A report on the application of draft criteria for identification of High Conservation Value Aquatic Ecosystem (HCVAE) on mound springs in Western Australia

Produced for the Aquatic Ecosystem Task Group, Department of Environment, Water and Heritage and the Arts

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Executive Summary

The purpose of this report is to test the draft criteria for listing a site as a High Conservation Value Aquatic Ecosystem (HCVAE) on organic mound (tumulus) springs in Western Australia. The draft criteria were trialled on ground water dependant ecosystems in order to compliment testing on surface water systems in Eastern Australia. The result of this pilot study will be reported back to the Aquatic Ecosystem Task Group (AETG), to assist in refining the criteria.

Mound springs are naturally occurring ground water discharge points, usually with a peaty soil. They appear as clumps of dense vegetation often in a surrounding dry area. In WA, these are reported as groups of individual mound springs (a suite) as well as individual springs. In W.A. there are 13 suites comprised of 96 individual springs.

Available data for mound springs in W.A. was aggregated to compile, a spatially referenced layer of all known sites. Each of the draft criteria was initially applied to all of the mound spring suites. This was then followed by completing “Individual Suite Assessment Forms” so that a comprehensive investigation was completed.

Through the application of the draft criteria, seven out of the thirteen suites of mound springs have been captured as HCVAE. Where possible, individual mound springs were selected instead of an entire suite. However, in some cases, it was required to list the whole suite.

Most suites were identified as HCVAE under the criterion of “distinctiveness”. However, more than two sites were also identified by the criteria “representativeness” and “evolutionary history”. The criterion of “naturalness” did not identify any sites as HCVAE, but this is at least partly explained by the lack of an agreed definition and method of application.

Advantages and disadvantages to the application of each criterion were identified as well as recommendations for the future application of those criteria.

“International recognition” was the easiest criterion to apply, due to the concrete nature of this identifier. However, this criterion is not necessarily a discerning identifier as extensive information has to be available on a site before it can be considered for listing under an international convention. There are often political and social barriers to listing and long delays even when site information supports listing. Site specific data is not available for the majority of mound springs that would support nomination.

The criterion of “representativeness” was complex to apply due to the need to use a bioregionalisation model that was functional across the whole state. The distribution of groundwater or aquifer systems was the most appropriate for mound springs. A further layer for application of this criterion was added by assessing how the other criteria were met for each moundspring on each type of aquifer. Further development of this criterion is required to improve the objective rigor of application.

The criterion of “diversity” was found to be an effective identifier of HCVAE if sufficient data is available. However, the use of mean and standard deviation as parameters introduces biases

in the calculation due to the variation in field methods and as well as the omission of sites where data was not available.

The criterion of “distinctiveness” had the advantage of using listed rare and threatened flora, fauna and communities as objective identifiers. Threat analysis was conducted using spatial layers and where good coverage was available, for example for fire, this was an effective indicator of a system’s integrity. However, it is considered that the analysis of threats is inappropriate at the HCVAE assessment stage and should only be taken into account when comparing between sites that have been identified as possible HCVAE.

The criterion of “critical habitat” incorporates climate change issues through the specification of a site supporting species in time of stress. This was especially advantageous for ground water dependant ecosystems. Although, the specifications for a regional bird population count and a site supporting 10% of a species assemblage or community could not be applied to mound springs due to the lack of reliable survey data. The application guidance for this criterion will need further development.

Out of the two complementary criteria, the criterion of “evolutionary history” was the most applicable due to being able to define objective application parameters.

In general, the study found that the draft criteria were useful for identifying sites as HCVAE where up-to-date and detailed information was available. The more remote and less researched sites were less likely to be identified by the specifications of the draft criteria.

The scope of this project included only WA’s mound spring sites. Analysis of data on all mound springs across Australia would give a more comprehensive application of the draft criteria. This is particularly relevant for the criteria of “representativeness”, “diversity”, “critical habitat” and “naturalness”

1. Introduction.

1.1. Project Outline

The purpose of this report is to test the draft criteria for listing a site as a High Conservation Value Aquatic Ecosystem (HCVAE) on organic mound (tumulus) springs in Western Australia. The known mound spring sites in WA have been collated and an assessment made of how many of the HCVAE criteria apply to each site. Justification of how the criteria have been met is provided and an analysis of the knowledge gaps and an evaluation of the effectiveness of the criteria in identifying HCVAEs are also presented. A spatial dataset has been generated, containing location data and empirical data associated with each site.

This project was developed to test the draft criteria on ground water dependant ecosystems in order to compliment testing on surface water systems in Eastern Australia. The result of this pilot study will be reported back to the Aquatic Ecosystem Task Group (AETG), to assist in refining the criteria.

1.2. Description of Mound Springs

- Mound springs occur at natural ground water discharge points. Water discharges to the surface forming wetland areas in otherwise predominantly dry regions. They support an unusual community of flora and fauna and are also a refuge habitat for outlier populations of various species. They exist both inland and on tidal flats.
- Mound springs mainly occur on porous, highly productive aquifers. Those of Eastern Australia are expressed from separate aquifer systems from the mound springs of Western Australia.
- The mound springs of Eastern Australia (including Northern Queensland) all occur on the Great Artesian Basin (GAB) and are mainly in arid or semi arid climatic zones. The GAB mound springs are classified into super-groups which make up spring groups and spring complexes. There are 13 super-groups and 336 spring groups. They are further classified as either recharge or discharge super-groups. Their soil type is calcareous tufta and springs are in the form of either seepages or mounds.
- The mound springs in Western Australia occur on smaller isolated aquifers. Unlike those described in the eastern states, many mound springs in WA occur on low to moderately productive aquifers. Again, in contrast to those in the eastern states, the mound springs in WA are comprised entirely of peat soils that build up to form a mound. This mound is often surrounded by a moat of water. They occur in arid, semi-arid and tropical climates. The WA mound springs are divided into suites (Table 1) that are comprised of numerous individual springs. There is no sub-classification of these suites so far.

Table 1. Distinguishing features of mound springs in Western Australia

Mound Springs Suites in WA	Seasonal / Permanent	Fresh / Saline	Type of Aquifer	Structure (raised / flat)
SCP	inundated	Fresh	Shallow	Raised
Three Springs	inundated	Fresh	Deep and Extensive plus Local	Raised
Mandora Marsh	inundated	Fresh with some salinity	Shallow	Raised
Dragon Tree Soak	inundated	Fresh	Shallow	Raised
Willie Springs	inundated	Fresh (on tidal flat)	Deep and Extensive	Raised
Bunda Bunda	inundated	Fresh	Shallow	Raised
Lollywell Springs	inundated	Fresh	Deep and Extensive	Raised (low)
Disaster Bay	inundated	Fresh (on tidal flat)	Deep and Extensive	Raised (low)
Big Springs	inundated	Fresh (on tidal flat)	Shallow	Raised and Seepages (flat)
Black Springs	Mound damp, Moat permanently inundated	Fresh	Local	Raised
North Kimberly Mounds	inundated	Fresh	Local	Raised
Kachana			Local	
Carlton Hill			Deep and Extensive plus Local	

1.3. List of Sites

The mound springs in Western Australia can be divided into suites (numerous mound springs that are connected hydrogeologically and share common biota assemblages) and individual mound springs that make up these suites (table 2). There are 13 suites identified in WA with a total of 96 individual mound springs. These are concentrated mainly in the Swan Coastal Plain and Rangeland regions of Western Australia.

Table 2 Names of suites and individual mound springs

Mound Spring Suite	Individual Mound Springs	Mound Spring Suite	Individual Mound Springs
Swan Coastal Plain	Meechin 01	**Three Springs**	JB02
	King 01		JB 05
	Kings 02		JB 37
	Nursery 01		MSTS 1
	Gaston Road		MSTS 01a, 01b, 01c JB 09
Mandora Marsh Mounds	Anna Plains 01		MSTS 2
	Anna Plains 02		MSTS 02
	Anna Plains 03		MSTS 02JB
	Anna Plains 04		MSTS 03, JB 03
	Stockyard Mounds		MSTS 04, JB 04
	Fern Mounds		MSTS 05a, 05b, JB 07a, 07b, JB 10
	Melaleuca Spring		
	Linear Spring		MSTS 06, JB06
	Top / Sump Spring		MSTS 07, JB 32
	Sporolius Spring		MSTS 07a
	Spring 1		MSTS 08, JB 12
	Spring 2		MSTS 09, JB 17
	Spring 3		MSTS 10
	Spring 4		MSTS 11, JB 19
	Spring 5		MSTS 12, JB13
Dragon Tree Soak	Dragon Tree Soak 01		MSTS 15a
Willie Springs	Willie Springs 01		YAN 01
Bunda Bunda	Bunda 01; Bunda 02	**North Kimberly Mounds**	Drysdale 1a
			Drysdale 2a, 2b
Disaster Bay	DisasterB 01		Drysdale 3a, 3b
Black Springs	Black Spring 01a, 01b		GibbR1
Kachana	Individual springs not known		Mt. Elizabeth 1a, 1b, 1c, 1d
	Attack Spring and King Gordon Spring (Unknown location). Other individual springs not known		Mt. Elizabeth 3a, 3b
			Mt. Elizabeth 4
Big Springs	Bigs 01	**Big Springs**	BigS 14
	BigS 02		BigS 15
	BigS 03		BigS 16
	BigS 04		BigS 17
	BigS 05		BigS 18
	BigS 06		BigS 19
	BigS 07		BigS 20
	BigS 08		BigS 21
	BigS 09		BigS 22
	BigS 10		BigS 23
	BigS 11	**Suites = 13**	
	BigS 12	**Mounds springs = 96**	
	BigS 13		

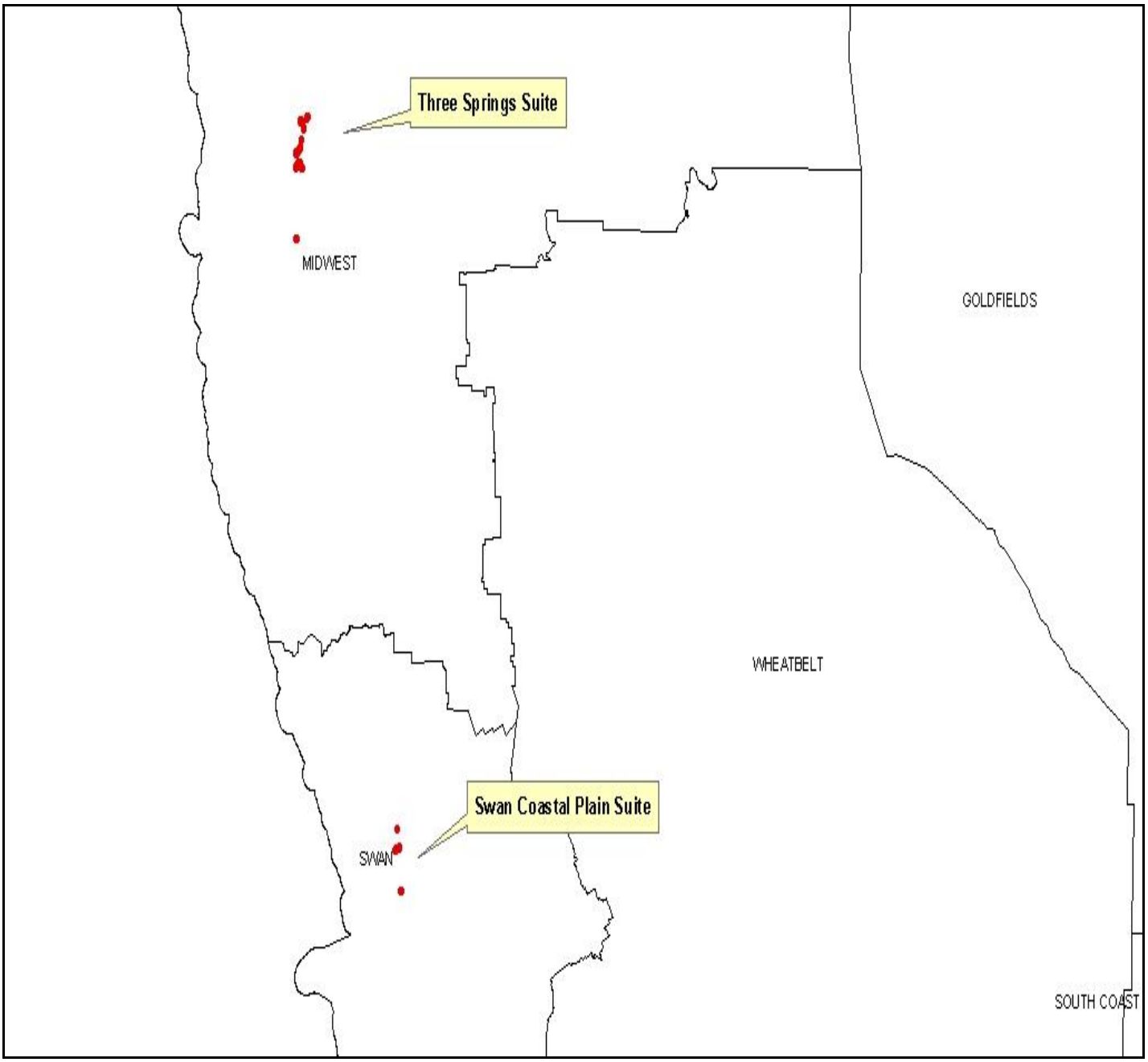

Figure 1. Location of suites of the Swan Coastal Plain and Midwest – See table 2 for individual mound springs

