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MOUND SPRINGS: SOUTH AUSTRALIAN CONSERVATION INITIATIVES

C.R. Harris

South Australian Department of Environment and Land Management, PO Box 667, Adelaide, SA 5001

Abstract

The mound springs of inland Australia are of outstanding scientific and cultural importance. Natural outlets for the waters of the Great Artesian Basin, they are found mostly on or near its margins. The most numerous and active are in the far north of South Australia. Parts of western Queensland still have active springs, but almost all in north-western New South Wales are now extinct, presumably because of aquifer draw-down in the wake of bore sinking.

As permanent sources of potable water in a desert environment they have been a focus for human activity over many years. Aboriginal occupation has been documented to at least 5000 years BP and almost all the springs are rich in archaeological material and mythological associations. Since European settlement they have been of strategic importance in exploration and in the location of pastoral stations, the Overland Telegraph and the old Ghan narrow gauge railway from Marree to Oodnadatta.

Biologically, they represent unusually specialised aquatic habitats, the discontinuity being analogous to islands and the isolation just as great for species with limited dispersal abilities. The result is an assemblage of plants and animals of evolutionary, biogeographic and ecological interest, with many endemic and relict species.

Heavily degraded by aquifer draw-down and over a century of pastoralism, the springs were given little attention until relatively recently. In the past decade two key areas have been acquired for the national parks system and ten important springs on pastoral country outside of the parks have been fenced. Important research has also been carried out, with a particular focus on the endemic elements of the invertebrate fauna.

These are positive achievements, but the remoteness of the localities where the springs occur presents a continuing difficulty for on-going conservation and management programs.

Introduction

Artesian springs occur throughout the world, but are particularly prominent in parts of central and inland Australia. Known locally as mound springs, they are natural outlets for the waters of the 1.76 million km^2 Great Artesian Basin, one of the largest of its kind in the world (Fig. 1).

Most of the numerous springs recorded for the Basin occur along its margins where the aquifers abut impervious basement rocks and where the confining beds are thin, although others occur as inliers where tectonism allows the waters to escape to the surface along fault lines and through fracture zones (Habermehl 1980, 1982). Since European settlement, aquifer draw-down in the wake of bore sinking has resulted in widespread flow decline and spring extinction. Western Queensland still has active springs, but almost all in north-western New South Wales are extinct. The far north of South Australia now has the most active and numerous springs.

Estimates of the actual number in South Australia vary, but the figure probably exceeds 600 (Badman 1991a). In the context of the surrounding landscape, all of the springs are small with flows varying from seepages to a maximum recording of 166 litres per second (L/s) for the main spring at Dalhousie, north-east of Oodnadatta (Williams 1974). The estimated flow from all mound springs in Australia is 1500 L/s, of which 62% (926 L/s) is from South Australian springs (Habermehl 1982). The waters are relatively high in dissolved solids, with total

dissolved solids (TDS) values ranging from below 2000 milligrams per litre (mg/L) for most of the springs at Dalhousie to around 8000 mg/L or more for some of the springs south-west of Lake Eyre (Williams 1974, Cobb 1975). Chemical precipitation of solids dissolved in the waters (particularly carbonates), along with the accumulation of wind blown and water borne particles, has resulted in many of the springs forming characteristic cones or mounds which give them the popular name "mound springs". In a geological time frame, the springs are dynamic, with abundant evidence of cyclic waxing, waning and extinction, but recent work has also documented considerable short term fluctuation in flow (Ponder *et al.* 1989, Olympic Dam Operations 1990, 1991, 1992).

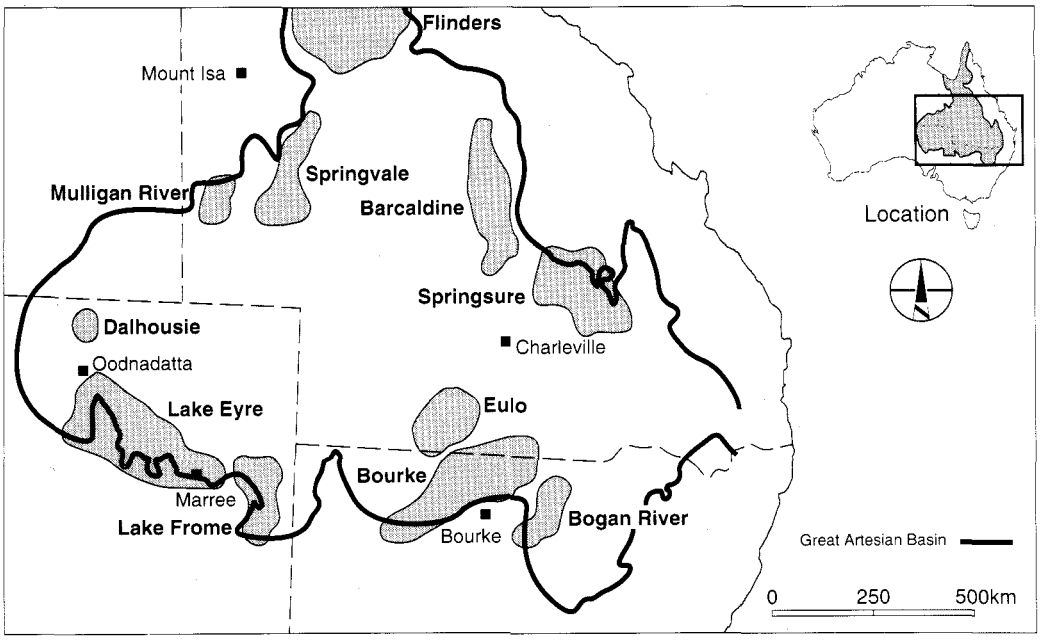

Fig. 1. Great Artesian Basin showing principal areas of mound spring activity. Modified from Habermehl (1980) & Ponder (1986).

