Department of
Environment and Conservation

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Resource Condition Report for a Significant Western Australian Wetland

Saunders Spring

2009

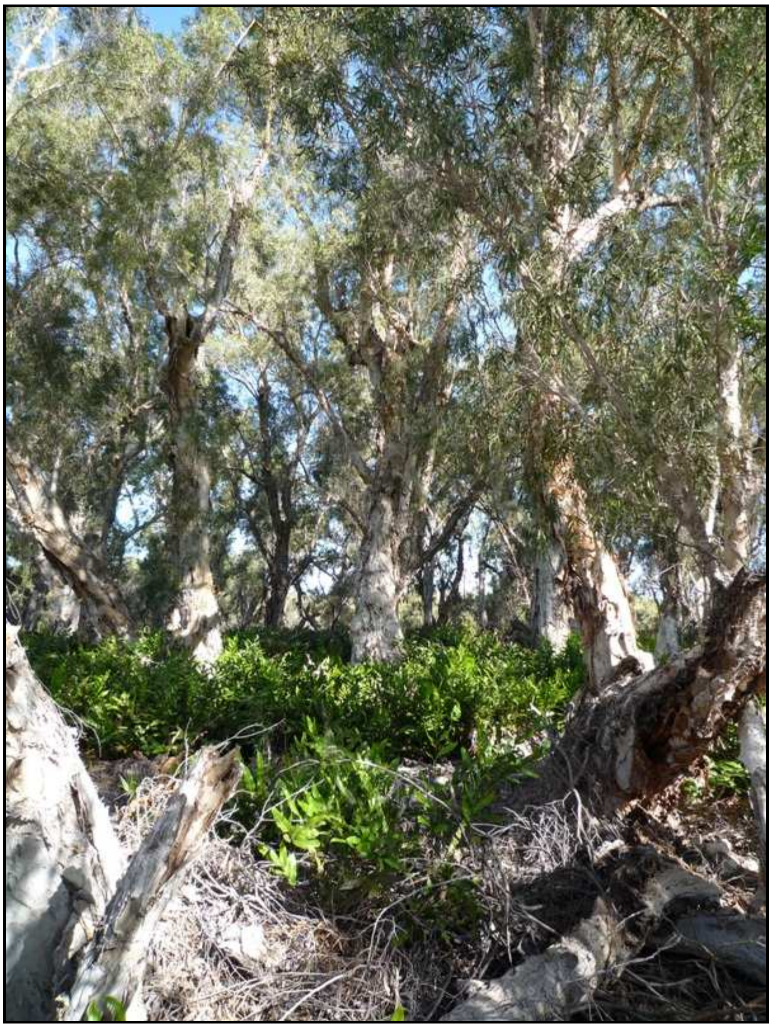

Figure 1 – Vegetation atop the peat deposit at Saunders Spring.

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Contents

1. Introduction

This Resource Condition Report (RCR) was prepared by the Inland Aquatic Integrity Resource Condition Monitoring (IAI RCM) project. It describes the ecological character and condition of Saunders Spring, a freshwater mound spring within the Eighty Mile Beach Ramsar site. The ecology of Saunders Spring is linked to that of the broader Mandora Marsh area, making it difficult to discuss the spring in isolation. As such, the RCR documents elements of Mandora Marsh that are relevant to assessing the condition of Saunders Spring. However, the primary intent of the document is to report on the condition of Saunders Spring, rather than that of Mandora Marsh in its entirety.

Saunders Spring is just one of a number of freshwater springs that emerge along a paleoriver channel that adjoins Mandora Marsh. The larger of the springs feature raised beds of accumulated peat, topped by dense vegetation and surrounded by a 'moat' of fresh water. Saunders Spring was selected for study in the current project because it is typical and representative of the raised-peat mound springs that occur in the area. It has also been fenced to exclude stock, making it a good candidate for condition monitoring.

1.1. Site Code

Directory of Important Wetlands in Australia: WA042

Register of the National Estate 'Registered' Place ID: 19827

Aboriginal Site of Significance ID: 14474 and 14478

Inland Aquatic Integrity Resource Condition Monitoring Project: RCM008

Transect Codes: RCM008-RQ1
RCM008-RQ2
RCM008-RQ3

1.2. Purpose of Resource Condition Report

The objective of the RCR is to summarise the available ecological information relevant to Saunders Spring and describe the key drivers of, and threats to, the system. This 'snapshot' of ecological character will provide context for future monitoring of the site and allow the effectiveness of management planning and actions to be gauged.

1.3. Relevant International Agreements and Legislation

The following is a summary of the key pieces of policy and legislation that are relevant to the conservation management of Saunders Spring.

International agreements

Ramsar Convention

The Convention on Wetlands, otherwise known as the Ramsar Convention, came into being in Ramsar, Iran in 1971 and was ratified in 1975. It provides the framework for local, regional and national actions, and international cooperation for the conservation and wise use of wetlands. Wetlands of international importance are selected on the basis of their international significance in terms of ecology, botany, zoology, limnology and/or hydrology.

Migratory bird bilateral agreements and conventions

Australia is party to a number of bilateral agreements, initiatives and conventions for the conservation of migratory birds that are relevant to Saunders Spring. The bilateral agreements are:

JAMBA - The Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment, 1974;

CAMBA - The Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment, 1986;

ROKAMBA - The Agreement between the Government of Australia and the Republic of Korea for the Protection of Migratory Birds and their Environment, 2006;

The Bonn Convention on Migratory Species (CMS) - The Bonn Convention adopts a framework in which countries with jurisdiction over any part of the range of a particular species co-operate to prevent migratory species becoming endangered. For Australian purposes, many of the species are migratory birds.

National legislation

The Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

The EPBC Act is the Australian Government's central piece of environmental legislation. It provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places. These are defined in the Act as matters of national environmental significance.

There are seven matters of national environmental significance to which the EPBC Act applies. Three of these are relevant to Saunders Spring:

- wetlands of international importance ('Ramsar' wetlands);
- nationally threatened species and ecological communities; and
- migratory species listed under international treaties JAMBA, CAMBA and CMS.

The EPBC Act regulates actions that will have, or are likely to have, a significant impact on any matter of national environmental significance. Such actions are subject to environmental assessment and approval under the EPBC Act. An 'action' includes a project, a development, an undertaking, an activity or series of activities (http://www.environment.gov.au/epbc/index.html).

Western Australian legislation

Wildlife Conservation Act 1950

This Act provides for the protection of wildlife. All native fauna in Western Australia are protected under section 14 and all native flora are protected under section 23 of the *Wildlife Conservation Act 1950*. The Act establishes licensing frameworks for the taking and possession of protected fauna, and establishes offences and penalties for interactions with fauna.

Aboriginal Heritage Act 1972

The purpose of this Act is to protect Aboriginal remains, relics and sites from undue interference, and to recognise the legitimate pursuit of Aboriginal customs and traditions. Under the Act, It is an offence for a person to excavate, destroy, damage or alter any Aboriginal site. The Act applies to all objects which are of sacred, ritual or ceremonial significance to persons of Aboriginal descent, or which are, or were, used for any purpose connected with the traditional cultural life of the Aboriginal people and the places where such objects are found. It also protects any sacred, ritual or ceremonial site, which is of importance and special significance to persons of Aboriginal descent. Finally, the Act states that, where a representative body of persons of Aboriginal descent who usually live subject to Aboriginal customary law, has an interest in a place, that place shall be available to that body for purposes sanctioned by the Aboriginal tradition relevant to that place.

Mandora Marsh contains two areas recognised as Aboriginal Sites of Significance (Yalayala and Goanna Site) due mythological and ceremonial significance.