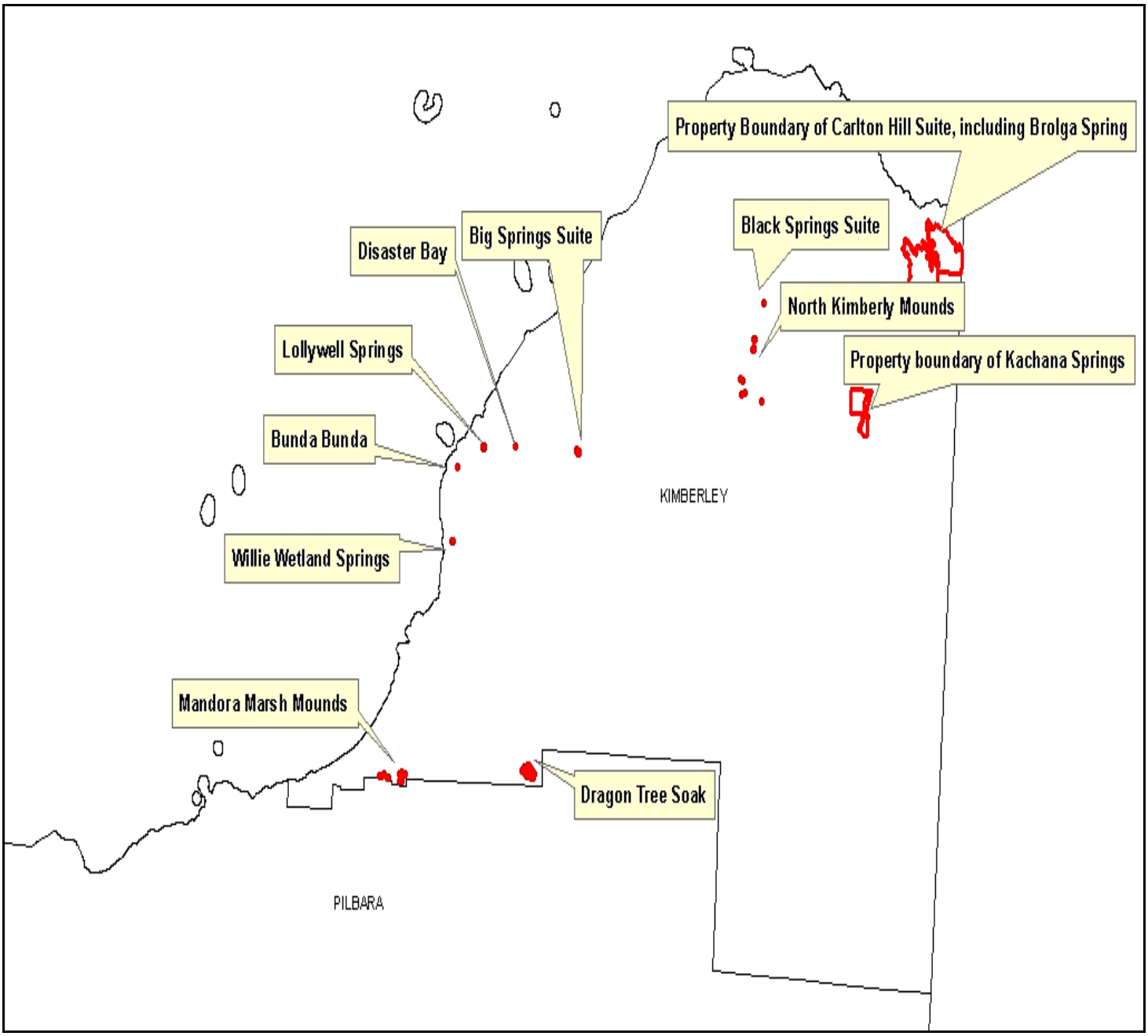

Figure 2. Location of Kimberly mound spring suites – see table two for individual mound springs

2. Limitations to Trial

Varied sources of information have been used to determine whether a site meets HCVAE criteria. Information sources included published reports, DEC records (e.g. Threatened Ecological Community Reports), Interim Recovery Plans, raw survey data and GIS datasets. All information is available through reports and datasets with the custodian, the Department of Environment and Conservation and is assumed to be scientifically correct.

The accuracy of information that was used in this assessment varied between sites. Information for some sites came from 3-4 general reports with some dating back to late 1980's. It is highly recommended that site visits should be conducted before listing sites as HCVAEs to verify that the sites have not changed since these reports were generated.

Significant information gaps exist for some mound spring suites and in some cases, assumptions were made using best available information to determine whether individual sites met criteria. Further research is required on these ecosystems to guarantee that similar levels and accuracy of data is used in applying the draft criteria to all mound spring sites and to be confident that a uniform application of the criteria has been applied across all of the mound spring suites and that the best examples of mound springs in WA have been selected as HCVAEs

The project has tested HCVAE criteria on mound springs in WA, however HCVAE criteria are focused on applicability at a national scale, for instance, the advice on application of the criteria "Distinctiveness". In this case, to gage condition of mound springs on a national scale was outside the scope of this project. To address this, general advice on the number and distribution of mound springs across Australia has been used as a compliment to information that is available on mound springs in WA.

3. Methodology

3.1. Overview of Methodology

Relevant data provided by government agencies was collected to compile the list of mound spring suites. Once this was completed, and a better understanding of the extent and occurrences of mound springs in WA was known, each suite was then plotted on a GIS system.

Each criterion was initially applied to all of the mound spring suites. This was then followed by completing "Individual Suite Assessment Forms" so that a comprehensive investigation was completed. Questions asked in the individual suite assessment reflect how the criteria were applied to mound springs. Questions also included additional information such as size and tenure so that a more complete picture of each suite was given.

3.2. International Recognition

Criterion 1: International recognition

at national level.

Any site will meet criterion 1 if it is listed under:

- *Ramsar Convention*
- *World Heritage Convention (where aquatic ecosystems attributes are explicit in statement against criteria)*
- *East Asian-Australasian shorebird Network*

3.2.1 Identification of Ramsar / World Heritage Areas (WHA) and East Asian-Australasian Shorebird Network (EAASN) sites

This criterion was applied by assessing whether mound spring suites or individual mound springs were listed individually or as part of a wetland system under the Ramsar Convention, World Heritage Convention or the East Asian-Australasian Shorebird Network.

The Department of Environment and Conservation, WA (DEC) maintain a website where Ramsar sites are listed and described (www.dec.wa.gov.au). A GIS layer established by DEC that identifies the location of the listed and draft proposed Ramsar Sites in WA. A Combination of these two tools was used to identify Ramsar Sites that included mound springs.

Australian World Heritage sites are listed on http://whc.unesco.org/en/list. Two are listed in Western Australia, those being Shark Bay and Purnululu National Park. Neither of these sites includes mound springs.

DEC also publicly lists sites under the East Asian-Australasian Shorebird Network. There are two sites for Western Australia, Parry Lagoons and Thompson Lake, neither of which include mound springs inside their boundary.

One suite of mound springs was captured by the criteria of International Recognition. The Mandora Marsh Mounds are incorporated into the Eighty Mile Beach Ramsar Site. There are 15 individual mound springs within this suite, all of which will go forward for HCVAE listing. It is worth noting that anecdotal information suggests that at least some of these mound springs within the suite have been highly modified by grazing practices and probably no longer meet other HCVAE criteria (pers. com. 1 2008).

Brolga Spring is 4km from the Ord River Floodplains Ramsar Boundary and it is likely that the aquifer source is hydrologically connected to the floodplain wetlands that are inside the Ramsar boundary. However, the significance of the hydrological connectivity has not been assessed adequately and was not used for the purposes of this analysis.

3.2.2 Draft Ramsar / WHA and EAASN Sites

DEC contracted a consultancy to Wetlands International – Oceania in 1999 (Jaensch and Watkins 1999) to assess suitability of wetlands in WA as candidate sites for nomination under the Ramsar Convention. The assessment was based on the requirement of meeting at least

one of the five criteria groups that was the Convention Recommendation (4.2, Resolution VI.2) at that time. This candidate list was also assessed in this trial in order to capture those mound spring suites which may be classified as HCVAE in the future. In the explanatory notes for the draft criteria, it states that places added in the future to these registers will then be placed on the HCVAE list.

Ellenbrook Swamp is a candidate site for nomination under the Ramsar Convention. However, the boundary for this site is 3km from Egerton Spring of the Swan Coastal Plain suite and the hydrological connectivity of these wetlands has not been adequately assessed to be used in this analysis.

Current candidate WHA sites for WA are Ningaloo-Cape Range National Park, Walpole Wilderness Area and Nambung National Park. Mound springs have not been identified at these sites. However, a further candidate site is being considered in the Kimberly bioregion (North West) which is known to contain a high concentration of mound springs.
At the time of writing, the nomination was yet to be put forward to the Commonwealth for National Heritage listing. However, the site meets WHA criteria and a provisional boundary has been established, which incorporates Willie Wetland Springs, Bunda Bunda Springs, Disaster Bay, Big Springs, Lollywell Springs, Black Springs and the North Kimberly Mounds (see Figure 2). (pers. Com 2 2008, June)

Information was not available on draft sites to be listed under the East Asian-Australasian Shorebird Network.

3.3. Representativeness

Criterion 2 Representativeness

a site that is assessed as an outstanding representative example of a particular wetland type when compared with similar wetlands at a national scale will meet Criterion 2.

A site may be recognized as a representative HCVAE aquatic ecosystem at national scale if it is:

- *of a spatial and temporal scale that illustrates the full characteristics of its class, for example a river intact from headwater to ocean or major convergence, or a wetland that responds periodically to cycles of water availability and is either,*
- *in natural or near-natural condition with the processes that sustain it intact or*
- *the only remaining example of such a system on a continental scale.*

3.3.1. Representative of a natural or near-natural condition with the processes that sustains it

Representativeness was applied by testing whether the mound springs were in a natural or near-natural condition in regards to the processes that sustain their hydrological and biological function. The spatial scale of mound springs is not extensive so the full characteristic of its class is essentially always captured and there are numerous examples of these systems remaining on a national scale. The mound springs which have been identified in available reports are all permanently wet and the temporal scale was not a useful delineator of naturalness.

Mound springs are expressions of groundwater systems, and as such, the mapped boundaries of aquifer systems were used to assess the representativeness of mound springs as it was more rigorous than using IBRA, Climatic Regions or Drainage Divisions.

Three types of aquifers have been identified in Western Australia (table 3); local aquifers (rocks of low permeability, fractured and weathered rocks), shallow aquifers (surficial sediments) and deep and extensive aquifers (sedimentary rocks) (Dept. of Water GIS layer 2008). To relate these aquifers to the national aquifer system (Commonwealth of Australia, GIS layer, 2008), local aquifers equate to low productivity aquifers, shallow aquifers equate to low to moderate productivity and deep and extensive aquifers equate to highly productive aquifers.

