INTERIM RECOVERY PLAN NO. 110

SEDGELANDS IN HOLOCENE DUNE SWALES

INTERIM RECOVERY PLAN 2002-2007

V. English, J. Blyth, N. Gibson, D. Pember, J. Davis, J. Tucker, P. Jennings, B. Walker

Photo: Val English

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Department of Conservation and Land Management
Western Australian Threatened Species and Communities Unit
PO Box 51, Wanneroo, WA 6946

Government of Western Australia

DEPARTMENT OF Conservation AND LAND MANAGEMENT
Conserving the nature of WA

Natural Heritage Trust
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FOREWORD

Interim Recovery Plans (IRPs) are developed within the framework laid down in Department of Conservation and Land Management (the Department) 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.

The Department is committed to ensuring that Critically Endangered, and where appropriate and feasible, other threatened 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 the Minister.

This Interim Recovery Plan will operate from May 2002 to April 2007 but will remain in force until withdrawn or replaced.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 reviewed after five years and the need for a full Recovery Plan assessed.

This IRP was approved by the Director of Nature Conservation on 24 September 2002. The provision of funds identified in this Interim Recovery Plan is dependent on budgetary and other constraints affecting the Department, as well as the need to address other priorities.

Information in this IRP was accurate at May 2002.

SUMMARY

Name: Sedgelands in Holocene dune swales

Description: The community occurs in linear damplands and occasionally sumplands, between Holocene dunes. Typical and common native species in the community are the shrubs *Muehlenbeckia adpressa, Acacia saligna* and *Xanthorrhoea preissii* and the herbs *Baumea juncea, Isolepis nodosa,* and *Poa porphyroclados.* Several exotic weeds are found in this community but generally at low cover values.

Department of Conservation and Land Management (the Department) Region(s): Swan

Department of Conservation and Land Management District(s): Swan Coastal District, and Regional Parks Unit

Shire(s): City of Rockingham, City of Mandurah, City of Wanneroo

Recovery Team: Ms V. English, Mr J. Blyth, Dr N. Gibson, Ms D Pember, Dr J. Davis, Mr J. Tucker, Dr P. Jennings.

Current status: Community assessed June 1996 as Critically Endangered
Note: Becher Point wetlands are also nominated as a Wetland of International Importance under the Ramsar Treaty, an important suite of wetlands in 'A Directory of Important Wetlands in Australia', and are on the Register of the National Estate.

Habitat requirements: Water regime is the primary abiotic determinant influencing characteristics of wetland plant communities. Depth, timing and duration of flooding and length of the dry period all affect vegetation composition and distribution (Froend and McComb 1993). The sedgelands in the damplands and sumplands of the Holocene dune swales would have relatively specific water regime requirements to maintain current biology, but be tolerant of seasonal and longer-term variations that reflect natural climatic patterns.

The typical wetland in which this community type occurs is a dampland that becomes water logged in winter, and retains relatively high moisture near the surface of the soil profile in summer. The plant community occasionally occurs in sumplands, which have shallow surface water - generally less than 20cm for up to 2 months of the year.

The soils of these wetlands are sands or sandy-loams with a pH of about 8.0. The soils are more saline close to the coast, and this reflects inputs from salt spray. Nutrient levels are similar to those reported for other Quindalup sands.

IRP objective(s): To maintain or improve the overall condition of the sedgelands in Holocene dune swales community and reduce the level of threat

Critical habitat: The critical habitat for the 'Sedgelands in Holocene dune swales' is the system of dunes and swales in which they occur, the fresh superficial groundwater that provides water to the swale wetlands, and the catchment for this groundwater.

Criteria for success:

- An increase in the area, number of occurrences, and completeness of a geomorphic age sequence of this community under conservation management.
- Maintenance in terms of diversity and basic composition of native species (as described in Gibson *et al*. 1994).
- Maintenance of water levels and quality in the wetlands that contain the community.
- Maintenance or improvement in the condition and extent of the community including reduction of exotic species.

Criterion for failure*:* Significant loss of area or major decline in the condition of the threatened ecological community, especially any occurrences that are significant in completing a geomorphic age transect.

Recovery Actions

ALL AREAS	Implement wetland management in response to results of monitoring
Establish a Recovery Team	Monitor the need for rehabilitation in the community
Identify all occurrences of the community	Undertake appropriate research and education projects
Liaise with relevant groups to implement this IRP	Design and implement a feral animal control program
Minimise further clearing of the community	**SCHEDULE 2 - AREA 2 PORT KENNEDY AREA, OUTSIDE PORT KENNEDY SCIENTIFIC PARK**
Minimise recreational disturbance to the community	Negotiate for appropriate management of other occurrences in Port Kennedy, outside Port Kennedy Scientific Park
Maintain hydrology and water quality	**SCHEDULE 3 - LAKE COOLOONGUP AND LAKE WALYUNGUP**
Design fire response plans	Reserve Lakes Cooloongup and Walyungup, and surrounding remnant vegetation
Apply fire response plans	**SCHEDULE 4 - AREA 4 - LAKE RICHMOND**
Design and implement a weed control strategy for the community	Negotiate to alter purpose of Lake Richmond reserve to Conservation and Recreation
Minimise damage to the community from UXO searches	Negotiate to reserve privately owned portion of Lake Richmond
Report on success of management strategies for wetlands	Ensure strategies for conserving the dune swale community are included in the Management Plan for the Lake Richmond reserve
Ensure any tourist developments do not impact the swale community	**SCHEDULE 5 - LARK HILL**
SCHEDULE 1 - PORT KENNEDY SCIENTIFIC PARK	Incorporate management strategies into planning for the Lark Hill Sporting and Recreation complex
Reserve Stage 2 proposed Conservation Zone	**SCHEDULE 6 - INDUSTRIAL PARK 14**
Employ Management Officer	Negotiate for appropriate management of the community at Industrial Park 14
Agree on location, and install vermin proof fence	**SCHEDULE 7 - YANCHEP**
Ensure hygiene washdown of machinery	Ensure strategies for conserving the dune swale community are included in the Management Plan for Yanchep National Park
Develop a fire history map of the area	**SCHEDULE 8 - PRESTON BEACH**
Ensure maintenance of strategic firebreaks	Determine management requirements of the community at Preston Beach
Establish permanent quadrats for monitoring	**SCHEDULE 9 - SECRET HARBOUR AND GOLDEN BAY**
Integrate data from flora and fauna studies into fire management plan	Negotiate for appropriate management of the community at Secret Harbour and Golden Bay
Implement groundwater monitoring	

1. BACKGROUND

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

The present known distribution of the Holocene swale community is almost entirely located within linear wetland depressions (swales) occurring between parallel sand ridges of the Rockingham - Becher Plain. Additional occurrences include a small area at Yanchep and a possible occurrence in a single swale at Preston Beach.

The Rockingham - Becher Plain has been formed through the accumulation of Holocene sediments and is of high geomorphological significance due to the information it provides about the evolutionary record of sea-level history and climatic changes. The best record occurs along a linear transect from Becher Point through to the hinterland, with the record preserved spanning the last 8,000 years (Semeniuk and Searle 1986) of the Holocene Epoch of the Quaternary Period.

Wetlands occur within the swales where the watertable is close to or at the ground surface in the wetter months of the year.

V & C Semeniuk Research Group (1991) and Hill *et al.* (1996) classified large and small wetlands within the Cooloongup, Becher and Peelhurst suites. The most typical form is that of the Becher Suite, which is made up of over 250 very small to small sumplands and damplands, many of which contain occurrences of this community.

The actual assemblage of species varies between occurrences of the threatened ecological community. In addition to the presence of the threatened community, the conservation values of the wetlands are primarily related to the geomorphic significance of the site and the respective location of the wetlands along the evolutionary time sequence. When conserved as a representative unit, the relative youth of the wetlands, and the range of wetlands of different ages in association with their geomorphic history, provide important opportunities for research on wetland evolution (V & C Semeniuk Research Group 1991). A number of excellent examples of wetlands between a few hundred and 4500 years of age have been reserved or are planned for reservation. Fewer examples from earlier in the time sequence, between 4500 and 7000 years of age are reserved. Wetlands of this age are known to exist at Lark Hill, east of Bakewell Drive in Port Kennedy, near Lakes Cooloongup and Walyungup, and at Yanchep.

