INTERIM RECOVERY PLAN NO. 56

Assemblages of Organic Mound (Tumulus) Springs of the Swan Coastal Plain

Interim Recovery Plan 2000-2003

by
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Photo: John Blyth

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FOREWORD

Interim Recovery Plans (IRPs) are developed within the framework laid down in Department of Conservation and Land Management (CALM) Policy Statements Nos 44 and 50

IRPs outline the recovery actions that are required to urgently address those threatening processes most affecting the ongoing survival of threatened taxa or ecological communities, and begin the recovery process.

CALM is committed to ensuring that Critically Endangered ecological communities are conserved through the preparation and implementation of Recovery Plans or Interim Recovery Plans and by ensuring that conservation action commences as soon as possible and always within one year of endorsement of that rank by CALM's Director of Nature Conservation.

This Interim Recovery Plan will operate from 28 February 2000 but will remain in force until withdrawn or replaced. It is intended that, if the ecological community is still ranked Critically Endangered, this IRP will be replaced by a full Recovery Plan after three years.

The provision of funds identified in this Interim Recovery Plan is dependent on budgetary and other constraints affecting CALM, as well as the need to address other priorities.

Information in this IRP was accurate at February 2000.

SUMMARY

Name: Community of Tumulus Springs (organic mound springs) of the Swan Coastal Plain

Description: The habitat of this community is characterised by continuous discharge of groundwater in raised areas of peat. The peat and surrounds provide a stable, permanently moist series of microhabitats. Intact vegetated tumulus springs are only found at three locations. There is a high level of heterogeneity of invertebrate fauna assemblages between these sites, but all are associated with a rich, healthy fauna. Groups commonly represented include Ostracoda, Nematoda, Cladocera, Copepoda, Oligochaeta, Tardigrada, Turbellaria and Insecta.

Typical and common native vascular plant species associated with the tumulus springs are the trees *Banksia littoralis*, *Melaleuca preissiana* and *Eucalyptus rudis*, and the shrubs *Agonis linearifolia, Pteridium esculentum, Astartea fascicularis* and *Cyclosorus interruptus*. The following non-vascular plants have also been located on peat mounds associated with the community: *Lycopodium serpentium* (bog clubmoss), *Riccardia aequicellularis*, *Jungermannia inundata*, *Goebelobryum unguiculatum* and *Hyalolepidozia longiscypha*.

Common weed species include *Isolepis prolifera* and *Pennisetum clandestinum*.

CALM Region(s): Swan

CALM District(s): Perth

Shire(s): Swan, Chittering

Recovery Team: To be established. Proposed membership: a limnologist with appropriate expertise, Water and Rivers Commission, Water Corporation, Northern Swan Landcare Group, Ellenbrook Catchment Coordinator, CALM Perth District and Threatened Species and Communities Unit.

Current status: Assessed 21 November 1995 as Critically Endangered

Habitat requirements: Some of the fauna species have no dormant stages and depend on the maintenance of a permanent supply of fresh water. Many vascular and non-vascular plant species that inhabit the mounds are also reliant on permanent moisture. The maintenance of hydrological processes in terms of both quality and quantity of water to the mounds is essential to sustain the tumulus spring communities.

IRP Objective(s): To maintain or improve the overall condition of the tumulus springs and the associated fauna and plant community in the known locations and reduce the level of threat, with the aim of reclassifying the community from Critically Endangered to Endangered.

Criteria for success:

1. An increase in the area of this community under conservation management.
2. Maintenance in terms of diversity and basic composition of native species (as described in Jasinska and Knott 1994; Ahmat 1993) as well as hydrological and biological processes, taking account of natural change of the community over time.
3. Improvement in the condition of the habitat, in terms of re-establishment of fringing buffer vegetation, reduction of numbers of exotic species and of other threatening processes as defined in this document.

Criterion for failure: Significant loss of area or further modification of occurrences of the threatened ecological community.

Summary of Recovery Actions:

1. Establish Recovery Team	13. Acquire Occurrence 2

2. Clarify and monitor extent and boundaries	14. Fence Occurrence 2
3. Liaise with land owners and managers	15. Ensure visitor accessways do not impact springs
4. Disseminate information	16. Seek to acquire Occurrence 3
5. Install markers	17. Fence Occurrence 3
6. Monitor water levels and quality	18. Conduct research
7. Manage water levels and quality	19. Monitor dieback
8. Monitor flora and fauna	20. Monitor weed populations
9. Develop Fire Management Plans	21. Replant and restock springs and buffer areas
10 Implement Fire Management Plans, implement dieback hygiene	22. Rehabilitate recharge catchments and wetlands adjacent to springs
11. Ensure earthworks do not impact community	23. Report on management strategies
12. Implement weed control	

1. BACKGROUND

1.1 History, defining characteristics of ecological community, conservation significance and status

The heavy clay soils of the Guildford Formation on the eastern side of the Swan Coastal Plain have been formed through the accumulation of deposits eroded from the hills of the Darling Range to the east. Between Bayswater and Muchea on the eastern extremities of the Bassendean Dune system, the tumulus (Latin meaning 'little mound') springs historically occurred where the sands and clays meet. The Bassendean sands contain the large superficial aquifer known as the Gnangara Mound. This groundwater is forced to the surface at a series of discharge points on the eastern boundary of the aquifer where waters encounter the relatively impervious Guildford clays. Discharge areas form springs, bogs, and swamps.

In the case of the tumulus springs, there is continuous growth of vegetation that causes the formation of peat around the permanent water supply. Water continues to penetrate the increasingly elevated peat layers due to the pressure created by local and regional hydrological forces. Where water finds a 'preferred pathway' or conduit through the soil, water movement is much faster than normal groundwater flow. Such conduits or pipes may carry sand and silt to the surface, where it is deposited as a 'collar' of increasing height, so enhancing the formation of mounds (A. Davidson[1] Personal communication).

Historically, the tumulus springs were common within their narrow range. The swamps, lakes, dams and springs form a north - south line parallel to the Darling Scarp, and corresponding to the junction between the Bassendean Sands and the Guildford Clays. Some of these groundwater discharge points are located within the western groundwater catchment of Ellen Brook. The tumulus springs have typically been excavated to create farm dams or cleared and sealed with limestone to provide pasture for horses and cattle.

The remaining vegetated tumulus springs have an overstorey of moisture loving species including *Melaleuca preissiana*, *Banksia littoralis, Agonis linearifolia* and *Eucalyptus rudis*. Common understorey species include *Agonis linearifolia, Pteridium esculentum, Astartea fascicularis* and *Cyclosorus interruptus*. The following non-vascular plant species have also been located on peat mounds associated with the community (Jasinska and Knott 1994): *Lycopodium serpentium* (bog clubmoss), *Riccardia aequicellularis*, *Jungermannia inundata*, *Goebelobryum unguiculatum* and *Hyalolepidozia longiscypha*. Common weed species associated with the mounds include *Isolepis prolifera* (Budding Club-rush) and *Pennisetum clandestinum* (kikuyu).