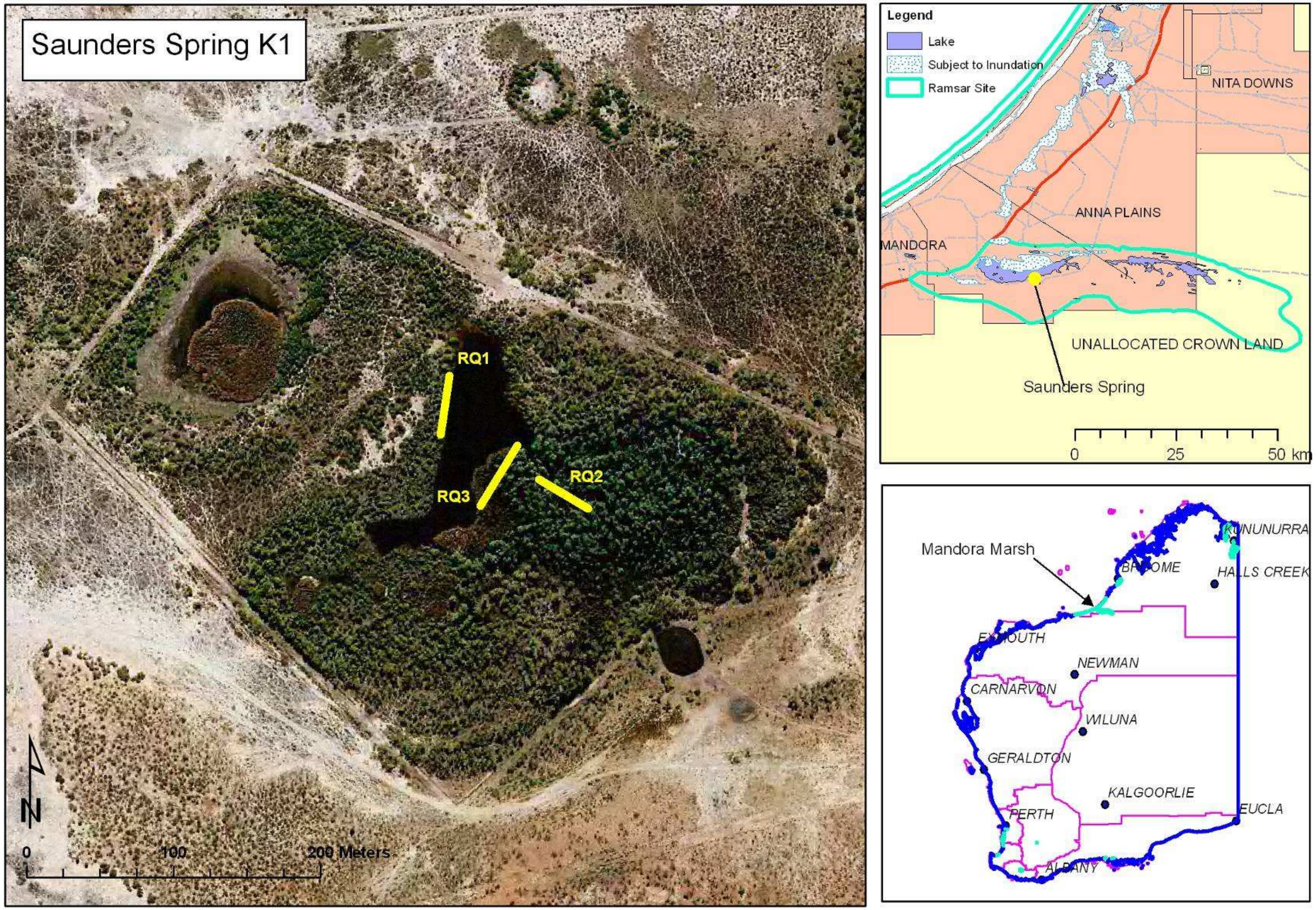

Figure 2 – Aerial photograph showing the location of riparian vegetation transects (RCM008-RQ1, RCM008-RQ2 and RCM008-RQ3) at Saunders Spring. The upper insert shows the location of the survey locations within the Mandora Marsh Ramsar site. The lower insert shows the location of the marsh in the state of Western Australia. Department of Environment and Conservation regional boundaries are shown in pink.

2. Overview of Saunders Spring

2.1. Location and Cadastral Information

The Mandora Marsh System is approximately 150 km south-southwest of Broome in the Canning Basin of Western Australia (Figure 2). This area, on the northern edge of the Great Sandy Desert, is the transition between the state's Pilbara and Kimberley regions. The marsh system extends eastward from the sand dunes behind Eighty Mile Beach and is separated into western and eastern portions by the Great Northern Highway. Saunders Spring is situated in the eastern portion of Mandora Marsh. It is one of a number of freshwater springs known to emerge in the area.

The Ramsar nominated portion of Mandora Marsh, including Saunders Spring, is east of Great Northern Highway. It extends east–west for some 95 kilometres at latitude 19.75º S and includes Walyarta Lake, a braided saline channel system to its east, several small claypans, a number of freshwater springs and a broad area that is subject to periodic inundation. In total, the Ramsar site covers around 200,000 ha.

The majority of Mandora Mash lies on the Anna Plains pastoral lease, with a small area at the eastern end of the system designated as Unallocated Crown Land (UCL). Access to the marsh is through Anna Plains and landholder permission is required to enter the marsh. Anna Plains is an active pastoral lease and the primary land use at the marsh is cattle pastoralism.

2.2. IBRA Region

Mandora Marsh is located at the junction of the Great Sandy Desert (McLarty subregion) and Dampierland (Pindanland subregion) Interim Biogeographical Regionalisation of Australia (IBRA) regions. The main body of the Marsh is within the McLarty subregion, with the western portion of the system situated within the Pindanland subregion (Figure 8).

The McLarty subregion is mainly tree steppe, grading to shrub steppe in the south. It is characterised by red longitudinal sand dune fields with open hummock grassland of *Triodia pungens* and *T*. *schinzii* with scattered trees of *Owenia reticulata* and *Eucalyptus* sp. and shrubs of *Acacia* spp., *Grevillea wickhamii* and *G. refracta. Casuarina decaisneana* (Desert Oak) occurs in the far east of the region.

Smaller areas of gently undulating laterised upland support shrub steppe such as *Acacia pachycarpa* shrublands over *T. pungens* hummock grass. There are also calcrete and evaporite surfaces associated with occluded palaeo-drainage systems that traverse the desert. These include extensive salt lake chains with samphire low shrublands and *Melaleuca glomerata* – *M. lasiandra* shrublands. Finally, the subregion includes fine-textured red-brown dunes of the Mandora Paleoriver System and the gravel surfaces of Anketell Ridge along its northern margin (Graham 2001a).

The hinterland of Eighty Mile Beach lies within the Pindanland IBRA subregion. This hinterland is a fine-textured sand-sheet with subdued dunes and includes the paleodelta of the Fitzroy River (Graham 2001b).

2.3. Climate

A Bureau of Meteorology weather station is located at the Mandora Station homestead (latitude 19.74º S, longitude 120.84º E), approximately 25 km from the western edge of the marsh. Records have been kept at Mandora homestead since 1913 (Bureau of Meteorology 2009).

Mandora experiences a semi-arid monsoonal climate. The station receives a mean annual rainfall of 373 mm with approximately 80% of that falling between December and March (Figure 3). Rainfall in the area is strongly influenced by cyclonic activity, resulting in a large degree of variability. For example, total annual rainfall has ranged from 19 mm in 1924 to 1,034 mm in 2000. Annual evaporation is not recorded at Mandora; the nearest available measurement is at

Broome airport (165 km to the north) where mean annual evaporation is 2774 mm. Mean maxima and minima temperatures at Mandora are 36.9ºC / 23.9ºC in March and 28.8ºC / 12.4ºC in July.

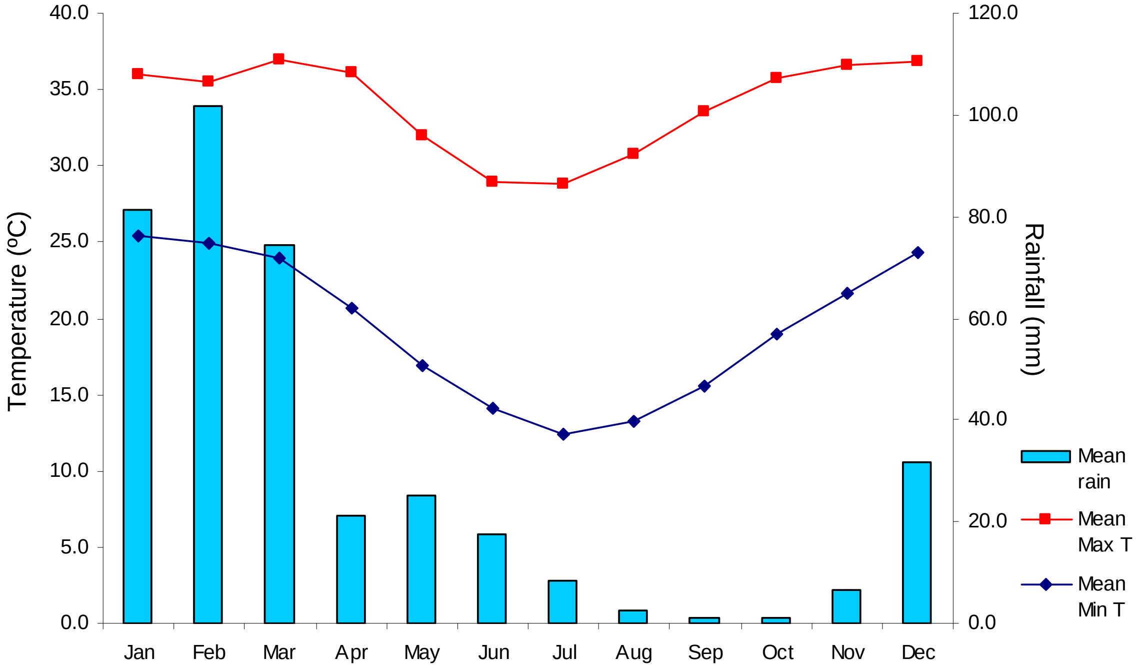

Figure 3 – Climatic means for Mandora Station, approximately 25 km west of Mandora Marsh.

Saunders Spring was surveyed by the IAI RCM project on the 16th of May 2008. In the twelve months preceding this survey, Mandora received 237 mm of rain. The majority (181 mm) fell in February, with no rainfall recorded after the 10th of March.