The vegetation composition of the wetlands is likely to be related to both age and proximity to the watertable. It is unknown to what extent fire has influenced the present structure or composition of the community. Typical and common native species are the shrubs *Muehlenbeckia adpressa, Acacia saligna and Xanthorrhoea preissii,* the sedges *Baumea juncea, Isolepis nodosa,* and the grass *Poa porphyroclados.* A list of taxa located in the community occurs at Appendix 1.

1.2 Description of occurrences

The total area occupied by the sedgelands in Holocene dune swale community as described by Gibson *et al*. (1994) is approximately 130 ha. The community type is only recorded from 10 areas (Table 1)

Table 1: Extent and location of occurrences

Area Number	Location	Estimated area
Occurrences located on the Rockingham Becher Plain		
1	Port Kennedy Scientific Park (PKSP)	~60 ha
2	Port Kennedy area, outside of PKSP (not including Lark Hill,	~10 ha

	but including area east of Bakewell Drive; and near the coast north of Port Kennedy Drive)	
3	Lark Hill	~8 ha
4	Industrial Park 14 (IP 14)	~10 ha
5	Rail loop, boundary of Rockingham and Challenger	~1 ha
6	Secret Harbour, Golden Bay area (outside of the Port Kennedy Scientific Park)	~23 ha
7	Lakes Walyungup/Cooloongup	~2 ha
8	Lake Richmond	~11 ha
Occurrences located outside the Rockingham Becher Plain		
9	Yanchep National Park	<1 ha
10	Preston Beach	~5 ha

The floristics of the wetlands in the swale at Preston Beach, needs to be surveyed and analysed to confirm that the areas contain the sedgelands in Holocene dune swales community. The plant community that occurs in the other areas has been determined by multi-variate analysis of plot data (Gibson *et al*. 1994; DEP 1996) or through other surveys (Trudgen and Weston 1998; V. English personal observation).

Other possible occurrences of Holocene dunes may be found at the north eastern corner of the Becher Plain, south of Lancelin, Cheynes Beach, Dunsborough and at Leda. These areas should be investigated to see whether they support occurrences of the Holocene dune swale community.

Investigations have indicated that Holocene dunes at Alkimos, Jurien and the Swan River at Shelley do not contain areas that are floristically representative of the community type. A small occurrence of the community probably occurred at Whitfords but was essentially destroyed by urban development.

Sub-groups of the community have been identified by Department of Environmental Protection (1996) and Trudgen and Weston (1998). Essentially, sub-groupings appear to relate to variations in depth to groundwater and in age of the dunes ([1]B. Keighery personal communication). However, these sub-groups are all termed ‘sedgelands in Holocene dune swales’, and are grouped here as the same plant community.

1.3 Biology and ecology

Most of the wetlands are damplands (waterlogged with high moisture near the surface in summer) with some sumplands (seasonal inundation usually for less than 2 months of the year). The sedgeland community also occurs adjacent to the waterbodies of Lakes Walyungup, Cooloongup and Richmond. The community in these situations is typically a dense, species-poor sedgeland dominated by *Baumea juncea* and *Isolepis nodosa*.

Half a dozen weed taxa are known to occur in the community type but they generally form only a very minor component of the vegetation and pose no serious threat at this time except in localised disturbed areas.

In some of the older swales near Lakes Walyungup and Cooloongup and at Yanchep, an open tree cover has developed over the sedgeland, probably reflecting the more protected nature of these areas compared to those closer to the coast. At Lake Walyungup, swamp banksia (*Banksia littoralis*) forms

[1] Bronwen Keighery, Department of Environmental Protection

the canopy while at Yanchep and Lake Cooloongup tuart (*Eucalyptus gomphocephala*) dominates the overstorey. Both species are known to tolerate damp conditions.

1.4 Hydrology

Most of the available hydrological data have been derived from studies of the Becher Suite wetlands at the Port Kennedy site (refer Bowman, Bishaw Gorham 1994a). Other data occur in V & C Semeniuk Research Group (1991).

Both long term regional data (up to 24 years of records) and short term site specific data at Port Kennedy indicate that the seasonal watertable fluctuation in the swale wetlands is low, generally less than 0.5 m. Although maximum watertable levels range from 0.4 m to 1.9 m below ground, some of the wetlands (sumplands) contain very limited areas of surface water during the winter months. These areas are generally very small, being typically less than 50-100 m^2. The typical wetland within the occurrences around Port Kennedy is a dampland which is waterlogged in winter, and retains relatively high soil moisture at the surface of the soil profile in summer. Although the wetlands are expected to be strongly influenced by their proximity to the watertable, they also rely on direct rainfall.

Structure plans for the south-west corridor, in which the Port Kennedy site and its surrounds are located (Department of Planning and Urban Development 1993), indicate significant additional urbanisation will occur in future years. Water tables are likely to rise in the superficial aquifer as a consequence of further clearing in the catchment. Rising water-tables have the potential to cause longer and deeper wetting of these wetlands and therefore to significantly modify the ecological community.

1.5 Threatening processes

The remnant Holocene dune swale communities and wetlands of the Rockingham - Becher Plain have been subject to extensive historical disturbance. Most of these processes, with the exception of those related to use as a bombing range, are still common to most known occurrences of the community:

- Clearing
- Hydrological changes
- Changes to groundwater quality
- Slashing to clear unexploded ordnance (UXO)
- Disturbance due to recreational use / maintenance activities
- Inappropriate fire regimes
- Increased weed invasion
- Grazing by cattle and rabbits
- Erosion of coastal dunes

Clearing

Rapid urbanisation and expansion of the Rockingham Region has occurred over the past 5 years, with extensive clearing of wetlands. Only about 20% of the original area of the swale wetlands now remains on the Rockingham - Becher Plain. Other areas of the Swan Coastal Plain such as Whitfords that may have supported the community have been cleared. Occurrences at Yanchep are within National Park and have not been cleared extensively. The Preston Beach occurrence is located on private land and National Park, and a portion may be threatened by clearing.

Hydrological changes

The wetlands have subtle topographic relief and therefore soil moisture, vegetation and habitats could be affected by relatively small ‘unnatural’ watertable alterations. Increased urbanisation may result in

a rise in the groundwater level. Alternatively, uncontrolled extraction from irrigation bores may lower groundwater levels, especially in summer. As indicated in Section 1.4, a major consideration for wetland management is the recognition of the importance of shallow groundwater levels upon the ecological function of sumplands and damplands, and hence the viability of the Holocene swale community. Where urbanisation occurs careful monitoring associated with a reactive management capacity will be needed to ensure that water extraction can be used as a tool to avoid excessive wetting of the swale wetlands in winter/spring, and that extraction for irrigation does not result in unacceptable drawdown in the summer months. The use of water-sensitive design can be used to reduce irrigation requirements. In 2002 the Department of Environment, Water and Catchment Protection will release a report about the impact of bores, and this will provide information that is likely to be useful in determining the future management of bores near occurrences of the Holocene dune swales community.

For the purpose of comparison, reference monitoring needs to be undertaken in wetland areas where extraction or urbanisation are unlikely to impact groundwater eg Preston Beach or Yanchep. This would allow determination of the level of natural fluctuations. Only impacts that occur as a result of extraction, urbanisation or other human activities should be ameliorated.

Changes to groundwater quality

There are risks of nutrient, pesticide and other contamination of the groundwater due to increasing urbanisation and golf course development in areas adjacent to wetlands. Groundwater abstraction for irrigation purposes may also allow saltwater intrusion into the shallow aquifer in areas close to the coast. Use of the wetlands as rubbish disposal sites also has the potential to cause groundwater contamination. Hydraulic gradient at the watertable is very low therefore movement of any contaminated water from the site will be a slow process.

All occurrences of the community located on the Rockingham Becher Plain are likely to be under threat from altered groundwater quality and levels. Occurrences in Yanchep where market gardens and other agricultural pursuits are encroaching may also be threatened by these processes. Preston Beach occurrences are adjacent to privately owned remnant vegetation and may be threatened by such hydrological changes in the future associated with land use changes.