Like those elsewhere in the Basin, the South Australian springs occur in arid and semi-arid country giving them an importance out of all proportion to their relatively small size. The presence of endemic and relict species reflects the unusually specialised nature of the habitat for fauna (Ponder 1986), whilst their potable waters have provided a focus for human activity over thousands of years (Harris 1981). Aboriginal people relied heavily on them in dry times, European explorers used them as "stepping stones" to the interior, early pastoral stations were centred on them and the alignments of the Overland Telegraph and the narrow gauge Ghan railway line between Marree and Oodnadatta were largely dictated by the alignment of the springs (Fig. 2).

Harris (1981) reviewed the natural and human history of the springs and concluded on a relatively pessimistic note: the biology of the springs was poorly known, there was little interest in them, they were severely degraded by over a century of pastoralism and aquifer draw-down, and new pressures were emerging in the form of the large Olympic Dam mining venture.

A decade on it is possible to be more optimistic. Interest in the springs has increased markedly, a great deal of new research has been undertaken and a range of important conservation measures initiated. This paper reviews current knowledge of the springs, assesses the recent conservation measures and looks to management needs in the future.

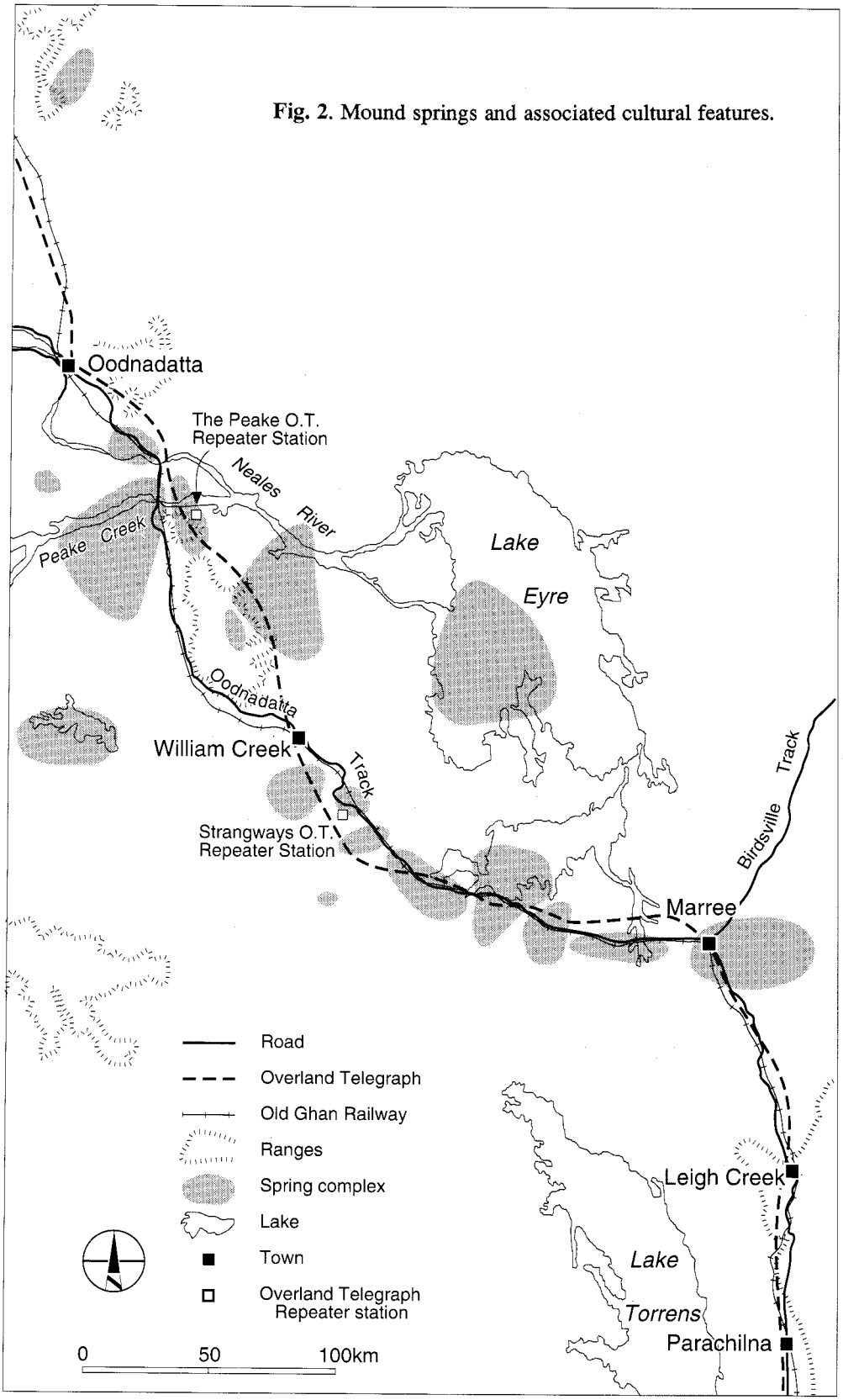

Fig. 2. Mound springs and associated cultural features.

Biological status

Flora

At the time of the 1981 review only one botanical survey of any significance had been conducted, of springs west and south-west of Lake Eyre in 1978. Harris (1981) referred to some of the findings, including the discovery of the endemic salt pipewort *Eriocaulon carsonii* at Hermit Hill on Finniss Springs station, but the results of the 1978 survey were not published formally until some years later (Symon 1985).