The highest value suite within each aquifer was determined on how many other criteria each suite met, including the two complementary criteria. This was the most convenient approach to assess which assemblages were in the best condition. GIS tools were used to identify the type of aquifer that each mound spring suite was connected to.

Table 3: Mound spring suites and connected aquifer system type

	Local Aquifer	Deep and Extensive	Shallow
SCP			X
Three Springs		X	
	X		
Mandora Marsh			X
Dragon Tree Soak			X
Willie Creek Springs		X	
Bunda Bunda			X
Lollywell Springs		X	
Disaster Bay		X	
Big Springs			X
Black Springs	X		
North Kimberly Mounds	X		
Kachana	X		
Carlton Hill	X	X	
Brolga Spring		X	

There are three suites on local aquifers, five on deep and extensive aquifers and five on shallow aquifers.
The Three Springs suite is connected to two different aquifer systems, a local aquifer and a deep and extensive aquifer.
Using all of the criteria, it was possible to determine which suites met the most criteria And thus considered the best representatives of their relevant aquifers. These were the Swan Coastal Plain suite, the Three Springs suite and Kachana Springs.

3.4 Diversity

Criterion 3 Diversity

To meet the threshold for national significance, a site must demonstrate diversity in any of the following ways.

- ***For diversity of aquatic ecosystem types or classes***
  - *incorporate at least 3 or more aquatic ecosystem types or classes that are hydrologically connected and interdependent*
- ***for diversity of communities***
  - *include all or most of the communities typical of that ecosystem class*
- ***for species diversity***
  - *have a species diversity (specify index) that exceeds the expected diversity or is more than 2 standard deviations from mean or*
  - *have a high diversity of taxi at higher taxonomic levels (genus, family)*

3.4.1 Diversity of Aquatic Ecosystem types or classes and Diversity of Communities:
The specification for a site to have a diverse ecosystem type or class, states that the site needs to incorporate at least 3 or more aquatic ecosystem types or classes that are hydrologically connected and interdependent. However, the scale of available information for mound springs generally classified only a single type of ecosystem and this criteria was not able to be applied in this analysis.

This was also the case for the specification on diversity of communities and the scale and paucity of available information for mound springs meant that this criterion was not able to be applied in this analysis.

3.4.2 Diversity of Species
Which suite has a species diversity (specify index) that exceeds the expected diversity or is more than two standard deviations from the mean?
There is no relevant index available for this specification, so the mean and standard deviation was derived from calculations of available aquatic invertebrate data. An initial result of a recent survey on invertebrates in the Kimberly (provided by DEC's Science division) was combined with existing reported data from the Swan Coastal Plain suite and the Three Springs suite.

In order to maintain consistency with the collaboration of these two sources, the mound spring with the highest reported species count in the Swan Coastal Plain suite and Three Spring suite were added not the combined species count the whole suite (see appendices 3). This was so that it was uniform with the Kimberly result. Data was available for representative mound springs of 8 suites. Dragon Tree Soak, Willie Wetland Springs, the Carlton Hill suite and Disaster Bay had no data. Aquatic invertebrates were chosen as they are the fauna that is most often surveyed with direct relevance to mound springs.
The mean number of species was 35 with a standard deviation of 21.
Therefore a suite will be listed under this specification if it has more than two deviations greater than the mean or greater than 76 species recorded.
The only suite that met this specification was the Kachana Springs Suite with 89 species recorded.

3.4.3 Which suite has a high diversity of taxa at high taxonomic levels?
Aquatic invertebrate data was again used to give a numerical threshold for "high diversity". The mean and standard deviation of genus, family and order was calculated. A site was considered to have high diversity if it was greater than one standard deviation from the mean. One as opposed to two standard deviations was used as the delineation because desired diversity would be unrealistically set with two standard deviations.

The average number of genera was 37, with a standard deviation of 18. This meant that a site needed to have 55 or more genera in order to be captured under this specification.
The average number of families was 14, with a standard deviation of 4, meaning a site would be captured if it had 18 or more different families represented.
The average number of orders is 4 with a standard deviation of 2, giving 6 orders or above as the threshold for this specification.

3.5 Distinctiveness

Criterion 4 Distinctiveness
For HCVAE at national level, the site must meet at least one of the following attributes:

- *The rare and threatened species and communities*
  - ➢ *must meet national thresholds for listing under EPBC, either by their listing under the EPBC Act or by rigorous application of the EPBC guidelines (Criteria and indicative thresholds).*
- *Rare, unusual and/or threatened aquatic ecosystem classes and geomorphological features will be assessed by expert opinion using available data sets. In future, these attributes will be assessed systematically through a bioregional and classification analysis.*
  - ➢ *classes and features must be rare on a continental scale.*
- *Threatened aquatic ecosystem classes or habitats will be isolated by analysis of key threatening processes with impacts across a national scale, the rate of progress of change and scale of impact, together with an assessment of pre 1790 distribution of these classes or features.*
  - ➢ *Threatened ecosystem classes or habitats must*

have been lost to a significant degree nation-wide or

be an uncommon type that is specifically under threat, resulting in decline in occurrence or condition, nation-wide

3.5.1 Which suites represent a rare or endangered wetland type?
The rarity of mound springs as a geomorphic type in WA and at the national level is self evident. There are 13 identified suites of mound springs in WA, consisting of 96 individual mound springs. Of the total 851 wetlands listed on the Directory of Important Wetlands of Australia (DIWA sites), only 16 of these are associated with mound springs (Environment Australia 2001). This supports the finding of Jankisa and Knott (1998) – "mound springs are rare wetland types in themselves due to unique hydrology and specific macro-invertebrate habitat". However, it was considered impractical to classify all Mound springs as HCVAE, based on the narrow application of this one criterion. Therefore it was decided to further assess the applicability of other specifications under distinctiveness to allow greater a discernment of biodiversity value.

3.5.2 Which suites have rare and threatened species and communities?
GIS tools were used to determine whether a particular suite incorporated endangered or vulnerable fauna and / or rare flora. As required, the listed flora and fauna under the national EPBC Act were used as these are representative at the national scale and not just Western Australia. This introduces issues that are related to the many differences between state and national listings often due to lag periods for incorporating new information into the national lists as well as differing criteria and endorsement processes.

On DEC's GIS layer for threatened and priority fauna, fauna are listed as endangered, vulnerable or priority (P1, P2, P3, P4 & P5). Fauna listed as endangered and vulnerable within this state list are fauna that are protected under the national EPBC act. Therefore, only endangered and vulnerable fauna, not priority fauna, were used in the application of this criterion. References are still made to priority fauna in the tables as additional information, as their status may change, but were not used in the assessment. In order for a fauna to be considered related to a mound spring, it had to be recorded within 2km of the mound spring boundary.

The GIS layer was used similarly for flora, where the state listed declared and endangered flora is subdivided into extinct, rare and priority species. Those classified as rare are protected under national listing and only these were used as a basis for listing as HCVAE. Listed Flora was captured where it occurred within 100m of a mound spring.

Mound spring suites that contained rare or threatened flora and fauna, were analysed further to select individual mound springs within each suite which were especially important for the species.

- *Fauna*

Two suites were found to be within 2km of endangered or vulnerable fauna. Dragon Tree Soak has an endangered mammal surveyed on the actual mound spring. It also has two priority (P4) bird species. The Swan Coastal Plain suite also has vulnerable fauna within 2km of its mound springs. The Egerton Spring has a vulnerable mammal with 1.3km of it. Hence, this mound spring will be prioritized. It also has a priority (P5) fauna within 1km. Another mound spring within this suite (Alpace01) has a priority (P3) fauna within 1.1km. Brolga spring also has threatened molluscs within 1km of its boundary.

- *Flora*

No suite was found to be within 100m of rare flora. The Swan Coastal Plain suite has numerous rare flora species within 2km of the springs, but none of those flora species were close enough to be deemed reliant on the mound springs. Likewise, the Three Springs suite is also very close to rare flora. One of the springs (MSTS 15a) is within 300m of a rare flora species, but again this was not considered dependent. This site does have a buffer of 220m, which if included means this rare flora is only 150m away. Again, if the status of these flora changes to rare in the future, this analysis will change.

- *Rare or Threatened Communities*

There are state and national listed Threatened Ecological Communities. For the purpose of identifying national HCVAE, only the national TEC list was used as this is protected under the

EPBC Act. The Swan Coastal Plain Suite is the only listed national TEC that consists of Mound Springs in WA
Mound Springs listed on the state TEC are the Swan Coastal Plain suite, the Three Spring suite, Mandora Marsh Mounds, Dragon Tree Soak, Bunda Bunda, Big Springs, Black Spring and North Kimberly Mounds. There is a considerable time lag between being listed at state level advancing to national listing. These suites may become listed nationally in the future.

3.5.3 Which suites have threatened ecosystems classes or habitats that have been lost to a significant degree nation wide?
Geomorphic features of limited occurrence at continental scale
This specification was applied by analysis of changes in vegetation extent since pre-European cover. This was complimented by reported decline in range and occurrence within the TEC Database.
Pre-European vegetation was used as an indicator of habitats that have been lost to a significant degree and thus also an indicator of geomorphic features that are of limited occurrence on a national scale.

The Swan Coastal Plain (SCP) Suite, is known to have been common within its original narrow distribution between Guildford and Muchea. It is now known from only three occurrences, totaling less than eight hectares and has gone from at least 97% of its original range. It is listed in the TEC database as its range has been reduced by > 90% since European settlement. The SCP Suite is in an IBRA region that is classified as having the second highest percentage of vegetation loss within Australia.

The Three Spring Suite is likely to be a remnant of its original extent as it lies just north of the main Wheatbelt area. This area has been extensively cleared for agriculture. Most springs that were lost in agricultural areas in the Swan Coastal Plain were in-filled with limestone, and anecdotal evidence suggests that this practice also occurred in the Three Springs Suite. Some of the individual springs in the Three Springs Suite have also been excavated. The Three Springs Suite is within an IBRA region that is classified as having the third highest percentage of vegetation loss in Australia and the suite range has been reduced by 40-70% since European settlement.

All other suites are within IBRA regions that have a very low percentage of vegetation loss and occupy most or all of their former geographic range or that their range is unknown, but thought to be small.

3.5.4 Which suites have threatened ecosystems classes or habitats that consist of an uncommon type that is specifically under threat, resulting in decline in occurrence or condition, nation wide?
Mound springs are an uncommon geomorphic type of wetland. In order to maximise the discernment of biodiversity values, within these sites, the application of this criteria focused on the threats to these sites. The most significant threatening processes to mound springs are changes to fire regime, abstraction from bores on their aquifers, mining and grazing (and other agricultural impacts). A suite was deemed to be severely threatened if it was subject to three or more of these threatening processes.

- *Fire*

All of the mound spring habitats in the Kimberly are particularly under threat from frequent fire events. The IBRA regions for the Kimberly have the highest percentage of fire scars. A fire is not a direct threat to the occurrence of a mound spring, but is a definite threat to the ecological function of a mound spring. Fire impacts critically on vegetation and water temperature of organic mound springs.

Testing of fire in an attempt to control the invasive plant, *Phragmites australis, and as a possible management tool to* increase endemic vegetation cover on mound springs in South Australia failed to show any benefits from fire. Other research conducted by Edith Cowan University on the Groundwater of the Gnangara Mound, indicated that aquatic macro-invertebrates are adversely affected by the incidence of fire (Benier and Horwitz, 2003). This research found a full recovery of wetland function could be made, if another fire event did not occur within a decade. However, records indicate that around 50% of the Kimberley area is burnt every year and the suites in the Kimberly are unlikely not to be burnt more than once in 10 years.

In comparison to mound springs of the Great Artesian Basin, WA has a higher percentage of its mound springs under the threat of fire from changed fire regimes. Estimates suggest (as exact boundaries of GAB springs is unknown and super-groups are larger than suites), 11 out of the 13 suites in WA are under threat from increased frequency of fire events, compared to 3 super-groups from the 13 in the GAB. Combining these areas means that14 of the 26 suites / super-groups (over half) are under threat from increased fire frequency.