An example of the current management and monitoring of the groundwater and wetlands at the Port Kennedy development is presented as Appendix 2.

Slashing to clear UXO

Most of the Rockingham - Becher Plain was used heavily as a bombing range during World War 2. In addition to physical disturbance and fires resulting from this activity, searching for UXO over much of the Rockingham - Becher Plain has occurred on at least two occasions since this time. UXO searching requires slashing of all vegetation to ground level and most of the wetlands in the area have been affected by this process. With development of more sensitive equipment, the Police Emergency Service wishes to conduct further searching with associated slashing of vegetation in all areas where soil disturbance may occur.

Occurrences of the community at Yanchep and Preston Beach are not under threat from slashing for UXO.

Disturbance due to recreational use / maintenance activities

Areas that contain the community have historically been used as rubbish disposal sites, for off-road vehicle and motor bike circuits, by horse riders, for management tracks and firebreaks, as grazing areas for cattle and horses, and as sources of peat.

Occurrences at Yanchep and Preston Beach are more remote from urban areas than occurrences on the Rockingham Becher Plain and are likely to have historically been less impacted by recreational activities.

Inappropriate fire regimes

Fires are likely to have a significant effect on the vegetation composition in Mediterranean ecosystems (Gill *et al*. 1981). Within the Port Kennedy site, over 43 fires occurred between 1985 and 1999. Fires have either been deliberately lit by vandals, or have escaped from camp fires lit by squatters or campers along the beach. It is likely that the fire frequency in the Holocene dune swale community has increased greatly since European settlement.

The Lake Richmond and Lark Hill areas have also been burnt frequently in recent years, as they are close to urban areas. Occurrences at Preston Beach and Yanchep have probably been subject to significantly fewer fires as the areas are more remote. Historical fire frequency at Industrial Park 14 and at Lakes Cooloongup and Walyungup is not known. However, the IP14 area has been subject to fire very recently (during 2000-2001) and weed levels suggest fire frequency has been high historically.

Increased weed invasion

Weed invasion is most significant in areas where human activity and feral animal numbers are highest, particularly within wetlands adjacent to off-road vehicle tracks. *Typha* sp. has invaded at least two wetlands in the Port Kennedy area where excavation for peat has occurred. Weed invasion is also exacerbated by frequent fire.

Grazing by cattle and rabbits

Historically, Preston Beach and much of the Rockingham Becher Plain, have been pastoral areas and selectively grazed by cattle. High numbers of rabbits have invaded the Port Kennedy area, selectively grazed more palatable species, and caused damage to vegetation with high densities of warrens.

Erosion of coastal dunes

In July 1996, natural erosion due to storm surge events caused a breach in the barrier dunes to the Cooloongup Suite wetland located at the tip of Becher Point, resulting in salt-water inundation of the wetland.

Dune blow outs have occurred as a result of four wheel drives in areas at the southern end of the Port Kennedy Scientific Park. Destabilisation of these dunes can result in sand filling the dune swales and covering the community. Erosion potential maps for the Port Kennedy area occur in Environmental Capability & EarthScience Pty Ltd (1994) and Bowman Bishaw Gorham (1994b). Disturbance in areas of high potential erosion risk should be minimised.

There are no erosion potential maps for other areas where the community occurs. Dune management should ensure in future that any disturbance to the barrier dunes or other dunes adjacent to the dune swale community is not the result of human activity.

The frequency of storms has declined significantly since the late 1940s and early 1950s. Inundation by seawater, and erosion could become highly significant processes if storm frequencies were to again increase (P. Sanderson[2], personal communication).

[2] Dr Peta Sanderson, Department of Geography, University of Notre Dame

1.6 Conservation status

The community meets the following criteria (from English and Blyth, 1997, 1999) for Critically Endangered (CR) ecological communities:

B iii) Current distribution is limited and there may be many occurrences but total area is very small and each occurrence 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 or improving natural biological and non biological attributes of the occurrences of the community. Particular emphasis will be placed on occurrences that cover the full geomorphological age sequence.

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

Guide For Decision-Makers

Section 1.5 provides details of current and possible future threats. Proposed developments in the region of the sedgeland community require assessment. No developments should be approved unless the proponent can demonstrate that they will have no significant impact on the community. Direct clearing of the community, or developments that lead to changes in either quality or levels of groundwater, would be expected to have a significant impact on the threatened ecological community.

2. RECOVERY AIM AND CRITERIA

The aim is to maintain or improve the overall condition of the Holocene dune swales wetland community and reduce the level of threat.

2.1 Criteria for success

- An increase in the area, number of occurrences, and completeness of a geomorphic age sequence of this community under conservation management.
- Maintenance in terms of diversity and basic composition of native species (as described in Gibson *et al*. 1994).
- Maintenance of water levels and quality in the wetlands that contain the community.
- Maintenance or improvement in the condition and extent of the community including reduction of exotic species

2.2 Criterion for failure

Significant loss of area or major decline in the condition of the threatened ecological community, especially any occurrences that are significant in completing a geomorphic age transect.

3. RECOVERY ACTIONS

Actions 3.1 to 3.12 refer to all occurrences of the community. Specific recommendations for particular areas are held in Schedules 1 to 9.

Note: The Proposed Port Kennedy and Rockingham Parks Management Framework (Alan Tingay and Associates 1997) provides a framework for managing some of the areas that contain this community, including the Port Kennedy Scientific Park, Lake Richmond, Lake Cooloongup and Lake Walyungup areas.

The preparation of a management plan for the Rockingham Lakes Regional Park (which includes all of the above mentioned areas) will be a strategic document providing broad management direction. The plan will coordinate existing and future planning and management for the Rockingham Lakes Regional Park.

The Rockingham Lakes Regional Park Management Plan will be a statutory document for lands vested in the Conservation Commission of Western Australia. The Plan will outline the future tenure arrangements and relevant managing agencies for all areas within the Park. This IRP provides more detailed guidelines for the management of the threatened community. Implementation of the IRP for the sedgelands in Holocene dune swales will be consistent with the overall direction of the Rockingham Lakes Regional Park Management Plan.

3.1 Establish a Recovery Team

Responsibility: the Department (Western Australian Threatened Species and Communities Unit (WATSCU))
Cost: $1,000
Completion date: Completed.

3.2 Identify all occurrences of the community

Occurrences of the community, particularly those significant in completing a geomorphic age sequence, will be identified.

The number, age and extent of occurrences of the community on the Rockingham / Becher Plain and other likely areas, as listed below will be clarified:

(i) The north eastern portion of the Becher Plain and the Secret Harbour area:
(ii) Holocene dunes with wetlands around Preston Beach.
(iii) South of Lancelin,
(iv) Cheynes Beach,
(v) Dunsborough,
(vi) Leda;
(vii) near Lakes Cooloongup and Walyungup.

Responsibility: the Department WATSCU; Recovery Team
Cost: Total of $5,000 for floristic plots, data on condition and extent, and report for Lark Hill, Preston Beach and some other likely areas.
Completion date: June 2003

3.3 Liaise with relevant groups to implement this IRP

A number of the occurrences of the community are managed by authorities other than the Department, are unvested, or privately owned. The involvement, wherever possible and practical, of land managers, local community groups and industry in the recovery of the community is therefore essential to the recovery process.

Other stakeholders should be consulted on management of the community as they are identified.

Responsibility: Recovery Team, the Department

Cost: $10,000 p.a. for all liaison (not including vehicle costs)
Completion date: Ongoing
Priority: Essential and ongoing

3.4 Minimise further clearing of the community

Further clearing or destruction by other means especially of good examples of the older stages of the wetland will be minimised wherever possible by acquisition, negotiation and planning.

Responsibility: the Department (Swan Coastal District, Regional Parks Unit) relevant Local Authorities, Department of Planning and Infrastructure
Cost: Costs of all liaison included in 3.3, other costs to be determined
Priority: Essential
Completion date: Ongoing

3.5 Minimise recreational disturbance to the community

A strategy will be developed to minimise disturbance due to recreational use and development and management activities, particularly in relation to the introduction or spread of weeds. This will be used to provide advice to managers of all occurrences of the community and will be incorporated into the full Recovery Plan if required.