2.4. Wetland Type

The Ramsar information sheet for Mandora Marsh describes the main body of Walyarta Lake, the neighbouring braided channel and surrounding claypans as permanent, seasonal and intermittent saline/brackish/alkaline marshes/pools (see Section 3.1). A significant reason for the Ramsar nomination of the site is the presence of classical raised peat bogs. However, these springs are not identified in the section of the nomination that describes the wetland types found at the site. The mound springs of Mandora Marsh, including Saunders Spring, should be identified as type "Xp – forested peatlands". A saline creek that enters the eastern end of Mandora Marsh is another important feature of the Mandora Marsh System, as it supports the most inland occurrence of mangroves in Australia.

2.5. Ramsar Criteria

Eighty Mile Beach and Mandora Marsh were jointly recognised as a wetland system of international significance under the Ramsar Convention in 1993. The nomination was originally based on the importance of Eighty Mile Beach to migratory birds and the marsh's unique landscape values (Jones 1993). The importance of the marsh to threatened species and waterbirds has since also been recognised (Halse *et al.* 2005).

Mandora Marsh is designated as a wetland of international importance under criteria 1, 2, 4, 5 and 6 of the Ramsar Convention. Saunders Spring, along with other freshwater springs within the Ramsar site, contributes to at least three of these Ramsar criteria (1, 2 and 3).

These criteria are as follows:

1. It contains a representative, rare, or unique example of a natural or near-natural wetland type found in the appropriate biogeographic region.
2. It supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
3. It supports populations of plant, and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
4. It supports plant and/or animals species at a critical stage in their life cycles, or provides refuge during adverse conditions.
5. It regularly supports 20,000 or more waterbirds.
6. It regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.

Criterion one states that a wetland is of international importance if it is a rare or unique example of a wetland type found in the appropriate biogeographic region. Freshwater mound springs are rare in arid environments. It is also unusual for saline and freshwater springs to exist in close proximity as they do at this site.

The mound springs at Mandora Marsh are identified by the Department of Environment and Conservation (DEC) as Threatened Ecological Communities (TEC). However, this TEC is not yet nationally recognised under the EPBC Act. Wetlands that support TECs are considered to be of international significance under criterion two of the Ramsar Convention.

The springs also make a significant contribution to the regional diversity of flora and fauna – the third criterion for an internationally important wetland under the Ramsar Convention. This is due to the co-occurrence of saline and freshwater springs giving rise to unusual vegetation associations. Plants that are able to tolerate saline conditions occur in close proximity to species reliant on fresh water. The unique communities that result are not replicated elsewhere in the region.

Criterion four of the Ramsar Convention states that a wetland is of international significance if it supports species at critical stages of their life cycles. The mound springs of Mandora Marsh provide long-term permanent freshwater and stable habitat in which aquatic fauna may survive periods of aridity. Mound springs often support relictual species (remnants of a more widespread distribution in earlier geological times) and locally endemic species (Ponder 1986). The limited surveys that have been undertaken at the Mandora Marsh mound springs suggest that the aquatic invertebrate communities that occur there are characteristic and significant (Storey *et al.* in press).

2.6. Values of Saunders Spring

Values are the internal principles that guide the behaviour of an individual or group. Value systems determine the importance people place on the natural environment and how they view their place within it. Divergent values may result in people pursuing different objectives in relation to nature conservation, having different reasons for desiring a commonly agreed outcome, or favouring different mechanisms to achieve it. Because of this, it is important to be explicit about the values that are driving conservation activities at a wetland.

The Conceptual Framework for Managing Natural Biodiversity in the Western Australian Wheatbelt (Wallace 2003) identified eight reasons that humans value natural biodiversity:

a. Consumptive use

Consumptive use is gaining benefit from products derived from the natural environment, without these products going through a market place, for example, the collection and personal use of firewood or ‘bushtucker’. Archaeological evidence suggests that the Mandora Marsh mound springs have been used as a source of fresh water by numerous generations (Vernes 2007).

b. Productive use

Productive use values are derived from market transactions involving products derived from the natural environment. For example, firewood may be collected and exchanged for money or another commodity. Saunders Spring is used as a source of fresh water, fodder and shelter for stock (Figure 4). In this instance, the wetland is valued because it is able to contribute to the productivity of a commercial pastoral enterprise.

c. Opportunities for future use

Not all uses of the natural environment may be apparent at present. The potential for future benefit from the natural environment is maximised by maintaining the greatest possible biodiversity. Every lost taxa or ecosystem represents lost opportunities. Saunders Spring may support endemic or rare taxa. Such unique features would increase the potential for future opportunities to present.

d. Ecosystem services

There are many naturally occurring phenomena that bring enormous benefit to mankind. For instance, plants generate oxygen, insects pollinate food crops and wetlands mitigate floods by regulating water flows. The term 'ecosystem services', is used as a broad umbrella to cover the myriad of benefits delivered, directly or indirectly, to humankind by healthy ecosystems. Saunders Spring, being part of the larger Mandora Marsh, delivers considerable ecosystem services, including the provision of habitat for a large number of waterbirds.

e. Amenity

Amenity describes features of the natural environment that make life more pleasant for people. For instance, pleasant views and shade or wind shelter from a stand of trees. It is difficult to quantify the amenity value of a site as remote as Saunders Spring.

f. Scientific and educational uses

Parts of the natural environment that remain relatively unmodified by human activity represent great educational opportunities. Such sites allow us to learn about the changes that have occurred to the natural world. They are also 'control' sites that allow us to benchmark other, altered habitats. Saunders Spring is esteemed by the scientific community as a good example of a raised peat-bog mound spring in an arid environment. It contains a distinctive suite of biotic and non-biotic components that present opportunities for advancing the science of wetland ecology.

g. Recreation

Many recreational activities rely on the natural environment (bird watching, canoeing, wildflower tourism, etc.) or are greatly enhanced by it (hiking, cycling, horse riding, photography, etc.). Recreation may deliver economic benefit derived from tourism and also delivers spiritual and physical health benefits to the recreator. Mandora Marsh is a popular bird watching site, although the mound springs make a relatively small contribution to the area's bird habitat.

h. Spiritual/philosophical values

People's spiritual and philosophical reasons for valuing the natural environment are numerous and diverse. One commonly cited is the 'sense of place' that people derive from elements of their environment. This is evident in many Aboriginal and rural Australians, who strongly identify themselves with their natural environment. Many people also believe that nature has inherent value or a right to exist that is independent of any benefit delivered to humans. A sense of spiritual well-being may be derived from the knowledge of healthy environments, even if the individual has no contact with them. The freshwater springs of Mandora Marsh are of cultural significance to the local Aboriginal people. Permanent, fresh water in an otherwise arid region is an important resource and archaeological evidence suggests that these springs have been used for many generations (Vernes 2007).

The intent of nature conservation is usually to maintain the ecosystem services, future opportunities and scientific and educational uses at a given site. Doing so is likely to have positive effects on the amenity, recreational potential and spiritual/philosophical values to which the site's natural environment contributes. Consumptive and productive uses of the natural environment are not usually considered, as these are often incompatible with nature conservation. That said, Mandora Marsh forms part of an active pastoral lease and is likely to be esteemed by the lessees for its productive values. These conflicting value sets should be considered when attempting to implement conservation management at the site.

Figure 4 –This dam is fed by the spring, but has been constructed away from the area of highest conservation significance.

3. Critical Components and Processes of the Ecology of Saunders Spring

The primary objective of the Saunders Spring Resource Condition Report (RCR) is to identify, describe and quantify the critical components and drivers of the spring's natural environment. These components and processes determine the site's ecological character and are the variables that should be addressed in any ongoing monitoring.

Climate and geomorphology are the most important drivers of wetland ecosystems. Between them, they determine the position of a wetland in the landscape and the type and hydrological regime of that wetland. In turn, a wetland's position, type and hydrology exert a strong influence on its biota and biochemical properties and processes.

A summary of the findings of the 2008 Inland Aquatic Integrity Resource Condition Monitoring (IAI RCM) survey of Saunders Spring is shown in Table 1. This is followed by a more detailed description of the critical components of the site's ecological character, including the findings of previous studies.

Table 1 – Summary of the findings of the 2008 IAI RCM survey at Saunders Spring.

Component	**Summary Description**
Geomorphology	A raised bed of accumulated peat surrounded by a moat of freshwater.
Hydrology	A freshwater aquifer within a paleoriver channel, expressed as a spring.
Water Quality	Marginally sub-saline with nitrogen and phosphorous enrichment.
Soils	Marine sediments deposited during a period of higher sea levels overlain by a peat accumulation up to 2 m in height.
Littoral Vegetation	The peat bed is topped by a forest of *Melaleuca* sp. up to 20 m in height along with *Schoenoplectus formosa*, *S. litoralis*, *Typha domingensis* and *Acrostichum speciosum*. Emergent *T. domingensis* and *Fimbristylis ferruginea* fringe the standing water body. Riparian vegetation surrounding the moat is a dense shrubland dominated by *Acacia saligna.*
Aquatic Invertebrates	40 species, representing 21 families.
Fish	No fish species have been recorded at Saunders Spring.
Waterbirds	55 species of waterbird at Mandora Marsh.
Terrestrial Vertebrates	22 mammals have been recorded at Mandora Marsh.

