and for future generations.

The Department of Water, Land and Biodiversity Conservation (DWLBC) strives to ensure that our natural resources are managed so that they are available for all users, including the environment.

In order for us to best manage these natural resources it is imperative that we have a sound knowledge of their condition and how they are likely to respond to management changes. DWLBC scientific and technical staff continues to improve this knowledge through undertaking investigations, technical reviews and resource modelling.

**Scott Ashby**  
**CHIEF EXECUTIVE**  
**DEPARTMENT OF WATER, LAND AND BIODIVERSITY CONSERVATION**



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# SUMMARY

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The Knowledge and Information Division of DWLBC is working with the South Australian Arid Lands (SAAL) Natural Resource Management (NRM) Board, South Australian Native Title Unit and Aboriginal people of the Gawler Ranges to identify culturally significant rock-holes in the Gawler Ranges. Most pastoralists in the Gawler Ranges area have registered an Indigenous Land Use Agreement (ILUA) which acknowledges the different rights and interests that parties have in land and water. This agreement allows negotiations of Native Title in a framework that respectfully meets the needs of individual pastoralists and the Aboriginal communities. This program seeks to engage both communities in negotiating Aboriginal access to rock-holes on pastoral land identified from ILUA in the Gawler Ranges.

Water in the arid landscape has played a significant role in occupation and settlement since humans first arrived in Australia more than 60,000 years ago. For Aboriginal people in the arid areas of South Australia rock-holes provided a crucial water supply but also facilitated access to a wider area and a larger range of resources. Aboriginal routes in arid areas were largely governed by the occurrence and distribution of rock-holes with tracks radiating out from them. The more important water supplies usually have a totemic significance and play a very important part in Aboriginal ceremonial and social life and were often central trading locations. The Aboriginal people of the Gawler Ranges region include the Barngarla, Kokatha and the Wirangu people.

Due to lack of surface water, pastoralism was not developed in the area until wells were sunk and watering points were installed across the landscape. Today, pastoralism mostly accesses bore water and rarely the water collection points on the granite outcrops therefore creating the perfect opportunity for both pastoralists and Indigenous people to work together in maintaining these culturally significant water resources. However to adequately understand the relationship between these components anthropologists, ecologists and pastoral consultants are working with both communities to integrate management of land, water and cultural practices.

The first stage of the ecological component of the program was to review biological and physical form literature on rock-holes to conceptualise the function, processes and ecological value of rock-holes and their surrounding ecosystem in the arid interior to determine the ecological field information that needs to be collected for the next stage of the ecological component of this program.

Rock-holes or gnammas, an Aboriginal Western Desert term often used by scientists, exist in a variety of environments and rock types, this project is concerned with those that exist in the Gawler Ranges and are located on granite outcrops. Rock-holes form on granite outcrops due to chemical weathering processes and are filled by localised rainfall events. Rainfall frequency, evaporation rate and size and depth of the hole along with animal and human uses will determine whether the holes contain water for weeks or months. This information was used to form a conceptual diagram, which determines the ecosystem:

1. Drivers (granite outcrop morphology),
2. Processes (rainfall frequency, evaporation rate, animal usage) and,
3. Features (siltation, stock and feral animal presence, distance to alternative watering point).

Key findings from the literature review on scientific studies on rock-holes were:

- On granite outcrops when the slope is less than 20° rock-hole formation occurs.
- Plants and animals associated with granite outcrops and rock-holes are not largely recorded for South Australia.
- Studies of plants and aquatic invertebrates in Western Australia have found rock-holes species endemic to the rock-hole environment. Species associated with rock-holes and outcrops occur across the landscape in a similar fashion to the Island Biogeography theory (an "island" of suitable habitat surrounded by an expanse of unsuitable habitat).
- Generally, terrestrial animals are not restricted to granite outcrops and with the instalment of watering points by pastoralists in the Gawler Ranges region, mammal and bird reliance of the rock-holes would have decreased.
- Aquatic and terrestrial animals associated with rock-holes may live out their entire life cycles in the rain-filled pools while other utilise the water either opportunistically or dependently.
- Rock-holes may contain submerged aquatic plants or plants that grow in the sediment of the holes during the drying process. Seeds of these plants will survive in the sediment till the next inundation.
- Like the aquatic plants, aquatic invertebrates that complete their life cycle in the rock-holes deposit thick-shelled eggs into the sediment of the holes. Little information exists on these aquatic communities in the arid areas of Australia.

The second stage will involve undertaking ecological field assessments and recording Aboriginal ecological knowledge of the rock-holes to prioritise monitoring and management of the rock-holes. The first field visit allowed the Aboriginal people, landholders, anthropologists and ecologist to come together and meet each other while visiting rock-holes of interest.

The next stage of undertaking the ecological assessments at the rock-holes are due to start in 2009. Once the ecological field assessments are completed the outcomes will be married with the cultural assessment giving the SAAL NRM Board information on which rock-holes are to be protected for either ecological or cultural purposes or both. This process will be completed over a longer term, as at time of writing this report two rock-holes had been visited from the 43 identified in the Native Title Claim area. The ILUA process does not cover all the rock-hole locations across the Gawler Ranges and are mainly interested in visiting the culturally significant sites. It is recommended for ecological mapping and prioritisation that rock-holes where no cultural information is being collected that ecological assessments are still undertaken so that a management plan for rock-holes across the ranges can be determined.

The survey of rock-holes in the Gawler Ranges will be used as a pilot study for undertaking this type of collaborative work and aims to be extended into other NRM regions in the future.

# 1. INTRODUCTION

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This report will be an evolving report that will be updated as more information and understanding of rock-holes is researched in the Gawler Ranges of South Australia as part of this project process. Version 1 is a review of current knowledge on rock-holes to formulate a background and conceptual understanding of rock-holes across the landscape.

## **1.1 WHAT IS A ROCK-HOLE?**

A rock-hole is typically referred to as a gnamma, which are holes/pools that contain water and are commonly found in granite outcrops especially on the top of granite domes across Australia. The word 'gnamma' is of Aboriginal origin and comes from the Western Desert group of languages that are spoken over a large proportion of the arid areas that extend from South Australia into the Northern Territory and Western Australia (Bayley 1997; Bindon 1997).

Throughout this report a rock-hole will typically be referred to as a gnamma when citing other peoples work who use this term in the Australian scientific community (Bayly, 1997; Bindon 1997; Campbell 1997; Bayly, 1999; Timms, 2006).

## **1.2 PROJECT OBJECTIVES**

The ecological role in this project is to visit rock-holes with Aboriginal people of the Gawler Ranges to determine which ones are ecologically significant in the arid landscape determined by the duration of water in the rock-holes and the flora and fauna associated with them. The first phase of the project will develop a conceptual diagram indicating the drivers and processes to determine the ecological function of the rock-holes in the landscape.

Outcomes:

- Engaging Aboriginal people, SAAL NRM Board and DWLBC with water management in the arid areas of SA.
- Re engaging Aboriginal access to land, water and culture via the Indigenous Land Use Agreement (ILUA) process.
- Documenting extent, distribution and current condition of rock-hole water resources across the Gawler Ranges.
- Developing conceptual diagram of rock-holes process and function.

### **1.3 ABORIGINAL ACCESS TO WATER**

Recently the report 'Aboriginal Access to Water Across Australia' was released by the Government of South Australia (Simpson, 2008). Some key components of the report that relate directly to this program and project are:

- "Governments across Australia are in the early stage of formally recognising Aboriginal relationships with water for spiritual, cultural and economic purposes. This is reflected in the National Water Initiative (NWI) where Indigenous representation is needed in water planning and for all states and territories to reassess the way in which they, through policy, legislation and programs, provide Aboriginal access to water" (pp 5).
- "A fundamental challenge for policy makers is to provide for and support Aboriginal relationships to land and waters in ways, which do not ultimately fragment them" (pp 7).
- "Access to country has been identified as a major issue for communities... In remote areas limited roads, high costs and lack of support services make country harder to visit and thus maintain" (pp 17).
- "Reports are indicating water sites are becoming less well known in the remote arid areas as Elders who knew their location pass away" (pp 17).
- "Generally there are defined rules in Aboriginal societies as to who can speak for which part of 'country', which highlights the necessity to seek both male and female perspectives" (pp 32).
- Neither Aboriginal communities nor their water needs are homogenous with regional diversities between cultures making a national approach for Aboriginal issues in relation to water 'impossible'. Some groups may be more concerned with drinking water, some with the preservation of culture and country, others with economic development.



## 2. ROCK-HOLES AS A WATER RESOURCE

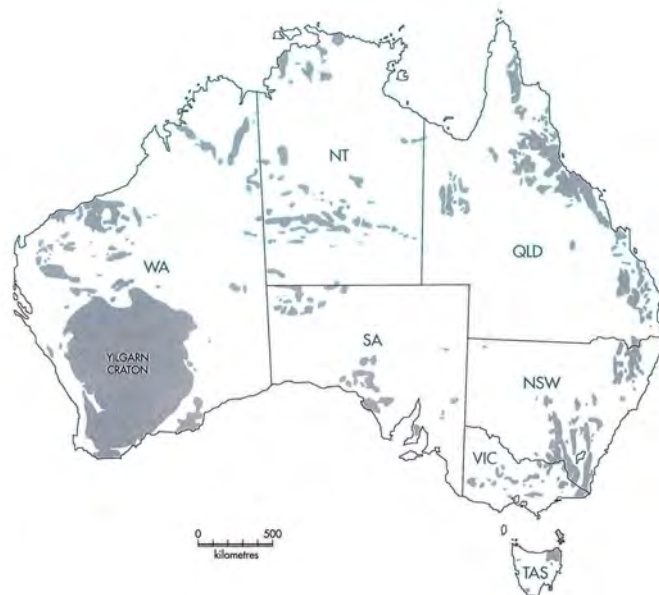
### 2.1 FORMATION

Rock-holes in the Gawler Ranges commonly exist as holes or depressions on the surface of granite domes and outcrops. Granite inselbergs (islands) are prominent landscape features in the Gawler Ranges and in other areas of the state like the Eyre Peninsula, the spatial occurrence of granite outcrops across Australia is widely distributed in each state (Figure 2.1). Inselbergs are typically dome, pavement and tumulus shaped (Figure 2.2 and 2.3) with other granite features including scattered boulders or haystacks eg. Murphy's Haystacks on the Eyre Peninsula.