The peat mounds may provide a permanently moist refuge for fauna that historically had a wider distribution. Consequently, relictual species may be protected from climatic changes and survive in these mounds. Some of these species may have no dormant period and would be killed if the mounds dried out (E. Jasinska[2] personal communication). Although there is a high level of heterogeneity in the fauna associated with mounds, common groups include Ostracoda, Nematoda, Acarina, Amphipoda, Cladocera, Copepoda, Decapoda, Oligochaeta, Annelida, Tardigrada, Turbellaria and Insecta.

The significance of the tumulus springs was recognised in the Conservation Through Reserves Committee recommendations (Department of Conservation and Environment 1983) that referred to sites just east and south of reserve 46622 on Faull Street, Muchea. Recommendation C25 referred to the need for survey, discussions with owners and a report on the conservation of the flora, and noted that ways to protect the conservation values should be sought. The same report also recommended that Geological Survey should investigate the hydrology of the area with a view to preventing adverse impact from local groundwater drawdown. None of the recommendation were implemented prior to 1996, and the springs and associated peat mounds have been progressively destroyed by grazing, levelling and packing with limestone, or have dried up (Jasinska and Knott 1994).

[1] Angas Davidson, Water and Rivers Commission Commission, 3 Plain Street, Perth, WA, 6004
[2] Edyta Jasinska, formerly Zoology Department, University of Western Australia, Stirling Highway, Nedlands, WA 6009

In the last few years, the integrated process of updating the 'System 6' Conservation Through Reserves System Recommendations (DEP 1997) and the Ministry for Planning Urban Bushland Strategic Plan, has resulted in Perth's Bushplan (State of Western Australia 1998). Occurrences 2 and 3 are within the Bushplan area and are recorded in the Bushplan document. Any proposed developments likely to adversely affect those occurrences will need to be assessed under the Bushplan process (State of Western Australia 1998).

Table 1 Extent and location of occurrences

Occurrence Number	Location	Estimated area of tumulus springs
Occurrence 1	Reserve 46622, Faull Street, Muchea	1.4 ha
Occurrence 2	Private land, Ellenbrook	2 ha
Occurrence 3	Private land, Bullsbrook	4 ha

1.2 Description of Occurrences

Intact tumulus springs (uncleared) are only known from three locations; Egerton Stud about 2 km south of the junction of Maralla and Halden Roads, Ellen Brook; private property in Bullsbrook; and the recently purchased reserve on Faull Street in Muchea. These three remaining spring areas differ in structure of the mounds, presumably as a result of differences in hydrogeology or history of formation.

Occurrence 1 is in the recently purchased area now gazetted as a nature reserve on Faull Street in Muchea and contains a series of boggy peat mounds up to two metres tall. Temporary pools occur where peat has been burnt. Water oozes from the soil, or flows out from discrete vertical channels from the peat mounds. Cattle grazed the area in the past, but have now been excluded by the erection of a fence around the newly acquired reserve area.

The vegetation composition of the tumulus springs in the Faull Street reserve is likely to have been altered by grazing, as the area has apparently been intermittently grazed for many years. It is unknown to what extent fire has influenced the present structure or composition of the community. The combination of grazing and fire would almost certainly have increased the invasion of exotic species such as *Pennisetum clandestinum* and *Isolepis prolifera* into the community.

Occurrence 2 consists of a series of permanent springs flowing from a large area of peat mounds. Water oozes from the whole surface of the mounds and from discrete channels (Jasinska and Knott 1994). Low reeds, rushes, liverworts and club mosses cover the mounds. Part of the catchment is probably a dune to the west covered with *Banksia* woodland. A pine plantation occurs further west again. The water from the springs forms a stream that then feeds into a dam.

Occurrence 3 consists of a large series of mainly solid mounds with very small patches of bog (~ 1 - 4 m^2) immediately surrounding some of the more active spring discharges that support tall trees, bracken fern and dense mats of tall sedges. A narrow (1 - 4 m wide) strip of boggy ground provides shallow (1 - 10 cm deep) permanent water near the eastern margin of the tumulus outcrop. Some of the mounds appear to have been burnt through and now occur as deep holes in the line of springs. The catchment is likely to include *Banksia* woodland on a dune to the west (owned by the same landholder) and possibly the very boggy land to the north (owned by a different landholder) that appears to be burnt or excavated tumulus springs.

1.3 Biological and ecological characteristics

The tumulus springs are permanently moist, and some are also associated with permanent pools and surface water. Many of the invertebrate animals and the vascular and non-vascular plant species present are adapted to this permanent moisture and the areas probably act as refugia from climate change (drying) for certain species (Jasinska and Knott 1994). Some of the invertebrate species do not have dormant stages and would not survive if the peat mounds were to dry out. In particular, Jasinska and Knott (1994) identified an amphipod that is the only known species of a newly discovered genus that is a Gondwanic relic, in the tumulus springs at Egerton. Water quality decline, for example excessive nutrient input, is also a likely threat to the survival of some of the tumulus spring species.

Species lists, including vascular and non-vascular plants and invertebrates for the intact mound spring areas are at Appendices 1, 2, and 3.

A number of non-vascular plants were historically recorded in Occurrence 1, and have more recently been located in Occurrence 2 (Jasinska and Knott 1994; see Appendices 1 and 2). Some of these taxa are significant as they usually only occur in the far south-west of the state (Jasinska and Knott 1994), but can occur in the spring areas as a result of the permanently moist microenvironment, and possibly due to other specific conditions associated with the sites. These taxa have not been recorded recently from the Faull Street reserve, possibly as a result of too frequent hot fires, grazing and other disturbances.

The occurrence of *Hibbertia perfoliata* in Occurrences 2 and 3 is of particular significance as it was historically recorded for the Swan Coastal Plain, but until recently was believed to have become extinct in that area (G. Keighery[3] Personal communication). It seems the taxon can only survive in permanently wet thickets where disturbance levels are relatively low. Such areas have almost completely disappeared from the Swan Coastal Plain although they are still relatively common in the Jarrah forest - a stronghold of *Hibbertia perfoliata*.

1.4 Hydrology

Hydrological information on the tumulus springs is limited. The springs are believed to be fed by a complicated network of conduits whose conformation has been determined by the geology of the stratum where the clays of the Guildford Formation interdigitate with the sands of the Bassendean Dunes. Evidence for the underground flow being in confined conduits is provided by large pieces of material, for example, the carapaces of crustaceans, that bubble up in the spring waters (E. Jasinska Personal communication). Also, the pressure required to push water through the peat mounds could presumably only originate from confined flow and not from diffuse groundwater sources (J. Kite[4], A. Davidson Personal communication). The presence of complicated channels is inferred from the fact that springs have apparently dried up and re-emerged some distance away, when spring flow is interrupted; for example, when springs are excavated (Ahmat 1993). This suggests the springs emanate from a series of channels, and diversion to an alternative path of least resistance can occur (Jasinska and Knott 1994). Also, anecdotal information indicates that during excavation of one spring area the earthworks exposed 'rabbit burrow-like' conduits carrying loose sand and water within the Guildford Clay layer.