The situation was changing, however, the catalyst for important new surveys in the early 1980s being the Olympic Dam mining venture. Extensive exploration work by the Western Mining Corporation in the 1970s had confirmed the presence of major reserves of copper, uranium and gold in ore bodies to the west of Lake Torrens, and it was clear from feasibility studies that the extraction and processing of these would require large quantities of water, up to 33 megalitres per day (ML/d) being forecast. The favoured source was the Great Artesian Basin, the southern margins of which are approximately 100 km north of the mine site, but it was apparent from the outset that extraction at the rates proposed would create a localised draw-down cone in the aquifer and adversely affect nearby mound spring flows (Kinhill-Stearns Roger 1982). The Olympic Dam mining proposal had been controversial from the start, with very strong opposition from anti-uranium interests, and the threat to mound springs in the vicinity of the proposed bore field further heightened the controversy (Ferguson 1985).

To fulfil environmental impact assessment procedures and allay some of the concerns, the mining consortium commissioned a series of detailed studies of the mound springs likely to be affected. The botanical component of this work was significant, involving sampling for species incidence and relative abundance in 250 springs and bores from near Marree to Lake Cadibarrawirracanna west of William Creek (Kinhill Stearns 1984a). The mine has since commenced production and systematic monitoring of the vegetation at selected springs in the vicinity of the production bore field is being carried out by the mining company as part of a broad program of environmental audit (Olympic Dam Operations 1990, 1991, 1992).

At the same time that the environmental impact surveys were conducted, the then South Australian Department of Environment and Planning (name recently changed to South Australian Department of Environment and Land Management) commenced a complementary study of the remaining springs in South Australia, excluding Dalhousie, the biology of which was receiving separate attention at that time. The subsequent report (Social and Ecological Assessment 1985) recorded, among other things, the rediscovery of *E. carsonii* at Public House Springs north of the Flinders Ranges. Before its discovery by Symon at Hermit Hill in 1978, the species was known from only two late nineteenth century collections, one from Public House Springs and the other from the type locality near Louth in north-western New South Wales. It was subsequently found at Elizabeth Springs in western Queensland (Ponder 1985) and in 1986 was collected at mound springs on the western side of Peery Lake in north-western New South Wales by a party from the Western Lands Commission and the Royal Botanic Gardens Sydney (Goodson, *pers. comm.* 1986).

Although well away from any draw-down impact associated with the Olympic Dam mining venture, the large and impressive Dalhousie Springs attracted considerable attention and work throughout the 1980s, with botanical surveys reported by Symon (1984) and Mollemans (1989). One hundred species of terrestrial and semi-aquatic plants were recorded, including the endemic *Nicotiana burbidgeae* and the relict duck weed *Lemna disperma* and blady grass *Imperata cylindrica.*

Reviewing the various botanical surveys of the 1980s, Lange and Fatchen (1990) highlighted the fact that there was great variation between springs. Some of the differences could probably

be explained by variation in water chemistry, but in most cases the species combinations were bewildering, suggesting that random colonisation and extinction processes were largely responsible: no evidence of orderly succession reflecting spring age and activity could be found. At the same time, they did identify a number of common characteristics, pointing out that whilst the aquatic habitat provided by the springs was minuscule, it had retained a range of relict and endemic species including *E. carsonii* which appeared to be of tropical origins, and cutting grass, *Gahnia trifida* and spike rush, *Baumea juncea,* which are widely disjunct from their main populations in more southern temperate regions. They also pointed out that the actual spring-specific flora of aquatic and semi aquatic plants is small, only a dozen or so species being present, including the endemics and relicts. Species diversity, it was found, was related to a rise in the number of springs rather than an increase in the area of an individual spring (Kinhill Stearns 1984a, Olympic Dam Operations 1990 1991, 1992), something which has interesting conservation implications (see later). The flora of the spring surrounds, whilst relatively rich by comparison with the spring-specific flora, comprise species not generally reliant on their waters.

Fauna

Island biogeography theory, applied in several of the botanical surveys referred to above, was also seen to be relevant in a number of the faunal studies conducted in the 1980s. As Ponder (1989) has pointed out, the habitat provided by permanent water in an arid environment is analogous to islands, the discontinuity being just as marked, and a diverse invertebrate fauna with many endemic species is present.

The endemic fauna is dominated by hydrobiid molluscs and crustaceans, animals with limited mobility and dispersal potential. Until the early 1980s they had attracted relatively little attention: the phreatoicid isopod, *Phreatomerus latipes,* had been described (Chilton 1922) along with an ostracod, *Ngarawa dirga* (De Deckker 1979), but as with the flora it was the Olympic Dam mining venture and environmental impact assessment work associated with it which provided the stimulus and funding for important new work (Kinhill-Stearns Roger 1982, Kinhill Stearns 1983, Kinhill Stearns 1984a). Amongst the results published to date are ten new species of hydrobiid snails in two new endemic genera (*Fonscochlea* and *Trochidrobia*) from springs between Marree and Oodnadatta (Ponder *et al.* 1989), at least six undescribed species of hydrobiids in a new endemic genus from Dalhousie (Ponder 1989), undescribed endemic ostracods (Ponder 1986), a macrostomid flatworm - the first record of the order from Australia (Sluys 1986), possibly endemic ostracods and copepods at Dalhousie (Zeidler 1989), a new genus and species of phreatic amphipod, *Phreatochiltonia anophthalma,* from Dalhousie Springs and undescribed amphipods of the genus *Austrochiltonia* (Zeidler 1991). The hydrobiids especially display many features associated with island faunas, including adaptive radiation in which habitat partitioning and size displacement are evident (Ponder *et al.* 1989). Other endemics, such as *P. anophthalma* at Dalhousie, may be relicts descended from species which were more widespread when central Australia was wetter than it is today (Zeidler 1991).