3.1. Geology and Hydrology

Mandora Marsh is thought to have been an estuarine river mouth until a marine regression occurred approximately 4000 years ago. Until that time, the marsh was the outlet for a large paleodrainage channel called the Wallal Paleoriver. The paleoriver channel has been infilled with alluvial and aeolian material during the relative arid conditions that have prevailed for the last 65 million years. The freshwater springs that occur on the southern and eastern side of Mandora Marsh are thought to lie along the course of the Wallal paleoriver (Aussie Heritage 2007).

Although no detailed study of the hydrology of Mandora Marsh has been attempted, anecdotal evidence suggests that there are three main components of the system. The most important hydrological input is overland water flow during periods of cyclonic activity (Halse *et al.* 2005). Halse *et al.* (2005) examined the relationship between cyclonic events, rainfall and flooding of Mandora Marsh, and waterbird numbers. They found that the marsh had flooded (defined as water over-topping the Great Northern Highway and filling the western portion of the system) on six known occasions. In each of these years, the site received more than 800 mm of rain. This much rain was rarely received in years when the marsh did not flood. Importantly for the freshwater springs, flooding is also thought to cause recharge of the shallow freshwater aquifer beneath the marsh (Figure 5).

A lesser contribution to the hydrology of the marsh is the input of water from Salt Creek. This permanent, saline creek runs for about 20 km between Walyarta Lake and the eastern braided drainage channel. It is appears to be fed by a series of springs and may also be connected to the ocean by an aquifer (Graham 1999). Salt Creek is important in its own right as it supports a unique mangrove community, but it is not thought to have any influence on the marsh's freshwater springs.

The springs are the third component of the system's hydrology. A shallow, freshwater aquifer is thought to occur within the channel of a paleoriver that runs into the marsh. Mound springs occur where the water from this aquifer reaches the surface. Recharge of the aquifer occurs when the marsh fills, making the hydrology of the broader marsh area important to the persistence of Saunders, and other, springs.

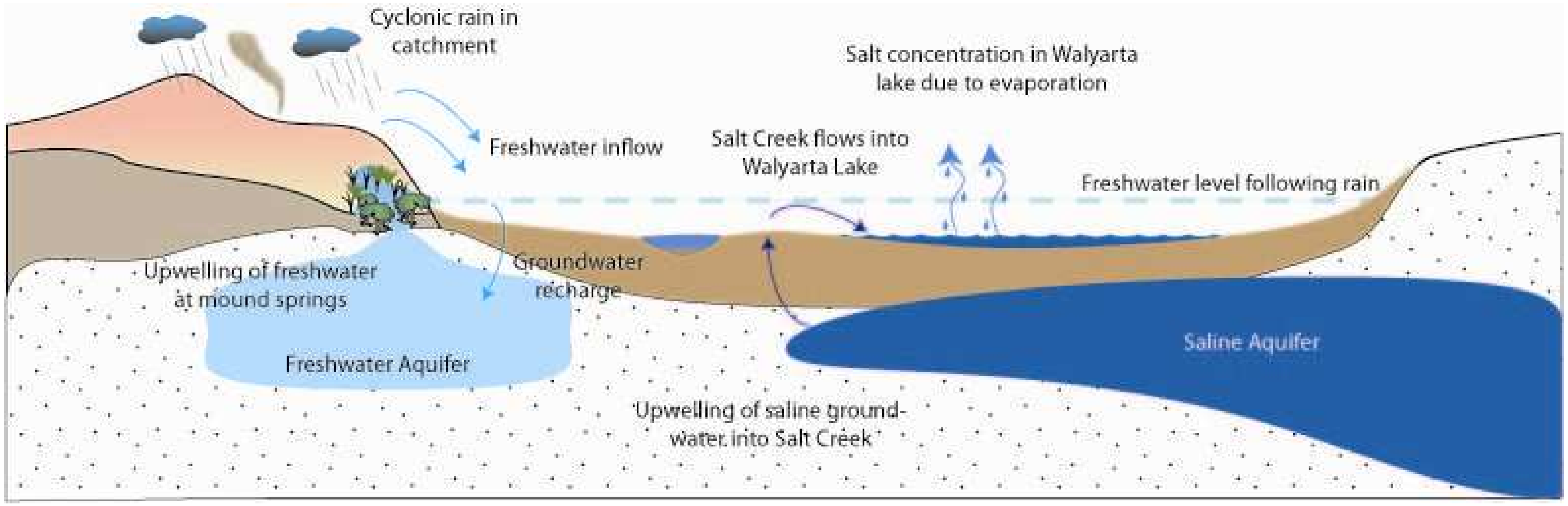

Figure 5 – Conceptual model of the hydrology of Mandora Marsh.

The system is primarily driven by overland flow of fresh water following cyclonic rains in the catchment. Underlying saline and freshwater aquifers contribute relatively small amounts of water, but these inputs are important to the ecology of the system.

3.2. Water Quality and sediments

At the time of the IAI RCM survey, the water at Saunders Spring was marginally sub-saline (TDS 3.5 g/L). Total nitrogen concentration (1,300 µg/L) was just above that suggested as a trigger value (350-1,200) indicating enrichment of wetlands in tropical Australia in the ANZECC/ARMCANZ (2000) guidelines. Total soluble nitrogen was greater than total nitrogen, which may indicate contamination of the filtered sample (Table 2). However, sampling by Storey *et al*. (in press) in 1999 suggested even higher concentrations of both total soluble nitrogen (5,200 µg/L) and total soluble phosphorus (710 µg/L), both well in excess of the guideline trigger values (10-50 µg/L) for total (unfiltered) phosphorus. This undoubtedly reflects use of the springs by cattle in recent and historical times. Fencing of the spring in recent years (albeit now damaged) may have limited stock access and so reduced nutrient concentrations in the spring.

Table 2 – Water chemistry parameters recorded at Saunders Spring in 2008 and by Storey *et al* in 1999.

	Mandora Marsh Survey SS Oct 1999	RCM RCM008 May 2008
pH	9.21	8.42
Alkalinity (mg/L)	198	270
TDS (g/L)	1.27	3.5
Turbidity (NTU)	32	6.1
Colour (TCU)	66	170
Total nitrogen (ug/L)	-	1300
Total phosphorus (ug/L)	-	40
Total soluble nitrogen (ug/L)	5200	1500
Total soluble phosphorus (ug/L)	710	20
Chlorophyll (ug/L)	-	3.5
Na (mg/L)	353	1140
Mg (mg/L)	24	87.8
Ca (mg/L)	48	136
K (mg/L)	26	28.9
Cl (mg/L)	460	1660
SO_4 (mg/L)	169	563
HCO_3 (mg/L)	237	329
CO_3 (mg/L)	-	0.5

Samples taken from Saunders Spring at the time of the IAI RCM survey showed that sediments in the 'moat' surrounding the spring are composed of sand (35%) and silt/clay (64%).

3.3. Littoral Vegetation

The vegetation of Saunders Spring can be roughly divided into three zones (Figure 9). Topping the peat mound is a forest of *Sesbania formosa* with scattered *Melaleuca* sp. Trees of both taxa reach up to 20 metres in height. Beneath the trees is a dense ground cover of *Acrostichum speciosum* (Figure 6 and Table 3).

Table 3 - The percentage canopy cover of each species in 25 m^2 quadrats along riparian transect RCM008-RQ2 at Saunders Spring.

Species	Quadrat (m)/% layer cover							
	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
Sesbania formosa.	70	70	60	40	30	40	60	70
Acrostichum speciosum	100	95	98	85	90	100	100	90
Bare soil	0	0	0	10	5	0	0	5
Logs	0	5	2	5	5	0	0	5

The raised mound is surrounded by a shallow 'moat' of fresh water. Growing around and in the water are *Typha domingensis* and *Fimbristylis ferruginea* (Figure 6 and Table 4).

Figure 6 – (Left) Riparian zone vegetation at Saunders Spring, dominated by *Typha domingensis* and *Fimbristylis ferruginea.* (Right) Vegetation atop the mound spring showing a dense understorey of *Acrostichum speciosum* beneath *Sesbania formosa*

Table 4 - The percentage canopy cover of each species in 25 m^2 quadrats along riparian transect RCM008-RQ3 at Saunders Spring.

Species	Quadrat (m)/% layer cover							
	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
Typha domingensis.	0	0	100	100	100	100	100	100
Fimbristylis ferruginea.	50	50	0	0	0	0	0	0

Outside the moat, the vegetation graduates into more terrestrial communities. Fringing the outside of the moat is a dense *Acacia ampliceps* shrubland (Figure 7). The understorey vegetation is composed of (in order of dominance) *Neobassium astrocarpa*, *Cyanichum carnosum*, *Eliocharis* sp., *Zygophyllum compressum*, *Solanum esuriale* and *Tecticornia* sp. The weed *Flaveria australasica* was also recorded here. Table 5 shows the estimated percentage canopy cover of each species along transect RCM008-RQ1, established within this vegetation community.

Table 5 – The percentage canopy cover of each species in 25m^2 quadrats along riparian transect number 1 at Saunders Spring.