Responsibility: the Department, relevant Local Authorities, Recovery Team
Cost: $2,000
Priority: Essential
Completion date: Ongoing

3.6 Maintain hydrology and water quality

A strategy will be designed to ensure watertable height and water quality remain appropriate to the natural wetland community, through monitoring and ongoing management. This strategy will be incorporated into the full Recovery Plan if required.

Responsibility: Recovery Team, relevant Local Authorities
Cost: To be determined
Priority: Essential
Completion date: Ongoing

3.7 Design fire response plans

A fire response plan (FRP) that is appropriate for the wetland community will be developed.

In the Port Kennedy Scientific Park no planned burn will be implemented for this community for the life of this IRP, unless results of future studies suggest this is inappropriate, as many occurrences of this community have recently been subject to very frequent fire.

Responsibility: Recovery Team, the Department (Swan Coastal District, Regional Parks Unit), relevant Local Authorities, other managers of occurrences of the community
Cost: $200
Priority: Essential (FRP for Port Kennedy Scientific Park, and Lakes Cooloongup and Walyungup reserves complete)
Completion date: Ongoing (Updated annually)

3.8 Apply fire response plans

Responsibility: Recovery Team, the Department (Swan Coastal District and Regional Parks Unit), relevant Local Authorities, other managers of occurrences of the TEC
Cost: $5,000 p.a.
Priority: Essential (Fire Response and Fire Action Plans are complete for Port Kennedy; these can be adapted for other areas).
Completion date: Implementation ongoing.

3.9 Design and implement a weed control strategy for the community

For areas within the Rockingham Lakes Regional Park, this strategy will be done as part of the weed control strategy for the Regional Park. Weed removal and control is predominantly required in deeper wetlands (*Typha*) and on the edges of the threatened community.

Ongoing monitoring will determine success of weed control measures. A weed map will initially be produced to determine priority areas for weed control.

Responsibility: Recovery Team, the Department (Regional Parks Unit, WA Threatened Species and Communities Unit (WATSCU), and Swan Coastal District), relevant Local Authorities, other managers of occurrences of the TEC
Cost: Weed map $6,000, $2000 per year thereafter for implementation (for Port Kennedy Scientific Park; cost for other areas to be determined)
Priority: Essential
Completion date: Design - December 2003, implementation – ongoing.

3. 10 Minimise damage to the community from UXO searches

Liaison will be maintained to prevent damage to the threatened community from slashing and other activities during searches for UXO.

UXO slashing will be implemented as follows:

i) If there is no soil disturbance and limited human access likely in the future, then slashing for UXO is not necessary
ii) If UXO search is necessary, it is to be done in consultation with the appropriate District staff from the Department
iii) The conditions held in (i) and (ii) be placed on developments by the City of Rockingham and private property.

Responsibility: Recovery Team, relevant Local Authorities, UXO Branch - Fire and Emergency Services
Cost: Costs of all liaison for this community included in 3.3
Priority: Essential, ongoing

3.11 Report on success of management strategies for wetlands

Annual reports will be prepared by the Recovery Team.

Responsibility: the Department, Recovery Team
Cost: $1,500 pa. If a full Recovery Plan for the community is required, the final report under this IRP will be presented as part of, or complementary to, that plan.
Priority: Essential
Completion date: Annual reporting

3.12 Ensure any tourist developments do not impact the swale community

The site of any tourist developments or displays will be designed to minimise impact on the swale community and will provide information on the significance of the wetland areas, the need to conserve them, and how this is being done. This will be done as part of the Rockingham Lakes Regional Park Management Plan.

Walk trails will be designed such that hydrology around wetlands is not altered and that there is no direct disturbance of the community.

Responsibility: Recovery Team, the Department (Swan Coastal District and Regional Parks Unit), City of Rockingham and local owners
Cost: Costs of liaison included in 3.3
Priority: Desirable
Completion date: Completion date dependent on the Rockingham Lakes Regional Parks Management Plan.

SCHEDULE 1 - AREA 1 PORT KENNEDY SCIENTIFIC PARK
(Note 1: many recommendations are adapted from Bowman, Bishaw, Gorham, 1994a).

3.13 Reserve Stage 2 proposed Conservation Zone

The Stage 2 Area at Port Kennedy that contains the swale wetland community has been reserved as an A Class reserve for Conservation of Flora and Fauna under the care, control and management of the Conservation Commission (Ministerial Condition 2).

Any development of Stage 2 is to be referred to the Environmental Protection Authority and is subject to Environmental Impact Assessment (Ministerial Condition 17). There should be no impact on the Holocene dune swale community from any future development. The Department and Conservation Commission will provide comment on development proposals that may impact the area.

Responsibility: the Department and Department of Land Administration (DOLA)
Cost: Costs of liaison included in 3.3
Priority: Urgent and essential
Completion date: Completed August 1997, ongoing for future developments

3.14 Employ Management Officer

Responsibility: the Department (Swan Coastal District)
Cost: $12,500 p.a.
Priority: Urgent
Completion date: Completed

3.15 Agree on location, and install vermin proof fence

The fence will be located such that wetland areas are protected and not impacted. There was six kilometres of fencing in place as at October 1997, another 3 km is required on the northern boundary. The fence needs to be completed as a matter of urgency as local urbanisation is leading to an increase in feral animals and increased predation on local fauna. In addition, four wheel drives are still accessing the area and causing damage.

Responsibility: the Department / PK Resorts or successor
Cost: $120,000
Priority: Urgent
Completion date: December 2002.

3.16 Ensure hygiene washdown of machinery

All machinery used in the Port Kennedy Scientific Park area will be free of weed seed and soil prior to entering the site.

Responsibility: the Department
Cost: Costs to be underwritten by user of machinery
Priority: Urgent and immediate

3.17 Develop a fire history map of the area

This plan has mainly been prepared by memory and covers the last five to seven years. This map is updated annually.

Responsibility: the Department (Swan Coastal District), Recovery Team
Cost: $500 pa
Priority: Urgent
Completion date: Fire history map is complete, updating of map is ongoing.

3.18 Ensure maintenance of strategic firebreaks

Firebreaks will be maintained or new strategic fire breaks constructed on surrounding lands to help prevent fire spreading to the community.

Existing tracks not required as firebreaks will be rehabilitated. No new fire breaks will be constructed on occurrences and preference will be given to closure of tracks that go through the sedgeland community. Limestone may be used to stabilise sections of sand firebreaks.

Cost of firebreaks will depend on the final design held in the Fire Response Plan.

Responsibility: the Department (Swan Coastal District and Regional Parks Unit); liaison with surrounding landholders
Cost: Cost of firebreaks will be determined on completion of Fire Response Plan; costs of liaison included in 3.3
Priority: Urgent
Completion date**:** December 2002

3.19 Establish permanent quadrats for monitoring

A project that involves flora survey of permanently marked transects in coastal areas termed ‘Surveying WA's Littoral Ecology (SWALE)’ has been initiated in Port Kennedy Scientific Park. The project is funded by Coastwest. and the project is managed by the Department, the Regional Herbarium, and the Rockingham Regional Environment Centre. The project involves 20 regional Herbaria. The sites within the park have been located to include the threatened wetlands, beach ridge plain and Becher Point. The topography and ground water level will also be monitored to check for natural changes versus human impacts. Following the second monitoring period, data will be analysed and compared as part of the full Recovery Plan, if developed.

Responsibility: the Department (Science Division, Swan Coastal District) Recovery Team
Cost: $5,000 for 1 plot in each of 10 wetlands including field survey, specimen identification, and databasing for 1 monitoring period. Cost of reporting should be included in costs of the second monitoring, to allow time for data analysis and report writing.
Priority: Urgent
Completion date: Ongoing

3.20 Integrate data from flora and fauna studies into fire management plan

The fire regime will be altered if the fire frequency is found to be having adverse impacts, such as increased weed invasion.

Responsibility: the Department (Swan Coastal District), Recovery Team
Cost: Action will be incorporated into 3.8
Priority: Urgent
Completion date: Analysis and response to data ongoing.