Many other invertebrates, especially insects, are associated with the springs. Although little work has been done on them, the high rate of endemism found in the hydrobiids and crustaceans is not expected because most of them (in the adult phase at least) are mobile and presumably capable of ready dispersal between springs and other water bodies in the region (Mitchell 1985).

Much the same can be said of the vertebrate fauna. The springs do provide habitat which is utilised by a range of birds, mammals and reptiles, but none rely solely on the springs and all are distributed widely throughout the region (Badman 1985, 1991b, Thompson 1985, West 1985, Smith 1989). Fish, with more limited powers of dispersal, represent something of an exception to this general pattern, with three of the eight native species present in the mound springs being endemic to Dalhousie: the Dalhousie catfish, *Neosilurus sp. nov.* Dalhousie

hardy head, *Craterocephalus dalhousiensis* and the Dalhousie goby, *Chlamydogobius sp. nov.* It is unclear whether the endemic species have evolved in isolation from stocks originating beyond Dalhousie or are relict populations (Glover 1989).

Palaeobiology

Faunal and plant fossils have been found at a number of mound springs, but are not common. Symon (1985) recorded peat deposits suitable for pollen analysis and Boyd (1989, 1990) reported on such work at Dalhousie Springs. The peat layers examined were found to contain macroscopic remains of plants and fossil pollen, mostly representative of the current wetland flora, although a Pleistocene conglomerate at Dalhousie has moulds and casts of female fruiting cones, bark and wood probably referable to *Allocasuarina*, a genus no longer occurring at the springs.

Boyd (1990) has reviewed other findings at springs, including fossil hydrobiids (probably of Pleistocene age) at Hermit Hill similar to those still present, suggesting early, rapid speciation, and fossil ostracods from a sediment core at Coward Springs. Teeth and a mandible referable to *Diprotodon* sp. have been found at Herrgott Springs near Marree and a *Diprotodon* mandible at Welcome Springs west of Marree.

Cultural heritage

The importance of the mound springs to successive generations of Aboriginal and European communities had been stressed by Harris (1981), but to complement the biological studies underway the then South Australian Department of Environment and Planning commissioned surveys of Aboriginal archaeology and anthropology, and non-Aboriginal cultural heritage associated with the mound springs.

The archaeological work was based on a field survey covering the springs from Lakes Frome and Callabonna west to Strangways Springs on the old Ghan railway (Kinhill Stearns 1985). The survey was later extended to include the springs at Dalhousie and those between William Creek and Oodnadatta (Lampert 1985, 1989). Florek (1987) reported work in progress on unnamed mound spring sites at Lake Eyre South. The surveys confirmed that many of the springs had been major habitation sites, with artefact densities up to 600/m^2. The tools present were typically of late Holocene age with tulas, pirris, microliths and seed grinders prominent. Both stratigraphy and artefact typology indicated an age within the past 5000 years, although at two springs west of Marree there was some evidence of older artefacts.

Field work for the anthropological study was carried out in September 1984, but the report drew extensively on work carried out over the previous 20 years when much detail on individual springs had been obtained from the Aboriginal people in the region (Hercus and Sutton 1985). The information presented on 134 springs is a major contribution to the literature and demonstrates clearly both the utilitarian and mythological significance of the springs to Aboriginal communities.

The assessment of the non-Aboriginal cultural heritage was based on a literature and archival search, and field work carried out in March-April 1984. The report when presented consisted of a thematic treatment of exploration, pastoralism, the Overland Telegraph, transport, settlement and mining; and a volume of data sheets providing field and archival details on 78 individual items and sites (Kinhill Stearns 1984b). The rich cultural heritage of the springs and their nexus with the pastoral industry, Overland Telegraph and old Ghan railway has also attracted much popular interest, general articles published including Wood (1982) and McGowan (1990).

Conservation initiatives

Establishing priorities

The biological and cultural heritage studies commissioned by the then Department of Environment and Planning aimed to provide data which could be used for comparative purposes in the Olympic Dam environmental impact assessment process, and to provide a basis for establishing conservation priorities for the springs. In relation to the second of these, there was a commitment within Government by the early 1980s to provide the kind of protection recommended by Harris (1981), namely inclusion of the most important springs in the national parks system and fencing for a range of others. Given funding limitations, however, priorities were needed - it was clearly out of the question to acquire or fence anything more than a very small proportion of the hundreds of springs.

The most direct basis for establishing priorities came from the biological survey carried out by Social and Ecological Assessment (1985). In the report, springs were assessed for biological value on the basis of species diversity, rarity status of species present, naturalness (i.e. spring condition) and perceived vulnerability to damage. An overall rating of high, medium or low was then given with a subsequent ranking as shown in Table 1.

Table 1. Overall ranking of mound springs (Social and Ecological Assessment 1985)

1	Dalhousie Springs
2	Freeling Springs
3	Hermit Springs
4	Old Finniss Springs
5	West Finniss Springs
6	Blanche Cup and Bubbler Springs Group
7	Strangways Springs (Telegraph Reserve)
8	Nilpinna Springs
9	Bopeechee Springs
10	The Fountain or Big Perry Springs
11	Big Cadna-owie Springs
12	Twelve Springs
13	Coward Springs and/or Warburton Springs
14	Davenport Springs

NB: Dalhousie, Hermit Springs and others near Lake Eyre were not in the Social and Ecological Assessment field survey, but available information on them was assessed and they were included in the overall ranking.