Species	Quadrat (m)/% layer cover							
	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
Acacia saligna	80	80	90	80	60	80	80	90
Neobassium astrocarpa	40	40	40	30	20	10	5	0
Flaveria australasica	10	0	0	0	0	2	0	0
Cyanichum carnosum	5	5	10	10	15	15	15	5
Solanum esuriale	0	0	0	1	0	0	0	0
Eliocharis sp.	5	5	5	5	5	5	5	5
Zygophyllum compressum	0	0	0	0	2	0	0	0
Tecticornia sp.	0	0	0	0	0	0	0	10

Figure 7 – (Left) Transect RCM008-RQ1 showing moderate to dense *Acacia saligna* over various herbs and grasses. (Right) Further from the water body, the *Acacia* is heavily disturbed and *Halosarcia* spp. become dominant

Further from the spring, *Halosarcia* species become dominant (Figure 7). The boundary between shrubland and succulent steppe is made artificially sharp by the presence of a fence that excludes stock from the spring.

In total, 178 different plant taxa have been collected from the immediate vicinity of Mandora Marsh. These are listed in Appendix 1. The WA Herbarium has no records of flora specimens collected specifically at Saunders Spring. Vegetation mapping of Mandora Marsh and Saunders Spring are presented in Figure 8 and Figure 9 respectively.

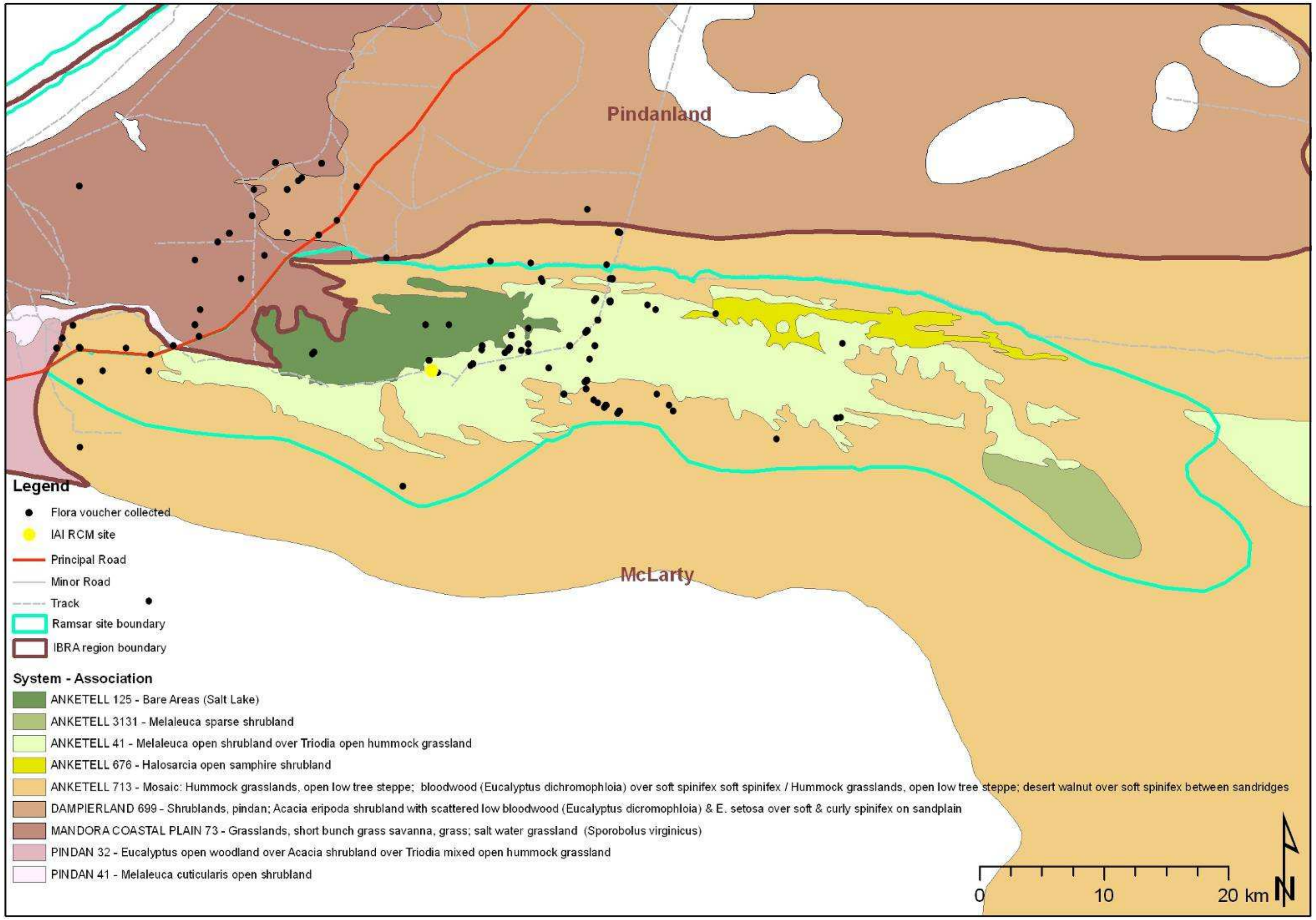

Figure 8 – Vegetation System Association mapping of the Mandora Marsh area (Note that the freshwater springs are too small to be identified as unique vegetation associations at this scale).

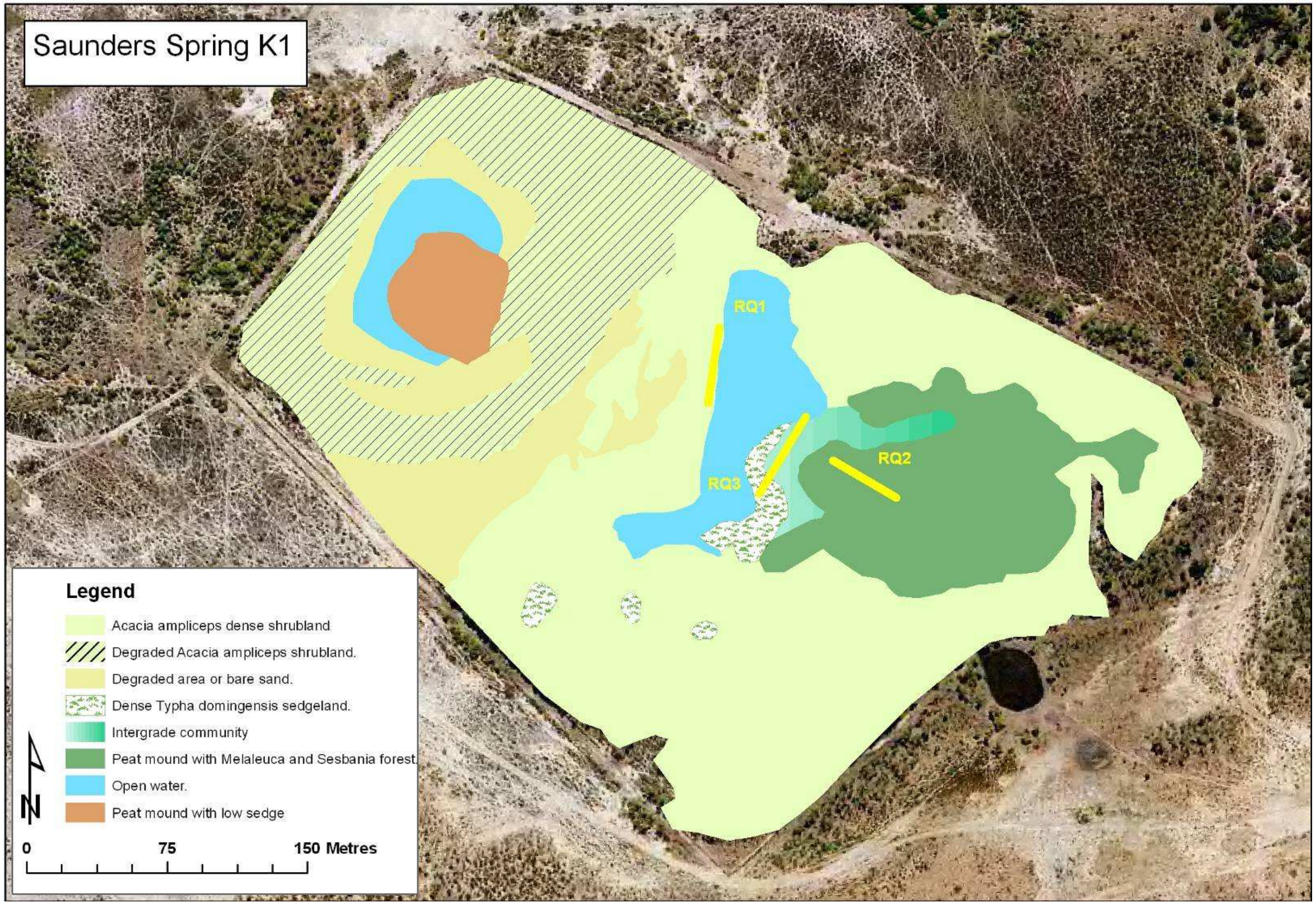

Figure 9 – Broad vegetation communities at Saunders Spring; Boundaries have been digitised from an aerial photograph captured in October 2001 at a scale of 1:40,000. Orthorectification has an error margin of $^{+}/-$ 5 m.