A rock-hole or gnamma, is the product of chemical weathering produced by water (Bayly 1999). Talbot (1912) grouped them into those that develop along cracks and sheet joints, and others that are eroded by carbonic acid produced by the decomposition of plant material trapped in an initial depression (taken from Bindon, 1997). Bayly (1999) groups gnammas into two basic forms: pits and pans and describes them as follows:

- Pit-gnammas are typically hemispherical in shape and sub-circular in outline with a large depth to surface area ratio and often contain water for extended monthly periods (Figure 2.4).
- Pan-gnammas have flat floors and sloping sidewalls with a small depth to surface area ratio and often contain water for a limited time of weeks rather than months (Figure 2.5). Pan-gnammas are highly irregular in outline and it is common for one pan-gnamma to grow into another.

Both types of rock-hole occur on the upper surfaces of inselbergs where the inclination is less than 20 degrees (Bayly, 1999) indicating a threshold for rock-hole formation.



**Figure 2.1 Distribution of granitoid rocks in Australia (Bayly, 1999)**

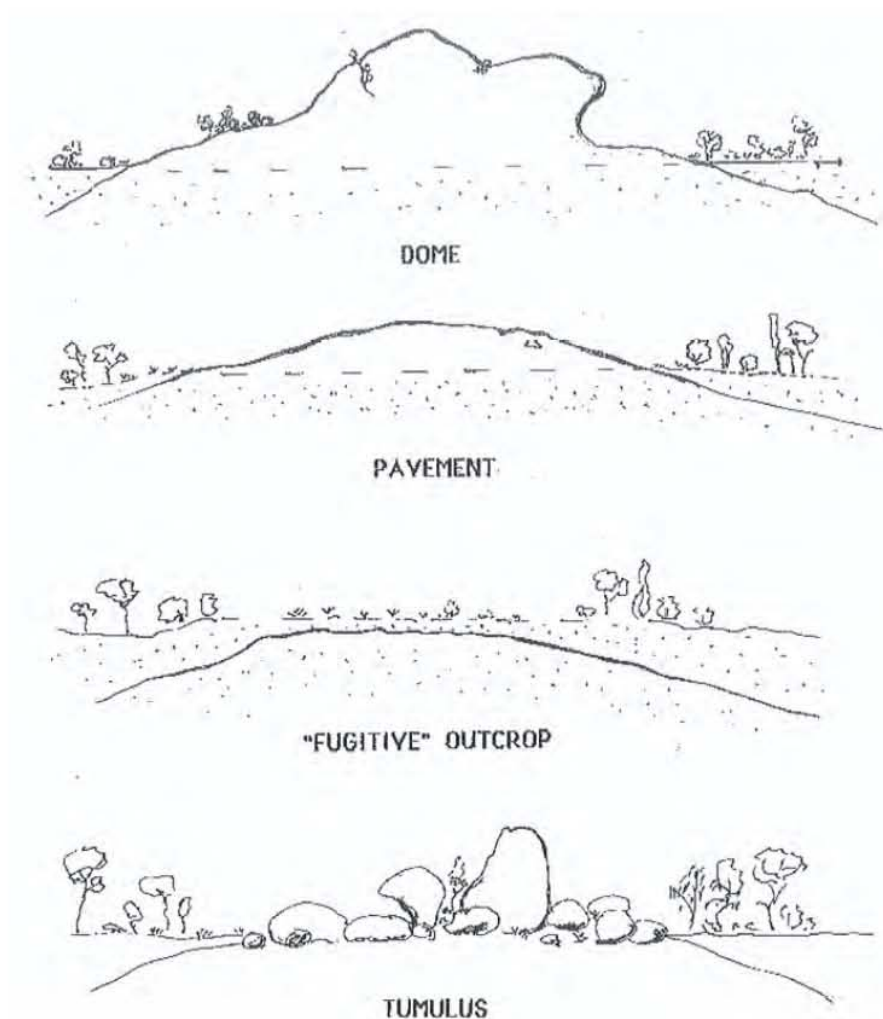


Figure 2.2 Examples of the different topographic forms of granite outcrops (Main, 1997)

**This photo has been removed for cultural purposes.**

Figure 2.3 Example of a pavement-shaped (left) and tumulus-shaped (right) granite outcrop in the Gawler Ranges on Wilgena Station (M. White, 2008)

**This photo has been removed for cultural purposes.**

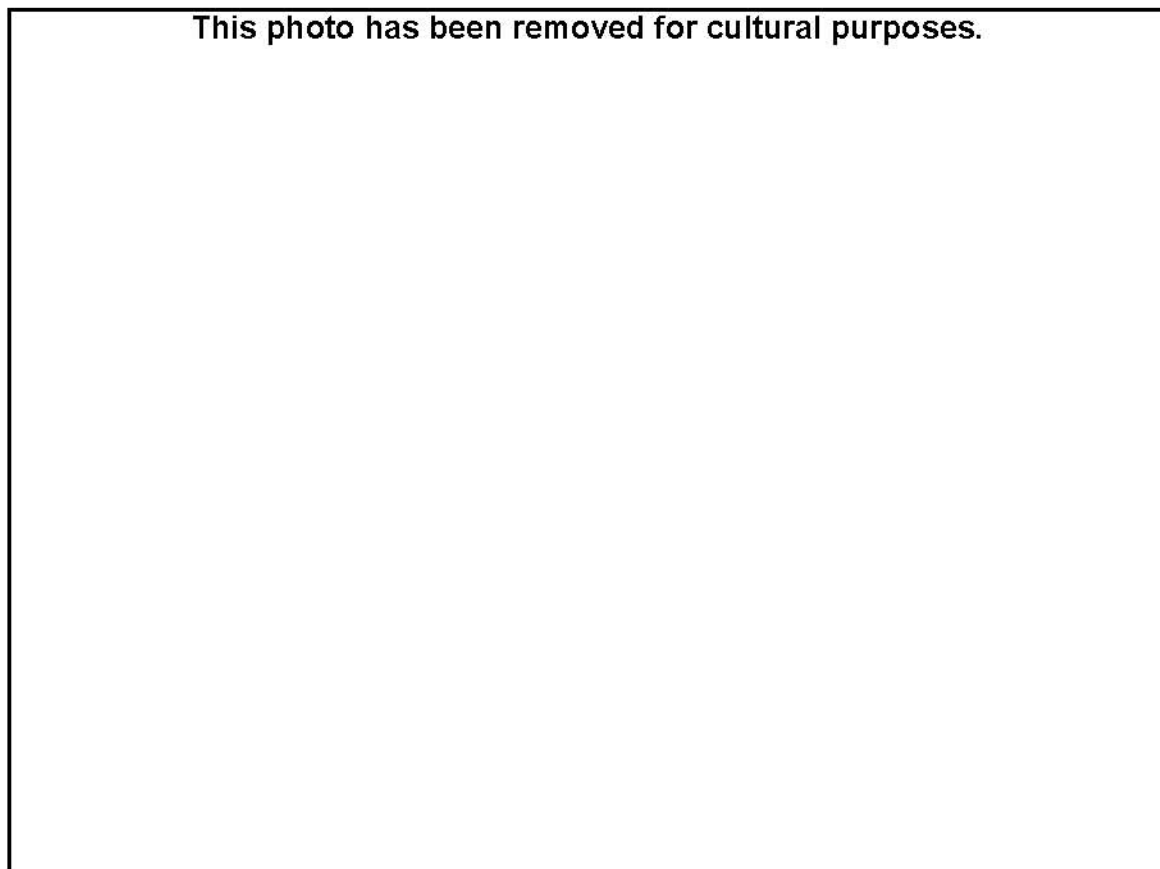
**Figure 2.4** Example of a deep pit-gnamma that contains water for extended periods in the Gawler Ranges Area (photograph from the Kokatha Mula website, 2008)

**This photo has been removed for cultural purposes.**

**Figure 2.5** Examples of pan-gnammas that contain water for shorter durations in the Gawler Ranges at Wilgena Station (M.White, 2008)

Soaks are associated with granite outcrops and are the zone where run-off from rainfall occurs. Due to the aridity of the Gawler Range climate, rather than using the term 'soak' which better describes these features in higher rainfall areas; these features will be referred to as 'aprons' (Main, 1997). The descending edges of outcrops frequently fan out onto aprons of varying width. Soil depths of the aprons vary and are seasonally waterlogged, damp or dry which may constrain or attract vegetation and soil living invertebrates (Main, 1997). In semi-arid and arid regions, the aprons and seepage lines are an extension of the surrounding indigenous grasses, shrubs and trees (Figure 2.6) though some species like the Rock Isotome (*Isotome petraea*) preferentially grow on granite substrate soil. In summer the aprons may provide important seasonal habitat of damp refuge areas for invertebrates and vertebrates like frogs and lizards (Main, 1997).