For methodological reasons, no comparable ranking was attempted in the cultural heritage surveys, but findings and priorities were cross-referenced to the biological rankings when a final list for conservation measures was compiled.

Acquisition of Dalhousie

At the same time that this work was underway, an important decision was taken within government to acquire Dalhousie Springs, an outstanding area which would emerge as a top priority for the national parks system in any method of ranking or scoring. The desirability of

acquisition had been mooted as early as 1970 (Harris 1989, Cohen 1989) but the lessee of Mount Dare Station was unwilling to sell. Following an inspection of the springs by senior officers of the then Department of Environment and Planning in late 1983, negotiations were reopened and in May 1984 State Cabinet approved purchase of the entire station (7769 km^2). All domestic livestock were removed by May 1985 and on 21 November 1985 the area was formally constituted and named Witjira National Park under the provisions of the South Australian *National Parks and Wildlife Act 1972* (Fig. 3).

Fencing of selected springs

The incorporation of Dalhousie into the national parks system was welcomed within and outside of government as a major breakthrough in mound springs conservation, but in parallel with this initiative, work continued on plans to fence a number of the more important springs elsewhere in the region. The final list for fencing was based on the priorities established in the surveys, but with some changes following consultation with the lessees of the pastoral properties involved (Table 2, Fig. 3).

Table 2. Springs fenced by South Australian Government, 1986-88

Name of spring	Pastoral station	Length of fencing (metres)	Area (ha)
Blanche Cup	Stuart Creek	396	1.0
The Bubbler	Stuart Creek	1231	6.3
Strangways	Anna Creek	242	0.1
Old Nilpinna	Nilpinna	830	4.0
Big Cadna-owie	Allandale	186	0.2
Big Perry	The Peake	631	2.7
Tarlton	The Peake	1273	9.2
The Fountain	The Peake	323	0.7
Outside	The Peake	294	0.4
Twelve Mile	The Peake	1004	2.6

Raising the necessary funds proved to be more difficult than first expected and it was some time before sufficient State, Commonwealth and private funds could be drawn together. Difficulties were also encountered in securing private contractors for what amounted to small jobs in remote areas, but a contract was eventually let for the first three springs, Blanche Cup, The Bubbler and Strangways. The fences erected were standard for the cattle country north of the Dog Fence, but funding constraints prevented them being rabbit netted. Stiles for pedestrian access were constructed and visitor information signs explaining the origins and significance of the springs were erected adjacent to the pedestrian access points. A number of technical problems were faced during the construction, caused mainly by hard limestone rock associated with the springs, but the work was completed by September 1986.

The balance of the springs to be fenced were in even remoter country, and because of the difficulties in engaging a contractor, the work was undertaken by field staff of the South Australian National Parks and Wildlife Service and completed in late 1988. Reflecting their remoteness from routes taken by the general public, comprehensive visitor information was not provided at these springs.