3.4. Aquatic Invertebrates

A survey of Saunders Spring in 1999 collected twenty-two species of aquatic invertebrates. All of these were macroinvertebrate, despite the application of methods suitable for microinvertebrate survey (Storey *et al.* in press). Several taxa were also collected by taking coring from the peat on the mound.

The IAI RCM survey in May 2008 (Table 6) collected almost twice as many taxa as the 1999 survey. This was despite a lower sampling effort in the IAI RCM survey (no plankton sample was taken) and slightly higher salinity in 2008 than 1999 (Table 2).

The invertebrate fauna of Saunders Spring consists mostly of widespread species, though the chironomid *Polypedilum prasiogaster*, mosquito *Anopheles farauti* and dragonfly *Neurothemis stigmatizans stigmatizans* were not recorded in the Pilbara during the Pilbara Biological Survey (A. Pinder pers. obs.). *A. farauti* is a tropical species, at least one form of which is capable of carrying malaria. *P. prasiogaster* is an eastern Australian species that occurs as far north as tropical Queensland, but this identification requires confirmation. *N stigmatizans stigmatizans* is a northern Australian species. The diversity of non-insect invertebrates is very low and some insect groups (particularly trichopterans, lepidopterans and mayflies) known to occur in the bioregion are absent.

The increase in invertebrate diversity between 1999 and 2008 may be attributable to reduced disturbance from cattle following fencing of the site. The lack of non-insect invertebrates may indicate that the system is still somewhat disturbed, although Saunders Spring is probably not naturally species rich due to low habitat diversity and shallow water depth.

Table 6 – Aquatic invertebrates collected from Saunders Spring by the IAI RCM Survey in May 2008.

Class	Order	Family	Lowest ID	Sample*
Gastropoda	Basommatophora	Planorbidae	*Gyraulus* sp.	2,3
Oligochaeta	Tubificida	Naididae	*Dero furcata*	1
			Dero cf *sawayai*	3
			Pristina longiseta	1,3
Arachnida	Acariformes	Arrenuridae	*Arrenurus tricornutus*	3
			Arrenurus nr *purpureus* (RCM)	3
Insecta	Coleoptera	Dytiscidae	*Hydroglyphus grammopterus* (=*trilineatus*)	1
			Eretes australis	3
			Bidessini	1,2
		Hydrophilidae	*Berosus australiae*	2
			Berosus nicholasi	1,2
			Berosus vijae	1,2
			Paranacaena horni	3
			Paracymus pygmaeus	3
		Scirtidae	Scirtidae sp.	3
		Hydrochidae	*Hydrochus* sp.	2
	Diptera	Culicidae	*Anopheles (Cellia) farauti*	2,3
			Culex (Culex) annulirostris	3
		Ceratopogonidae	*Bezzia* sp.	2
			Culicoides sp.	2
			Monohelea sp.	2,3

Class	Order	Family	Lowest ID	Sample*
Insecta	Diptera	Ceratopogonidae	Dasyhelea sp.	2,3
		Psychodidae	Psychodinae sp. 3 (SAP)	2,3
		Stratiomyidae	Stratiomyidae	3
		Empididae	*Hemerodromia* sp.	1
		Dolichopodidae	*Dolichopodidae* sp. B (SAP)	1,2
		Syrphidae	Syrphidae	3
		Chironomidae	*Procladius paludicola*	1,2
			Procladius paludicola P1 (no U-claws)	1
			Tanytarsus fuscithorax/semibarbitarsus	3
			Tanytarsus 'K12' (PSW)	1,2
			Chironomus sp.	2,3
			Polypedilum nubifer	1,2
			Polypedilum prasiogaster	3
			Polypedilum nr. *convexum* (PSW)	3
	Hemiptera	Mesoveliidae	*Mesovelia vittigera*	3
		Belostomatidae	*Diplonychus* sp.	3
		Corixidae	*Micronecta virgata*	1,2,3
		Notonectidae	*Anisops nasuta*	2
	Odonata	Aeshnidae	*Aeshna brevistyla*	3
		Libellulidae	*Neurothemis stigmatizans stigmatizans*	2
			Orthetrum caledonicum	3
			Trapezostigma loewii	2
		Hemicorduliidae	*Hemicordulia* sp.	2
		-	*Zygoptera*	3

* Samples 1, 2 and 3 denote the three sub-samples:

1. Sediment: Muddy sediment without macrophyte.
2. Sediment: Muddy sediment without macrophyte.
3. Macrophyte: Dense Characeae in front of *Typha*.

3.5. Fish

No fish species have been recorded at Saunders Spring. A new, apparently endemic goby has been discovered in Salt Creek (CALM 2003). Following extensive flooding in 1999, Spangled Perch (*Madigania unicolour*) were widespread in the neighbouring braided saline channel system Walyarta Lake (Graham 1999).

3.6. Waterbirds

Mandora Marsh is an important site for waterbirds. A total of 55 species of waterbirds, including 19 shorebirds (waders), 7 ducks, 2 grebes, 4 darters and cormorants, 6 herons and egrets, 7 rails and crakes, and 4 gulls and terns have been recorded at the site (Graham 1999). Of these, at least 13 species have been recorded breeding in the marsh. However, it is unlikely that Saunders Spring, or the other freshwater springs at the marsh, provide much habitat to these species. No waterbirds or shorebirds were observed using the spring at the time of the IAI RCM survey.

3.7. Terrestrial Vertebrates

A total of 22 mammals, including 4 dasyurids, 2 macropods, 4 native mice, 3 native bats, and 6 feral species have been recorded at Mandora Marsh. At least 49 reptiles and 6 amphibians also occur at the Marsh (Graham 1999). Of particular significance is the vulnerable Bilby (*Macrotis lagotis*) that is listed under the EPBC Act and has been recorded in sandy sites nearby. The influence (if any) of Saunders or other springs on the ecology of any of these animals is unknown. The IAI RCM survey did not record any vertebrate taxa at Saunders Spring.

4. Interactions between Ecological Components at Saunders Spring

An appreciation of the interactions between the elements of a wetland ecosystem is essential to understanding the condition of the system. Although components of a wetland are often monitored and managed as discrete entities, they exist as nodes in a complex ecological web. Documenting the full extent of the interactions that occur at a wetland would be impractical. However, it is essential to identify key interactions that define the system's ecological character. Table 7 and Figure 10 summarise the interactions between key components and processes at Saunders Spring.

Hale and Butcher (2007) justified the equivalence of Ramsar nomination criteria and primary determinants of ecological character. Accordingly, the primary determinants of ecological character at Saunders Spring are:

- The characteristics that make the site a representative, rare or unique example of a natural or near-natural wetland type within its biogeographic region. *A good example of a classical raised peat bog located in the arid tropics.*
- Vulnerable, endangered or critically endangered species or threatened ecological communities that occur at the site. *The raised peat bog vegetation community.*
- Plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region. *The saline and fresh water dependant plant communities that occur in close association.*
- Plants and/or animal species that utilise the site at a critical stage in their life cycles, or take refuge there during adverse conditions. *Aquatic invertebrates and* Melaleuca*/*Sesbania *communities.*

A simplified summary of the factors required to maintain these features is presented in Figure 10. The most important element of the biota at Saunders Spring is the *Melaleuca* and *Sesbania* forest growing on the raised peat bog. This forest has formed the organic sediment that makes the site unique and continues to protect and maintain it. The persistence of the forest is dependant upon the hydrology of the system, particularly the continued availability of reasonably fresh water. The aquatic invertebrate community of the mound spring makes a smaller contribution to the site's character. That community is reliant on the availability of habitat, particularly water quality and food sources.

Table 7 summarises the interactions between key components and processes at Saunders Spring. The table lists the components that are directly responsible for the provision of each service or benefit of the wetland and the biotic and abiotic factors that support or impact these components. Also listed are the key threats that may affect the components or processes. This information assists in the identification of the primary determinants of ecological character.

Table 7 – The relationship between the services and benefits delivered by Saunders Spring and the key components and processes that support them.