The watertable level in the Gnangara Mound would need to be sufficient to create an adequate head of pressure to drive the springs. The local hydrological pressure created in parts of the aquifer within the dunes adjacent to each of the spring areas is also likely to be significant in terms of maintaining the spring flow (E. Jasinska, A. Davidson Personal communication). Rainfall falling on the dunes adjacent to the springs would be involved in recharge of the local conduits feeding the springs (E. Jasinska, A Davidson Personal communication). The maintenance of the flora and fauna of the tumulus springs would also depend on sustaining the quality of the water of the Gnangara Mound and of the local water mounds in dunes adjacent to each of the spring areas.

A trend of falling water tables in the general area is evident since around 1976 (Greay 1993). A corresponding decline in annual rainfall since around 1976 may have contributed to this lowering of watertables. Drawdown of the superficial aquifer, the Gnangara Mound to the west, may also have contributed. The previous owner of the recently declared reserve on Faull Street, Muchea noted that some of the springs on the property have dried up in living memory, probably as a result of decline of the water table (Ahmat 1993).

The area in which the tumulus springs occur is characterised by much valued heavy soils, which were historically extensively cleared for agriculture. Clearing is likely to have increased surface runoff and recharge of the groundwater in the localised area and may have acted to counteract drawdown to some extent. The springs on the Faull Street reserve are located on the Muchea townsite lots. There is little

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uncleared vegetation there, however, so that additional recharge of the superficial aquifer as a result of further clearing for development in the localised area is unlikely. Changes in the level of the water table are very likely to influence the hydrology of these wetlands as they are likely to be almost entirely dependent on groundwater for water supply. This issue is discussed further under threatening processes.

The groundwater supplying Occurrence 1 is likely to flow mainly from the west, and possibly with some contribution of flow from the north (E. Jasinska Personal communication). The main water supply for the springs within the reserve is likely to be deep below the surface and from the local water mound in the denuded dune to the west that is also part of the reserve (A. Davidson Personal communication). Land management practices on this land and possibly other land adjacent to the west therefore have the potential to influence the conservation of water quality and quantity to these springs. Deep-rooted vegetation such as trees that originally occurred on the dune in the reserve would probably have drawn relatively large quantities of water from this local groundwater mound. A balance between loss of water through transpiration and gaining water through increased infiltration needs be determined for appropriate management of these dunes. Such hydrological considerations should be considered in planning the revegetation of such dunes.

A line of highly degraded peat mounds occurs to the north of the reserve area that contains Occurrence 1 and links to those on the reserve. A dense area of the non-local tree, *Eucalyptus camaldulensis* (River Gum) occurs on these peat mounds and may be drawing larger quantities of water than the original vegetation.

The supply of groundwater to the tumulus springs at Occurrence 2 is likely to be mainly from the west, with the pressure head and recharge being supplied by the large dune (E. Jasinska, A. Davidson Personal communication). A seasonal wetland occurs to the east of this dune, with the tumulus springs further east again. Groundwater flowing from the dune is likely to move in the general direction of the wetland in between the springs and the dune, and on towards the springs, confined under clay layers within conduits (E. Jasinska Personal communication). Major earthworks that may sever conduits supplying water to the springs, or extraction of groundwater in the vicinity of the dune, the seasonal wetland or within the spring area have the potential to severely disrupt water supply to these tumulus springs.

The supply of groundwater to Occurrence 3 appears likely to be mainly from the west, where *Banksia* woodland occurs on a dune (A. Davidson Personal communication). Groundwater abstraction in these areas, or within the springs themselves, has the potential to severely affect flows.

1.5 Threatening processes

1.5.1 Historical and current threatening processes

Clearing

Clearing for agriculture has been extensive on the heavy soils on the eastern side of the Swan Coastal Plain, with some 97% of all vegetation in the area cleared historically (Keighery and Trudgen 1992; CALM 1990). In particular, the tumulus springs on heavy soils were often perceived as a nuisance to farming practices as they were excessively wet and boggy. Consequently, almost all of these springs have been cleared, levelled, packed with limestone and planted with kikuyu grass; excavated and dammed; or the spring brooks dammed (Ahmat 1993).

Occurrence 1 is now contained within a reserve that is vested in the National Parks and Nature Conservation Authority for ‘Conservation of Flora and Fauna’. Occurrence 2 is planned to be set aside as Open Space within an extensive urban development. The springs in Occurrence 3 are currently in private ownership but there appears to be no immediate plan to develop them.

Dunes of varying sizes occur on the western side of all of the three remaining vegetated tumulus spring areas. Each of these is likely to provide important recharge areas, and to be involved in providing the hydraulic pressure head for the adjacent spring area. In addition, two of the dunes adjacent to spring areas are still vegetated (Occurrences 2 and 3) and vegetation is likely to be important for moisture retention and water

percolation into the sands. Vegetation, especially deep rooted plants such as trees, would draw on the local groundwater where roots could tap into this source.

In the case of Occurrence 1 the dune to the west has been largely denuded by a combined process of grazing and possibly dieback deaths and drought. Under normal circumstances, rainfall intersecting the dune surface contributes to recharge of the local groundwater mounds. However, the sands can become hydrophobic when dry and in the absence of vegetation, or following destruction of vegetation by fire (A. Davidson, E. Jasinska Personal communication). In this situation, most of the rainfall would drain off the dune as surface runoff and therefore not contribute to the groundwater recharge. Regrowth may help enhance penetration of rainfall in these circumstances (A. Davidson, Personal communication).

Plant species can also contribute to the hydrophobic nature of soils (A. Davidson, Personal communication). Introduced grasses such as Veldt grass (*Ehrharta calycina*) cause soils to repel water and should be kept away from the spring areas themselves and the adjacent dunes.

Hydrological Changes

The flora and fauna that inhabit the tumulus springs are likely to be entirely dependent on the permanent supply of fresh water (E. Jasinska, Personal communication). As mentioned, some of the tumulus springs in reserve 46622 on Faull Street have dried up relatively recently. This is possibly due to groundwater drawdown, but is perhaps exacerbated by declining rainfall. There are no obvious large groundwater abstraction areas in the spring's recharge zone (J. Kite, Personal communication). It is obviously imperative, however, that the recharge area and the discharge areas of each of the springs are conserved (Ahmat 1993). Controls on groundwater abstraction and minimisation of pollution of the groundwater, exercised through planning and impact assessment, are therefore essential for the conservation of the springs.

Where animal droppings and other nutrient sources can contaminate surface or groundwater entering the springs, enhanced nutrient levels are likely to favour weed invasion and possibly to alter water quality such that some components of the fauna cannot survive. Nutrient input is most likely to be from very localised areas in the case of surface flow into the springs, so landuse in areas close to the springs may also be very important for conservation of the water quality. On the other hand it may be possible for sources of pollution to enter the groundwater that eventually enters the springs from sources much more distant.