Aboriginal people, early white explorers (Harvey Johnston, 1941; Bindon, 1997) and scientists (Bayly 1999, Pinder 2000, Bayly, 2001; Timms, 2006) conclude that rock-holes are filled by localised rainfall events, whereby the sub-catchment (rock-face) funnels water into the holes and depressions. The duration of water in the rock-holes is dependent upon a number of factors including; rainfall frequency, evaporation rate, size and depth of the hole.

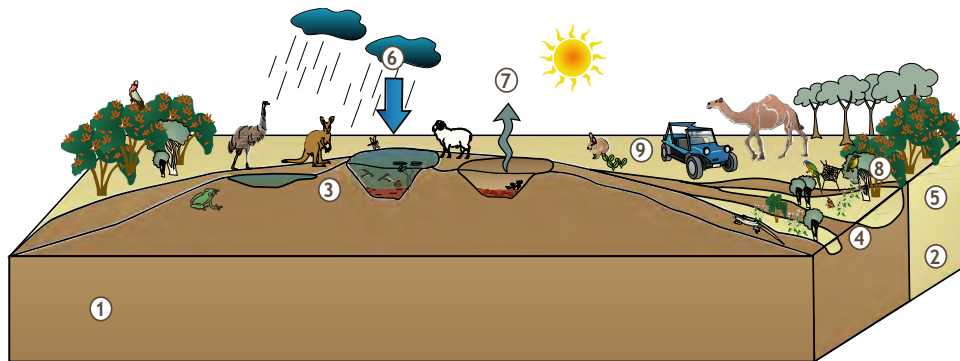


**Figure 2.6** Example of the vegetation associated with the apron run-off zone of a granite outcrop in the Gawler Ranges (M. White, 2008)

## 2.2 CONCEPTUAL DIAGRAM

The literature review as summarised in the previous section provides the background knowledge that is integral in the development of a conceptual diagram on the ecological function of the rock-holes in the Gawler Ranges. The conceptual diagram developed for this project is presented below (Figure 2.7)

### Rock-Holes



Rock-holes form on granite surfaces due to chemical weathering processes. Rock-holes only occur when the slope is <20 degrees, as steeper gradients have faster surface run-off therefore reducing collection of water in depressions which limits rock-hole formation. Rock-holes vary in size, shape and depth with the two main forms being a pit or a pan. The pit rock-holes are deep with a small surface area while the pan rock-holes are shallow with a large surface area. Localised rainfall fill the rock-holes with the deeper pit holes holding water for longer periods of time.

The main influences on water duration in the rock-holes in the arid areas are; use by animals as a water source, rainfall frequency and season (cooler months having lower evaporation rates). In the parks, reserves and Aboriginal lands in the arid areas, rock-holes are the main source of water for terrestrial fauna. In pastoral areas bores and dams have increased water across the landscape reducing the dependency of fauna on rock-holes as a water source.

The extent and distribution of the flora and fauna associated with the rock-holes is not well known for the arid areas of South Australia however, studies on rock-holes in south-western Western Australia have showed high levels of species endemism between individual outcrops and areas.

These granite outcrops and rock-holes are highly important to Aboriginal people as traditionally they were the main source of water for Aboriginal movement across the landscape and they continue to play a significant role in lawre, ceremony and cultural responsibility.

### Features

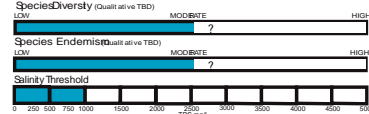
- ① Granite outcrop
- ② Sediments
- ③ Pit or pan rock-holes formed by chemical weathering processed
- ④ Apron/soak areas located on edge of granite outcrop or in a weathered depression
- ⑤ Localised recharge through surface water run-off

### Threats

- ⑨ Camels can drink a rock-hole dry in one sitting, while stock may use them when man-made watering points aren't available. Rabbits reduce regeneration of seedlings around rock outcrops. People may disturb and cause damage to rock-holes and outcrops.

### Processes

- ⑥ Rainfall is the driving variable. Terrestrial animals opportunistically use rock-holes while aquatic invertebrates complete their whole life-cycles within the water body.
- ⑦ Evaporation, shading and animal use determines the duration of water. During the drying phase, animals continue to use the rock-holes, invertebrates lay drought resistant eggs and wetland plants grow in the moist sediment.
- ⑧ Due to soil type (granites) and the extra surface run-off from the outcrops, specific species and dense plant associations form in depressions and along edges of outcrops providing habitat for birds, reptiles & insects.



**Figure 2.7 Conceptual Diagram of the functions and processes occurring at rock-hole in the Gawler Ranges**



## 3. WATER IN THE ARID LANDSCAPE

### 3.1 INDIGENOUS

Aboriginal routes were largely governed by the occurrence and distribution of rock-holes with tracks radiating out from them in many regions. The topography and water supplies in the western portion of South Australia determined the direction and position of Aboriginal routes (Harvey Johnston, 1941). Rock-holes were also a reliable source of water lasting for some months and were used to allow Aboriginal travel between ephemeral sources utilising game and plants responding to local rainfall. The more important water supplies usually have a totemic<sup>1</sup> significance and play a very important part in Aboriginal ceremonial and social life and were often central trading locations. Granite domes are also important to Aboriginal law and ceremony, with outcrops indicating ancestral movement across the landscape.

For Aboriginal people, granite outcrops where rock-holes exist not only provided a crucial water supply in the arid areas but also facilitated access to a wide range of resources. Bindon (1997) details different resources associated with granite outcrops which are briefly summarised below:

- Medicinally important plants like the Rock Isotome (*Isotome petraea*) (Figure 3.1) and edible plants like the Adijikoh or Warrain Yam (*Dioscorea hastifolia*) favour soil around granite outcrops.
- Plants like the Quandong (*Santalum acuminatum*) (Figure 3.1) and Kurrajong (*Brachychiton gregorii*) favour the run-off zone where rainfall concentrates. These trees have fruit, wood and medicinal properties but also attract emus and other bird-life.
- The plants and water at the outcrops attract macropods and reptiles, many of which also contributed to Aboriginal diet.

Bindon (1997) also describes Aboriginal techniques of securing food and water at the rock-holes:

- Larger rocks placed over the hole to 'cap' them, which slowed evaporation and discouraged animal use.
- In some instances brush fences were made which funnelled animals into a trap, the Aboriginal people utilising the natural occurrence of 'appropriately' placed rocks.
- Lizard traps were also used, whereby rocks were placed in a way that increased lizard habitat and allowed for easier capture.
- With water being both vital and scarce in the arid regions, water quality was maintained by Aborigines who would put sticks into the rock-holes allowing both entry and escape for small birds, reptiles and mammals to prevent the animals from dying in the water and fouling it making it undrinkable.

<sup>1</sup>A person's totem links them to an ancestor and ensures the totem's survival. Some examples are hunting or collecting certain totemic food at certain times; with regards to totemic rock-holes certain people may be responsible for maintaining them.



The Aboriginal people of the Gawler Ranges region include the Barngarla, Kokatha and the Wirangu people. The knowledge gained from undertaking this project with Aboriginal people of the Gawler ranges will contribute to understanding the ecological significance of rock-holes in the arid landscape and what changes may have happened at some sites since white settlement of the area. The project also demonstrates rich cultural significance of Aboriginal rock-hole management and the need to secure ongoing engagement of Aboriginal people in future management approaches.



**Figure 3.1** From left to right; Rock Istome (*Istome petraea*) growing on the edge of a granite pavement, and Quandong (*Santalum acuminatum*) growing in a sand-dune field in the Yellabinna Reserve in the Gawler Ranges (M. White, 2008)

## **3.2 EUROPEAN**

Water in the arid Australian landscape has played a significant role in settlement and occupation since humans first arrived in the area more than 60,000 years ago. In Western Australia much of the state's exploration by white survey teams in the 1800's was only accomplished by persuading or coercing Aboriginal people to reveal water sources found on or adjacent to granite domes (Bindon, 1997).

In South Australia the first white explorer to visit and name the area 'Gawler Ranges' was Edward John Eyre in 1839. On his journey, Eyre procured water from rock-holes that had recently filled from rain but were fast evaporating. Due to his expedition not finding any permanent sources of water, further exploration into this area did not occur again till 1857 (sourced from Robinson et al, 1988). The 1857 expedition of Stephen Hack reported first-rate salt-bush country with wide green well grassed valleys, though Major Warburton's report (1858) on the value of the land was not as glowing as he pointed out that the water supply was sourced solely on a few rock-holes "whose content may supply twenty to thirty natives visiting the area once or twice a year, but would be inadequate for even a hundred head of cattle" (sourced from Robinson et al, 1988). Most pastoral leases were taken up in the Gawler Ranges in the early 1860's, though the importance of water soon became apparent



when the Yardea rock-holes became dry and horses had to be taken 10 miles to be watered at Conical Hill, the first wells started being sunk in 1864 to secure water for pastoralism.

The early white settlers in the Gawler Ranges knew the value of the granite domes as water collection areas and often cemented stones walls along them to feed a large collection point increasing water availability at a site. Figure 3.2 illustrates a stonewall along the edge of a granite pavement feeding a stone tank on Lake Everard Station in the Gawler Ranges.

Pastoralism in the Gawler Ranges was regulated by water, though once flocks were increased the second challenge was to prevent dingos from taking stock. Post 1905, more country was developed for pastoralism once the dog-fence was erected.