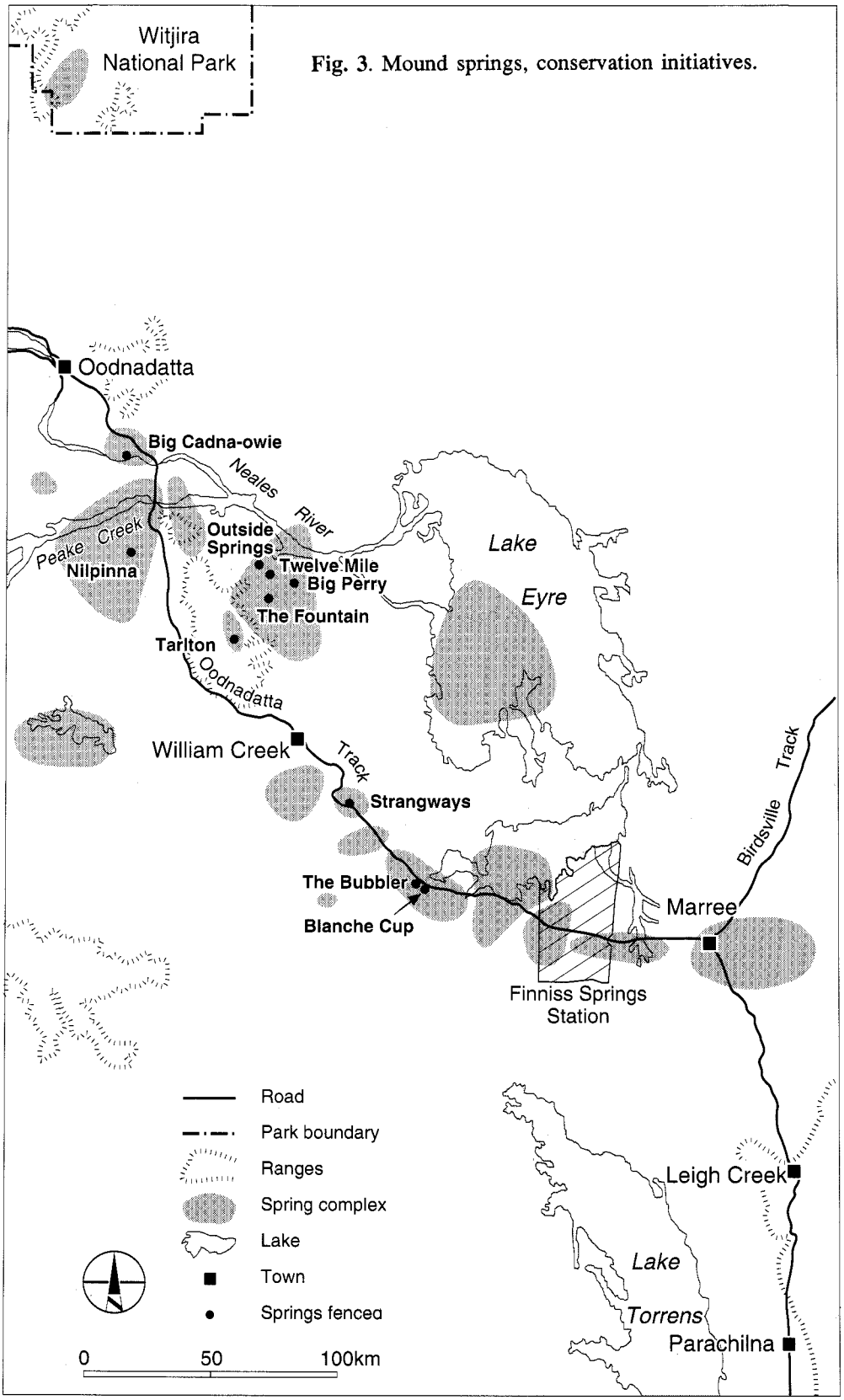

Fig. 3. Mound springs, conservation initiatives.

Acquisition of Finniss Springs

A notable omission from the fencing program was Hermit Hill and its adjacent mound springs on Finniss Springs station. As noted above, attention had been drawn to Hermit Hill when *E. carsonii* was discovered at it in 1978 and the subsequent environmental impact assessment and regional surveys had confirmed the importance of the locality. Some progress was made towards securing Commonwealth funds to fence the springs in the mid 1980s, but because of pastoral lease complexities the initiative lapsed.

Several years later negotiations were resumed, and in August 1991 it was announced that the State Government would acquire the entire (1492 km^2) Finniss Springs Station (Fig. 3). The principal motivation was mound springs conservation, but its importance to Aboriginal people having traditional ties with the area was also an important consideration. Final details are yet to be worked through, but it is intended that the area will become part of Lake Eyre National Park with the local Aboriginal community being given a lease over the former station area in a joint management arrangement similar to that already announced for Witjira National Park.

Listing of heritage sites

Over the past decade a number of important cultural heritage sites associated with the springs have been listed under both State and Commonwealth legislation.

Table 3 lists sites registered under the provisions of the *South Australian Heritage Act 1978*, and Table 4 lists non-Aboriginal heritage sites registered under the provisions of the Commonwealth's *Australian Heritage Commission Act 1975*. All Aboriginal sites and artefacts are protected under the provisions of the South Australian *Aboriginal Heritage Act 1988* and a number of individual Aboriginal sites at or near springs have been listed on the Commonwealth Register of the National Estate. Both pieces of South Australian legislation provide strong statutory protection for Aboriginal and non-Aboriginal heritage sites, but the Commonwealth legislation can only apply to activities undertaken or funded by the Commonwealth Government - it does not otherwise provide any legal constraint on landholders or on the actions of state and local government. More usefully, listing under the Commonwealth legislation can provide a basis for some Commonwealth financial assistance, and under the National Estate Grants Program funds were made available to the then South Australian Department of Environment and Planning in 1988-89 for stabilisation of the ruins at The Peake Overland Telegraph Repeater Station.

Table 3. Non-Aboriginal cultural heritage sites on State Heritage Register (*South Australian Heritage Act 1978*)

Site	Date entered
Strangways Springs Overland Telegraph Repeater Station	2/11/86
Curdimurka Railway Siding	8/11/84
Algebuckinna Railway Bridge	2/11/86
The Peake Overland Telegraph Repeater Station	28/5/87

Future management needs

Much has been achieved over the past decade. A great deal of new information has been gathered, two highly important areas have been acquired for the national parks system, cultural heritage sites have been listed and ten of the high priority springs have been fenced to exclude stock. The gains are encouraging, but on the ground some important management issues need to be faced.

Table 4. Non-Aboriginal cultural heritage sites on Register of National Estate (*Australian Heritage Commission Act 1975*)

Site	Date entered
Stuart Creek Railway Bridge	28/9/82
The Peake Overland Telegraph Repeater Station	14/5/91
Algebuckinna Railway Bridge	28/9/82
Curdimurka Railway Siding	26/3/85
Strangways Springs Overland Telegraph Repeater Station*	

* Nominated but not yet entered

National parks issues

The acquisition of Dalhousie and Finniss Springs has removed domestic stock pressures on those springs, but new pressures are arising, particularly from sharply increasing visitor numbers. Systematic records are not available, but it is known that visitation rates at Dalhousie increased very considerably when it became part of the parks system. Finniss Springs does not have the popular appeal of Dalhousie, but it is very accessible - straddling as it does the main Marree-Oodnadatta road - and increased visitation is inevitable.

The accompanying problems, including trampling, compaction of spring margins and pollution and disturbance from washing and bathing can be observed and documented readily enough, but the appropriate management responses (on-site works and supervision, and visitor information) require capital and labour resources which are in short supply. Some on-site works have been carried out at Witjira National Park and more are planned, but for the moment there is no permanent ranger presence at the park and none can be expected in the foreseeable future at Finniss Springs.

The situation should improve in the future and even in a temporary management vacuum the net gain from the cessation of stocking is positive. With this in mind, some planning for an additional park to protect mound springs is underway, although the model being evaluated is rather different to both Dalhousie and Finniss Springs. Instead of occupying a large contiguous area, it is likely to be of an archipelago character, taking in key spring groups south-east of Oodnadatta, but leaving the intervening country under pastoral lease.