Grazing

The tumulus springs of Occurrence 1 have been subject to intermittent grazing, as they were located in a paddock that supplied permanent rich pasture. Grazing is likely to have caused alterations to the species composition through the selective grazing of edible species, the introduction of weeds as a result of trampling, and through general disturbance. This may well have contributed to the decline of non-vascular plants that have been recorded historically in Occurrence 1 (refer Appendix 1). Weeds are also likely to be favoured by increased nutrient levels from animal droppings.

The tumulus springs on Occurrence 3 may have historically been subject to grazing, but no stock are currently kept in the fenced area adjacent to the springs. This spring area is covered in extremely dense vegetation that would be relatively impenetrable to stock. Following fires, however, the dense vegetation cover would be destroyed, and stock would be able to graze the area.

Occurrence 2 does not appear to have been grazed historically (G. Keighery Personal communication).

Increased weed invasion due to grazing and other disturbances

As mentioned above, grazing alters species composition through selective foraging, and causes increased weed invasion. The two major weed species in the tumulus springs in the Faull Street reserve are *Isolepis prolifera* and *Pennisetum clandestinum*. The tumulus springs of Occurrence 3 are relatively weed free, but weeds are encroaching from the perimeter of the area, perhaps from where fire and other disturbances have historically been more frequent. *Rubus* sp. (Blackberry) and *Ficus carica* (Fig) occur immediately adjacent to the springs and some Budding Club-rush (*Isolepis prolifera*) occurs on the mounds themselves.

Weeds may also impact the community in areas of influence. *Eucalyptus camaldulensis* has invaded the denuded mounds to the north of Occurrence 1 (on the adjacent landholder's property). These trees may be contributing to the drawdown of water from the spring area, although this would be unlikely if the water supply is mainly from the west (A. Davidson Personal communication).

Altered fire regimes

Fires are likely to have a significant effect on the vegetation composition in Mediterranean ecosystems (Gill *et al.* 1981). It is also likely that the fire regime around each of the spring areas has been altered since European settlement, especially those located in agricultural areas (Occurrences 1 and 3). Stratigraphic coring of the peat would help elucidate the fire history of these springs.

The wetland vegetation associated with the springs is likely to be less adapted to more frequent hot fires than upland vegetation as the sites are permanently moist and are unlikely to have historically burnt as readily. In addition, the build up of peat makes the areas very prone to fires that occur in very dry seasons. An increase in the frequency of hot fires is likely to impact both the wetland-adapted flora and fauna.

As this community is not well studied, little is known of the community's requirements in terms of fire regime to maintain plant species composition. As fires can destroy the peat mounds, however, it can be assumed that conservation of the communities depends on hot fires being excluded during seasons when the mounds are drier and are flammable.

The risk of fire is increased by the presence of grassy weeds in the understorey at the Faull Street reserve site (Occurrence 1), as they are likely to be considerably more flammable than original native species in the herb layer.

Dieback

It is not known if the community type is susceptible to dieback caused by *Phytophthora* species. However, the plants that inhabit the tumulus springs themselves are largely species that are thought not to be sensitive to such dieback. In particular, *Melaleuca preissii* and the sedges that dominate the community are not dieback sensitive (Helyar 1994). *Hibbertia perfoliata* is listed as a dieback indicator on the Swan Coastal Plain by Helyar (1994), however, and therefore may be susceptible to the disease in that area. This may in part explain its near disappearance from the Swan Coastal Plain.

Banksia woodlands occur on the dunes to the west of each of the remaining tumulus springs. These dunes are likely to be important in the local hydrology of the springs. *Banksias* are deep rooted species that are likely to draw on local groundwater. *Banksia* communities are very susceptible to dieback caused by *Phytophthora* species and are often severely affected by its introduction. Loss of *Banksias* and other dieback susceptible species may actually increase local groundwater recharge unless replaced with species that increase the hydrophobic nature of the soil, as has occurred at the Faull Street reserve with the introduction of Veldt-grass. Dry, bare soil as occurs in parts of the dune adjacent to Occurrence 1 is also strongly hydrophobic, however. Replacement of the *Banksia* woodlands adjacent to the springs with species that use more water, such as taller trees, would also impact the springs through drawdown of the groundwater table.

The dune to the west of the springs in the Faull Street reserve has been severely degraded, presumably initially through clearing, then from continued loss of juvenile plants through grazing. Dieback may also have impacted the *Banksia* community by killing mature and juvenile individuals of susceptible species.

It is not known if the springs or the adjacent *Banksia* woodlands at Occurrence 2 or 3 are infected with dieback or other diseases.

Risk of introduction or further spread of disease should be minimised by ensuring good hygiene procedures. This would help ensure that current hydrological regimes are maintained in groundwater in dunes close to the springs. Such hygiene procedures would involve washdown of any equipment prior to undertaking works in the remnant vegetation surrounding the community, as well as within the springs themselves.

1.6 Conservation status

The community meets the following criteria for Critically Endangered (CR) ecological communities (English and Blyth 1997):

A) The estimated geographic range, and/or total area occupied, and/or number of discrete occurrences since European settlement have been reduced by at least 90% and both of the following apply (i and ii);

i) geographic range, and/or total area occupied and/or number of discrete occurrences are continuing to decline such that total destruction of the community is imminent (within approximately 5 years)

ii) modification throughout its range is continuing such that in the immediate future (within approximately 5 years) the community is unlikely to be capable of being substantially rehabilitated

B) Current distribution is limited, and both of the following apply (i and ii):

i) geographic range and/or number of discrete occurrences, and/or area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the immediate future (within approximately 5 years)

ii) there are very few occurrences, each of which is small and/or isolated and extremely vulnerable to known threatening processes.

1.7 Strategy for recovery

- To identify, and influence the management of, the areas in which the community occurs, so maintaining natural biological and non-biological attributes of the sites and the current area covered by the community.

- To conduct appropriate research into the ecological characteristics of the community to develop further understanding about the management actions required to maintain or improve the condition of the community.

2. RECOVERY AIM AND CRITERIA

2.1 Aim

To maintain or improve the overall condition of the community of tumulus springs and reduce the level of threat, with the aim of relcassifying it from Critically Endangered to Endangered

2.2.1 Criteria for success

An increase in the area, and number of occurrences, of this community under conservation management.

Maintenance in terms of diversity and basic composition of native species (as described in Ahmat 1993; Jasinska and Knott 1994) as well as hydrological and biological processes, taking account of natural change of the community over time.

Improvement in the condition of the habitat, in terms of re-establishment of fringing buffer vegetation, reduction of numbers of exotic species and of other threatening processes as defined in this document.

2.2.2 Criterion for failure

Significant loss of area or further modification of occurrences of the threatened ecological community.

3.0 RECOVERY ACTIONS

Note: The responsible authority is frequently listed as the relevant CALM District. This refers largely to initiating and guiding actions. However, in general the relevant CALM District, in cooperation with the Western Australian Threatened Species and Communities Unit (WATSCU) and the Recovery Team has the primary responsibility for securing funds for recovery actions.

3.1 Establish a Recovery Team

Proposed membership: a limnologist with appropriate expertise, Water and Rivers Commission, Water Corporation, Northern Swan Landcare Group, Ellenbrook Catchment Coordinator, CALM Perth District and Threatened Species and Communities Unit.