Benefit or Service	Component	Factors Influencing Component		Threats and Threatening Activities
		Biotic	Abiotic	
Productive Value Beef production	Cattle	Plants palatable to stock	Availability of fresh water Periodic inundation events Groundwater level and salinity	Loss of access to water points due to conservation activities Changes to hydrology affecting fodder availability Grazing competition from feral pests Groundwater extraction for agriculture
Cultural, spiritual, recreational and scientific values	Possible sites of significance to local Aboriginal people Landscape amenity Unique vegetation communities Aquatic invertebrate communities	Vegetation communities Significant flora Endemic fauna Habitat extent and distribution Invertebrate populations (food source) Phytoplankton (food source) Benthic plant biomass	Soils and sediments Nutrient concentrations Water salinity and pH Groundwater level Water turbidity	Grazing by cattle and introduced pests Pugging by cattle Alteration to hydrology due to climate change, groundwater extraction or catchment perturbation Inappropriate fire regimes Excessive nutrient inputs from stock or proposed cotton farm Possible mining Weeds
Ecological Services: Contains a representative, rare or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region. Supports a Threatened Ecological Community	Raised peat-bog mound spring in an arid environment	Vegetation communities	Water quality Hydrology Organic sediments	Alteration to hydrology due to climate change, groundwater extraction or catchment perturbation Excessive nutrient inputs from stock or proposed cotton farm Possible mining Weeds Fire

		Factors Influencing Component		
Ecological Services: Supports plants and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions	Aquatic invertebrate communities and other taxa reliant on the spring as a refuge during dry periods or that persist at the spring as a relictual population	Aquatic invertebrates *Melaleuca* forest community	Hydrology (especially permanence of water) Nutrient concentrations Water salinity and pH	Grazing by cattle and introduced pests Pugging by cattle Alteration to hydrology due to climate change, groundwater extraction or catchment perturbation Inappropriate fire regimes Excessive nutrient inputs from stock or proposed cotton farm Possible mining Weeds

Primary Determinants of Ecological Character

(the contribution Saunders Spring makes to the Ramsar nomination of Mandora Marsh)

The characteristics that make the site a representative, rare or unique example of a natural or near-natural wetland type within its biogeographic region. *A good example of a classical raised peat bog located in the arid tropics.*

Vulnerable, endangered or critically endangered species or threatened ecological communities that occur at the site*. The raised peat bog vegetation community.*

Plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region. *The saline and fresh water dependant plant communities that occur in close association.*

Plants and/or animal species that utilise the site at a critical stage in their life cycles, or take refuge there during adverse conditions. *Aquatic invertebrates and* Melaleuca/Sesbania *communities.*

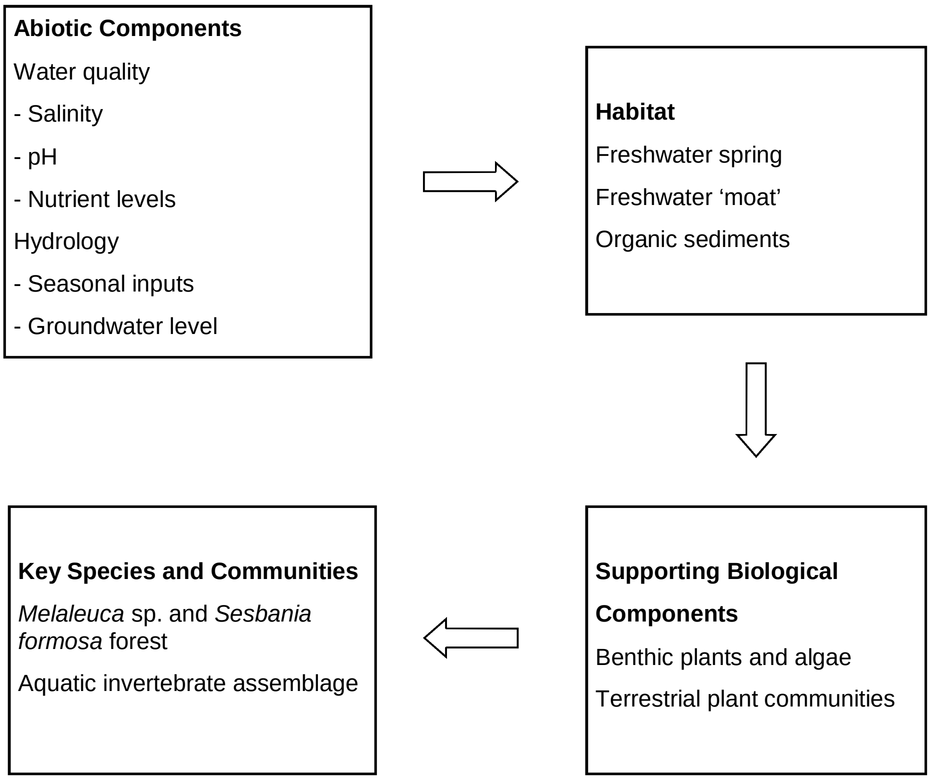

Figure 10 – Schematic depiction of the interactions between critical components of the Saunders Spring ecosystem.

5. Threats to the Ecology of Saunders Spring

The aim for conservation management at Saunders Spring is to maintain those elements of the ecology that contribute to Mandora Marsh's nomination as a Ramsar wetland. The critical components of the ecology are the geomorphologic, hydrologic and water quality factors. These factors are the primary determinants of the site's ecological character. They are influenced by, and exert an influence on, the plant communities that surround the water body, the aquatic invertebrate and benthic vegetation communities that inhabit the water body, and the existing threatening processes. Also of importance are the elements of the system that contribute to its cultural and scientific value. These are the same as the aforementioned influences on the primary determinants of ecological character, with the addition of landscape amenity.

Threats to Saunders Spring must be considered in relation to their likelihood of causing failure of the management goals for the site. These are to maintain the distinctive geomorphology of Saunders Spring and the vegetation community that led to its formation, and to maintain the current richness and diversity of aquatic invertebrates in the water body. An assessment of each threatening process was conducted to assess the probability that goal failure would result as a consequence of each particular threatening process. The results of this assessment are presented in Table 8.

The greatest threat to the ecology of Saunders Spring is the impact of pastoral operations. Cattle access the springs on Mandora Marsh in pursuit of water, fodder and shelter. They cause significant damage to the soil structure and vegetation, increasing the likelihood of erosion of valuable topsoil and creating an opportunity for weeds to become established. Cattle also introduce nutrients to the site, decreasing water quality and potentially causing eutrophic conditions. Finally, cattle are a vector for the introduction of weeds. Weeds are not currently present in large numbers at the site, but the continued presence of stock around the spring increase the risk of weed introduction.

Another impact associated with pastoralism is groundwater extraction. The freshwater aquifer that feeds Saunders Spring is exploited to provide drinking water for stock. Little is known about the hydrology of the system and so the effects of groundwater extraction are not quantified. There is no anecdotal evidence of any reduction in flow from freshwater springs in the area or other indicators of a lowered water table.

A proposed cotton farm on land adjoining the marsh would, most probably, result in severely altered hydrology. This farm is proposed to operate using groundwater extracted from the shallow aquifer underlying the marsh. Extraction of such commercial quantities of water would almost certainly be devastating for Saunders Spring.

Mining activities are another potential threat. The entire marsh, including its unique mound springs, is subject to mining exploration licenses. Exploration would be very damaging to the marsh environment, but a mine site would incur greater damage. Mining at Mandora would likely require significant dewatering, causing severe alteration to the hydrology of the system.

Feral animals appear to be present at Mandora Marsh in significant numbers. Aside from the farmed cattle; cats, foxes, camels and donkeys all inhabit the marsh. These cause degradation to vegetation and soil, predate native species and disrupt waterbird breeding.

There is evidence of an unidentified plant disease affecting the mangrove fern at Saunders Spring (Figure 11). This disease, which seems to result in leaf death, was not widespread, but should be monitored.

Figure 11 – Evidence of a plant pathogen affecting the leaves of the mangrove at Saunders Spring.

It is likely that fire would have a negative impact on the vegetation of Saunders Spring. This site has been effectively isolated from fire, due to the non-flammable nature of surrounding vegetation, for several thousand years. It is unlikely that a fire would take hold at the site, as damp conditions prevail all year round. However, if there were a fire, it could remove both vegetation and the organic soil of the mound spring.

Finally, the potential effects of climate change are uncertain. In general, north-western Australia is not expected to experience significant change in total rainfall (CSIRO 2007). However, it is postulated that rainfall may become more sporadic, with heavier falls in less frequent events. The possible effects of this change on the Saunders Spring ecosystem are uncertain and will require ongoing monitoring. Prolonged periods of drought may result in depletion of the aquifer, which feeds Saunders Spring. This would result in the death of the spring's vegetation and loss of its raised peat-bed. More intense cyclonic activity brings with it the threat of greater periods and areas of inundation. It is not clear if this may have a deleterious impact on Saunders Spring or its vegetation. Cyclones also bring the risk of wind damage and the *Melaleuca* and *Sesbania* forest on the mound is likely to be vulnerable in such an event.

Table 8 – Threat assessment for Saunders Spring.

An estimate is provided of the perceived likelihood of goal failure resulting from the impacts of each identified threat category.

Goals: To maintain the distinctive geomorphology of Saunders Spring and the vegetation community that led to its formation.

To maintain the current richness and diversity of aquatic invertebrates in the water body at Saunders Spring.

Threat category	Management issue	Probability that threat will cause goal failure with:		Assumptions underlying initial probability assessment and explanatory notes
		Existing management	Extra management	
Altered biogeochemical processes	Hydrological processes, particularly salinity	0	0	Assumes no change to surrounding land use. Salinisation of the aquifer that feeds Saunders Spring may occur if excessive groundwater extraction occurs.
	Carbon cycle and climate change	0.1	0.1	Modelling suggests that the Mandora area may experience more cyclonic activity in the future. This may increase the likelihood of flooding at the marsh, the impacts of which are unclear. It is feasible that greater depths and periods of inundation could have negative impacts on the vegetation of Saunders Spring.
Impacts of introduced plants and animals	Environmental weeds	0.05	0	There are currently no weeds present on the mound spring and the likelihood of the introduction of invasive species seems low. This risk could be eliminated with regular checks of the site for weed species.
	Herbivory, wallowing and trampling by introduced species	0.25	0	Stock animals are clearly having deleterious impacts as they access the spring for water and food. A stock exclusion fence is present, but was in poor repair at the time of the site visit. Maintaining that fence will minimise the risk of stock impacts.
Impacts of problem native species	Parrots	0	0	No impacts observed.
	Kangaroos	0	0	No impacts observed.
Impacts of disease	Plant pathogens	0.01	0.01	Evidence of a plant pathogen was observed at Saunders Spring, although the impacts were not widespread.
Detrimental regimes of physical disturbance events	Fire regimes	0.05	0.05	The vegetation at the site is obviously long unburnt. This is likely to be the natural situation as carbon dating of Eil Eil Spring has shown the peat mound to be ~7000 years old. Throughout this period, the springs would have been isolated from fire by the wide expanse of non-flammable succulent steppe surrounding them. The accidental or deliberate introduction of fire to Saunders Spring would probably be highly detrimental, but is not readily controlled.