To assess threat by fire, fire scarred areas were mapped for the years 1993 to 2006 for WA. A suite with three fires over a ten year period was considered to have a significant threat of fire. As stated in the Interim Recovery Plan for the Three Springs suite, too frequent fires are a potential concern for all occurrences.

Once a suite was identified as being under threat, individual springs within that suite were then examined to determine those under the greatest threat from fire.

Dragon Tree Soak, Willie Springs, Lollywell Springs, Disaster Bay, Black Springs, North Kimberly Mounds, Kachana and Carlton Hill all had at least three fires within the last ten years; most had much more than three fires. Some individual mound springs had as many as seven fires within a ten year period.

Individual mound springs have not generally been mapped at both Kachana and Carlton Hill stations (exception is Brolga Spring) and station property boundaries have been used as the default. This is likely to over-estimate fire exposure for instance, at Carlton Hill, where we know the location of one spring (Brolga Spring) only 2 fires out of the 12 fires that have occurred on that property have included the spring.

- *Bores on aquifers*

A GIS dataset for WA Department of Water active bores was used to determine which aquifers have water extracted from them. Mudd, G. (1998) demonstrated the impacts from bores on the quality and quantity of water being fed to mound springs which can lead to degradation and in some cases extinction of effected spring-groups. This was illustrated through a case study on the impacts of the Olympic Dam in South Australia, although, a

much larger scale, similar impacts will be reflected where the ratio of abstraction to aquifer size is similar.

The Swan Coastal Plain suite, the Three Springs suite, Willie Wetland Springs (Bunda Bunda and Disaster Bay are on the same aquifer but much further away from bore) and Brolga Springs are all on aquifers that have operating bores on them and have potential threat from water abstraction.

- *Mining*

The threat of mining was analyzed by GIS techniques as well. If a suite / spring had an active exploration tenement on it, it was deemed to be under threat. Those with pending exploration tenements were not included. Tenure was also factored into the analysis of threats as tenure influences if extra permission needs to be sought, for example permission from the minister is required to explore on Crown Reserve and it is illegal to explore in environmentally sensitive areas. Mining exploration is permitted within sites listed under the Ramsar Convention, if the Minister is satisfied that it does not impact on the ecological character of the site.

Mandora Marsh Mound Springs, Big Springs and Kachana Springs all have mining tenements on crown lease or private land and were considered to be under the most significant threat from mining activity.

- *Grazing and other agricultural impacts*

Threats from agricultural landuse, such as grazing, soil compaction and weed invasion were investigated through the available literature on each suite. Grazing causes alterations to the species composition through selective grazing of edible species, encourages weeds as a result of trampling of native vegetation and increased nutrient availability from animal droppings. Six springs from the Three Springs suite have been converted to dams or fully cleared. Only one spring in the Mandora Marsh suite is fenced to prevent cattle grazing (this is currently breached – pers. com. 2008 May). Dragon Tree Soak has camels trampling over it. Willie Wetland Springs and Big Springs are being grazed by cattle, while Kachana Springs is also subject to cattle grazing as well as soil compaction and weed invasion.

Willie Wetland Springs had significant threat to it. There are operational bores on its aquifer, it is becoming increasingly under threat by the clearing for urban expansion of Broome and feral cats and foxes are reported to be affecting bird numbers.
Kachana Springs also is subject to heavy threat. There have been six fires over a ten year period. Where it is most likely that the mound springs are, there have been nine fires over an 11 year period, cattle grazing, soil compaction, weeds and an active mining lease.

3.6 Critical Habitat

Criterion 5: Critical habitat

at national level an HCVAE will be one or more of the following*:*

- *a major location for very large numbers of individuals (e.g. 20 000 waterbirds), either of one species or numbers of species, or*
- *a location that typically sustains wetland species under conditions of stress, as shown by the large numbers of individuals that are attracted to that site under conditions such as drought or,*
- *the location for intensive breeding activity, notably for birds or fish. It may attract species that do not inhabit the area in mature stages but use the area solely for breeding or,*
- *a place that is the most utilised by migratory birds at a regional scale, or*
- *considered significant for life cycle of some species if it maintains a natural regime of drying and wetting that is critical for the existence of those species and/or communities.*
- *supports at least 10% of a dependent species suite or community.*

3.6.1 Species Data

Survey data was analyzed to see if any suite met this criterion. However data was very limited and made this difficult.

- *Invertebrates*

The paucity of aquatic invertebrate data for mound springs in WA is reflected across many wetland types in WA. There have been two invertebrate studies conducted on the SCP suite, one in 1998 by Janksia and Knott and the other in 2004 by Pinder. There are two invertebrate reports completed in 2001 and 2006 by Pinder et. al. on the Three Springs suite. Also, invertebrate sampling has been undertaken at the majority of Kimberly springs (Big Springs, Bunda Bunda, Kachana, Lollywell Springs and Black Spring). Most springs have only been surveyed once, leading to an overall lack of data to assess community and population trends of invertebrates on mound springs in WA. Therefore, it is difficult to state if the fauna surveyed represent 10% of the population, as it is unknown what the true population actually is. There have been new species described on some mound springs. However, again it is unknown whether these are new because they are rare and highly endemic or new because of a low number of surveys.

- *Birds / Mammals / Reptiles / Amphibians*

The only report of bird activity on mound springs is for Mandora Marsh. This is a survey for the whole marsh area and not specifically the mound springs. Other than that, there are no surveys or reports that have been conducted to study either birds, mammals, reptiles or amphibians that inhabit mound springs.

3.6.2 Which suites provide habitat for unusually large numbers of a particular species of interest (e.g. 20,000 water birds), either one species or a number of species?

Mound springs generally occupy a small area. The largest mound spring in WA (Big Springs 01a, 01b) is 59 hectares. No mound spring will be large enough to support up to 20,000 water birds, but dedicated bird monitoring has not been conducted for most mound springs in WA.

3.6.3 Does any suite sustain wetland species under condition of stress, as shown by large numbers that are attracted there under conditions such as drought?
Due to their small geographical extent, mound springs will not support large number of species. However, the mound springs in Western Australia appear to provide important refuge habitat for some species in semi-arid regions as they are a permanent sources of water.

3.6.4 Is any suite a location for intensive breeding activity, notably for bird or fish? It may be only used for breeding and not in mature stages?
There is no specific study on species' breeding on mound springs. The survey of Mandora Marsh does indicate fish and bird breeding in the area, but does not detail if any such activity was related to the mound springs.

3.6.5 Is any suite most utilized by migratory birds at a regional stage?
There is no data showing whether migratory birds use mound springs.

3.6.6 Which suites provide habitat for species at a critical life stage?
The survey of invertebrates on the Swan Coastal Plain shows that some species present do not have a dormant stage, therefore are reliant on the availability of water from mound springs for all their life stages. This is the only survey that highlights life stages of invertebrates in mound springs.

3.7 Evolutionary History

Criterion 6 Evolutionary History

Sites which have met at least one core criterion at national level will meet supplementary criterion 6 if they meet at least one of the following:

- *Habitat for an unusually high diversity of endemic taxa with limited geographical distribution*
- *Habitat for a diversity of taxa endemic at higher taxonomic levels (genus or above)*
- *Habitat for a group of endemic species suggesting a centre of speciation*
- *Habitat for a sequence of related taxa indicative of evolutionary processes*
- *Habitat for iconic species recognized as 'living fossils', relictual species that appear as key links in evolution*

3.7.1 Survey Results
The suites of the Swan Coastal Plain, Mandora Marsh Mounds and Dragon Tree Soak have had Gondwanan species surveyed or carbon dating and pollen dating conducted on them.
As there is no specific data on centre of speciation, the Biodiversity Audit 2002 for WA was used as a guide. For the central Kimberly area, it lists Camaenid land snails. There is an EPBC mollusc recorded within 2km of Brolga spring. This may be an indication of a centre of speciation, but would need to be clarified further in order to be captured properly under this specification. However, it is probably unlikely the mound spring itself could be classified as a center of speciation.

3.8 Naturalness

Sites that met criteria 1-5 were assessed for naturalness. Those being, Swan Coastal Plain Suite, Three Springs Suite, Mandora Marsh Mounds, Willie Wetland Springs, Dragon Tree Soak, Kachana Springs and Carlton Hill Suite.

Of those suites, naturalness is most useful for assessing suites that do not have rigorous scientific surveying completed. Thus, while we do not know what biotic or abiotic diversity exists, we can assess whether they are largely in tact and the level of disturbance. Those with little biological data are also in the most inaccessible regions.

Brolga Spring and Kachana Springs would be captured under this specification.

Another approach would be to assess condition of springs. However, this would require an agreed approach for determining condition of aquatic ecosystems and the current paucity of information for all springs prevented this approach.

4. Results

Table 4: Moundsprings identified by each Criterion

Criteria	**Number of Suites that meet Criteria**
International Recognition	**1** - Mandora Marsh Mounds (all mound springs)
Representativeness	**3 -** Swan Coastal Plain, Three Springs and Kachana Springs
Diversity	**2** - Three Springs and Kachana
Distinctiveness	**6** – Swan Coastal Plain, Mandora Marsh Mounds, Willie Wetland Springs, Dragon Tree Soak, Kachana Springs and Carlton Hill Suite
Critical Habitat	**2** – Swan Coastal Plain and Mandora Marsh Mounds
Evolutionary History	**3** – Swan Coastal Plain, Mandora Marsh Mounds and Dragon Tree Soak.
Naturalness	Kachana and Carlton Hill (Brolga Spring)

Table 5: Justification for inclusion of Suites as HCVAE

Suites	Justification
Swan Coastal Plain	Best example of mound springs on shallow aquifer. The entire suite is on the national TEC (EPBC) list and has rare fauna (Southern Brown Bandicoot) listed under the EPBC Act with 2km of Egerton Spring. It has been cleared to a significant degree, has numerous bores feeding from its aquifer and hence the aquifer has shown declining water levels. The suite is thought to provide increasing refuge habitat for species due to climate change. This is especially true of the Gondwanan relict at Egerton. Egerton Spring is described as pristine. Egerton Spring also has the best buffer. All other mound springs have either a buffer for half their boundary or a very thin buffer. The whole suite has been chosen as it is all listed under the EPBC act.
Three Springs	Best example of mound spring on a Deep and Extensive aquifer and also where two aquifers overlay each other. It has 18 different family surveyed on it, which is one standard deviation from the mean. It is reported to appear to be a perennial moist habitat in a dry region for outlier species.
Mandora Marsh Mounds	Ramsar Site. The whole Mandora Marsh area has been surveyed for birds, there are numerous species with populations of over 20,000 and more relevant to critical habitat, this surveyed also showed bird breeding on site. A further survey in 1999, which netted birds over mound springs showed Black-winged Stilt to be utilizing the mound springs, which is part of their largest breed site. Under threat from grazing, water pumping and active mine tenements. The White Mangrove is considered to be a relict stand from when sea levels were higher and radio carbon dating shows active peat forming for 7000 years which indicates general climatic stability. All mound springs are buffered by surrounded marsh land.
Willie Wetlands Springs	There are operational bores on its aquifer, it is becoming increasingly under threat by the clearing for urban expansion of Broome and feral cats and foxes are reported to be affecting bird numbers. Due to the number of threats it was Distinctiveness. This site is fully buffered by surrounding vegetation.
Dragon Tree Soak	Dragon Tree Soak has a rare fauna on it. It has an active mining lease on it, trampling from camels and four fires over a ten year period. It is also regarded as a relict of the riverine vegetation found along the palaeo-river in the wetter of the early to mid Holocene. Carbon dating and pollen record indicate climatic stability. It has two relict species; *Typha domingensis* (bulrush) and Sesbania formosa (dragon tree). There is no aerial photography for this suite to check if it is buffered however it is very likely it is fully buffered.
Kachana Springs	Best example of a mound spring on a local aquifer. It has a species count of (89) which is more than to standard deviations from the mean (77). It has 70 different genus, which is more than one standard deviation from the mean. There have been six fires over a ten year period. Where it is most likely that the springs are, there have been nine fires over an 11 year period, cattle grazing, soil compaction, weeds and an active mining lease.
Carlton Hill Suite	There is threatened fauna within 1km of Brolga Spring. This is a mollusc. Relict species of snail are recorded for this area and are reported to occur in rainforested area. Brolga Spring is vegetated by rainforest. Brolga spring is fully buffered by surrounding vegetation. It is likely any other occurrences would be fully buffered also.