Camels accessing water from rock-holes in the Gawler Ranges most likely started after 1879 when Afghan camel teams were first used west of Port Augusta (Robinson et al, 1988). Camel teams replaced bullocks for hauling fencing, well-sinking and wood-carting materials and it is assumed that they would have used the rock-holes for water in a similar fashion to the supply route from Fowlers Bay to Coward Springs. Camel teams were also used in carting railway sleepers when the train line was first established in the Tarcoola area, again it can be assumed they would have sourced the rock-holes for water.

It can be surmised that Aboriginal people, explorers, Afghans and pastoralists relied on rock-holes in the Gawler Ranges at some stage for existence.



**Figure 3.2** A granite pavement on Lake Everard Station in the Gawler Ranges that has had a stone wall cemented around its base to feed a water collection point (M. White, 2005)



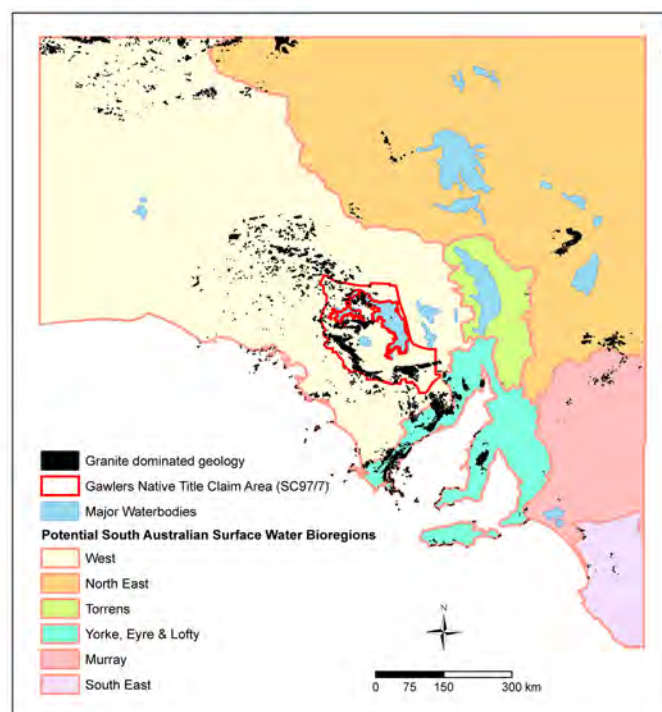
## 4. THE ECOLOGY OF ROCK-HOLES

### 4.1 LOCATIONS

The location of rock-holes in the Gawler Ranges is being investigated for both cultural and ecological reasons. If certain rock-holes are classified as restricted for cultural reasons this report will not detail the location of those rock-holes.

Based on surface water basins and biota genetic distinctiveness the South Australian Surface Water Aquatic Bioregions have been developed (Scholz and Fee, 2008). These regions overlaid with the locations of granite outcrops in South Australia allow a draft grouping of where some ecological distinctiveness between outcrops may occur (Figure 4.1). This grouping of rock-holes could be fundamental for targeting field investigations and prioritising management.

Research by the South Australian Native Title Unit has traced the location of rock-holes from Aboriginal people and historical records. Rock-holes were important when both explorers and pastoralists were first visiting the different parts of the state and they marked rock-holes, soaks, waterholes and other water sources on cadastral maps and surveyor diagrams. Initial data from the Warburton Range Pastoral Lease Field Diagrams (PLFD) dating from the late 1800's to the early 1900's record the capacity of water that rock-holes could hold (Table A in Appendix A). This information is valuable in knowing where the larger and more permanent rock-holes exist across the landscape; this information will help in prioritising which rock-holes to visit and which ones may be of ecological importance.



**Figure 4.1** Distribution of granite dominated geology in South Australia overlaid with the South Australian Aquatic Bioregions, this map incorporates data which is Commonwealth of Australia (Geoscience Australia) 2009.

## 4.2 PLANTS

In Western Australia an extensive survey and record search found 1,320 plant taxa occurring on granite outcrops (Hopper et al, 1997). The study (Hopper et al, 1997) also acknowledges that some plants are missing from the extensive Western Australian list, with it being expected that outcrops in the more arid parts of the Western Australia also having Spinifex (*Triodia* spp.) and lemon (*Cymbopogon* spp.) grasses associated with them.

The most diverse outcrops were those in the heavier rainfall area of the southwest where some outcrops had up to 200 species with many endemics. The study found species richness and local endemism declined with increasing aridity, so much that the plants associated with granite outcrops in the Kimberly and Pilbara regions showed little discontinuity in species from the surrounding vegetation (Hopper et al, 1997).

Plants associated with granite outcrops are not largely recorded for South Australia except for a few plants listed in Bayly, 1997 (Table 2 in Appendix A). This project is a unique opportunity to not only survey the rock outcrops but to record traditional knowledge of plants associated with these landscape features.

Coping with variable climatic conditions is the most significant survival strategy faced by granite outcrop plants. Few organisms can tolerate the harsh rock surface environment and they tend to be occupied by cryptogamic crusts of lichens such as *Siphula decumbens* (Bayly, 1999) though outcrops with higher rainfalls often have extensive moss swards (Hopper et al, 1997; Bayly, 1999).

Other plants with survival strategies existing on granite outcrops include resurrection plants, tubers and succulents. Resurrection plants like the Woolly Cloak Fern, *Cheilanthes lasiophylla* occur in rocky areas the Gawler Ranges and are able to withstand desiccation through the drying out of their leaves, which then rehydrate upon rainfall. Underground tubers are a common strategy of granite outcrop herbs such as lily's, orchids, sundews and reeds (Hopper et al, 1997). On the October 2008 field visit, the Aboriginal women talked about a tuber that they use at outcrops but were unable to find on that trip. Another strategy of surviving is succulence such as some Portulaca's (*Calandrinia* spp.), which were observed growing at some granite outcrops in the Gawler Ranges on the October 2008 field trip.

Rock-holes contain plants growing on the sediment at the bottom of the hole either when inundated or upon drying. Rock-holes on Western Australian outcrops comprise of quillworts (*Isoetes*, Isoetaceae), mudmats (*Glossostigma*, Scrophulariaceae), milfoils (*Myriophyllum*, Haloragaceae) and crassulas (Crassulaceae) (Hopper et al, 1997). Little information about plants growing in South Australian rock-holes and outcrops exist though some are listed in Table 2 in Appendix A, this list could be increased by both field surveys and a herbarium record search. Current rock-hole recovery work being undertaken by the Kokatha Mula Nation on the Eyre Peninsula has recorded the Swamp Lily (*Ottelia ovalifolia*) occurring in a rock-hole after being cleaned in the Pureba Conservation Park (Kokatha Mula, 2008). This species isn't listed from survey work at rock-holes in Western Australia, which demonstrates that species not previously recorded in rock-holes exist in South Australian rock-holes and in the Gawler Ranges region.

## 4.3 ANIMALS

Both aquatic and terrestrial animals are associated with rock-holes. Some live out their life cycles directly in the rain-filled pools while others utilise the water either opportunistically or dependently.

Generally, terrestrial animals are not restricted to granite outcrops but the number of animals recorded at outcrops suggests that they are an important seasonal resource for many animals or as temporary refuge for the fauna of the surrounding habitat (Withers and Edward, 1997).

### Mammals

Four primary metapopulations of the Yellow-footed Rock Wallaby (*Petrogale xanthopus xanthopus*) have been recorded in the Gawler Ranges favouring rhyolite rock formations or protective caves (Lethbridge, 2004). Prior to fox introduction, the species may have occurred on less protected rocky areas and possibly granite outcrops but due to predation and competition with other animals especially foxes, goats, rabbits and stock for habitat, food and water resources, current populations are restricted to protective areas.

From the 1985 Gawler Ranges Biological Survey, three species of mouse (which included the introduced House Mouse) were captured in rocky areas associated with spinifex (native mice) and chenopod shrubland (introduced mice). Larger mammals that might utilize the rock outcrops as habitat or for water are listed (Table 3 in Appendix A).

### Birds

In Harvey Johnston's (1941) description of Aboriginal routes in the western portion of South Australia whereby routes follow water sources especially rock-holes he describes the presence of small birds (finches, pigeons, parrots), galahs and emus associated with these outcrop areas. These birds once were dependant on the rock-holes for water before pastoralism installed watering points across the landscape making water more available.

Various plants like the quandong favour the rim of granite outcrops where run-off is concentrated and will attract birds like emus that forage for the fruit (Bindon, 1997). These productive soak (apron) areas may also provide habitat for small birds that prefer dense vegetation thickets to live in.

### Reptiles and Amphibians

Skinks, geckos and dragons are reptiles associated with granite outcrops. Lizards will forage for insects and plants on the outcrops and take refuge in the cracks and crevices. In arid areas, boom periods of foraging will be after heavy-rainfall periods when there will be an abundance of insects and plants for lizards to feed upon. The 1985 Biological Survey of the Gawler Ranges (Robinson et al, 1988) identified 12 species of reptiles associated with rock outcrops (Table 3 in Appendix A). One small dragon species was sighted at the Bulpara Hill granite outcrop during the October 2008 field visit.

Frogs and tadpoles have been observed at rock-holes on granite inselbergs in Western Australia (Bayly, 1999) with Jocqué et al (2007) recording large densities of *Crinia* tadpoles and surmised that tadpoles indirectly influence primary productivity and macro invertebrate

richness due their presence increasing nutrient availability in a rock pool by their sediment processing habits.

The literature suggests that rock-holes and outcrops are a resource utilised by both reptiles and amphibians for different reasons. Lizards take refuge while amphibians use the rock-holes as breeding grounds. Ehmann (2005) describes three species of frogs occurring in the Gawler Ranges, these species may use the rock-holes as breeding grounds after heavy rainfall periods (Table 3 in Appendix A).