Responsibility: CALM (WATSCU)
Cost: $0
Completion date: Year 1

3.2 Clarify and continue to monitor the extent and boundaries of the community

Extent of occurrences should be monitored every two years. Boundaries can be determined from current aerial photographs and minimal on-site checking. This information should be added to the threatened ecological community database as recommended in English and Blyth (1997). English and Blyth (1997) also recommend the establishment of a Geographic Information System database for information on threatened ecological communities. When this is available, boundary information for occurrences of the community should be included. The extent of Occurrences 1 and 3 has been determined from survey and aerial photographs, but not that of Occurrence 2.

Likely habitat has been searched extensively for additional occurrences of the community, particularly on the edge of the Commonwealth bombing range, without success (E. Jasinska Personal communication). Such areas should be further surveyed for the community.

Responsibility: CALM (Perth District; WATSCU)
Cost: $500 pa
Completion Date: Ongoing

3.3 Liaise with current land owners, land managers and other interested groups to implement recommendations held in this IRP

Two of the three surviving occurrences of the community are privately owned (Occurrences 2 and 3). The involvement of land managers, local community groups and industry in the recovery of the community wherever possible and practical is therefore essential to the recovery process.

Members of the Northern Swan Landcare Group are also keen to be involved in the management of Occurrence 3.

Responsibility: CALM (Perth District; WATSCU)
Cost: Costs of all liaison for occurrences of this community $2,500 (not including vehicle costs)
Completion date: Ongoing

3.4 Disseminate information about the community

To prevent accidental destruction and gain public support for its conservation, it is recommended that information about the community be provided by local CALM staff to all stakeholders including landholders, and managers of land that contains the community. This would include information from the threatened ecological community database, and maps indicating the location of the community. Information

about private land should only be provided to the landholder, unless permission is granted by the landholder to allow wider dissemination of the data. This action is recommended in English and Blyth (1997).

Local CALM staff should ensure regular liaison with owners of land containing the community to ensure threatened ecological community information is up to date.

A publicity campaign utilising signs on site, local media and poster displays in prominent areas should be undertaken to encourage awareness about this threatened ecological community. Information on the community has been included in conservation magazines (Blyth and English 1996; Cresswell *et al*. 1996), and is included in the World Wide Web on the World Wide Fund for Nature's (WWF) site.

Visitors to the sites that contain occurrences should be provided information about the impact of dieback and procedures to avoid spreading the disease. This may include the use of signs on site, and interpretive information.

Responsibility: CALM (Corporate Relations Division Perth, Perth District; WATSCU), landholders
Cost: $4,000
Completion date: Ongoing

3.5 Install markers to indicate the location of the community

CALM mark, or encourage landholders to mark the occurrences that occur alongside tracks, roads and firebreaks with the same pegs as used to mark threatened flora, to reduce the likelihood of accidental destruction. This action is recommended in English and Blyth (1997) and will be included in a future policy on Threatened Ecological Communities being prepared by CALM.

Responsibility: CALM (Perth District; WATSCU); in consultation with land owners
Cost: $300
Completion date: Year 1

3.6 Monitor water levels and quality

Install monitoring bores for the springs (taking care not to impact the spring areas) and in adjacent areas of interest where extraction or monitoring bores do not currently exist.

WATSCU has provided $1,000 to help fund the installation of bores and CALM's Perth District has offered to help with installation and ongoing monitoring of bores for Occurrence 1. Water and Rivers Commission has agreed to use this money in a collaborative research and monitoring program for this spring area following a request from CALM. Clear guidelines for monitoring procedures and reporting should be developed.

Groundwater levels are routinely monitored by Water and Rivers Commission (WRC) in specific areas and data for areas close to occurrences of the community should be analysed.

Responsibility: CALM (Perth District) in collaboration with WRC, owners of spring areas and adjacent landholders
Cost: Costs to be determined
Completion date: Ongoing.

3.7 Manage water quality and quantity

Any developments or activities that would adversely impact the quality or quantity of the groundwater supply to the spring areas should be avoided.

Activities to be avoided include those that would increase groundwater drawdown, in particular direct extraction from conduits supplying the mounds (these are probably mainly to the west, but possibly also to

the north of spring areas); avoidance of pollution of groundwater by overuse of fertilisers, herbicides and pesticides on surrounding lands or as caused by inadequate drainage control; prevention of major earthworks that have the potential to sever conduits that carry the groundwater to the mounds; and prevention of clearing of the dunes to the west of each of the springs so that current hydrological regimes are maintained. Developments such as rubbish dumps and petrol stations that may pollute groundwater should also be avoided in catchment areas for the springs.

Responsibility: CALM (Perth District) in liaison with Water and Rivers Commission (WRC), Ministry for Planning (MFP), Department of Environmental Protection (DEP), surrounding landholders
Cost: Costs of liaison included in 3.3
Completion date: Ongoing.

3.8 Monitor the flora and fauna of tumulus springs

Data collected should include weed levels, plant species diversity, species composition of flora and fauna (including micro-invertebrates).

A comprehensive survey of vascular plants or weed levels has not been undertaken for any of the spring areas, and would be essential for future comparison. A fauna survey is being completed for Occurrence 3 (E. Jasinska, personal communication).

Occurrences should be monitored two-yearly to provide information on condition. This information should be added to the threatened ecological community database as recommended in English and Blyth (1997).

Floristic plots should be put in all occurrences (total of 3 plots). Data on all native and weed species, and density or cover values for each species would be essential for determining changes over time (eg as a result of too frequent fire). Line intercept and photographic methods as described in Hopkins *et al.* (1987) could be utilised to monitor these parameters.

English and Blyth (1997) also recommend the establishment of a Geographic Information System database for information on threatened ecological communities. When this is available, boundary information should be included.

Responsibility: CALM (Perth District; WATSCU); in collaboration with WRC and Zoology Dept University of Western Australia
Cost: $1,500 every second year (for flora monitoring - total of 3 plots in the community) for field survey, specimen identification, and databasing for 1 monitoring period. $5,000 for one monitoring period for fauna survey, water analysis and reporting
Completion date: Ongoing

3.9 Develop and implement Fire Management Plans

3.9.1 Develop and implement fire management plans that encompass the following (3.9.1 - 3.9.4) and are most appropriate for ensuring peat mounds do not burn, to reducing weed invasion and permitting the natural development of the tumulus spring communities

There is a need for research into recovery of the community from wild fires (to be completed under Action 3.8 - monitoring), and to determine the implications of findings for management. This would also include developing a fire history map of the occurrences, which is updated annually.

Occurrence 1 was degraded by a burn in May 1994 and should not be burnt again during the life of this plan. A buffer area within the *Banksia* woodland to the west of Occurrence 3 on King's property was burnt in mid-1996 and should not be burnt again for several years. For Occurrences 2 and 3, appropriate fire management may include a regime of infrequent cool burns around the perimeter of the mounds to create a buffer of low fuels around the extremely fire sensitive peat mounds. Fire management strategies should ensure that peat

mounds do not burn. Care should be taken not to further degrade the wooded dune to the west of each of the springs as those areas are likely to be important for maintaining the hydrology of the springs.