Seven out of the thirteen suites have been captured through the HVCAE criteria. Those being, Swan Coastal Plain suite, Three Springs suite, Mandora Marsh Mounds, Willie Wetland Springs, Dragon Tree Soak, Kachana Springs and Carlton Hill suite.

For Willie Wetlands and Dragon Tree Soak there is only one mound spring or mound springs are so close they are considered to be one site, therefore individual mound springs will not need to be chosen for these suites.

Brolga Spring is the one mound spring that is known from Carlton Hill and had rare fauna within 2km.

There is no need to pick an individual mound spring for the Mandora Marsh Mounds, as all have been selected due to fact they are part of a Ramsar site.

The whole of the Swan Coastal Plain suite is listed under the EPBC Act and therefore is identified as a HCVAE. If a single mound spring had to be chosen from within this suite, Egerton spring stands out as this had also both a rare fauna within 2km and a Gondwanan relict surveyed on it. Even though, this mound spring had the disadvantage of being on freehold land, it was still chosen as it was on the interim list of the national estate. It is also the second largest mound spring at 3.6ha.

Individual mound springs are not known from Kachana Springs and it is difficult to identify a particular one that meets HCVAE. This suite should be prioritized for further research.

The Three Springs suite consists of numerous separated mound springs so an analysis of each mound spring was conducted and a prioritization model established. MSTS 1 (not MSTS 01a, 01b and 01c) was chosen as this had the most number of aquatic invertebrate species present. This is also an example of a mound spring on both the deep and extensive aquifer and a local aquifer, so is identified as representative. However, it is important to note there is no dense buffer protecting this spring as some others still retain.

4.1 Mound springs that are captured by draft HCVAE criteria

Swan Coastal Plain (whole suite, best mound spring = Egerton Spring)
Three Springs (MSTS 1)
Mandora Marsh Mounds (whole suite)
Willie Wetland Springs (whole suite)
Dragon Tree Soak (whole suite)
Kachana Springs
Carlton Hill Suite (Brolga Spring)

5. Discussion

5.1 International Recognition

Criterion 1 was relatively straightforward to apply in identification of whether mound springs could be considered HCVAEs.

5.1.1 Usefulness of International Recognition Criteria

This criterion is advantageous as it is straight forward and not open to misinterpretation. The information on each of the convention sites was easily accessible and publicly available.

For a site to be listed under an international convention, it must go through a rigorous nomination assessment. It also must meet the internationally agreed criteria for listing. Therefore, if it can be demonstrated that a site meets these international criteria, it is important that they are listed as HCVAE.

5.1.2 Drawbacks of International recognition Criteria

The majority of mound springs that have been identified and remain in-tact in WA are concentrated in the Rangelands of WA. However, there is a substantial lack of data from these sites, as their remoteness makes them costly and sometimes difficult to survey. In order to be recognized under any of the above conventions, a site needs to have a substantial amount of research that supports the application of the listing criteria. For example, most of the sites that are currently listed under the Ramsar Convention rely heavily on bird data for criteria assessment. Therefore, if little biological data exists for a site due to its remoteness or the fact that extensive fish population data has not been collected, it will not be assessed for inclusion as a convention site and thus not be captured by this criterion. There is also often a long lag-time between sites that are recognised as candidate sites for nomination under international conventions due to meeting the listing criteria, and their actual nomination, due to protracted public consultation processes and lack of public support.

5.1.3 Recommendations of how the criteria of International Recognition should be applied in the future.

The issue can be partly solved by completing desk-top studies of which sites meet the listing criteria of international conventions and using these candidate lists to apply the HCVAE criteria 1. There is no short-term solution for assessing sites which lack the baseline data to apply the listing criteria for international conventions. The general recommendation would be that a standard protocol should be developed for prioritising data collection in wetland inventory projects that allows for comprehensive baseline survey of wetlands for meeting listing criteria of the three recognised international conventions/agreements.

5.1.4 Convention of Biological Diversity

The suites of mound springs on the Swan Coastal Plain and in Three Springs are fully consistent with the Convention of Biological Diversity. Criteria (a) of this convention states “Ecosystems that contain high diversity, large numbers of endemic or threatened species, or wilderness, that are required by migratory species that are of social,

economic, scientific or cultural importance, or that are representative, unique or associated with key evolutionary or other biological processes" are consistent with convention. Criteria (a) of the Convention on Biological Diversity has elements and standards in common with the HCVAE criteria and it may be useful to include "criteria (a) of CBD" under the HCVAE criterion for international recognition. The other criteria in this convention are not relevant in identification of HCVAEs

5.2 Representativeness

Representativeness was a complex criterion to apply for identification of HCVAEs. A number of bioregionalisation models were considered for applying this criterion. The most useful model was the mapped aquifer boundaries, as this described the hydrological connectivity the mound springs.

Other Considerations - IBRA Vs Climatic Regions Vs Drainage Division

5.2.1 IBRA

IBRA regions are based on rock, soil, vegetation and other terrestrial environmental aspects of a particular region. All mound springs in WA are vegetated. Therefore, if mound springs are representative of a particular IBRA region they will represent the certain biophysical attributes assigned to that region.

GIS tools were used to determine the mound springs present in each IBRA region. In order to have a mound spring representative of a larger and more appropriate geographic area, the use of IBRA (Australia) not sub IBRA (WA) was used.

For some IBRA regions, there was only one suite of mound springs. For example, the Three Springs suite is the only representative mound spring on the Geralton Sandplains. Likewise, the Swan Coastal Plain Suite is the only representative on the Swan Coastal Plain IBRA. For others, such as the North Kimberly and Dampierland IBRA, there are numerous suites present. Further analysis of individual moundsprings within these suites is required to select the best representative example.

5.2.2 Climatic Regions

Assessment of climatic regions, based on seasonal rainfall, illustrate the mound springs occurring in different wetter and dryer climates. Lower rainfall impacts on the amount of recharge to deeper ground water aquifers. If rainfall is very low, it suggests an increased threat exists from water abstraction activities and a potential for a decline in water levels of the aquifer. This is intensified by climate change. Classifying moundsprings according to climatic region illustrate suites in areas with increased recharge and climate threat.

GIS tools were used to determine the climatic region of each moundspring. There is an overlap within the Mandora Marsh Mounds Suite. Of the four mound springs that have been documented (there have been reports of up to 12 – Coote, pers. Comm. 2008) in this suite, two are within the summer dominant (350-650mm) climate and two within an arid climate. This would assist in prioritizing individual mound springs within this suite,

as the two in the arid zone are the only mound springs represented in that climatic region.

5.2.3 Drainage Divisions

There are four drainage divisions occurring in WA; the Timor Sea Division, the Indian Ocean Division, the South West Coast Division and the Western Plateau Division. They are primarily based on river basins and defined by both the major topographic features of Australia and the main climatic zones to give broadly homogeneous hydrologic regions. Again, GIS tools were used to determine the drainage division which suites occurred in.

An alternative to prioritising mound spring suites on how many other HCVAE criteria they met, their land tenure was used as a surrogate for level of protection afforded them and was considered a more practical method for prioritision. Mound springs on crown reserve were prioritised above springs on other tenure.

Seven mound spring suites were identified as representative by using IBRA as the bioregionalisation model and tenure as an overlay for identifying those under the highest level of protection. These were the Swan Coastal Plain suite, Three Springs suite, Kachana Spring, Carlton Hill Suite, Black Springs, Lollywell Springs and Dragon Tree Soak. All are on Crown Reserves or are the only represented suite in their particular IBRA.

By using Climatic Regions as the bioregionalisation model and overlaid with tenure for identifying those under the highest level of protection, five spring suites or parts of were identified as representative. These were Black Springs, Lollywell Springs and half of Dragon Tree Soak. Also, two mound springs within the Mandora Marsh Mounds suite, the Swan Coastal Plain suite and the Three Springs suite are prioitised as they are the only representation of mound spring within their particular climatic region.

Black Springs, Lollywell Springs, Swan Coastal Plain suite and half of Dragon Tree Soak are prioitised when using Drainage Division and Tenure. Half of Three Springs suite will also be prioritized as that is the only representative on the Indian Ocean Division.

Using Climatic Regions has the advantage of associating representativeness on a larger geographic region than either IBRA or drainage divisions. However, it has the disadvantage of climatic regions extending further past the WA state boundary than the other two models. As this trial has only examined mound springs that occur in WA, and since some climatic regions extend into the Great Artesian Basin (e.g. the Arid Climatic Region), there are more mound springs in other states in the same climatic region. Using this method introduces higher likelihood that innacurate representation is given unless data on a national scale is available.

Drainage Divisions extend over the boarder of WA but do not intercept where mound springs occur in other states. Using IBRA or Drainage Divisions over climatic region is

more accurate as they both incorporate biophysical characteristics of a region and reduce issues associated with not being able to access national datasets.

Groundwater does not always reflect surface water drainage and is therefore a more accurate method to apply the representativeness criteria for identifying moundsprings and all groundwater dependent ecosystems for HCVAEs. However, the accuracy of mapping layers for groundwater may be an issue in some regions and reason to use other bioregionalisation models. Three moundspring suites were identified as meeting the representative criteria using the mapping layer of groundwater systems in WA.

Table 6: Suites in relation to their IBRA, Drainage Division and Climatic Region

	IBRA	Drainage Division	Climatic Region
Swan Coastal Plain	Swan Coastal Plain	South West Coast	Winter Dominant (500-800mm)
Three Springs	Geraldton Sandplains	Indian Ocean (ex. one in South West Coast)	Winter Dominant (250 – 500)
Mandora Marsh	Great Sandy Desert	Western Plateau	Summer Dominant (350 – 650mm)
Dragon Tree Soak	Great Sandy Desert	Western Plateau	Summer Dominant (350 – 650mm)
Willie Springs	Dampierland	Timor Sea Division	Summer Dominant (350 – 650)
Bunda Bunda	Dampierland	Timor Sea Division	Summer Dominant (650 – 1200)
Lollywell Springs	Dampierland	Timor Sea Division	Summer Dominant (650 – 1200)
Disaster Bay	Dampierland	Timor Sea Division	Summer Dominant (650 – 1200)
Big Springs	Dampierland	Timor Sea Division	Summer Dominant (650 – 1200)
Black Springs	North Kimberly	Timor Sea Division	Summer Dominant (650 – 1200)
North Kimberly Mounds	North Kimberly	Timor Sea Division	Summer Dominant (650 – 1200)
Kachana	Central Kimberly	Timor Sea Division	Summer Dominant (650 – 1200)
Carlton Hill	Victoria Bonaparte	Timor Sea Division	Summer Dominant (650 – 1200)

Table 7: Summary of moundspring suites in relation to their IBRA, Drainage Division and Climatic Region

Bioregionalisation	Number of Prioritized Suites
IBRA & Tenure	7
Climatic Regions & Tenure	6
Drainage Division & Tenure	5
Groundwater Regions	3

5.2.4 Integrated Marine and Coastal Regionalisation of Australia (IMCRA).
This spatial framework for classifying Australia's marine environment into bioregions is not usefull as it does not extend inland to cover the majority of Mound springs.

5.2.5 Usefulness of Representativeness Criteria
The representaiveness criteria is relatively straightforward to apply using GIS datasets. Whilst relying on accuracte GIS layers, the criteria did not require a lot of records or biological data on the sites to apply the first step of this criterion.

5.2.6 Drawbacks of Representativeness Criteria
Ecosystems at the interface of land and marine environments may not be captured accurately with separate IBRA and IMCRA bioregionalisations. This is the case with the Mandora Marsh Mounds and Brolga Spring.

The Ramsar classification method, leads to all mound springs being classified as one type. All mound springs within a suite may not be exactly the same and springs within the suite need to be prioritized for HCVAE. Likewise, all suites may not be the same (some have tidal interflats, some wholly ground water fed). Western Australia and other states of Australia have their own typologies for mound springs. There is no coordinated method for cross application of separate typologies. For example, there are sub-divided recharge and discharge mound spring groups in eastern Australia, but all are on the one aquifer system, while in Western Australia there is one classification of suites of mound springs, but they occure on differentiated aquifers. There are also no super-groups of springs in Western Australia. The eastern classification is not appropriate for mound springs in Western Australia. This makes comparisons on a continental scale difficult. More detailed and nationally agreed classification methods are needed for mound springs.