## **Invertebrates**

A variety of macro invertebrate crustaceans of microscopic size and larger, like clam shrimp, fairy shrimp (Figure 4.2), copepods, cladocerans and ostracods occur in rock-holes shortly after they fill with rain-water (Bayly, 1999; Bayly, 2001). These animals feed from detritus, bacteria and algae to rapidly mature and deposit thick-shelled resting eggs that remain in the sediment once the pools dry out. These eggs can endure high temperatures and may lie dormant for several years until heavy rains renew the pools and the life cycle repeats itself. Timms (2006) found two large species of clam shrimps (branchiopods) in pan-gnammas on the Upper Eyre Peninsula and twelve species in Western Australia.



**Figure 4.2 Two types of macro invertebrate crustaceans of Branchiopods, fairy shrimp (left) and clam shrimp (right) that may occur in rock-holes**

The biological survey on granite outcrops in Western Australia, the most intensively studied outcrops in Australia, highlighted the need for conservation of these freshwater refuge habitats due to freshwater wetland depletion in the wheatbelt from salinisation. The survey recorded 230 species from outcrops with 50 species identified as endemic to the regions or singular outcrops (Pinder et al, 2000) with Bayly (1997) finding a significant positive correlation between species richness and pool volume and pool area.

Other larger invertebrates like midges, backswimmers, and beetles also inhabit granite rock-pools and prey upon crustaceans; unlike crustaceans they do not produce drought-resistant eggs and will fly to more permanent bodies of water for refuge during the drying of a rock-hole.

Terrestrial invertebrates like spiders, springtails, stick-insects, termites and earwigs have also been found to occur on granite outcrops and feed on other insects either inhabiting the

outcrop or surrounding vegetation, some insects like stick-insects will directly feed off the lichen on the rock itself (Bayly, 1999). A few terrestrial arthropods, primarily *Teyl* spiders, chiromid fly, *Archaeochlus*, some species of pseudoscorpian (*Synsphyronus*) and an embiopteran insect (*Notoligotoma*) may also be restricted to granite outcrops in Western Australia (Withers and Edward, 1997).

## **4.4 MANAGEMENT CONSIDERATIONS**

Mammals and birds either opportunistically or dependently use rock-holes for water though stock-watering points installed by pastoralists would have significantly decreased the usage on the rock-holes.

This project will record the threat caused by introduced mammals to rock-holes and outcrops. Some animals like camels can drink a hole dry while others, like goats may cause the water quality to deteriorate due to their habit of urinating at the site. Vegetation condition at sites will also be recorded as an indication of grazing pressure at these watering points. This information will then be transferred into prioritisation of management actions across the landscape.

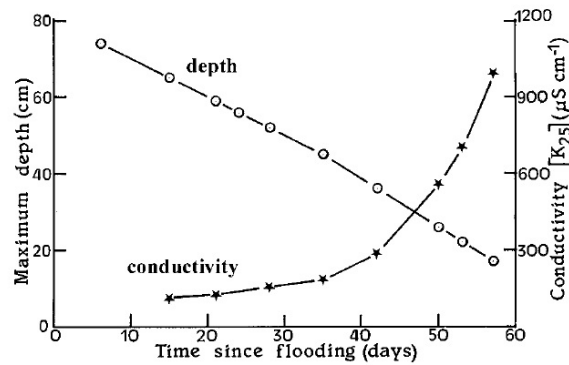
Drought resistant eggs of macro invertebrates and plants are deposited in the sediment of the rock-holes and it is important that these systems are fully understood so that guidelines for cleaning of rock-holes can be made. The findings of Bayly (2001) highlight the need for more information to be collected from rock-holes existing in the arid areas to determine management guidelines for cleaning and protecting rock-holes. In 1998 Bayly (2001) sampled one rock-hole in Central Australia near Papunya after a rainfall event over an eight-week period until the hole dried out. The fauna assemblage of this rock-hole was markedly different from those that Bayly (1982, 1997) had previously sampled in Western Australia. The presence of the fairy shrimp *Streptocephalus*, a taxon long believed not to exist in Australia and two new species of *Ilyocypris* (Crustacea: Ostracoda) and *Dorylaimus* (Nematoda: Dorylaimida) were discovered.

The ecological value of rock-holes may be determined in the Gawler Ranges by undertaking some targeted sampling of macro invertebrates and plants in the rock-holes after rainfall events.

## **4.5 SUMMARY**

The literature review and conceptualisation of the processes of the rock-holes now allow for targeted field-information that needs to be collected to determine which rock-holes may be ecologically significant in the landscape. Field information that needs to be collected is briefly described in the following table (Table 4.1)

Plants and animals completing life cycles in the rock-holes depend upon ideal equilibrium of sediment load and water column depth to survive. During the eight week drying of the rock-hole in central Australia (Bayly, 2001), conductivity sharply increased after 40 days once the water level was less than 40cm deep though the final conductivity was still indicative of fresh water (Figure 4.3).



**Figure 4.3** Temporal changes in maximum depth and electrical conductivity of the Warumpi Hill rock-hole, near Papunya in Central Australia (Bayly, 2001)

Once sediments build up in the pit-gnammas it may limit the time that they have to complete their life cycle, it is vital that some sediment stays in the rock-holes for the seed and eggs to survive in until the next inundation period.

**Table 4.1** Field Information to be collected as part of the ecological assessment of rock-holes

Assemblage	Feature	Comments
Landform	Identify if outcrop/dome has pit or pan gnammas	Map and measure dimensions and depth of each pit/pan to determine water volume. Locate water marks for depth average. Measure depth of soil in bottom of pit to determine potential egg-bank and seed-bank presence.
Water	Rock-hole	Record pH, conductivity and temperature.
Plants	Rock-hole	Identify species present.
	Outcrop / dome	Identify species present.
	Soak	Identify species present.
	Surrounding area	Determine surrounding vegetation association.
Animals	Rock-hole	Species present if water is present (may depend upon funding, as macro-invertebrates will need to be sent to a laboratory for identification).
	Outcrop, soak and surrounds	Species present (scats and tracks) and habitat availability.



## 5. FIELD VISITS

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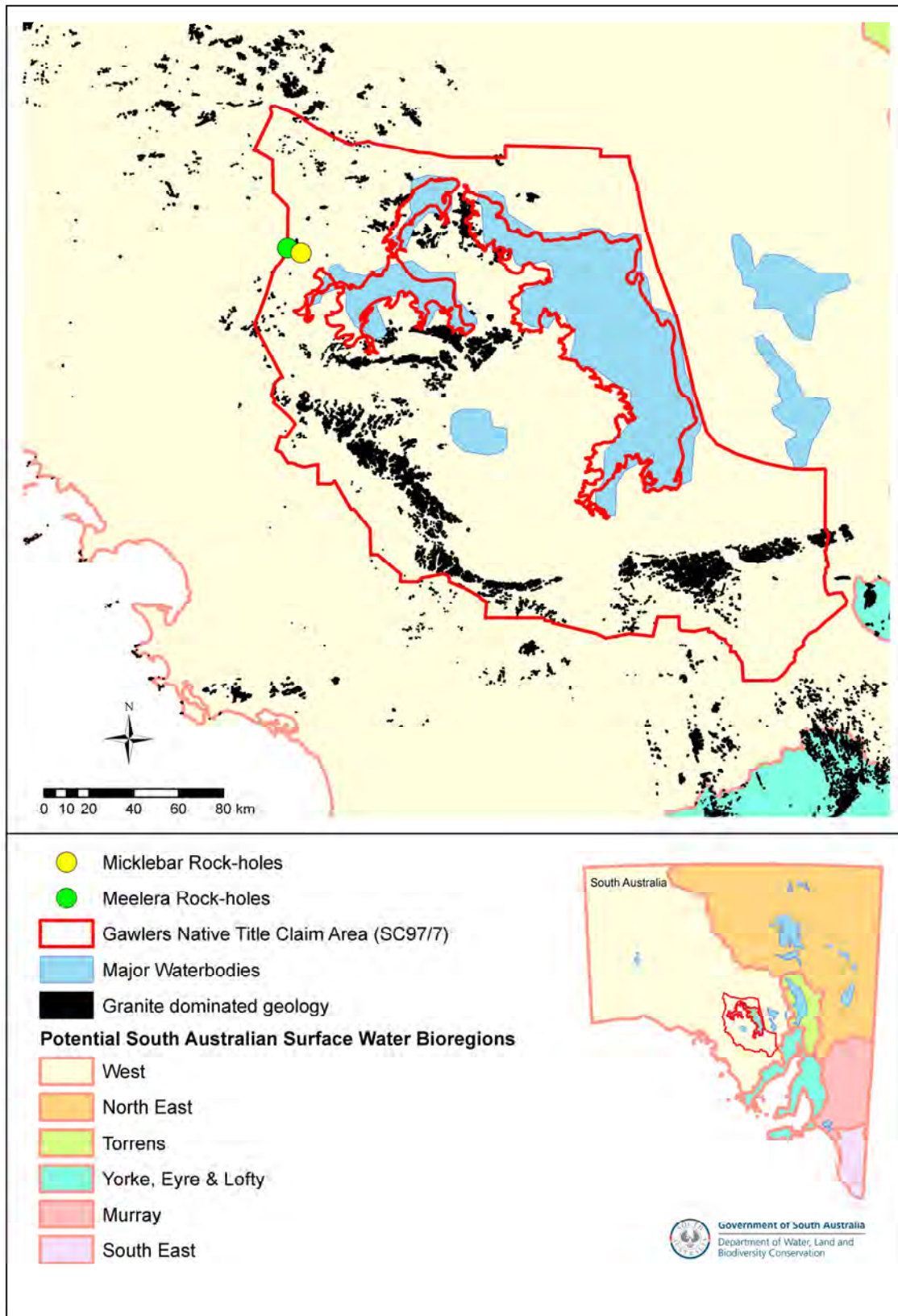
The Knowledge and Information Division of DWLBC is working with the South Australian Arid Lands (SAAL) NRM Board, South Australian Native Title Unit and Aboriginal people of the Gawler Ranges to identify culturally significant rock-holes in the Gawler Ranges. The Gawler Ranges has registered an Indigenous Land Use Agreement which acknowledges the different rights and interests that parties have in land and water, this agreement allows negotiations of Native Title in a framework that respectfully meets the needs of all. The project has adopted protocols and procedures for working with culturally sensitive information, which has lead to a positive engagement with the Aboriginal community.