A Fire Management Plan has been developed for Talbot Road bushland by WA Fire and Rescue Service, Shire of Swan and CALM. It specifies no planned burns without consultation with CALM, no construction of new fire breaks, a fire-fighting strategy, implementation of dieback hygiene for all vehicles, routine fuel and weed monitoring, and maintenance of fire breaks. A similar plan should be developed for all occurrences of this community, using the plan for Talbot Road bushland as a guide. CALM's Perth and Mundaring Districts are developing Fire Management Plans for all remnants in their districts that contain occurrences of threatened ecological communities. Close liaison with all stakeholders is required to develop Fire Management Plans.

Responsibility: CALM (Perth District; WATSCU), WA Fire and Rescue Service, Bush Fire Brigades, in liaison with all stakeholders
Cost: Cost of plan development $2,550
Completion date: Year 1

3.9.2 Ensure maintenance of appropriate strategic firebreaks to help prevent fire spreading to the spring communities

Firebreaks have been constructed around the springs in Occurrences 1 and 3, and no additional firebreaks should be constructed in these remnants. No new firebreaks should be constructed on or close to occurrences of the Tumulus community. In the event of upgrading existing firebreaks, or establishing new ones at Occurrence 2, being considered it must be ensured that hygiene procedures are followed. Further, no major earthworks should be conducted for firebreaks on the dune to the west or north of each of the spring areas where conduits supplying water to the springs may occur. Controlled burns that may become wildfires in drier conditions and result in the peat mounds being burnt should be avoided.

Strategic firebreaks have been constructed around the tumulus springs at Occurrence 3 (~June 1996) - hire of machinery funded by CALM (subsidised by Swan Shire), with volunteer labour provided by the Bullsbrook Volunteer Bushfire Brigade.

Maintenance of existing firebreaks is appropriate where firebreaks are already constructed, unless maintenance is likely to cause spread or intensification of dieback or otherwise degrade the community. No new fire breaks should be constructed or existing breaks upgraded around occurrences of this community on CALM-managed lands without the approval of the Director of Nature Conservation. Local CALM staff should be involved in planning fire break construction and maintenance for all occurrences of the community.

Responsibility: CALM (Perth District), landholders
Cost: Cost of firebreak maintenance $900 pa; costs of liaison included in 3.3
Completion date: Ongoing.

3.9.3 Liaise with surrounding landholders to ensure strategies for fuel reduction on their lands do not impact the community

In particular, there should be no earthworks to construct firebreaks on degraded mounds to the north of the spring areas in reserve 46622 or adjacent to Occurrence 3 as such works may sever conduits supplying water to the springs; and controlled burns that may become wildfires in drier conditions and result in the peat mounds being burnt should be avoided.

Responsibility: CALM (Perth District); liaison with surrounding landholders
Cost: Costs of liaison included in 3.3
Completion date: Ongoing.

3.9.4 Ensure fire suppression strategy does not impact community

Ensure fire fighting authorities recognise the importance of not constructing new tracks during their operations, including during wildfires. The use of heavy machinery to create new fire breaks, or to upgrade old ones, within the community should be avoided as additional disturbance would encourage further weed invasion and could damage water conduits. Further, chemicals that may be toxic to any part of the community should not be used. Guidelines for appropriate fire suppression actions should be developed.

A local CALM staff member should be present during wildfires and controlled burns in remnants that contain occurrences of the community, to advise on protecting the conservation values of the community.

Responsibility: CALM (Perth District); liaison with local Bush Fire Brigades and WA Fire and Rescue Service
Cost: Costs of liaison included in 3.3; additional funds for CALM District staff to attend wildfires in the community $300 pa
Completion date: Ongoing

3.10 Ensure earthworks in area of influence do not impact community

Liaise with relevant landholders to ensure earthworks near the springs and on adjacent lands that may impact the hydrology are avoided. For example, levelling or performing earthworks on adjacent lands, in particular on the denuded mounds to the north of springs on reserve 46622 and north of Occurrence 3 may impact the flow to the mounds.

Use existing planning and environmental assessment procedures to ensure no earthworks occur on the peat mounds or in adjacent areas that are likely to contain conduits carrying water to the springs including the seasonal wetland and the dune to the west at Egerton. There should be no unnecessary clearing of springs or the adjacent remnant vegetation buffers.

Responsibility: CALM (Perth District)in liaison with Water and Rivers Commission, Department of Environmental Protection and Ministry for Planning; liaison with landholders
Cost: Costs of liaison included in 3.3
Completion date: Ongoing.

3.11 Design and conduct research

Staff of Water and Rivers Commission will be undertaking research into the hydrology of the spring areas (see 3.5 also). Researchers from University of Western Australia have expressed interest in investigating the palaeobiology of the peat mounds.

Research should be designed to increase the understanding of the biological and ecological characteristics of the community to assist future management decisions. Such research could include:

1. Investigating the hydrogeology of the spring areas.

2. Investigating the palaeobiology of tumulus springs through peat studies.

3. The development of a monitoring system for flora, fauna, water levels and quality. Protocols will be developed based on recommendations held in English and Blyth (1997).

4. Significant biological processes in the community such as faunal interactions.

5. The potential impacts of water pollution such as pesticides, herbicides and fertilisers on the spring biota.

Responsibility: CALM (Perth District; CALMScience Division; WATSCU); in collaboration with University of Western Australia and WRC

Cost: Recovery Team to determine costs and likely funds available through other sources and to recommend a research program and sources of funds to CALM
Completion date: To be determined

3.12 Ensure hygiene conditions near the community

Occurrences have not been tested for presence of dieback, and the susceptibility of the flora species in the community to the disease is not known. Risk of introduction or amplification of disease should therefore be minimised by ensuring good hygiene procedures. This would involve washdown of any equipment used adjacent to the community, and restricting access by vehicles and machinery to dry soil conditions.

No vehicle should access bushland areas on or near the community. Standard practice should be for all vehicles using tracks adjacent to occurrences to be free of soil, and plant propagules and for all soil imported into the area to be tested and only dieback free soils used.

Major earthworks are likely adjacent to Occurrence 2. Any soil imported into the vicinity of the spring areas including the adjacent *Banksia* woodlands, should be dieback free.

Responsibility: All personnel using machinery near occurrences
Cost: Costs of all liaison to be undertaken by CALM (Perth District), is included in 3.3; other costs to be underwritten by user of machinery
Completion date: Ongoing

3.13 Monitor dieback

All of the dunes adjacent to spring areas are vegetated with *Banksia* woodlands that are commonly very susceptible to dieback caused by *Phytophthora* species. The dune adjacent to Occurrence 1 appears to have been historically denuded, in part at least, by dieback infection.

The dieback fronts adjacent to occurrences should be monitored at least every five years in summer and flagging marking the front replaced regularly. Additional plot information (refer 3.8) would provide useful monitoring data for all sites.