Choosing the most representative suite of an aquifer based on how many other criteria it meets has difficulties. The suites that meet more than two criteria are those that have extensive research already conducted on them. Therefore, the most representative example may not necessarily be the best example; but reflect those sites that have the most research data available. This may be omitting those sites that have higher biodiversity values from being identified as a HCVAE.

To obtain a more accurate assessment of national representativeness, this criteria would need to be applied to all mound springs in Australia. Mound springs in eastern Australia are all on a deep and extensive aquifer system and this may effect the application of this criteria.

5.2.7 Recommendations of how the criteria of Representativeness should be applied in the future

Choosing the best representative moundspring suite by assessment of how the other criteria were met on that type of aquifer, was the option chosen as no alternative was

given. Guidance should be given as to how the best representative example could be chosen irrespective of the other criteria. A condition analysis would be beneficial. This could be possible using wetland indicators. For example with mound springs, flow rate, temperature, salinity, inundation, species richness and / or indicator species could be assessed as indicators of mound spring condition. If condition analysis was adopted, there would be a need to ensure more degraded but yet bioregionally important mound springs would not be omitted. It would also require some baseline studies of mound springs. Further classification of some aquatic ecosystem (for example fresh water ecosystems) is essential for a more comprehensive implementation of this criterion.

5.3 Diversity

5.3.1 Usefulness of Diversity Criteria

This criterion is effective where biological data is available for sites and most accurate where approxiamately equivalent amounts of data have been collected at sites. Using means and standard deviations as discriminators reduces some of the subjectivity in criteria application, but is still reliant on many assumptions regarding data collection protocols and homogeneity of data.

5.3.2 Drawbacks of Diversity Criteria

Using two standard deviations from the mean yielded a very high numerical threshold. Applying the diversity criteria using survey data from mound springs involved comparing data on mound springs that had extensive survey with survey data from mound springs that had limited work completed on them. This invariably leads to issues of a lack of data homogeneity. For example, one mound spring (on Kachana Springs) had a very high species count, when compared to all other mound springs. It is not known if this is due to actual higher diversity or other factors such as the time of year of sampling. The unusually high species richness at this site brought up the mean and standard deviation, which lead to no other mound springs being captured under this application. If it simply has a higher diversity, then this is an advantage, but if it has a higher species count due to other factors, then other mound springs may be omitted due to other factors.

The mean and standard deviation was calculated from data on mound springs in Western Australia. For a national mean and standard deviation of species to be calculated, it would require data from sites in eastern Australia.

This criterion requires that biological data has been collected and it is difficult to capture the sites through this criterion that have not as yet had survey work conducted on them.

5.3.3 Recommendations of how the criteria of Diversity should be applied in the future

It is not possible to comment on recommendations for the first two specifications of this criterion, as they were not applicable to mound springs.

For the specification of higher diversity at higher taxonomic levels, one standard deviation from the mean is adequate. If two standard deviations were used, a numerical

threshold would be established that is too high and would not capture any sites. One standard deviation from the mean may suffice for diversity of species also.
Alternative numerical calculations should be devised and tested. Preferably, these calculations would incorporate number of possible sites, the number of actual sites with data and species richness and take into account of variable data homogeneity.

5.4 Distinctiveness

5.4.1 Usefulness of Distinctiveness Criteria

Applying the specification for EPBC listed species was relatively simple. Site reports were not required in order to apply this specification. This was also the case with analyzing the majority of threats. GIS datasets were available with information of most threats, for example fire scar coverage and bore sites.

The EBPC Act is widely used in Western Australia and is a good basis for listing of species and communities. It is a useful application method for this criterion.

5.4.2 Drawbacks of Distinctiveness Criteria

Although analysis of threats is very relevant to management of HCVAE sites, it should not be considered a specification for a site being listed as HCVAE. Sites should be listed primarily on their natural attributes and then once listed, managed with a focus on threats.

A high number of sites are identified using threats as an application of distinctiveness. Part of the reason for this is the majority of mound springs occur in the highest fire effected and grazed areas. Six suites have been captured by this criterion. These were sites with 3 or more threats. If a site was captured because it had one threat, all of the suites would have been captured. However, one significant threat could lead to the destruction of a mound spring. The severity of these threats needs to be captured.

The majority of mound springs did not have enough information to meet any of the specifications laid down in this criterion. This is especially prevalent as the only relevant fauna data was for aquatic invertebrates and there is a general lack of knowledge on their population numbers, distribution and trends in Western Australia. There is also substantially extra rare flora and fauna mapped on GIS for the South West and Wheatbelt regions of Western Australia than there is for the Rangeland region. Although this does reflect increasing loss of species due to land use pressures, it is also another sign of less survey work conducted in the this region.

5.4.3 Recommendations of how the criteria of Distinctiveness should be applied in the future

If threats continue to be a specification for distinctiveness, this needs to be refined. A number of threats need to be agreed as well as guidance provided on how the severity of each threat should be assessed. However, the analysis of threats should be considered after a site has already been classified as HCVAE, not in the initial nomination process.

Guidance needs to given on the definition of ecosystem types for this specific criterion. Mound springs can have an assemblage of plants associated with the top of the mound, and a different assemblage on the base of the mound (moat), these systems can feed into creeklines which feed into a marsh areas. While these can be small in scale, they are often critical habitat areas. In a national context, the importance of scale will need to be identified.

5.5 Critical Habitat

There was very little relevant information on mound springs to apply this criterion.

5.5.1 Usefulness of Critical Habitat Criteria

The specification for supporting species in time of stress captures mound springs, as mound springs provide permanent moist habitat in semi-arid dry region. This becomes especially important in conditions such as drought and may also indicate sites that will be significant for Climate Change. In turn, this reflects the usefulness of this specification in capturing ground water dependant systems, as the water source isn't as dependant on current whether patterns.

5.5.2 Drawbacks of Critical Habitat Criteria

A bird count of 20,000 is too high for use as a discriminator of mound spring sites, and an alternative regional calculation is required. However, the alternative calculation suggested was impossible to apply due to lack of reliable population counts. The same is applicable for analysing 10% of a species assemblage or community.

Only two suites have been captured under this criterion (Swan Coastal Plain Suites and Mandora Marsh Mounds). This is due to the fact that a lot of survey work has been conducted at these sites . If this were not the case, no suite would be captured through this application of the criterion.

5.5.3 Recommendations of how the criteria of Critical Habitat should be applied in the future

This application of this criterion needs extensive development, particularly for smaller sites. The habitats of outlier species should be included. Mound springs in the Kimberly are habitats for species more common in the south west or even other states but this is not being captured fully by the current specifications for application. Guidance should be provided on relevant population numbers for other fauna, such as aquatic invertebrates.

The specification for supporting species in time of stress is the only specification in all the criteria that in some way addresses climate change. The impacts of climate change on aquatic ecosystems needs to be weighted more in the criteria specifications.

5.6 Evolutionary history

5.6.1 Usefulness of Evolutionary History Criteria

This criterion was beneficial as a discriminator of moundspring sites as it included a specification for "living fossils". As mound springs are fed by deep groundwater sources, and exist on aquifers dating back to the Cretaceous and Jurassic eras, they contain

living relicts. These relicts were not captured elsewhere. This has the added benefit of listed mound springs with living relict being prioritised.

5.6.2 Drawbacks of Evolutionary History Criteria

Evolutionary History is a complimentary criterion. However, it requires a large amount of survey work and information to have been conducted on a site in order to be captured by this criterion. It requires more information than some of the essential criteria.

5.6.3 Recommendations of how the criteria of Evolutionary History should be applied in the future

5.7 Naturalness

5.7.1 Usefulness of Naturalness Criteria

In theory, this is a beneficial criterion and will add to the ability to discriminate between groundwater dependent ecosystems for identification of HCVAEs. If a site is on the borderline for listing and meets this criterion due to its remoteness, it could be used to compensate for a paucity of information on the site.

5.7.2 Drawbacks of Naturalness Criteria

As Naturalness is only being assessed on sites that meet criteria 1-5, it is not capturing poorly known or unknown features or species. The majority of suites that meet criteria 1-5 are those with information available on them. Those mound springs that are poorly known or unknown are not captured through criteria 1-5, therefore will not be captured by the criterion of naturalness.

5.7.3 Recommendations of how the criteria of Naturalness should be applied in the future

Guidance should be provided on a more specific approach to assessing naturalness.

5.8 GIS

There are discrepancies when using GIS.

1. There are two moundspring suites (Kachana Springs and the Carlton Hill Suite) that are known to exist from early survey work in the Kimberley. However, the exact location of individual mound springs within these suites are not known. In order to represent these sites in the GIS system, the property boundary was used as the surrogate location. This is problematic for assessment for presence of rare flora / fauna. There is rare flora within the property boundary of Carlton Hill but whether these floras are within 100m of the actual mound springs is not known.

2. The majority of sites plotted on the GIS system were plotted by use of TEC polygons and latitudes and longitudes in technical reports. Some of the TEC suites and mound springs (e.g. Mandora Marsh Mounds) were estimated through use of aerial photography. The latitudes and longitudes within reports are not always correct. Therefore, there may be some site boundaries that are not accurate.

3. Some suites (e.g. Lollywell Springs) have mound springs very close to each other. An overall polygon was used in these cases.

4. Using GIS to determine if a suite has certain attributes (for example rare flora and fauna or bores) has limitations. This type of GIS information relies also on available data. Hence, there will be more flora and fauna plotted for the Swan Coastal Plain that for the Kimberly as there has been more surveys on the Swan Coastal Plain.

5.9 Aerial Photography

There is very limited aerial photography for Western Australia. This causes numerous problems such as determining the boundary of sites and determining if there is a vegetated buffer around a site. Seven whole suites do not have any aerial photography relating to them.

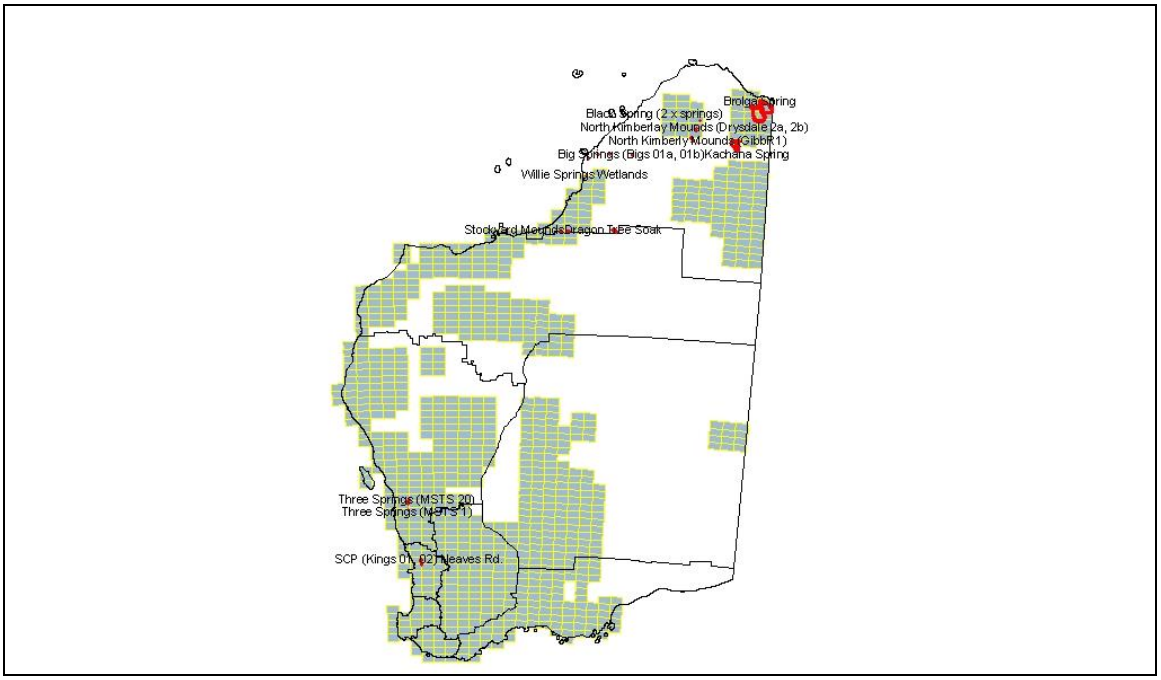

Figure 3 Extent of Aerial photography cover for mound springs in WA

5.10 Connectivity

It is important to look at landscape connectivity and / or hydro connectivity. This is in relation to analysis of threats under Distinctiveness. If a mound springs feeds into a creek (or vice versa), which feeds into a river, a full analysis of threats for that whole system should be analyzed. For example, the Three Springs suite flows into a creek which flows into Arrowsmith River. If there is a pollution leak into the river, this should be captured as a threat.