3.21 Implement groundwater monitoring

Includes monthly monitoring - to include the following: collection of water level and water quality information (see Appendix 2) from wetlands and from licensed bores in adjacent areas of interest; definition of the nutrient budget of the wetlands and development of a water budget (Ministerial Condition 12). These data will be included in the Full Recovery Plan, if developed.

Data should be provided to the Department of Environmental Protection and to the Recovery Team for this community.

Responsibility: PK Resorts or successor
Cost:
Nutrient sampling - $6,000 per month
Quarterly monitoring for saline intrusion ($3,000/yr)
Ongoing monitoring of lower aquifer levels (observation bore
levels ($3,000/yr)
Quarterly upstream plant tissue and soil nutrient analysis ($8,000/yr)
Total cost: To be determined
Priority: Urgent and ongoing
Completion date: Ongoing.

3.22 Implement wetland management in response to results of monitoring

If monitoring indicates adverse affects on wetlands an appropriate and immediate response will be made. In particular, a comprehensive groundwater management plan that is linked to groundwater abstraction licences may be required so that controls can be quickly applied if problems emerge.

Condition 12 of the original approval statement (issued by the Minster for the Environment on 16th August 1990) for the development states – "Prior to construction the proponent shall prepare and implement a groundwater monitoring and management program for the site and its environs to the satisfaction of the Minister for the Environment on advice of the Water Authority of Western Australia. In the event that adverse impacts occur to groundwater on or adjacent to the site as a result of the development, the proponent shall undertake remedial action to the satisfaction of the Environmental Protection Authority on advice of the Water Authority of Western Australia and the Department of Conservation and Land Management."

The interim 'Investigation' and 'Minimum' watertable levels at monitoring bores adjacent to wetlands within the conservation area are described in Table 2, below.

Table 2

Monitoring Bore	Interim 'Investigation' level (m AHD)	Interim ' Minimum' level (m AHD)
MB6	0.55	0.45
MB8	1.40	1.30

From: Management and monitoring of the groundwater and wetlands at the Port Kennedy development (Bowman, Bishaw, Gorham 1994a).

Responsibility: PK Resorts or successor
Cost: Costs to be underwritten by Port Kennedy Resorts or their successor
Priority: Urgent
Completion date: Ongoing.

3.23 Monitor the need for rehabilitation in the community

Dune blow outs, such as those in the southern end of the Port Kennedy Scientific Park, should be photographically monitored to help determine priority areas for rehabilitation. Results of weed monitoring should also be used to decide priority rehabilitation areas.

Further funding for rehabilitation will be required if it is found that the secondary dune systems are moving into the sedgeland community as a result of human activities.

Responsibility: the Department (Swan Coastal District), Recovery Team
Cost: $500 pa
Priority: Desirable
Completion date: Ongoing

3.24 Undertake appropriate research and education projects

Possible research projects suggested by J. Searle occur in Appendix 3. Other possible research includes invertebrate and floristic analysis of the wetlands, evolutionary ecology, hydrology and/or geomorphology of wetlands.

Responsibility: the Department (Swan Coastal District), Recovery Team
Cost: $5,000 pa
Priority: Desirable
Completion date: 2005

3.25 Design and implement a feral animal control program

A rabbit control program will be developed and implemented in the Port Kennedy Scientific Park (in conjunction with fox, feral dog and feral cat control). In particular, the program will focus on areas where the vegetation is most impacted by rabbit warrens and grazing. Care will be taken not to impact local fauna. The use of 1080 baiting for rabbits and foxes may be most appropriate for use in this reserve where macropods that are vulnerable to pindone are present, however, 1080 will not be used until the perimeter fence is completed.

Responsibility: the Department (Swan Coastal District) and Science Division)
Cost: $2,500 for signage, $5,000 pa for baiting
Priority: Urgent
Completion date: Ongoing

SCHEDULE 2 - AREA 2 PORT KENNEDY AREA, OUTSIDE PORT KENNEDY SCIENTIFIC PARK (not including Lark Hill)

3.26 Negotiate for appropriate management of other occurrences in Port Kennedy, outside Port Kennedy Scientific Park

The land tenure of the occurrences of the sedgeland community north of Port Kennedy Drive, and between Bakewell Drive and Ennis Avenue will be identified. Appropriate management actions to conserve the community will then be determined, including negotiations for declaration of areas as conservation reserve if necessary.

Responsibility: Recovery Team, the Department
Cost: Costs of liaison included in 3.3, other costs to be determined
Priority: Urgent
Completion date: Identification of occurrences, and negotiations on land tenure are continuing

SCHEDULE 3 - AREA 3 - LAKE COOLOONGUP AND LAKE WALYUNGUP

3.27 Reserve Lakes Cooloongup and Walyungup, and surrounding remnant vegetation

The areas that contain the swale wetland community will be sought as Class A reserve for Conservation of Flora and Fauna under the care, control and management of the Conservation Commission.

The Department is currently managing the area as part of the Rockingham Lakes Regional Park through a management agreement with the Western Australian Planning Commission (under Section 16 of the Conservation and Land Management Act).

Responsibility: the Department, Department of Planning and Infrastructure (DPI) and DOLA.
Cost: To be determined
Priority: Urgent
Completion date: To be determined

SCHEDULE 4 - AREA 4 - LAKE RICHMOND

3.28 Negotiate to alter purpose of Lake Richmond reserve to Conservation and Recreation

The part of Lake Richmond that is vested in the City of Rockingham (Reserve number 9458) is for the purpose of Conservation and Public Recreation.

Responsibility: the Department, City of Rockingham and DOLA
Cost: Costs of liaison included in 3.3
Priority: Urgent
Completion date: Completed December 2000

3.29 Negotiate to reserve privately owned portion of Lake Richmond

Negotiations will continue to include the privately owned portion of the lake bed and foreshore and an appropriate buffer strip around the lake in the reserve that contains the remainder of lake. The remainder of the lake bed, and the surrounding remnant that contains the community is under the care, control and management of the City of Rockingham.

Environmental Protection Authority (EPA) has determined an appropriate buffer width of remnant vegetation that will occur between the lake bed and developments.

Responsibility: the Department (Regional Parks Unit), Recovery Team, City of Rockingham; EPA; DOLA
Cost: Costs of liaison included in 3.3
Priority: Urgent
Completion date: Completed.

3.30 Ensure strategies for conserving the dune swale community are included in the Management Plan for the Lake Richmond reserve

This would require the continuation of management of access, developing an appropriate fire regime and a weed control strategy.

Responsibility: City of Rockingham
Cost: Costs of liaison included in 3.3
Priority: Urgent
Completion date: Completed

SCHEDULE 5 - AREA 5 LARK HILL

3.31 Incorporate management strategies into planning for the Lark Hill Regional Sport and Recreation complex

Planning for the Lark Hill Regional Sport and Recreation Complex needs to address reservation of wetland areas, and adequate buffers around each wetland site; controlling access through fencing; developing and implementing an appropriate fire regime; monitoring and responding to wetland condition, water levels and quality; and weed and rabbit control.

Responsibility: Recovery Team, City of Rockingham
Cost: Costs of liaison included in 3.3; other costs to be determined
Priority: Urgent
Completion date: December 2003

SCHEDULE 6 - AREA 6 INDUSTRIAL PARK (IP) 14

3.32 Negotiate for appropriate management of the community at IP 14

The land tenure of the sedgeland community at IP14, including the bushland area bounded by the Rockingham rail loop will be identified. Appropriate management actions to conserve the community will then be determined, including negotiations for declaration as conservation reserve if necessary.

Responsibility: Recovery Team, the Department
Cost: Costs of liaison included in 3.3; other costs to be determined
Priority: Urgent
Completion date: Negotiations on land tenure are continuing.

SCHEDULE 7 - AREA 7 Yanchep

3.33 Ensure strategies for conserving the dune swale community are included in the Management Plan for Yanchep National Park

Responsibility: the Department (Swan Coastal District)
Cost: Costs of liaison included in 3.3
Priority: Urgent
Completion date: When Management Plan for the Park is reviewed.

SCHEDULE 8 - AREA 8 - PRESTON BEACH

3.34 Determine management requirements of the community at Preston Beach

The land tenure of the sedgeland community at Preston Beach will be determined. This will help identify appropriate management actions to conserve the community, including the group responsible for the care, control and management of the area, if necessary.