Responsibility: CALM (Perth District) in liaison with landholders
Cost: $3,000
Completion date: Ongoing

3.14 Monitor weeds

Weed populations should be accurately mapped and appropriate manual methods of weed control determined for spring areas. Herbicides should only be used close to spring areas if research indicates they do not have toxic effects on native fauna and flora of the springs.

Weed levels should be monitored under Action 3.8.

Responsibility: CALM (Perth District)
Cost: $1,000 every second year for mapping boundaries of weed species that are high priority for control such as *Watsonia*, kikuyu and *Isolepis prolifera*; Weed monitoring to be incorporated into Action 3.8
Completion date: Ongoing

3.15 Implement weed control and rehabilitation

Rehabilitation should be undertaken following development of a 'Rehabilitation Plan'. Rehabilitation would include weed control and replanting - where grazing and other disturbances have depleted native species; and restocking with appropriate fauna if this is indicated as necessary under Action 3.8. Replanting, and

restocking of the spring area with appropriate fauna could be based on results of findings of Action 3.8, or palaeobiological study if undertaken, and on previous fauna studies (Jasinska and Knott 1994; Ahmat 1993).

Initial stages of rehabilitation for reserve 46622 (Occurrence 1) should involve control of invasive perennial weeds in, or immediately adjacent to the springs eg *Isolepis prolifera* (budding club rush) and *Pennisetum clandestinum* (kikuyu) and their replacement with appropriate local species taken from the same reserve. Other grassy weeds that increase the hydrophobic nature of soils on the dunes to the west of the springs in the Faull Street reserve should be eradicated and replaced with shrubs native to the site.

The invasive weeds - *Rubus* sp. (blackberry), *Ficus carica* (fig), *Pennisetum clandestinum* and *Isolepis prolifera* that occur on the edge of the spring area in Occurrence 3 would be highest priority for control at that site. Members of the Northern Swan Landcare Group have expressed interest in helping manage this site, including weed control.

Weed invasion in Occurrence 2 appears to be a lesser threat than potential drying of the springs.

Responsibility: CALM (Perth District); in liaison with landholders
Cost: Weed control - $2,000 pa (springs and buffers - Occurrence 1 and 3); costs of replanting and restocking to be determined when the Rehabilitation Plan is developed
Completion date: Ongoing

3.16 Rehabilitate recharge catchment zones and adjacent wetland areas

Liaise with landholders to remove the tree weeds that may be contributing to drawdown of the springs. Seek permission to remove or thin the *Eucalyptus camaldulensis* (a non-local River Gum) on denuded mounds to the north of reserve 46622 (on the adjacent landholder's property). The dune to the west of the tumulus springs in reserve 46622 should be revegetated with local species that may aid water infiltration and recharge. Heath species, rather than trees would use less water and would be preferred for rehabilitation of this dune. In addition, revegetating or maintaining healthy vegetation on the dunes adjacent and to the west at each site may help sustain the current hydrological regime of the local recharge zones.

A kikuyu paddock (approximately 0.5 ha in area) occurs adjacent to the east side of Occurrence 3. This area should be rehabilitated to local wetland shrubs.

Responsibility: CALM (Perth District), in liaison with landholders
Cost: Costs of liaison included in 3.3; costs to be determined through the Rehabilitation Plan developed under Action 3.15. Likely costs for Occurrence 1 - $35,000; Occurrence 3 - $5,000
Completion date: Year 2

3.17 Report on success of management strategies for tumulus springs

Reporting will be part of annual reports prepared by the Recovery Team for CALM's Corporate Executive. A final report would be presented as part of or complementary to the full recovery plan for the community, if a full recovery plan is necessary.

Responsibility: CALM (Perth District; WATSCU); Recovery Team
Cost: $0
Completion date: Year 3.

SPECIFIC CONSERVATION MANAGEMENT ACTIONS REQUIRED - EGERTON - OCCURRENCE 2

3.18 Seek to have Occurrence 2 (at Egerton Stud) and an adequate buffer area reserved

Continue liaison with developer of the site containing the springs at Egerton to have the tumulus springs and an adequate buffer of remnant vegetation around the springs reserved. Objective of negotiations to be for declaration of area as Class A reserve for the purpose of 'Conservation of Flora and Fauna' vested in the National Parks and Nature Conservation Authority.

The vegetated dune to the west of the community probably provides catchment and a pressure head for the tumulus springs. The maintenance of healthy vegetation on the dune is therefore likely to help maintain the current hydrological regime of the local groundwater supply for the springs. This dune, the seasonal wetland to the west that may also influence the hydrology of the springs, and a remnant vegetation buffer should, if possible, be included in the reserve area.

Responsibility: CALM (Perth District, Land Administration Section; WATSCU), in liaison with Department of Environmental Protection (DEP), Ministry for Planning (MFP), landholders, DOLA
Cost: Costs of liaison included in 3.3; costs associated with acquisition to be determined
Completion date: To be determined

3.19 Fence Occurrence 2

Liaise with the landowner to determine appropriate location of fences for the occurrence and a suitable remnant vegetation buffer area, and ensure that the community is properly protected by fencing.

Responsibility: CALM (Perth District); landholder
Cost: Costs of liaison included in 3.3; costs of fencing to be determined
Completion date: Year 1

3.20 Ensure visitor access-ways do not impact the tumulus springs

Any visitor access-ways including walk/cycle paths and boardwalks should be designed not to impact hydrology around tumulus springs and to minimise direct disturbance of the springs.

Responsibility: CALM (Perth District) in liaison with landholder
Cost: Costs of liaison included in 3.3
Completion date: Ongoing

SPECIFIC ACTIONS REQUIRED - OCCURRENCE 3

3.21 Seek to acquire Occurrence 3

CALM is negotiating possible purchase of the tumulus springs and an adequate buffer area. A suitable buffer would include at least the adjacent dune to the west, and to the driveway on the eastern side (approximately 100 metres east of the springs). If purchased, the area should be declared Class A reserve for the purpose of 'Conservation of Flora and Fauna' vested in the NPNCA.

Responsibility: CALM (Perth District; Land Administration Section; WATSCU)
Cost: Market price of land at time of purchase. Funds consistent with an estimated value from the Valuer General's Office are available from the National Reserve System Program of Environment Australia and CALM
Completion date: Year 1

3.22 Fence Occurrence 3

The location of fences will depend on the boundaries of the land acquired. Fences should be located to protect the occurrence and a suitable remnant vegetation buffer.