Commander (2003) found that land use changes such as farming practices influenced recharge even more than declining rainfall. This makes including connectivity increasingly important.

5.11 Species data

As highlighted by the Three Springs report, there is a lack of expertise to identify some of the invertebrates. Unless this expertise is found, trying to classify mound springs as HCVAE will continue to be problematic. For example, in the surveys completed on the Three Springs suite, the poor taxonomic understanding of bahtynelids meant that species determination was not possible. This is further complicated by the fact that there are not many comparable invertebrate studies to compare findings to. In general, too little is known about the biology and ecology of a mound spring communities.

5.12 Choice of listing a suite or an individual mound spring

Pinder and Pennifold (2001) concluded for invertebrate species at Three Springs that "although it is unlikely that any element of this subset is restricted to these particular springs, taken together they form a suite that may not occur in other aquatic habitats". This highlights the interdependence of mound springs within a suite. Most available information is on whole suites and not individual mound springs. It is then questionable whether a whole suite should be identified for listing and not just an individual mound spring. If this is followed, it would potentially lead to the listing of over 55 individual mound springs instead of the current 24.

6. Conclusion

In conclusion, the draft HCVAE criteria do capture ground water dependant ecosystems once there is appropriate individual site information for those systems. Through the application of the draft criteria, seven suites or mound springs have been highlighted for inclusion as HCVAE sites.

However, this trial did not have access to national datasets and application of some criteria did not include analysis on a national scale. For instance criteria 2, Representativeness and criteria 3, Diversity require national datasets to accurately apply them in identification of national HCVAEs. It follows there is a need to establish better linkages between datasets from the whole of Australia, including mapping so that trials can be conducted on a national level. Also, further classification of certain aquatic ecosystems, such as ground water dependant ecosystems needs to be agreed on a national level so that the continental extent of similar ecosystems is easily identifiable.

Some terminology needs to be agreed on including moundspring and aquifer typology. This was made evident through the analysis of mound springs. It was difficult to know if a super-group of mound springs in eastern Australia was similar to a suite of mound springs in Western Australia and vice versa. This hindered making comparisons on a national level.

All would be captured if relevant information as for Swan Coastal Plain suite and Mandora Marsh Mounds was available. If a site initially is considered appropriate for HCVAE listing but there is not enough survey work completed funding should be made available to facilitate this.

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Appendix 1 – Individual Site Assessments

Name of Suite: Swan Coastal Plain

Details of available information on this suite:

- TEC Database
- National TEC Site Description
- GIS System.
- English, V. and Blyth, J (2000) *Suites of Organic Mound (Tumulus) Springs of the Swan Coastal Plain – Interim Recovery Plan 2000-2003* Perth, Western Australia
- Department of Conservation and Land Management (2006). *Community of Tumulus (organic mound) springs of the Swan Coastal Plain Interim Recovery Plan 2005-2010. Interim Recovery Plan No. 198*. Perth, Western Australia
- Jasinska, E.J. and Knott, B. (1994) *Aquatic Fauna in Gnangara Mound discharge areas of the Ellen Brook catchment, Western Australia.*
- Pinder, A. (2002) *Report on December 2002 sampling on Gnangara Mound Springs.*
- May, J.E. and McKenzie, N.L. (2002) *A Biodiversity Audit of Western Australia's 53 Biogeographical Sub regions in 2002*. Calm

Accuracy of GIS site:
Poor – good

Number of mound springs known to occur within the suite:
5 – One is very new so not in documentation.

International Recognition: No
Is this suite listed under any of the three international conventions? - No it is fully consistent with the Convention on Biological Diversity.

Is it a proposed site for any of the three international conventions? - No.

Representativeness: Yes
What type of aquifer is the suite on? - Shallow aquifer – surficial sediments.
On the Gnangara mound, an extensive unconfined aquifer.

How many other suites are on this type of aquifer? - There are four other suites on shallow aquifers.

How many other criteria does the suite meet? - 3.

Does this site meet more other criteria that any other site on this aquifer? - Yes.

Diversity: No
Does the suite have a species diversity (specify index) that exceeds the expected diversity or is more than 2 standard deviations from the mean? - No; the invertebrate

species count for the Suite of the Swan Coastal Plain is 43, this is above the mean but below two standard deviations from the mean.

Does the suite have a higher diversity of taxa at higher taxonomic levels (genus, family)? - No, the number of different genus, families and orders surveyed didn't reach above one standard deviation from the mean.

Distinctiveness: Yes
Is the suite on the national TEC List? - Yes, this community is listed under the Commonwealth's EPBC Act 1999 as 'endangered'.

Has the suite any rare fauna protected under the EPBC Act? - Yes, Egerton Spring has a vulnerable mammal with 1.3km of it, which is the Southern Brown Bandicoot *Isoodon obesulus.* It also has a priority (P5) fauna within 1km. Another mound spring within this suite (Alpace01) has a priority (P3) fauna within 1.1km.

Has the suite any rare flora protected under the EPBC ACT? - No: The Swan Coastal Plain suite has numerous rare floras within 2km of the mound springs but none of the flora was close enough to be deemed reliant on those mound springs.

Is the suite on a tidal flat? - No.

Is the suite consisting of both raised and flat mounds? - No.

Has the suite been lost to a significant degree nation-wide? - Yes; Clearing. The SCP Suite is in an IBRA (Australia) region that is classified as having the second highest percentage of vegetation loss.

Is the suite an uncommon type that is specifically under threat, resulting in decline in occurrence or condition, nation-wide? – Yes, cattle grazing and infilling of some mound springs with limestone for pastoral use. Historically, the suite of mound springs was widespread within their narrow range. 97% of vegetation has been cleared on the Swan Coastal Plain. There is increasing fragmentation, loss of remnants and lack of recruitment. Since 1976, there has been a trend of falling water table in general on the Gnangara mound. There is a corresponding decline in rainfall. There are numerous bores on the Gnangara Mound. There is proposed clearing of vegetation and possible leveling of the dune west of The occurrence at Ellen brook, as part of a residential development, has the potential to alter the hydrology of this mound spring area Gymkhana event that occurs adjacent to Meechin 01, Bullsbrook has the potential to adversely impact water chemistry, only 45meters away. There is some weed encroachment; King 01, 02 Neaves Road is relatively free of weeds. There has also been a changed fire regime.

Critical Habitat: Yes
Is the suite important for the life cycle of a species? – Yes, some of the species do not have dormant stages and would die out if the mound dried. This is the case of the

identified amphipod (Jasinska and Knott 1994) that is a Gondwanic relic. This was found in the mound spring at Egerton.

Does the suite support at least 10% of a dependant species suite or community? - Not enough Information.

Is the suite providing habitats to species in time of stress? – Yes, most flora and fauna on these mounds are adapted to permanently moist habitat, the mounds are thought to provide increasing refuge due to climate change (drying) for certain species.

Evolutionary History: Yes
Is the suite a habitat for unusually high diversity of endemic taxa with limited geographical distribution? - Not enough information, the geographical distribution of macro-invertebrates unknown.

Is the suite habitat for a diversity of taxa endemic at higher taxonomic levels (genus or above)? - No.

Is the suite habitat for a group of endemic species suggesting a centre of speciation? - No.

Is the suite habitat for a sequence of related taxa indicative of evolutionary process? - No.

Is the suite habitat for iconic species recognized as “living fossils”, relictual species that appear as key links in evolution? – Yes, the permanent moist habitat may provide refuge for fauna that historically has a wider distribution, consequently, relict species may be protected from climate change and survive in these mounds. Three of the sites contain different species of Gondwanan relict endemic to the site, these are known from nowhere else. Aturdia; Notoaturinae gen. nov. sp. – Gondwanan relict known only from the mound spring at Bullsbrook; Anisitisiellidae; anisitisirlledae sp. Nov. – gondwanan relict known only from Peters tumulus springs.

Naturalness
Its condition is described as good – recovery would occur in the short to medium term with minimum intervention.

Other relevant Information:

Size	EG 01 – 3.6ha
	Peters 01 – 1.2ha
	Meechin 01 – 1ha
	Kings 02 – 6ha
	Nursery 01 – 2ha
	Alpace 01 – 1.2ha

Interesting Flora surveyed? - Outlier species recorded that usually only occur in the South West Australia.
Hibbertia perfoliata is especially significant as it was taught to be extinct on the Swan Coastal Plain. It is believed to require permanently wet habitats that are relatively undisturbed.
Kings 01, 02 Neaves Road is weed free.

Interesting Fauna surveyed (including invertebrates)? - Although there is a high level of heterogeneity in the fauna associated with mounds, common groups include Ostracoda, Nematoda, Acarina, Amphipoda, Cladocera, Copepoda, Decapoda, Oligochaeta, Annelida, Tardigrada, Turbellaria and Insecta.

What is the Tenure of the suite?
Peters 01 – Crown Reserve
Kings 01 – Half Crown Reserve, half freehold
Meechin 01, Nursery 01, EG01 and Alpace 01 freehold.

What IBRA does the suite belong to? - Swan Coastal Plain

What Climatic Region does the suite to? - Winter Dominant (500-800mm).

Is the suite listed on the state TEC List? - Yes

Is it listed on state PEC list? - N/A

Range of Community? - Narrow endemic, total range < 500 square km or 100 km linear

What is the lithology of the suite? - Sand over Gravel.

What is the geological age of the aquifer of the suite? - Quaternary over Cretaceous over Jurassic

What type of water is in the suite? - Fresh

Is the suite a raised tumulus spring (mound spring)? - Yes

Comments on suite:
Full aerial photography available and extensive GIS datasets

Does this Site meet the Criteria for inclusion as a HCVAE?
Yes
Which mound spring should be listed as HCVAE and Why?
Whole suite as it is all listed under EPBC Act. Egerton spring has a rare fauna within 1km and has a Gondwanan relict.

Name of Site: Three Springs

Details of available information on the suite:

- TEC Database
- GIS System.
- Pinder, A. and Pennifold, M.G. *A Survey of Aquatic Invertebrates of Some Organic Mound Springs in the Shire of Three Spring, Western Australia.*
- Pinder, A., Stratford, L. and McRae, J. (2006) *Report on August 2001 sampling of invertebrate suites at mound springs of the Three Springs area.*
- Rees, R. and Broun, G. (2005). *Suites of organic mound springs of the Three springs area interim recovery plan 2005-2010*

Accuracy of GIS site:
The Three Springs Suite was plotted with the aid of TEC polygons. The boundary accuracy for each mound spring is good – very good. They were firstly identified using aerial photographs and then site visited to confirm occurrence.

Number of mound springs known to occur within the suite: 34

International Recognition: No
Is this suite listed under any of the three international conventions? - No; It is fully consistent with the Convention on Biological Diversity.

Is it a proposed site for any of the three international conventions? - No.

Representativeness: Yes
What type of aquifer is the suite on? - The Three Springs Suite is unique in a sense that it covers two different aquifers; Deep and Extensive – Sedimentary Rocks and Local Aquifers - Rocks of Low permeability, fractured and weathered rocks. This is the only suite that consists of both of these aquifers. It is most probable that the mound springs are all fed from the Deep and Extensive aquifers but is just intersected by an overlaying local aquifer. It is still the only suite that has this occurring.

How many other suites are on this type of aquifer? - 0 – there are 4 other suites on Deep and extensive aquifers and 3 other whole suites on local aquifers.