The survey of rock-holes in the Gawler Ranges will be used as a pilot study for undertaking this type of work and aims to then be extended into other NRM regions. The first field visit allowed the Aboriginal people, landholders, anthropologists and ecologist to come together and meet each other while visiting rock-holes of interest. In regards to the ecological survey, the first visit gave the ecologist an understanding of what type of landscape the rock-holes were located and the type of holes that exist.

The first stage of the ecological assessment is to map and collect information on the different rock-hole types to start prioritising longer term monitoring and management objectives.

### **5.1 OCTOBER 2008**

Two granite pavements (Meelera and Micklebar) were visited in the Gawler Ranges in October 2008 (Figure 5.1). Numerous rock-holes existed on each pavement of varying size and shape. Due to circumstances on the day, the ecologist was only able to visit Micklebar Rock-Holes whereby a rapid assessment of the site was conducted, none of the pit-gnammas at the Micklebar granite pavement contained water on that visit. The near-by rock-hole, Meelera had some pit-gnammas that contained water during the visit.



**Figure 5.1** Location of granite outcrops visited in the Gawler Ranges as part of this project in **October 2008**. This map incorporates data which is Commonwealth of Australia (Geoscience Australia) 2009.

## 5.2 MEELERA ROCK-HOLES

Four pit-gnammas on the Meelera pavement contained water at the time of visit on 8 October 2008. Due to the ecologist not visiting the pavement, no water sampling or vegetation notes were recorded but photographs of the rock-holes and granite outcrop taken by other team members and give some insight into the current state of the rock-holes at the outcrop. Photographs have not been included in this report as the Aboriginal claimant group have requested for cultural reasons due to the way the site was visited on the day that photos are not made public.

Meelera dome is located amongst a large sand-dune complex, with a variety of vegetation growing on and around the dome with some plants benefiting from the extra rainfall run-off on apron areas of the outcrop.

Rock-holes with water in them were in the drying stage indicated by lichen and algae 'water-marks' on the side of the hole. Rainfall data from the nearest meteorological station at Tarcoola recorded 11.6 mm of rain falling on 30 August and a total of 4 mm was recorded for the whole month of September before the visit to the rock-holes on 8 October 2008 (Bureau of Meteorology, 2008), this rainfall data was verified by the station managers of Wilgena, where the rock-holes exist. Evaporation is at its lowest at this time of the year in this region (May – September) giving reason to the existence of water in the pit-gnammas even with such a low rainfall record. The combination of winter rainfall, low evaporation rates and deep holes (pit-gnammas) increase the duration of water in the ephemeral rock-holes.

Plants were observed growing in the drying sediment of the one of the pit-gnammas (D.Blesing pers comm.). The plant might be Australian Mudwort (*Limosella australis*), a plant that grows in wet sediment in response to flooding, though without proper identification this cannot be confirmed. This is a wetland species that is commonly found in ephemeral wetlands and the silt of rock-holes (PlantNet, 2008; FloraBase, 2008) as the seed can tolerate drying and inundation conditions.

Aboriginal people had previously cleaned the rock-holes on the Meelera granite outcrop when visiting the site as part of their management objectives (date to be confirmed). The cleaning of the rock-holes includes removing dead animals and sometimes the silt and water and then placing a stick into the holes to allow small birds and animals to escape if they fall in.

Removal of water and silt may disrupt the breeding cycle and occurrence of macro invertebrates and it is recommended that some guidelines are developed to ensure the survival of these invertebrates at rock-holes before any future cleaning is undertaken.

The photos indicate that sedimentation of the pit-gnammas is currently not an issue, though the water may be fouled by animal dung but would not be considered a threat due to its minimal occurrence at the site.

### 5.3 MICKLEBAR ROCK-HOLES

The Aboriginal women in the field team had not visited this granite dome before; they had only visited Meelera Rock-holes on previous occasions even though they are located relatively close to each other (E. Wingfield and S.Haseldine pers com, 2008). The Aboriginal members of the group who have previous experience with 'cleaning' rock-holes believed that the rock-holes at the Micklebar granite dome were filling with sediment and needed to be cleaned out.

Micklebar Rock-holes are located approximately 5 km east of Meelera Rock-holes. Four pit-gnammas and a number of pan-gnammas are located on the Micklebar granite pavement. None of the holes were holding water at the time of the visit, 8 October 2008 though one hole had damp soil in the bottom.

Sediment was apparent in all four pit-gnammas (Figure 5.2) though depth of the sediment and size of each rock-hole was not measured. A large number of quandong seeds had collected in the pan-gnammas (Figure 5.3), believed to have been left behind by emus who feed on the fruit and would visit the outcrops for water, with the seeds being left behind in their scats.

There was one run-off zone on the edge of the granite pavement where *Istome petraea* was growing along with some other shrubs. An old Aboriginal wiltja (scrub hut) was also in this run-off zone (Figure 5.4). A Red-capped Robin was sighted in the vegetation thickets associated with the wiltja and run-off zone indicating the use of the vegetation even though the rock-holes were dry meaning that the area may still be important habitat even when there is no water.

**This photo has been removed for cultural purposes.**

**Figure 5.2 Dry pit-gnammas on the Micklebar granite pavement in the Gawler Ranges showing evidence of sediment collection in the bottom of the pits at 8 October 2008 (M.White, 2008)**

This photo has been removed for cultural purposes.

Figure 5.3 Quandong (*Santalum acuminatum*) seeds collected in the pan-gnammas on the Micklebar granite pavement in the Gawler Ranges, deposited by emus that feed on the fruit and drink at the rock-holes (M. White, 2008)

This photo has been removed for cultural purposes.

Figure 5.4 Shrubs and an Aboriginal Wiltja (scrub hut) associated with the run-off apron zone on the Micklebar granite pavement in the Gawler Ranges (M. White, 2008)





## 6. RECOMMENDATIONS

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It is recommended that this project sit within a larger state programme within DWLBC, Department of Environment and Heritage (DEH), the NRM Boards, and the Native Title Unit. The objective of such a programme is to engage Aboriginal people with water resource management in South Australia, especially the arid regions. This will be a pilot project for determining the path of future projects.

It is recommended that ecological and cultural information on rock-holes across the state in all the NRM Regions and DEH Parks and Reserves is collected and managed appropriately. A state-wide coverage and integration of Indigenous management of this water resource will be valuable in not only ensuring preservation of these rock-hole ecosystems but will also protect and respect Aboriginal cultural heritage.

It is recommended that the Aboriginal people and pastoralists of the Gawler Ranges are consulted with what output they would like from this project. This report meets the needs of the SAAL Board but perhaps a manual on rock-hole cleaning can be developed along with a pictorial education booklet about rock-hole sites and their corresponding stories may be preferred by the broader community.

It is recommended that as part of this project rock-holes outside the Native Title Boundary in the Gawler Ranges region still be visited. The role of this project is to map and determine the current state and condition of rock-holes across the whole region, once this process has further developed, decisions can then be made about the management of cultural and ecological significant sites.

There was concern on the October 2008 field trip by the Aboriginal women that the rock-holes on the Micklebar granite pavement contained too much sediment. At this stage, it is recommended that due to its close proximity to Meelera where the rock-holes are not suffering from sedimentation that the Micklebar holes are not cleaned until further discussion are had with the Aboriginal group to discuss the ecological findings from other studies about seed and egg bank deposits that may occur in the Micklebar rock-hole sediment. Once this discussion has been had, we can then further advance some guidelines on what depth of sediment should be left in holes during the cleaning process. It must also be considered that the current sediments at the site may contain important palaeoecology and anthropology records and should not be disturbed until more site visits are completed and it is fully understood what conditions the rock-holes are in across the region.

It is recommended that a component of the field investigations be centred on collecting aquatic invertebrate samples of the holes after rainfall. This type of sampling is currently beyond the scope of the second stage of work from January to June 2009, but should be considered as a sampling technique after June 2009 especially during the wetter months of June, October and February (BoM, 2008) when rock-holes fill from localised rainfall event.