Pastoralism/fencing

There is no doubt that stocking has a gross and generally deleterious impact on mound springs. Apart from the physical trampling and grazing, which is considerable, the organic pollution of what are relatively small water bodies can lead to algal growth and reduced oxygenation of the waters (Mitchell 1985). On the other hand, there is evidence that reducing or eliminating grazing can favour some species over others. At Hermit Hill, for example, a massive increase in *Phragmites australis* followed the removal of cattle for brucellosis and bovine tuberculosis control purposes in the early 1980s, displacing and reducing *E. carsonii* (Badman 1991a, Olympic Dam Operations 1990, 1991, 1992). While an example such as this might suggest a role for controlled grazing in the management of individual species, it does beg the question of floristics dynamics in the pre-European environment - it has to be assumed that *E. carsonii* was able to establish and persist in an environment free of grazing ungulates. Monitoring of plant and animal responses to fencing is clearly needed, but is a weakness in the current program. Only irregular monitoring of vegetation is occurring and resource constraints are such that some alternative needs to be found. In this context, a collaborative arrangement with tertiary institutions, through which students could be trained in monitoring techniques, might be an option worthy of investigation.

Overall, the Department of Environment and Land Management is stretched to its limits in maintaining the current fenced springs. None are rabbit netted and far more cattle pressure is being placed on the fencing than was anticipated. In May 1991 substantial damage was done to fences at the Fountain and Twelve Mile springs, with ten cattle perishing after breaking into the Fountain and becoming trapped within the exclosure, devastating the spring in the process. Feral donkeys remain a problem at Tarlton Springs and there has also been some theft (including an entire gate assembly from Twelve Mile Springs). Interestingly, there has been no theft or vandalism of any of the visitor information. The closest ranger presence the Department has is at Hawker, approximately 370 km by road from the most southerly of the fenced springs, and the current situation is clearly unsatisfactory. The solution favoured is to involve the pastoral lessees in day to day maintenance, and negotiations to that end are currently underway.

Given that maintenance has emerged as a more difficult issue than envisaged originally, the Department believes that a period of consolidation is necessary and it is likely to be some years before further fencing is undertaken. When resumed it may well be carried out within the framework of the archipelago park referred to above. It will also need to take into account further research being conducted by Ponder and others, and the island biogeography work referred to previously, the latter suggesting a strategy of maximising the number of springs conserved in a given locality, rather than concentrating on individual outlets (Ponder 1986).

Cultural heritage

The South Australian Aboriginal Heritage Act provides blanket protection for all Aboriginal sites and objects, but protection of non-Aboriginal sites requires a registration and listing process. Relatively few sites associated with the mound springs have been listed to date, reflecting the geographical remoteness of the springs, resource constraints and the pressure and priorities associated with sites in the more densely settled regions of the State.

A progressive increase in the number of sites and items listed can be expected, but there are practical limitations to this. Listing does provide legal protection against damaging actions, but as with cultural heritage sites generally the pressing need in many cases is for on-ground works, particularly physical protection for Aboriginal sites, stabilisation of ruins and the provision of visitor information for the steadily increasing number of travellers. As mentioned previously, work of this kind has recently been carried out at The Peake Overland Telegraph Repeater Station and some visitor information has also been provided at the Strangways Springs Overland Telegraph Repeater Station, but these are the only works carried out to date. As with fencing, the remote locations impose a high capital cost on works, but to this must be added ongoing maintenance and surveillance. In this context, there is possibly some scope for local assistance. The Aboriginal community generally has shown a strong interest in conservation of the springs and Arabana people at Marree have provided some valuable assistance with fencing maintenance, monitoring and signage throughout the 1980s. Given the traditional importance of the springs to these people, there may be room for more ambitious cooperative arrangements, not just on Finniss Springs, but throughout the mound spring country generally.

In the longer term, the national and international importance of the mound springs and their associated cultural heritage suggests a basis for more active Commonwealth Government funding and involvement. In this context, the South Australian Government has recently proposed to the Commonwealth that the springs be evaluated for possible inclusion on an indicative list for World Heritage nomination.

Mining

Consisting principally of geologically recent chemical precipitates and wind and water borne sediments, the mound springs offer limited prospects for economic mineralisation. Some interest has been shown in the presence of fluorine in mounds south of Lake Eyre (Forbes 1958), but most mineral exploration has been concerned with the country surrounding the springs, rather than the springs themselves.

In the latter context, cooperation between government agencies has resulted in special conditions being routinely applied to mineral exploration licences issued over the mound springs country, the object being to protect the springs from damage. A somewhat different situation has applied at Dalhousie where the area generally has been regarded as prospective for petroleum. Subject to a range of environmental safeguards, petroleum exploration rights were maintained when Witjira National Park was constituted in 1985, and in 1986 a trial was conducted in the mound springs area to test the environmental acceptability of low impact seismic survey techniques. The results demonstrated that at some cost (over double that for conventional techniques) environmental impact could be kept to a low level (Bleys *et al.* 1990).

From a petroleum industry perspective, the seismic work results were not encouraging and there has been no further exploration in the springs area. Apart from the now well-accepted biological and cultural heritage value of the springs, there is a growing appreciation of their importance as geological features (Krieg 1989) and with the exception of aquifer draw-down (next section) it seems unlikely that mining activity will pose any serious threats to mound springs in the foreseeable future.

Aquifer draw-down

The single most important threat to mound springs comes from aquifer draw-down. At worst, this can lead to cessation of flow and the extinction of entire aquatic animal populations (Ponder 1985, 1986, Ponder and Hershler 1984). The springs are dynamic, in both geological and short term time frames, but prior to the sinking of artesian bores from the late 1870s onwards a steady state existed where natural losses (through mound springs, vertical leakage and some lateral outflow) were balanced by recharge. With the subsequent extraction of groundwater from numerous flowing and non-flowing bores in the Basin, the potentiometric surface has now dropped to well below ground level in many areas and a visible sign of this is the decline and extinction of many mound springs.