Responsibility: Recovery Team, the Department (WATSCU)
Cost: Costs of liaison included in 3.3; other costs to be determined
Priority: Urgent
Completion date: December 2002

SCHEDULE 9 - AREA 9 SECRET HARBOUR AND GOLDEN BAY

3.35 Negotiate for appropriate management of the community at Secret Harbour and Golden Bay

The land tenure of the occurrences of the sedgeland community at Secret Harbour and Golden Bay will be identified. Appropriate management actions to conserve the community will then be determined, including negotiations for declaration of areas as conservation reserve if necessary.

Responsibility: Recovery Team, the Department
Cost: Costs of liaison included in 3.3; other costs to be determined
Priority: Urgent
Completion date: Identification of occurrences, and negotiations on land tenure are continuing

ACKNOWLEDGMENTS

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Tim Bowra	The Department's Regional Parks Unit
Bronwen Keighery and Natalie Thorning	Department of Environmental Protection
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Scott Wood	The Department, Mornington Region
James Searle	Consultant

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Species list for Sedgelands in Holocene dune swales

This species list was kindly provided by DEP. It is compiled from the combined quadrat records for seven quadrats identified in floristic community type 19 (including sites PB-1, PB-6, Rich01, Cool09 Cool14, Cool15, xyan10).

These quadrats came from the three studies outlined below.

- Gibson *et al.* (1994) – three (PB-1, PB-6, Cool09) 10m x 10m quadrats from public lands which were scored on two occasions.
- DEP (1996) – one (Rich01) 10m x 10m quadrats from public lands which were scored on one occasion.
- Keighery (1996) – Three relevés (Cool14, Cool15, xyan10), of approximately 100m2, from public lands, which were scored once.

Site code	Community type	Study code	Longitude datum AGD84	Latitude datum AGD84
Cool14	19b	GJKENV	115.78864	-32.28311
Cool15	19b	GJKENV	115.79034	-32.28208
COOL09	19b	SCP	115.76767	-32.32937
PB01	19a	SCP	115.73503	-32.38603
PB06	19a	SCP	115.74150	-32.37938
rich01	19a	SYS6ENV	115.71692	-32.28659
xyan10	19b	GJKENV	115.68381	-31.57571

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Floristic Community Type 19 (including sitesPB-1, PB-6, Rich01, Cool09, Cool14, Cool15, xyan10).

Compiled by Natalie Thorning 13/8/98, updated by Bronwen Keighery and Margaret Langley 7/June/2002 to include taxa from site Cool09, taxa nomenclature current as per Gibson *et al* 1994.

Aizoaceae
* *Carpobrotus edulis*

Anthericaceae
Tricoryne elatior

Apiaceae
Centella cordifolia
Daucus glochidiatus
Hydrocotyle diantha
Trachymene coerulea

Asteraceae
* *Aster subulatus*
* *Cirsium vulgare*
* *Conyza albida*
* *Conyza* sp. *scps*
Senecio ramosissimus
* *Sonchus asper*
* *Sonchus hydrophilus*
* *Sonchus oleraceus*

Caryophyllaceae
* *Cerastium glomeratum*

Chenopodiaceae
Rhagodia baccata subsp. *dioica*

Crassulaceae
* *Crassula glomerata*

Cyperaceae
Baumea juncea
Carex appressa
Gahnia trifida
Isolepis cernua
Isolepis nodosa
Lepidosperma "coastal terete" scps (BJK&NG 231)
Lepidosperma angustatum
Lepidosperma gladiatum
Lepidosperma longitudinale
Schoenus pleiostemoneus

Dasypogonaceae
Lomandra maritima

Epacridaceae
Leucopogon australis
Leucopogon parviflorus

Euphorbiaceae
Adriana quadripartita
* *Euphorbia peplus*
Phyllanthus calycinus

Geraniaceae
* *Geranium molle*
Geranium retrorsum
* *Pelargonium capitatum*
Pelargonium littorale

Goodeniaceae
Scaevola crassifolia

Haemodoraceae
Conostylis candicans

Iridaceae
* *Romulea rosea*

Juncaceae
Juncus kraussii

Lauraceae
Cassytha racemosa

Lobeliaceae
Lobelia alata

Loganiaceae
Logania vaginalis

Loranthaceae
Amyema miquelii

Malvaceae
Alyogyne huegelii var *glabrata* scps map

Mimosaceae
Acacia cochlearis
Acacia lasiocarpa
Acacia pulchella
Acacia rostellifera
Acacia saligna
Acacia truncata

Myoporaceae
Myoporum caprarioides

Myrtaceae
Eucalyptus gomphocephala
Eucalyptus rudis
Melaleuca rhaphiophylla

Onagraceae
Epilobium billardierianum subsp. *billardierianum*
Epilobium hirtigerum

Orchidaceae
Caladenia latifolia
Microtis media
Prasophyllum elatum

Oxalidaceae
Oxalis perennans

Papilionaceae
Hardenbergia comptoniana
Jacksonia furcellata
Kennedia coccinea
Kennedia prostrata

* *Melilotus indicus*
Templetonia retusa
* *Trifolium campestre*
* *Trifolium glomeratum*

Phormiaceae
Stypandra glauca

Poaceae
Agrostis avenacea
* *Briza minor*
* *Bromus diandrus*
Cynodon dactylon
* *Holcus* sp. *scps*
* *Lagurus ovatus*
* *Lolium rigidum*
* *Paspalum distichum*
Poa porphyroclados
Sporobolus virginicus
Stipa flavescens

Polygalaceae
Comesperma virgatum

Polygonaceae
Muehlenbeckia adpressa
* *Rumex crispus*

Primulaceae
* *Anagallis arvensis*
* *Anagallis arvensis* var. *arvensis* FPR
Samolus repens

Proteaceae
Banksia grandis
Banksia littoralis
Hakea prostrata

Ranunculaceae
Clematis linearifolia

Restionaceae
Loxocarya pubescens

Rhamnaceae
Spyridium globulosum
Trymalium albicans

Rubiaceae
* *Galium murale*
Opercularia hispidula
Opercularia vaginata

Scrophulariaceae
* *Dischisma arenarium*
* *Parentucellia viscosa*

Solanaceae

Anthocercis littorea
* *Solanum nigrum*

Stackhousiaceae
Stackhousia monogyna

Thymelaeaceae
Pimelea argentea

Urticaceae
Parietaria debilis

Xanthorrhoeaceae
Xanthorrhoea preissii

APPENDIX 2

GROUNDWATER LEVEL AND WATER QUALITY MONITORING CRITERIA: PORT KENNEDY
Criteria developed by Bowman, Bishaw, Gorham in response to Ministerial Condition 12 placed on the Port Kennedy Regional Recreation Centre development

The interim criteria of watertable drawdown have been developed in recognition of the uncertainty as to the long term natural watertable variations. Hence criteria propose both "minimum" acceptable watertable levels, as well as conservative "investigation" levels which would trigger detailed investigations to ascertain the causes and likely implications of reduced watertable levels, before the "minimum" criteria are reached.

The criteria relate to groundwater levels at the wetland in the conservation area which is closest to the proposed groundwater abstraction borefield, and is therefore the most vulnerable to watertable drawdown. Monitoring will be conducted at two strategic bores located in or adjacent to this closest conservation wetland, for direct assessment against the criteria.

Interim "investigation" water level criteria

The interim "investigation" level is proposed as the minimum watertable position which was measured during 1993-94, adjacent to the conservation wetland most likely to be impacted by groundwater drawdown.

This level has been chosen for the following reasons:

- It is a real, not predicted measurement.
- The summer of 1993-94 is considered to be an exceptionally dry season, and hence the nominated level represents the watertable towards the extreme of its natural range.
- Although extreme, it is not the lowest groundwater level predicted for the site over the past 50 years. (Note: Groundwater levels modelled for the 1940's and the 1970's were equal to or lower than the 1994 levels. Modelled groundwater levels at the site in 1974 and 1979 were 0.1m lower).

The structure and ecological function of vegetation within the Becher Suite wetlands and elsewhere within the conservation area would not be affected by a short term or incidental decline below this measured position, however investigations would be triggered if the this level was reached for two consecutive years, or if the "minimum" acceptable watertable level (see below) is reached at any time.