# APPENDICES

## APPENDIX A.

**Table A. Rock-hole data from Pastoral Lease Field Diagrams from 1899 - 1901**

Name	Supply	Remarks	Reference
Walbinna	600 gal (2,727 L)	One hole 500 gal and one hole 100 gal. No water fit for use.	Wilgena, PLFD Vol.11, No.494. 1901
Darebin	100 gal (455 L)	No water at time of fixing.	Wilgena, PLFD Vol.11, No.494. 1901
Mullina	150 gal (682 L)	Recently cleaned out and brushed in. No water at time of fixing.	Wilgena, PLFD Vol.11, No.494. 1901
Moolkra	50 gal (227L)	Poor and small holes. No water at time of fixing.	Wilgena, PLFD Vol.11, No.494. 1901
Coolbring	3,000 gal (13, 636 L)	Very poor catch. No water at time of fixing.	Wilgena, PLFD Vol.11, No.494. 1901
Adelbing	5,000 gal (22, 727 L)	Good hole and good catch. Roofed over. Full of water.	Wilgena, PLFD Vol.11, No.494. 1901
Wiltabbie	100 gal (445 L)	Poor and small holes. Dry.	Wilgena, PLFD Vol.11, No.494. 1901
Warna	200 gal (909 L)	Requires cleaning out. No water fit for use.	Wilgena, PLFD Vol.11, No.494. 1901
Keynella	500 gal (2,272 L)	Requires cleaning out. No water fit for use.	Wilgena, PLFD Vol.11, No.494. 1901
Bulpara	13,000 gal (59,091 L)	One hole 8,000 gal and 2 ft deep. One 5,000 and 3 ft deep. Full of water.	Wilgena, PLFD Vol.11, No.494. 1901
Twins	10 gal (45 L)		Wilgena, PLFD Vol.11, No. 492. 1899
Rock-hole unnamed	150 gal (682 L)	One hole 100 gal and several small holes.	Wilgena, PLFD Vol.11, No. 492. 1899
Rock-holes unnamed	8 gal (36 L)	Only very small holes.	Wilgena, PLFD Vol.11, No. 492. 1899
Carnding	80 gal (364 L)	Also several shallow holes holding large quantities of water for short times only.	Wilgena, PLFD Vol.11, No. 492. 1899
Pompeter	300 gal (1,364 L)	Poor shallow holes.	Wilgena, PLFD Vol.11, No. 483. 1899.

Name	Supply	Remarks	Reference
Konkaby	4,000 gal (18,181 L)	One hole 2,500 gal and one 300 gal. Also good shallow holes holding several thousand gallons for short time after rain.	Wilgena, PLFD Vol.11, No. 483. 1899.
Arcoordaby	4,000 gal (18,181 L)	Small embankment.	Wilgena/Arcoordaby, PLFD Vol.11, No. 478, 1899.
Tunkillia		Large shallow holes holding great quantity of water for short time only.	Wilgena/Arcoordaby, PLFD Vol.11, No. 478, 1899.
Pildinga	500 gal (2,273 L)		Wilgena/Arcoordaby, PLFD Vol.11, No. 478, 1899.
Swamps (W of Tunkilla)	9 months	Last time filled Jany 1897.	Wilgena/Arcoordaby, PLFD Vol.11, No. 478, 1899.
Rock-hole (near NW Arm Trig)	50 gal (227 L)		Wilgena/Arcoordaby, PLFD Vol.11, No. 478, 1899.
Talia	100 gal (455 L)	Very poor catch. No water at time of fixing.	Kychering, PLFD Vol. 11, No. 495, 1899.
Rock-hole (near SW corner of Lease 3115)	75 gal (341 L)	About 20 gallons at time of fixing.	Kychering, PLFD Vol. 11, No. 495, 1899.
Rock-hole (About 13 miles SE of Mt Finke)	50 gal (227 L)		Kychering, PLFD Vol. 11, No. 495, 1899.
Coladding		Fenced in. Water Reserve gazetted 23/6/10 (1910?)	Gibraltar, PLFD Vol. 11, No. 470, 1899.
Gibraltar		Soakage (poor)	Gibraltar, PLFD Vol. 11, No. 470, 1899.
Rock-hole			Muckanippie, PLFD Vol. 12, No. 501, 1899.
Soakage			Muckanippie, PLFD Vol. 12, No. 501, 1899.
Rock-hole	200 gal (909 L)		Mulgathing, PLFD Vol. 12, No. 502, 1899.
Soakages (2)			Mulgathing, PLFD Vol. 12, No. 502, 1899.

**Table B. Plants recorded as growing in pit and pan gnammas in South Australia (Bayly, 1999)**

Family	Species	Location	Comments
Isoetaceae	<i>Isoetes drummondii</i>	All southern states	
	<i>Isoetes muelleri</i>	All states except Tas	
Scrophulariaceae	<i>Glossostigma diandrum</i>	All states except NT	
	<i>Glossostigma cleistanthum</i>	SA, NSW, VIC	
	<i>Glossostigma drummondii</i>	WA, SA , VIC	
	<i>Glossostigma sp.</i>	WA, SA	Endemic to far south of WA and the Eyre Peninsula in SA (Carapsee Hill).
	<i>Limosella australis</i>	All states	
	<i>Limosella curdieana</i>	All states except WA	
	<i>Limosella granitica</i>	SA	Restricted to a few inselbergs on the Eyre Peninsula
Elatinaceae	<i>Elatine gratioloides</i>	SA	Found at gnamma pools on the upper Eyre Peninsula.
Crassulaceae	<i>Crassula peduncularis</i>	SA	Grows submerged on Wudinna Hill and Carapsee Hill (Eyre Peninsula)
Zannichelliaceae	<i>Lepilaena australis</i>	SA	Recorded from two pit-gnammas on Pildappa Rock (upper Eyre Peninsula).

**Table C. Mammals potentially using rock-holes in the arid lands (Robinson et al, 1985; Ehmann, 2005). \* Indicates introduced mammals**

<b>Species</b>	<b>Common Name</b>
* <i>Bos taurus</i>	Cow
* <i>Camelus dromedarius</i>	Camel
<i>Canis lupus dingo</i>	Dingo
* <i>Canis lupus familiaris</i>	Dog
* <i>Capra hircus</i>	Goat
* <i>Equus asinus</i>	Donkey
* <i>Equus caballus</i>	Horse
* <i>Felis catus</i>	Cat
* <i>Lepus capensis</i>	Hare
<i>Macropus fuliginosus</i>	Western Grey Kangaroo
<i>Macropus robustus</i>	Euro
<i>Macropus rufus</i>	Red Kangaroo
* <i>Mus domesticus</i>	House Mouse
* <i>Oryctolagus cuniculus</i>	Rabbit
* <i>Ovis aries</i>	Sheep
<i>Petrogale xanthopus xanthopus</i>	Yellow-footed Rock Wallaby
<i>Pseudomys bolami</i>	Bolam's Mouse
<i>Pseudomys hermannsburgensis</i>	Sandy Inland Mouse
* <i>Vulpes vulpes</i>	Fox

**Table D. Reptiles associated with rocky areas from the 1985 Gawler Ranges Biological Survey (Robinson et al, 1988). Also listed are frog species with a distribution range into the Gawler Ranges (Ehmann, 2005).**

Assemblage	Species	Habitat
Dragon-lizard	<i>Ctenophorus fionni</i>	Rocky areas
	<i>Tympanocryptis tetraporophora</i>	Especially on stony plains and hill.
Skink	<i>Cryptoblepharus plagiocephalus</i>	Arid eucalypt & acacia woodlands, and rock crevices.
	<i>Ctenotus robustus</i>	Variety of habits; dunes, heaths, savannah, mallee and rocky areas.
	<i>Ctenotus uber</i>	Chenopod shrublands, arid scrub, open woodland and small rock outcrops on open sandy and stony plains.
	<i>Egernia stokesii</i>	Rocky outcrops, stony hills and mountain ranges, shelters in deep crevices.
	<i>Egernia striolata</i>	Granite outcrops
	<i>Tiliqua occipitalis</i>	Stony areas associated with spinifex.
Gecko	<i>Diplodactylus elderi</i>	Broad range of arid habits including mallee, sand and stony hills.
	<i>Gehyra variegata</i>	Trees and granite outcrops
	<i>Heteronotia binoei</i>	Variety of habits including rock crevices
	<i>Underwoodisaurus milii</i>	May shelter in crevices but forages in grassed or sandy areas
Frog	<i>Neobatrachus centralis</i>	Burrowing frog found in flooded claypans after rain.
	<i>Neobatrachus pictus</i>	
	<i>Cyclorana platycephala</i>	



# GLOSSARY

**Aquatic community** — An association of interacting populations of aquatic organisms in a given water body or habitat

**Aquatic ecosystem** — The stream channel, lake or estuary bed, water, and/or biotic communities, and the habitat features that occur therein

**Aquatic habitat** — Environments characterised by the presence of standing or flowing water

**Arid lands** — In South Australia, arid lands are usually considered to be areas with an average annual rainfall of less than 250 mm and support pastoral activities instead of broadacre cropping

**Biodiversity** — (1) The number and variety of organisms found within a specified geographic region. (2) The variability among living organisms on the earth, including the variability within and between species and within and between ecosystems

**Biota** — All of the organisms at a particular locality

**BoM** — Bureau of Meteorology, Australia

**Diversity** — The distribution and abundance of different kinds of plant and animal species and communities in a specified area

**DWLBC** — Department of Water, Land and Biodiversity Conservation (Government of South Australia)

**EC** — Electrical conductivity; 1 EC unit = 1 micro-Siemen per centimetre ( $\mu\text{S}/\text{cm}$ ) measured at 25°C; commonly used as a measure of water salinity as it is quicker and easier than measurement by TDS

**Ecological indicators** — Plant or animal species, communities, or special habitats with a narrow range of ecological tolerance; for example, in forest areas, such indicators may be selected for emphasis and monitored during forest plan implementation because their presence and abundance serve as a barometer of ecological conditions within a management unit

**Ecological processes** — All biological, physical or chemical processes that maintain an ecosystem

**Ecological values** — The habitats, natural ecological processes and biodiversity of ecosystems

**Ecology** — The study of the relationships between living organisms and their environment

**Ecosystem** — Any system in which there is an interdependence upon, and interaction between, living organisms and their immediate physical, chemical and biological environment

**Endangered species** — (1) Any species in danger of extinction throughout all or a significant portion of its range

**Endemic** — A plant or animal restricted to a certain locality or region

**Ephemeral streams or wetlands** — Those streams or wetlands that usually contain water only on an occasional basis after rainfall events. Many arid zone streams and wetlands are ephemeral.