Responsibility: CALM (Perth District)

Cost: Costs of fencing to be determined (likely costs approximately $5,200)
Completion date: Year 2

Table 2: Summary of recovery actions

Recovery Action	Occurrences	Responsibility	Completion date
Establish Recovery Team	All	CALM (WATSCU)	Year 1
Clarify and monitor extent and boundaries	All	CALM (Perth District, WATSCU)	Ongoing
Liaise with land owners and managers	All	CALM (Perth District, WATSCU)	Ongoing
Disseminate information	All	CALM (Corporate Relations Division, Perth District, WATSCU)	Ongoing
Install markers	All	CALM (Perth District, WATSCU), liaison with landholders	Year 1
Monitor water quality and quantity	All	CALM (Perth District), WRC, liaison with landholders	Ongoing
Manage water quality and levels	All	CALM (Perth District); WRC, MFP, DEP, land owners	Ongoing
Monitor flora and fauna	All	CALM (Perth District, WATSCU); collaboration with UWA and WRC	Ongoing
Develop Fire Management Plans	All	CALM (Perth, District, WATSCU), WA Fire and Rescue Service, Bush Fire Brigades	Development of Fire Management Plans has begun. To be completed Year 1
Implement Fire Management Plans, implement dieback hygiene	All	CALM (Perth District), landholders, Bush Fire Brigades, Fire and Rescue Service	Ongoing
Ensure earthworks do not impact community	All	CALM (Perth District), landholders	Ongoing
Implement weed control	1, 3	CALM (Perth District), liaison with landholder	Ongoing
Acquire Occurrence 2	2	CALM (Perth District, Land Administration Section; WATSCU), DEP, MFP, DOLA	Timing to be determined
Fence Occurrence 2	2	CALM (Perth District), landholder	Timing to be determined
Ensure visitor accessways do not impact springs	2	CALM (Perth District), landholder	Ongoing
Seek to acquire Occurrence 3	3	CALM (Perth District, Land Administration Section; WATSCU)	Year 1
Fence Occurrence 3	3	CALM (Perth District)	Year 2
Conduct research	All	CALM (Perth District, WATSCU, CALMScience Division) UWA, WRC	No date set
Monitor dieback	All	CALM (Perth District)	Ongoing
Monitor weed populations	All	CALM (Perth, District)	Ongoing
Replant and restock spring and buffer areas	1, 3	CALM (Perth District)	Ongoing
Rehabilitate recharge catchments and wetlands adjacent to springs	1, 3	CALM (Perth District)	Ongoing
Report on management strategies	All	CALM (Perth District; WATSCU), Recovery Team	Year 3

Table 3: Summary of costs for each recovery action

Recovery Action	1998	1999	2000
Establish Recovery Team	-		
Clarify and monitor extent and boundaries	$500	$500	$500
Liaise with land owners and managers	1,000	1,000	500
Disseminate information	1,500	1,500	1,000
Install markers	300		
Monitor water levels and quality	To be determined		
Manage water levels and quality	-		
Monitor flora and fauna	6,500		6,500
Develop Fire Management Plans	2,550		
Implement Fire Management Plans, implement dieback hygiene	1,200	1,200	1,200
Ensure earthworks do not impact community	-		
Implement weed control	2,000	2,000	2,000
Acquire Occurrence 2	To be determined		
Fence Occurrence 2	To be determined		
Ensure visitor accessways do not impact springs	-		
Seek to acquire Occurrence 3 (costs of purchase and survey)	To be determined		
Fence Occurrence 3	~5,200		
Conduct research	To be determined		
Monitor dieback	3,000		
Monitor weed populations	1,000		1,000
Replant and restock springs and buffer areas	To be determined		
Rehabilitate recharge catchments and wetlands adjacent to springs	~20,000	~20,000	~10,000
Report on management strategies			
Total	**$44,750**	**$26,200**	**$22,700**

Summary of costs over three years
Total $93,650
(Costs excluded shown above)

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APPENDIX 1
SPECIES LIST - OCCURRENCE

VASCULAR PLANTS

Asteracea
* *Hypochaeris glabra*
Cyperaceae
Baumea riparia
* *Isolepis prolifera*
Droseraceae
Drosera macrantha
Drosera pulchella
Myrtaceae
Agonis linearifolia
Astartea fascicularis
* *Eucalyptus camaldulensis*
Eucalyptus todtiana
Melaleuca preissiana
Papilionaceae
Aotus cordifolia
Proteacea
Banksia littoralis
Banksia ilicifolia
Thelypteridaceae
Cyclosorus interruptu

NON- VASCULAR PLANTS (From Jasinska and Knott 1994)

Goelobyrum unguiculatum
Hyalolepidozia longiscypha
Jungermannia inundata
Riccardia Aequicellularis

INVERTEBRATE FAUNA (From Ahmat 1993)

CHELICERATA
Acarina

CRUSTACEA
Decapoda
Cherax quinquecarinatus

Ostracoda

?Hydracarina

Copepoda: Cyclopoida

Copepoda: Harpacticoida

ANNELIDA: Oligochaeta
Oligochaeta
Targigrada
Turbellaria 3
Turbellaria 4
Turbellaria 5
Turbellaria 6

NEMATODA
Nematoda
Flatworm

APPENDIX 2
SPECIES LIST - OCCURRENCE 2

VASCULAR PLANTS

Dilleniaceae
Hibbertia perfoliata
Droseraceae
Drosera pulchella
Lycopodiaceae
Lycopodium serpentinum
Myrtacea
Agonis linearifolia
Papilionaceae
Aotus cordifolia

NON - VASCULAR PLANTS (From Jasinska and Knott 1994)

Goelobyrum unguiculatum
Hyalolepidozia longiscypha
Jungermannia inundata
Riccardia Aequicellularis

INVERTEBRATES (From Jasinska and Knott 1994)

CHELICERATA

Acarina
Oribatida sp. s2
Limnesia sp. nov.

CRUSTACEA

Amphipoda
Amphipod gen. nov.

Cladocera
Ilyocryptus ?sordidus

Copepoda: Cyclopoida
Microcyclops sp5
Microcyclops sp6
Mixocyclops sp4
Paracyclops sp5
Paracyclops sp6
Paracyclops sp7
Paracyclops sp8

Copepoda: Harpacticoida
Harpacticoida spA (gigant)

Decapoda
Cherax quinquecarinatus (variant)

Ostracoda
Darwinula sp1

NEMATODA
Nematode sp1
Nematode sp3
Nematode sp16

ANNELIDA: Oligochaeta
Oligochaete sp11
Oligochaete sp12
Oligochaete sp13
Tubellaria spp

INSECTA

Diptera
Chironomidae

Coleoptera
Dystiscidae larvae

APPENDIX 3

SPECIES LIST - OCCURRENCE 3

VASCULAR PLANTS (identified by G. Keighery during site visit - January 1997)

Cyperaceae
Baumea articulata
Baumea vaginalis
Cyathochaeta teretifolia
* *Isolepis prolifera*
Lepidosperma ?gladiatum
Lepidosperma longitudinale
Tetraria capillaris

Dennstaedtiaceae
Pteridium esculentum

Dilleniaceae
Hibbertia perfoliata

Juncaceae
Juncus holoschoenus

Juncaginaceae
Triglochin procera

Lobeliaceae
Grommatotheca bergiana

Myrtaceae
Agonis linearifolia
Astartea fascicularis
Eucalyptus rudis
Melaleuca preissiana

Papillionaceae
Oxylobium linearifolia

Poaceae
* *Pennisetum clandestinum*

Proteaceae
Banksia littoralis

Rosaceae
Rubus sp.

Thelypteridaceae
Cyclosorus interruptus

VERTEBRATE FAUNA (W. Manson and P. Speldewinde,Personal communication)

Mammalia
Isoodon obesulus