Although it is believed that a new steady state for the Great Artesian Basin as a whole had been reached by the 1970s (Habermehl 1980), localised aquifer draw-down is clearly possible and, as noted above, was one of the main concerns expressed in the environmental impact assessment of the Olympic Dam mining venture. In response to the concerns, the State Government included a range of safeguards and conditions in the special water licence issued to the mining consortium in 1986, and monitoring since then has indicated that water extraction and accompanying aquifer draw-down is within the limits specified (Olympic Dam Operations 1990, 1991, 1992). This will still have a significant effect on some of the nearby springs, particularly Beatrice, Venable and Priscilla, but the environmental impact assessment process found that these springs had been heavily degraded by pastoralism and associated bore construction. It was also found that the aquatic fauna supported by mound springs likely to be affected by draw-down is replicated at springs which will not be affected (Department of Environment and Planning 1983, Kinhill Stearns 1984a).

A new development of some concern is the proposed establishment of a second bore field near Lake Eyre South. At the moment, around 15 ML/d is being pumped from the existing bore field and its north-westerly extension, about half the amount estimated to be needed when the

mine is in full production, and a second bore field was planned from the outset. The location proposed is approximately 35-40 km north-east of the environmentally sensitive and important Hermit Hill group of springs, and although no formal environmental impact assessment work has yet been carried out, the possible impact on Hermit Hill can be expected to be an important consideration. A discontinuity in the aquifer caused by an intervening fault and fracture zone has buffered Hermit Hill from the impact of draw-down associated with the existing bore field, but the South Australian Department of Mines and Energy has no evidence at this stage of any comparable discontinuity between Hermit Hill and the proposed new field.

On a broader scale, the Queensland, South Australian and New South Wales Governments, with Commonwealth financial assistance, are continuing a bore rehabilitation program. The reduction or elimination of previously uncontrolled or poorly controlled flow from bores can be expected to have a net positive effect on nearby mound springs, although the absence of any systematic monitoring of flows - other than those from four springs at Dalhousie and from springs near the production bore field for Olympic Dam - currently makes quantification of any gains impossible. Even where flow data for individual springs is available, short term perturbations, which are presumably natural, make interpretation and the identification of any trends very difficult, a notable example of this being Emerald Spring near Lake Eyre South (Table 5).

Table 5. Emerald Spring - flow rates

Year	Flow rate	Reference
1858	9.3 L/s	Babbage (South Australian Parliamentary Papers, 151/1858)
1860	1.1 L/s	Goyder (South Australian Parliamentary Papers, 167/1860)
1923	2.7 L/s	Cobb (1975)
1961	2.7 L/s	Cobb (1975)
1975	0.5 L/s	Cobb (1975)
1989 (Feb)	1.5 L/s	Olympic Dam Operations (1990)
1989 (June)	5.0 L/s	Olympic Dam Operations (1990)
1990 (Feb)	2.1 L/s	Olympic Dam Operations (1991)

Conclusions

A decade ago the future of South Australia's mound springs looked uncertain. In a call for their conservation, Harris (1981) wrote "If we are not to lose these unique features of our heritage, we must attend urgently to the relatively simple and inexpensive measures essential for their survival".

In the intervening years attention has been given to their conservation, and through research, fencing and national park initiatives, much has been achieved. At the same time, much remains to be done. South Australia still has many important springs and spring groups virtually unprotected and Queensland has yet to begin any systematic management programme for its springs. There are lessons to be learnt from the South Australian experience of the past decade and, whatever the particular circumstances, the following general considerations are likely to be relevant.

- An adequate database for comparing springs and establishing conservation priorities is essential, but cannot be compiled cheaply; as a guide, the South Australian government spent $92,000 on the natural and cultural heritage surveys of the mid 1980s.

- Acquisition of springs and management within the national parks system is the surest form of conservation, but is expensive and will be feasible only for the most important spring complexes.

- Fencing springs to exclude domestic livestock offers a lower cost alternative to acquisition, but the remote localities in which springs occur make the capital outlay relatively expensive (two to three times the cost of comparable fencing in more settled areas) and routine maintenance difficult (maintenance arrangements with local pastoralists should be considered for the latter).

- In fencing springs, emphasis should be placed on enclosing spring groups rather than individual springs; although initial costs will be higher, this will maximise biodiversity and minimise stock pressure on the fencing.

- Monitoring of plant and animal responses to fencing is essential but expensive for government agencies; collaborative arrangements with tertiary teaching institutions may reduce the costs and provide mutual benefit.

- Continuing research is needed, particularly into the ecology and dynamics of the plant and animal populations of the springs; the advances of the past decade notwithstanding, the taxonomy and habitat requirements of the invertebrate fauna especially are still poorly understood.

- Local Aboriginal communities have traditional ties with the springs and should be drawn into cooperative management arrangements.

- Systematic monitoring of flow rates is essential; in spite of short term perturbations and accompanying difficulty in data interpretation, flow rates are likely to provide the only reliable warning of aquifer draw down.

Clearly, management of the springs for their ongoing survival is not something to be undertaken lightly. At its most fundamental, it requires a long term commitment to funding and a high level of cooperation between a range of government and non government interests. Neither of these will come easily, but the need is great. Aboriginal people celebrated the springs in song cycles over thousands of years and Europeans continue to be impressed by the presence of the springs in some of Australia's most inhospitable desert. In every sense the springs are outstanding features of Australia's national estate.

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