Threat category	Management issue	Probability that threat will cause goal failure with:		Assumptions underlying initial probability assessment and explanatory notes
		Existing management	Extra management	
	Drought	0.05	0.05	An extended drought may result in the aquifer that feeds Saunders Spring becoming depleted. Effective management of this is not feasible.
	Flood	0.05	0.05	Extensive flooding of Mandora Marsh may have a detrimental impact on Saunders Spring. Effective management of this is not feasible.
Impacts of pollution	Herbicide, pesticide or fertiliser use and direct impacts	0	0	No cropping occurs in the catchment. This may change if the proposed cotton farm proceeds. Such an occurrence would require a recalculation of these probabilities.
Impacts of competing land uses	Recreation management	0	0	Very little recreation occurs at the site.
	Nutrient enrichment of the water body	0.2	0.2	Continued stock access to Saunders Spring will result in nutrient enrichment of the water body with highly detrimental impacts on aquatic plants and invertebrates.
	Urban and industrial development	??	??	Need to quantify the likelihood of the proposed cotton farm being approved and developed.
	Consumptive uses	0.1	0	The extraction of groundwater from the aquifer that feeds Saunders Spring has been classed as a consumptive use. The impact of this extraction does not appear to have been assessed.
	Illegal activities	0	0	No illegal activities appear likely at this site.
	Mines and quarries	??	??	Need to quantify the likelihood of proposed mineral exploration going ahead.
Insufficient ecological resources to maintain viable populations	Habitat, genetic exchange	0	0	The degree of isolation experienced by Saunders Spring does not appear to have changed. Its survival for approximately 7000 years suggests that it contains sufficient genetic resources to maintain viable populations.

6. Knowledge Gaps and Recommendations for Future Monitoring

Mandora Marsh area is relatively well studied (compared to other Kimberley sites) due to its importance to water birds. However, the mound springs in the area have been given little consideration. The available literature notes the unusual geomorphology of these features, but gives little insight into their ecology. For instance, none of the 178 plant specimens vouchered at Mandora Marsh come from Saunders Spring. The survey undertaken by the IAI RCM project will add considerably to our knowledge of the mound springs, but more work in this area is required.

Also lacking, is an understanding of the regional hydrology. The underlying reasons for the up welling of fresh water at the mound springs are not documented. This makes it difficult to quantify the risks involved with groundwater extraction in the area. The hydrology of the area may also be altered by climate change. The forecast scenario is for longer periods of aridity interspersed with more violent storms. The result of this may be less frequent periods of, but greater areas of, inundation. This is likely to affect the balance of ecology in the area. Ongoing monitoring may reveal the nature and magnitude of any impacts.

Finally, ongoing surveillance of the vegetation of Saunders Spring is recommended. The *Melaleuca* and *Sesbania* forest is a critical component of the site's ecology and appears to be affected by a disease. Cattle are also continuing to access the spring and damage the vegetation.

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Appendix 1

Table 9 – Plant specimens collected from the surroundings of Mandora Marsh (retrieved from the database of the Western Australian Herbarium on 4th July 2007).

Abutilon lepidum	*Eragrostis speciosa*	*Minuria integerrima*
Abutilon macrum	*Eriachne aristidea*	*Muellerolimon salicorniaceum*
Acacia adoxa	*Eriachne obtusa*	*Muntingia calabura*
Acacia ampliceps	*Eriachne* sp.	*Neobassia astrocarpa*
Acacia ampliceps x bivenosa	*Eucalyptus victrix*	*Newcastelia cladotricha*
Acacia anaticeps	*Euphorbia australis*	*Nicotiana heterantha*
Acacia ancistrocarpa	*Euphorbia myrtoides*	*Otion simplicifolium*
Acacia ancistrocarpa x drepanocarpa	*Euphorbia* sp.	*Owenia reticulata*
Acacia colei	*Fimbristylis caespitosa*	*Paractaenum refractum*
Acacia drepanocarpa	*Fimbristylis ferruginea*	*Paspalum vaginatum*
Acacia glaucocaesia	*Fimbristylis tristachya*	*Phyla nodiflora*
Acacia melleodora	*Flaveria australasica*	*Pluchea ferdinandi-muelleri*
Acacia monticola	*Frankenia ambita*	*Pluchea rubelliflora*
Acacia sabulosa	*Frankenia* sp.	*Pluchea* sp. B
Acacia sp. (Kimberley region)	*Fuirena incrassata*	*Polymeria ambigua*
Acacia sp. Ripon Hills	*Gardenia pyriformis*	*Ptilotus astrolasius*
Acacia stellaticeps	*Genus* sp.	*Ptilotus lanatus*
Acacia tumida	*Glinus oppositifolius*	*Ptilotus polystachyus*
Acrostichum speciosum	*Goodenia armitiana*	*Samolus* sp. Millstream
Adriana urticoides	*Gossypium australe*	*Santalum lanceolatum*
Aenictophyton reconditum	*Grevillea pyramidalis*	*Scaevola amblyanthera*
Aerva javanica	*Grevillea stenobotrya*	*Scaevola parvifolia*
Aristida contorta	*Grevillea wickhamii*	*Scaevola spinescens*
Aristida holathera	*Gymnanthera cunninghamii*	*Schoenoplectus subulatus*
Aristida sp.	*Gyrostemon tepperi*	*Schoenus falcatus*
Avicennia marina	*Hakea chordophylla*	*Senna glutinosa*
Bergia ammannioides	*Halgania solanacea*	*Senna notabilis*
Bonamia pannosa	*Halosarcia auriculata*	*Sesbania formosa*
Bulbostylis barbata	*Halosarcia auriculata*	*Sesuvium portulacastrum*
Calytrix carinata	*Halosarcia halocnemoides*	*Sida arenicola*
Cassytha filiformis	*Halosarcia indica*	*Sida fibulifera*
Cenchrus ciliaris	*Halosarcia* sp.	*Sida* sp. B
Centaurium spicatum	*Heliotropium curassavicum*	*Solanum esuriale*
Cleome uncifera	*Heliotropium glanduliferum*	*Solanum oligandrum*
Corchorus incanus	*Heliotropium* sp.	*Solanum* sp.

Corchorus sidoides	*Heliotropium transforme*	*Sorghum stipoideum*
Corchorus sp.	*Hemichroa diandra*	*Spermacoce occidentalis*
Corchorus walcottii	*Hibiscus apodus*	*Sporobolus virginicus*
Corymbia zygophylla	*Hibiscus leptocladus*	*Stemodia grossa*
Cressa australis	*Hibiscus pentaphyllus*	*Stemodia viscosa*
Crotalaria cunninghamii	*Indigofera haplophylla*	*Stigmina* sp.
Crotalaria ramosissima	*Indigofera linnaei*	*Streptoglossa bubakii*
Cucumis sp.	*Indigofera monophylla*	*Stylidium desertorum*
Cullen corallum	*Jacksonia aculeata*	*Stylobasium spathulatum*
Cullen pustulatum	*Keraudrenia nephrosperma*	*Tecticornia auriculata*
Cyanostegia cyanocalyx	*Lawrencia glomerata*	*Tephrosia rosea*
Cynanchum carnosum	*Lawrencia* sp.	*Tephrosia* sp. D
Cyperus conicus	*Lawrencia viridigrisea*	*Tephrosia uniovulata*
Cyperus squarrosus	*Leptochloa fusca*	*Terminalia cunninghamii*
Cyperus vaginatus	*Melaleuca alsophila*	*Timonius timon*
Dampiera cinerea	*Melaleuca argentea*	*Tinospora smilacina*
Digitaria brownii	*Melaleuca glomerata*	*Trianthema pilosa*
Dolichandrone heterophylla	*Melaleuca lasiandra*	*Trianthema triquetra*
Duboisia hopwoodii	*Melaleuca leucadendra*	*Trianthema turgidifolia*
Ehretia saligna	*Melaleuca nervosa*	*Tribulopis* sp.
Enneapogon robustissimus	*Melaleuca* sp.	*Velleia panduriformis*
Eragrostis cumingii	*Melaleuca viridiflora*	*Xerochloa imberbis*
Eragrostis eriopoda	*Melhania oblongifolia*	*Yakirra australiensis*
Eragrostis falcata	*Mimulus uvedaliae*	*Zygophyllum compressum*