**Erosion** — Natural breakdown and movement of soil and rock by water, wind or ice; the process may be accelerated by human activities

**Eutrophication** — Degradation of water quality due to enrichment by nutrients (primarily nitrogen and phosphorus), causing excessive plant growth and decay. See also algal bloom

**Evapotranspiration** — The total loss of water as a result of transpiration from plants and evaporation from land, and surface water bodies

**Geological features** — Include geological monuments, landscape amenity and the substrate of land systems and ecosystems

**Geomorphology** — The scientific study of the landforms on the Earth's surface and of the processes that have fashioned them

**GIS** — Geographic Information System; computer software linking geographic data (for example land parcels) to textual data (soil type, land value, ownership). It allows for a range of features, from simple map production to complex data analysis

**Groundwater** — Water occurring naturally below ground level or water pumped, diverted and released into a well for storage underground; see also 'underground water'

**Habitat** — The natural place or type of site in which an animal or plant, or communities of plants and animals, live

**Hydrology** — The study of the characteristics, occurrence, movement and utilisation of water on and below the Earth's surface and within its atmosphere; see also 'hydrogeology'

**Impact** — A change in the chemical, physical, or biological quality or condition of a water body caused by external sources

**Indigenous species** — A species that occurs naturally in a region

**Infrastructure** — Artificial lakes; dams or reservoirs; embankments, walls, channels or other works; buildings or structures; or pipes, machinery or other equipment

**Lake** — A natural lake, pond, lagoon, wetland or spring (whether modified or not) that includes part of a lake and a body of water declared by regulation to be a lake. A reference to a lake is a reference to either the bed, banks and shores of the lake or the water for the time being held by the bed, banks and shores of the lake, or both, depending on the context.

**Land** — Whether under water or not, and includes an interest in land and any building or structure fixed to the land

**Macro-invertebrates** — Aquatic invertebrates visible to the naked eye including insects, crustaceans, mollusks and worms that inhabit a river channel, pond, lake, wetland or ocean

**Model** — A conceptual or mathematical means of understanding elements of the real world that allows for predictions of outcomes given certain conditions. Examples include estimating storm run-off, assessing the impacts of dams or predicting ecological response to environmental change

**Monitoring** — (1) The repeated measurement of parameters to assess the current status and changes over time of the parameters measured (2) Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, animals, and other living things

**Native species** — Any animal and plant species originally in Australia; see also 'indigenous species'

**Natural resources** — Soil, water resources, geological features and landscapes, native vegetation, native animals and other native organisms, ecosystems

**NRM** — Natural Resources Management; all activities that involve the use or development of natural resources and/or that impact on the state and condition of natural resources, whether positively or negatively

**Population** — (1) For the purposes of natural resources planning, the set of individuals of the same species that occurs within the natural resource of interest. (2) An aggregate of interbreeding individuals of a biological species within a specified location

**Rehabilitation (of water bodies)** — Actions that improve the ecological health of a water body by reinstating important elements of the environment that existed prior to European settlement

**Restoration (of water bodies)** — Actions that reinstate the pre-European condition of a water body

**Stock use** — The taking of water to provide drinking water for stock other than stock subject to intensive farming (as defined by the Act)

**Surface water** — (a) water flowing over land (except in a watercourse), (i) after having fallen as rain or hail or having precipitated in any another manner, (ii) or after rising to the surface naturally from underground; (b) water of the kind referred to in paragraph (a) that has been collected in a dam or reservoir

**Sustainability** — The ability of an ecosystem to maintain ecological processes and functions, biological diversity, and productivity over time



**Taxa** — General term for a group identified by taxonomy, which is the science of describing, naming and classifying organisms

**Threatened species** — Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range

**Turbidity** — The cloudiness or haziness of water (or other fluid) caused by individual particles that are too small to be seen without magnification, thus being much like smoke in air; measured in Nephelometric Turbidity Units (NTU)

**Water column** — a section of water extending from the surface of a body of water to its bottom. In the sea or ocean, it is referred to as 'pelagic zone'

**Watercourse** — A river, creek or other natural watercourse (whether modified or not) and includes: a dam or reservoir that collects water flowing in a watercourse; a lake through which water flows; a channel (but not a channel declared by regulation to be excluded from the this definition) into which the water of a watercourse has been diverted; and part of a watercourse

**Water-dependent ecosystems** — Those parts of the environment, the species composition and natural ecological processes, that are determined by the permanent or temporary presence of flowing or standing water, above or below ground; the in-stream areas of rivers, riparian vegetation, springs, wetlands, floodplains, estuaries and lakes are all water-dependent ecosystems

**Water quality monitoring** — An integrated activity for evaluating the physical, chemical, and biological character of water in relation to human health, ecological conditions, and designated water uses

**WDE** — Water dependent ecosystem

**Wetlands** — Defined by the Act as a swamp or marsh and includes any land that is seasonally inundated with water. This definition encompasses a number of concepts that are more specifically described in the definition used in the Ramsar Convention on Wetlands of International Importance. This describes wetlands as areas of permanent or periodic to intermittent inundation, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tides does not exceed six metres.



# REFERENCES

- Bayly IAE, 1982, 'Invertebrate fauna and ecology of temporary pools on granite outcrops in southern Western Australia', in *Australian Journal of Marine and Freshwater Research*, 33, pp. 599-606
- Bayly IAE, 1997, 'Invertebrates of temporary water in gnamma on granite outcrops in Western Australia', in *Journal of the Royal Society of Western Australia*, 80, pp. 167-172
- Bayly IAE, 1999, *Rock of Ages: human use and natural history of Australian granites*, University of Western Australian Press, Nedlands
- Bayly IAE, 2001, 'Invertebrate occurrence and succession after episodic flooding of a central Australian rock-hole', in *Journal of the Royal Society of Western Australia*, 84, pp. 29-32
- Bindon PR, 1997, 'Aboriginal people and granite domes', in *Journal of the Royal Society of Western Australia*, 80, pp.173-179
- Bureau of Meteorology, 2008, Australia, <http://www.bom.gov.au/>
- Campbell EM, 1997, 'Granite Landforms', in *Journal of the Royal Society of Western Australia*, 80, pp. 101-112
- Ehmann H, 2005, *South Australian Rangelands and Aboriginal Lands Wildlife Management Manual: a resource handbook*, Department of Water Land and Biodiversity Conservation, Adelaide
- Florabase, Western Australian Flora, Australia, 2008, <http://florabase.calm.wa.gov.au/>
- Harvey Johnston T, 1941, 'Some Aboriginal Routes', in *Proceedings of the Royal Geographical Society of Australasia (South Australian Branch)*, Vol XL11, pp. 33- 65
- Hopper SD, Brown AP and Marchant NG, 1997, 'Plants of Western Australian granite outcrops', in *Journal of the Royal Society of Western Australia*, 80, pp. 141-158
- Jocqué M, Timms BV and Brendonck L, 2007, 'A contribution on the biodiversity and conservation of the freshwater fauna of rocky outcrops in the central Wheatbelt of Western Australia', in *Journal of the Royal Society of Western Australia*, 90, pp. 137-142
- Kokatha Mula Nation, 2008, Australia, <http://www.kokathamula.auspics.org.au/>
- Lethbridge MR, 2004, *The Survey of the Yellow-footed Rock-wallaby in the Gawler Ranges and Recommendations for further Monitoring*, Report to the Department for Environment & Heritage
- Main BY, 1997, 'Granite Outcrops: A collective ecosystem', in *Journal of the Royal Society of Western Australia*, 80, pp. 113-122
- Pinder AM, Halse SA, Sheil RJ and McRae JM, 2000, 'Granite outcrops in south-western Australia: a foci of diversification and refugia for aquatic invertebrates', in *Journal of the Royal Society of Western Australia*, 83, pp. 149-161
- PlantNet, Flora of New South Wales, 2008, Australia, <http://plantnet.rbgsyd.nsw.gov.au/floraonline.htm>
- Robinson AC, Casperson KD, Canty PD and Macdonald CA, 1988, 'A biological survey of the Gawler Ranges South Australia in October 1985', National Parks and Wildlife Service Department of Environment and Planning, South Australian Museum Department for the Arts, South Australia
- Simpson V, 2008, *Aboriginal Access to Water Across Australia*, prepared for the Department of Water Land and Biodiversity Conservation by Rural Solutions SA, August 2008.

Scholz G and Fee B, 2008, *A Framework for Identification of Wetland Condition Indicators: A National Trial – South Australia*, Project DEP19, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Adelaide

Talbot HWB, 1912, 'Geological investigations in part of the North Coolgardie and East Murchison goldfields', in *Geological Survey of Western Australia*, Bulletin 45, Perth

Timms BV, 2006, 'The large branchiopods (Crustacea: Branchiopoda) of gnammas (rock holes) in Australia', in *Journal of the Royal Society of Western Australia*, 89: 163-173

Withers PC and Edward DH, 1997, 'Terrestrial fauna of granite outcrops in Western Australia' in *Journal of the Royal Society of Western Australia*, 80, pp. 159-166