Interim "minimum" watertable criteria

In addition to the "investigation" criteria, interim "minimum" watertable criteria are proposed which must not be exceeded unless or until approved by the Minister for the Environment following consideration of the results of the aforementioned investigations.

The proposed criteria for the "minimum" watertable require that the watertable elevation should not fall by more than 0.10m below the minimum measured levels of 1993-94 (the "investigation" criteria) for a second consecutive year. Under this scenario, investigations would be triggered in the first year to ensure a positive and timely management response in the event that the watertable was being unacceptably drawn down.

A level of 0.1m drawdown has been chosen for the following reasons:

- Long term groundwater modelling conducted by Mackie Martin-PPK has optimised the borefield design to minimise impact on the conservation wetlands. The model predicts an average maximum drawdown of 0.09m in the nearest conservation wetland to the production bores over a five year period.
- Based on the known hydrology of the wetlands and consideration of dampland and sumpland ecology, an additional 0.1m drawdown over the natural long term variation of the watertable will not cause a significant impact to the wetlands.

Subject to possible review on the basis of the findings of the prior investigations, exceedance of the "minimum" criteria for two consecutive years would require an immediate cessation of further drawdown, so would assure

against possible deleterious impact to the dampland vegetation.

Criterion 1 - Watertable drawdown

Watertable drawdown due to abstraction for irrigation purposes is to be maintained within limits which do not significantly exceed the natural variation which can sustain the characteristic vegetation, flora and habitats of wetlands in the conservation areas.

In the event that the watertable minimum falls below the interim "investigation" level at any of the relevant bores during any two consecutive years or below the "minimum" level in any single year, then the proponent shall undertake investigations to ascertain the cause and likely implications of the drawdown, to the satisfaction of the Minister for the Environment upon advice from the Water and Rivers Commission, CALM, and the EPA. Results of all investigations will be reported to the Port Kennedy Board.

In the event that the watertable at any relevant bore reduces to below the interim "minimum" level for any two consecutive years, then the proponent shall immediately cease further groundwater abstraction which would further reduce the watertable within the relevant area, unless or until the Minister for the Environment, upon advice from the Water and Rivers Commission and the EPA agrees to refine the watertable drawdown criteria or to otherwise to allow further groundwater abstraction, based on the findings of the aforementioned investigations.

Water Quality In Shallow Aquifers

The Port Kennedy coastline is a discharge area for the shallow aquifers, where fresh groundwater flowing in a westerly direction discharges into the coastal marine waters. A salt water wedge is believed to exist near the coast in the lower profile of the shallow aquifers. The position and vertical profile of the salt water interface is maintained by flow and head conditions in the shallow aquifers, balanced against the head and (greater) density of the saline seawater.

Available regional and site data indicate that water quality in the upper parts of the shallow aquifers beneath the site is of potable quality. There is thought to be variation in salinity, pH, and ionic composition with depth in the aquifer and proximity to the shoreline such that the basal parts of the aquifers contain more saline water.

The location of the site over this discharge zone has two key implications for groundwater management.

(i) Beyond certain limits, which can be determined, abstraction from the shallow aquifers, either Safety Bay Sand or Rockingham Sand, could cause inland migration of the salt water wedge, or upconing of saline water from the base of the aquifers into the upper profile from where abstraction will occur. This would reduce the suitability of groundwater for irrigation and could introduce higher salinity levels to the near surface groundwater in the vicinity of the wetlands.

(ii) Contaminants which enter the superficial groundwater beneath the golf courses, with particular reference to nutrients, could potentially migrate with the groundwater and enter the coastal marine waters in Warnbro Sound, where water quality must meet the beneficial uses of the Marine Park.

It is relevant to note that the site will be serviced with reticulated sewage system and possibly a limited number of approved alternative on-site disposal systems with nutrient removal capability. Nutrient contamination from on-site sewage disposal is therefore not a factor which needs further attention.

On the basis of this background the beneficial uses of the shallow groundwater resources may be identified as:

- potable and irrigation water supply;
- environmental maintenance in regard to conservation area wetlands and water sources to Warnbro Sound and nearby coastal areas.

Quantitative interim groundwater quality criteria are proposed on the basis of the following considerations:

- Groundwater salinity should not exceed concentrations suitable for protection of wetland vegetation or for irrigation purposes.

- Groundwater nitrogen levels should not increase so as to contribute significantly to increasing nitrogen levels in the adjacent coastal waters of Warnbro Sound, which are nitrogen limited. Median nitrogen concentrations in Warnbro Sound waters should remain less than 0.015 mg/L of NO_3 nitrogen and less than 0.30 mg/L of total nitrogen.

- Groundwater phosphorus concentrations should not increase so as to cause possible adverse impact upon the predominantly dampland type wetlands and other vegetation within the conservation areas, which may be sensitive to substantially elevated phosphorus concentrations. Davis *et al.* (1993) found that Swan Coastal Plain wetlands with total phosphorus concentrations of less than 0.165 mg/L over summer displayed attributes of low to moderate nutrient enrichment, indicating that this may be a reasonable criterion for total phosphorus in the wetlands, although its significance in damplands is not known.

- Groundwater nutrient concentrations measured in the coastal region adjacent to Warnbro Sound are described in Table 2. The data for southern Warnbro Sound predate significant urbanisation to the east of the project area but indicate significantly elevated nitrogen levels, mostly as NO_3 nitrogen.

- Typical groundwater nutrient concentrations measured beneath residential areas, which are 2.5 - 5.0 mg/L total nitrogen and 0.05 - 0.10 mg/L total phosphorus.

Groundwater nutrient concentrations (mg/L) measured in the coastal area near southern and northern Warnbro Sound

Area		Tot N	NO_3-N	PO_4	Tot P
Southern	Minimum	2.03	1.10	0.08	0.02
	Maximum	3.87	3.00	0.08	0.04
	Average	2.65	2.16	0.08	0.03
	n	5	5	1	3
	Period	1981-86	1981-86	1985	1981-86
Northern	Min	0.03	0.01	0.03	0.05
	Max	0.86	0.06	0.03	0.05
	Average	0.41	0.03	0.03	0.05
	n	4	3	1	1
	Period	1983-86	1984-86	1985	1984

Notes: n = Number of data.
Source: EPA (1993) Contaminant inputs inventory of the southern metropolitan coastal waters of Perth.

On the basis of the foregoing, the interim criteria for groundwater quality are proposed as follows:

Criterion 2 - Groundwater Quality - Salinity

Abstraction from superficial aquifers should not render extractable groundwater non-potable, unsuitable for irrigation or detrimental to wetlands or other vegetation in the conservation areas. The "investigation" criterion for total dissolved salts in the superficial aquifer beneath the site is 800mg/L. The criterion for the maximum concentration of total dissolved salts is 1000 mg/L.

Criterion 3 Groundwater Quality - Nutrient Levels

Irrigation and fertilisation practice within the development is to be managed so as to maintain nutrient levels in the shallow groundwater at levels which do not significantly impair water quality or associated ecological function in wetlands located in the conservation areas, or in the surface waters of Warnbro Sound. The "investigation" criteria for nutrients in the superficial aquifer beneath the site are 3.5mg/L for total nitrogen and 0.12 mg/L for total phosphorus. The "maximum" criteria for nutrients are 5.0mg/L for total nitrogen and 0.165mg/L for total phosphorus.

Procedures for

(i) preventing water quality deterioration due to salinity increases caused by over-abstraction, and;

(ii) fertilisation and irrigation practice within the golf course.

are detailed subsequently in the Groundwater Management and Monitoring Programme and in the Water and Nutrient Conservation Plan.

In the event that groundwater quality beneath the site reduced below the interim "investigation" criteria, the proponent would undertake investigations to ascertain the cause and likely implications of the reduced quality, to the satisfaction of the Minister for the Environment upon advice from the Water and Rivers Commission, CALM, and the EPA. Results of all investigations will be reported to the Port Kennedy Board.

In the event that the groundwater salinity beneath the site increased to the interim "maximum" criterion, the proponent would cease further groundwater abstraction which may exacerbate the problem, unless or until the Minister for the Environment upon advice from the Water and Rivers Commission, CALM and the EPA agreed to refine the salinity criterion based on the findings of the aforementioned investigations.

In the event that the groundwater nutrient concentrations beneath the site increased to the interim "maximum" criteria, the proponent would amend fertiliser applications and horticultural management so as to avoid any further increase in groundwater nutrient concentrations, to the satisfaction of the Minister for the Environment upon advice from the Water and Rivers Commission, CALM, and the EPA, unless and until the Minister for the Environment upon advice from the Water and Rivers Commission, the EPA and CALM agreed to refine the nutrient criteria based on findings of the aforementioned investigations.

MONITORING PROGRAMME FOR PORT KENNEDY GROUNDWATER AND WETLANDS

Groundwater Levels

A network of existing and proposed monitor bores will be located within the Port Kennedy area. Water levels in each of the bores will be monitored on a monthly basis.

Thirteen shallow monitor bores within the Safety Bay aquifer currently exist. These will be cemented, capped and locked to reduce the continuing vandalism of bores on the site.

Measurements from two shallow monitoring bores located in conservation wetlands closest to the abstraction bores (MB6 and MB8) will be used to assess compliance with water level criteria.

Six 'deep' monitoring bores are proposed which will measure the Rockingham Sand aquifer. Each site will consist of a nest of three piezometers, with each piezometer screened at different levels within the aquifer system. Piezometric head data will be collected monthly.

Up to seven production bores are proposed. Two bores are currently developed with a further five to be implemented in association with the increased water demand over the course of development.

Piezometric head data will be collected monthly.

Groundwater Quality

Groundwater samples from the superficial aquifer will be collected on a monthly basis for the first year, and then on a quarterly basis from each monitoring bore and analysed for pH, total phosphorus, total nitrogen, oxidised nitrogen, chloride, sulphate, sodium, calcium and total dissolved salts. Other analyses may be occasionally conducted to address specific monitoring issues or other enquiries, and the list of analytes may be varied in consultation with Water and Rivers Commission and DEP.

Hydrocarbon and pesticide concentrations will be monitored quarterly in groundwater samples from bores MB6 and MB8.

Regional water quality data will be collated as a supplementary database and included in the annual monitoring report to assist to place the site data in a regional context.

Groundwater Consumption

Groundwater consumption quantities will be measured and recorded with breakdown of demand volumes within the golf course, initially on a weekly basis during the establishment phase and reducing to a monthly basis as appropriate when establishment is complete.

Meteorological data describing the rainfall and evaporation record is currently acquired on a daily basis via a weather station.

Dampland Monitoring

Groundwater levels

Most of the conservation wetlands are damplands which are characterised by a relatively dry regime, with waterlogged soil occurring for a short period (<2 months) while there is shallow (<20cm) surface water present.

Little research has been conducted on the impacts of altered water regimes on damplands, however, based on an understanding of vegetation biology, the following conclusions may be drawn:

Winter

A characteristic of damplands is the presence of vegetation that is able to tolerate ephemeral waterlogging or inundation. Hence maximum water levels are important in maintaining the dampland identity. Due to the lack of groundwater abstraction over the winter months, and the relatively high impermeability of the wetland soils in association with the apparent importance of rainfall in maintaining the wetlands of the site, groundwater modelling has predicted that the watertable will return to normal levels over the winter months. Hence abstraction is unlikely to have a significant impact on the natural winter water levels. However, increased groundwater levels as a consequence of regional urbanisation may occur.

Summer

Due to the relatively dry regime of the damplands, a small reduction in water level could lead to summer water stress in shallow rooted macrophytes. The setting of 'minimum' water level criteria (see below) within the predicted range, will reduce the probability of significant impact, however a monitoring regime to develop baseline data is required, should investigations of the impacts of groundwater drawdown be triggered by breach of the water level criteria in the future.

As such, it is important to obtain a better understanding of the composition of the wetland vegetation.

Proposed monitoring consists of the following:

1. Mapping and annual assessment of the composition, structure and zonation of the vegetation of significant wetlands. These wetlands occur along the most north eastern swale of the conservation zone, closest to the production borefield.

2. Reporting of results annually to EPA and CALM.

Groundwater Quality

The impact of nutrients on damplands, or their function as a nutrients sink is not well known.

As such, it is proposed to develop a nutrient budget for a range of representative dampland types, to determine base line information prior to long-term development.

Monitoring and analysis is proposed as follows:

1. N & P analysis to be conducted on:

Wetland soils	(Once only)
Plant samples	(Biannually)
Groundwater	(Monthly for the first year, then quarterly)

Wetland surface water (Monthly or when available)

2. Reporting of results annually to the EPA & CALM

Appendix 3

ROCKINGHAM – POSSIBLE BECHER POINT GEOLOGICAL AND GEOMORPHOLOGICAL RESEARCH PROJECT (J. Searle personal communication)

These projects would be ideal for Honours or Masters thesis research topics in Geology or Geomorphology. While not necessarily precisely geographically coincident with the Becher Point area they would contribute significantly to the further understanding the scientific significance of the Becher area and its long and short term evolution. With some ingenuity and initiative on the part of the students, support costs could be as low as about $5000/year for each project.

Peel Harbour (NE Warnbro Sound)- Here yesterday, gone the day after.

In the first half of last century Commander Archdeacon surveyed and sounded a small land locked harbour on the NE shore of Warnbro Sound. It was deep enough to take the timber ships of the day and sheltered enough to lie at anchor with their loading ports open. Yet when Archdeacon returned a few years later "Peel Harbour" had disappeared. For a bit more background see George Seddon, 1972, "A sense of place: A response to an environment; The Swan Coastal Plain" University WA Press 274p. Understanding what happened to Peel Harbour has implications for better understanding the long and short term evolution and the significance of geomorphic and stratigraphic record at Becher Point.

Paleo-environmental reconstruction of the early Holocene inundation of the Warnbro-Cockburn Depression - Why the early Holocene was not the best time to build canal estates in the Warnbro-Cockburn Depression.

The timing and impact of the early Holocene marine transgression into the Warnbro-Cockburn Depression is preserved in the stratigraphic sequence at the base of the bank sediment sequence underlying Becher Point. Interpretation of this record in terms of early Holocene inundation and environmental impact of the marine transgression could provide useful analogies for contemporary coastal management and postulated sea level responses to global warming.

Quantification of spatial and temporal scales of erosional events during the progradation of the Becher Point promontory.

Oh would it not be grand if the sand was here to stay, (the Carollean perspective on coastal dynamics). A knowledge of the scale of historical events helps to interpret present coastal dynamics and to predict changes under various parameters. Detailed stratigraphic and geomorphic documentation of erosional interfaces within the beach and near shore sequences of the Becher Point area coupled with dating would provide a quantitative base line for modelling of present and future events.

Geochemical indicators of sediment sources of the Holocene units at Becher Point- Carbonate sands ain’t carbonate sands yknow, Louie.

The source of carbonate sand can be reflected in bulk chemical compositions. The diagenetic instability of high magnesium carbonates means that sediment supplied from Pleistocene eolianites may be low in magnesium in comparison to materials supplied more directly from benthic organisms. Other geochemical indicators may also exist. Geochemical tracing of sediment sources combined with budget calculations can assist greatly in understanding long term coastal evolution processes.

GLOSSARY

Assemblage - a group of organisms that occur together.

Dampland - a seasonally waterlogged basin

Ecological community - a naturally occurring biological assemblage that occurs in a particular type of habitat.

Epoch - a particular period of time in geological history, marked by a particular event

Geomorphology - study of the characteristics, origin and development of land forms

Habitat - the areas in which an organism and/or assemblage of organisms lives

Holocene - from the last 10,000 years of geological history

Interdunal - between sand dunes

Quaternary period - from the last two million years of geological history

Sedgeland - a plant community dominated by members of the families Cyperaceae and Restionaceae

Sumpland - a seasonally inundated basin

Superficial aquifer - a major unconfined aquifer comprising the Quarternary - Tertiary sediments of the Swan Coastal Plain

Swale - an interdunal depression

Watertable - the level at which the saturated zone meets the unsaturated zone

UXO - unexploded ammunition