How many other criteria does the suite meet? - 2

Does this site meet more other criteria that any other site on this aquifer? - Yes

Diversity: Yes
Does the suite have a species diversity (specify index) that exceeds the expected diversity or is more than 2 standard deviations from the mean? - No; the representative mound spring has a specie count of 49, which is not above two standard deviations from the mean.

Does the suite have a higher diversity of taxa at higher taxonomic levels (genus, family.)? - Yes; surveys show there is 18 different families on this suite, which is one - standard deviation from the mean.

Distinctiveness: No
Is the suite on the national TEC List? - No.

Has the suite any rare fauna protected under the EPBC Act? - No.

Has the suite any rare flora protected under the EPBC ACT? - No; MSTS 15a) is within 300m of a rare flora, but this was not deemed close enough. This site does have a buffer of 220m, which if included means this rare flora is only 150m away.

Has the suite been lost to a significant degree nation-wide? – N/A

Is the suite an uncommon type that is specifically under threat, resulting in decline in occurrence or condition, nation-wide? - Yes; The suite is within an IBRA (Australia) region that is classified as having the third highest percentage of vegetation loss. Clearing – 80.3% of the shire of Three Springs has now been cleared for agriculture. Some of the mound springs has been converted to dams or completely cleared. There was originally 23 mound springs in the suite, there are now only 17 remaining. The range is reduced by 40-70% since European settlement. Hydrological Change – there are 2 DoA groundwater monitoring sites installed in the recharge area east of the mound springs, both of which are within the same basin subdivision as the mound springs. These both show a rise in groundwater; it is under significant artesian pressure.

Critical Habitat: Yes
Is the suite important for the life cycle of a species? - No.

Does the suite support at least 10% of a dependant species suite or community? - N/A

Is the suite providing habitats to species in time of stress? - For the northern outlier species, the mound springs appear to provide a perennially moist refuge in a dry region. Ideally, an extra study would be done to prove this.

Evolutionary History: No
Is the suite a habitat for unusually high diversity of endemic taxa with limited geographical distribution? - Not enough information – the geographic distribution of macro-invertebrates is unknown.

Is the suite habitat for a diversity of taxa endemic at higher taxonomic levels (genus or above)? Not enough information.

Is the suite habitat for a group of endemic species suggesting a centre of speciation? - Not enough information.

Is the suite habitat for a sequence of related taxa indicative of evolutionary process? - Not enough information.

Is the suite habitat for iconic species recognized as “living fossils”, relictual species that appear as key links in evolution? - No.

Other relevant Information:
Size? - Most mound springs between 0.5 and 3ha. The largest being 18ha.

Interesting Flora surveyed? - Three priority flora – *Dryandra stricta* (P3), *Eucalyptus diminuta* (P3), *Thomasia formosa* (P1).

Interesting Fauna surveyed (including invertebrates)? - Most groundwater invertebrates surveyed were at TST01 and TST03. Bathynellids surveyed in TST01 were in poor condition but those in TST 03 were not described species. So far, no bathnellids surveyed in Western Australia expect for south west and some taught to have restricted populations. Therefore, these mound springs may represent an outlier habitat for species of invertebrates that otherwise only occur in the South West. The suite supports a diverse suite of aquatic invertebrates, including some surface species which appear to be uncommon or absent in other types of aquatic habitats. There are several invertebrate groups (Polypedilum, Archaeosynthemis, Paracyclops, harpacticiod copepods, Candona and Aeolosoma).

What is the Tenure of the suite? - Crown Reserve and Freehold.

What IBRA does the suite belong to? - Geraldton Sandplains

What Climatic Region does the suite to? - Winter Dominant – 250-500mm.

Is the suite listed on the state TEC List? - Yes.

Is it listed on state PEC list? - N/A.

Range of Community? - Very narrow endemic community, total range <50 square km or <20 km linear.

What is the lithology of the suite? - Sand, Sandstone and Undifferentiated Extensive Sedimentary.

What is the geological age of the aquifer of this suite? - Cretaceous.

What type of water is in the suite? - Fresh.

Is the suite a raised Tumulus spring (mound spring)? - Yes.

Comments on suite:

Occurrences MSTS01, MSTS 02, MSTS 05, MSTS 11, MSTS 13 and MSTS 14 are also surveyed for invertebrates; the remaining mound springs have yet to be surveyed. The majority of species were found at MSTS 01. However, this property is not on reserve but on private property. It has been fenced and is in good condition (IRP Three Springs) but is also close to the track. TST01, TST 03 and TST 05, which are geographically close to each other have the highest species richness.

Does this Site meet the Criteria for inclusion as a HCVAE?
Yes

Which mound spring should be listed as HCVAE and Why?
Spring MSTS 01 because it has more diversity of species, is fenced and considered in good condition.

Name of Suite: Mandora Marsh

Details of available information on the suite:

1. DIWA Site Description
2. TEC Report
3. TEC Database
4. Graham, G. (1999) *A Land Management Assessment of Mandora Marsh and it's immediate surrounds*
5. Watkins, D. Brennan, K., Lange, C., Jaensch, R. and Finlayson, M. (1997) *Management Planning for Ramsar Sites in the Kimberly region of Western Australia : Report to the Dept. of Conservation and Land Management*
6. Storey, A., Halse, S.A. and Shiels, R. (2000) *Aquatic Fauna and Water Chemistry.* In : A Land Management Assessment of Mandora Marsh and its immediate surrounds.
7. GIS System
8. May, J.E. and McKenzie, N.L. (2002) *A Biodiversity Audit of Western Australia's 53 Biogeographical Sub regions in 2002*. Calm

Accuracy of GIS site:
The boundary information for the suite is poor. The area accuracy of most mound spring boundaries is + / - 2-5 ha.

Number of mound springs known to occur within the suite: 15

International Recognition: Yes
Is this suite listed under any of the three international conventions? - Yes; it is a listed under the Ramsar Convention. Mandora Marsh (which includes the 15 mound springs) is part of the Eighty Mile Beach Ramsar Site.

Is it a proposed site for any of the three international conventions? - N/A

Representativeness: No
What type of aquifer is the suite on? - Shallow.

How many other suites are on this type of aquifer? - 4

How many other criteria does the suite meet? - 1.

Does this site meet more other criteria that any other site on this aquifer? - No

Diversity: No
Does the suite have a species diversity (specify index) that exceeds the expected diversity or is more than 2 standard deviations from the mean? - Not enough information on invertebrates.

Does the suite have a higher diversity of taxa at higher taxonomic levels (genus, family)? - Not specifically mound springs but Mandora Marsh has high number (Graham, G. 1999).

Distinctiveness: Yes
Is the suite on the national TEC List? - No.

Has the suite any rare fauna protected under the EPBC Act? - No.

Has the suite any rare flora protected under the EPBC ACT? - No.

Has the suite been lost to a significant degree nation-wide? - No, it is in an IBRA (Australia) region that has the lowest loss of pre-European vegetation.

Is the suite an uncommon type that is specifically under threat, resulting in decline in occurrence or condition, nation-wide?

- Subject to periodic cyclonic events
- The majority of the suite is not under a significant threat from fire. Six of the mound springs had not been subject to fire over the last 12 years. Mound spring 5 has had 2 fires since 1998 and is only 230m away from the 1997 fire scar.
- Anna Plain 01, Anna Plain 02, Stockyard Mounds, Fern Spring and Melaleuca Spring are all on land that has mine tenements. This tenement is a license to explore and its status is pending. Future impacts from mining are clearing of vegetation, soil compaction, dust, introduction of weeds and diseases, increased risk of fire and contamination from hazardous products. There are also lined scars from mineral exploration conducted in the 1960's.
- As most of Mandora Marsh is on Crown Lease Pastoral Station (85%), the main land use of there is cattle production. Only 40% of the land on the pastoral station is fenced. The mound springs are also a source for cattle to drink from. Saunder Springs, Grants Spring and Fern Spring are affected most by this. Saunders Springs has been fenced and is reported to be recovering nicely.
- There is also one tourist operator who uses the mound springs but this is on an occasional basis.
- There are six bores on the site, each actively pump water. These are located around the western clay pan. These are located on the same aquifer as the whole suite, which is a shallow aquifer.
- soil Compaction

Critical Habitat: Yes
Is the suite a major location for very large numbers of individuals (e.g. 20,000 water birds), either one species or a number of species? - Yes; the Mandora Marsh Suite was surveyed in 1999 an 2000 for water birds. It was estimated in the two surveys to support 480,000 and 490,000 +/- 40,000 and 50,000 respectively. This was a survey of the whole Mandora Marsh and not just mound springs, therefore it is possible to say the suite meets this specification but not possible to say individual mound springs do.

Species with counts above 20,000 were:

- Black-winged Stilt *Himantopus himantopus*(180,000 and 220,000)
- Small Terns (mostly whickered) *Sterna nilotica, S. caspia, Chlidonias hybridus* (110,000)
- Hardheads *Aythya australis* (100,000)
- Straw-necked Ibis *Threskiornis spinicollis* (50,000)
- Eurasian Coots *Fulica atra* (40,000)
- Glossy Ibis *Plegadis falcinellus* (25,000)

A further survey in 1999, which netted birds over mound springs showed Black-winged Stilt to be utilizing the mound springs. The whole suite is estimated to be the largest breeding site in Australia for the Black-winged Stilt.

Is the suite important for the life cycle of a species? - No; the fore-mentioned survey also showed over 27 species of water birds breeding on site. It is estimated to be the largest breeding site in Australia for the Black-winged Stilt, Whiskered Tern, Gull-billed Terns and Hoary-headed Gebes. There is also a nesting colony of Pelicans which is significant on a national scale. Again, actual mound springs are not thought to be the habitat that these birds seek the most.

Is the suite a place that is most used by migratory birds at a regional scale? - The mound springs *may* provide temporary habitat for water birds moving within Australia (Watkins, D. Brennan, K., Lange, C., Jaensch, R. and Finlayson, M. (1997).

Does the suite support at least 10% of a dependant species suite or community? - Nearly 70% of Black Swan nested at Mondora Marsh in 1999 (Halse, S.A. 2005). Again this stat applies to whole marsh not just to mound springs.

Is the suite providing habitats to species in time of stress? - According to Watkins, D. Brennan, K., Lange, C., Jaensch, R. and Finlayson, M. (1997), the mound springs “may be an important drought refuge area for fauna of the Great Sandy Desert.

Evolutionary History: Yes
Is the suite a habitat for unusually high diversity of endemic taxa with limited geographical distribution? - Not enough Information.

Is the suite habitat for a diversity of taxa endemic at higher taxonomic levels (genus or above)? - Not enough information.

Is the suite habitat for a group of endemic species suggesting a centre of speciation? - Not enough information.

Is the suite habitat for a sequence of related taxa indicative of evolutionary process? - Not enough information.

Is the suite habitat for iconic species recognized as “living fossils”, relictual species that appear as key links in evolution? – Yes, the White Mangrove *Avicenna marina* stand is thought to be a relict stand from when sea levels were higher. Besides Lake MacLeod, this is the only other inland stand of this species in WA. Radio carbon dating show active peat forming for 7000 yrs indicating general climatic stability. The site has been used to study climate change.

Other relevant Information:
Size; - The Mound springs vary from 0.1ha to several hectares

Interesting Flora surveyed? - The suite is at the interface of Beards vegetation provinces of the Northern Botanical Province and Eremaean Botanical Province.
The presence of White Mangroves *Avicenna marina* along the salt creek is 40km from the sea, which is a rare distance. The trees grow 4m high on a creek that is not connected to the sea. It was suggested that this is a relict stand. Further surveys found other isolated stands of White Mangrove, but it is the stand at Stockyard Springs that has the highest and most dense population and are thought to nationally and internationally significant (Graham, G. 1999). There is also paperback *Melaleuca argentea* and white dragon tree *Sesbania Formosa* on the freshwater soaks, which are clearly distinguishable vegetation structure in the landscape.

Interesting Fauna surveyed (including invertebrates)? - There was a short survey conducted by the Dept. of Conservation and Land Management (1983) of the whole Mandora Marsh area. This recorded Red Kangaroo, Larapinta, Lesser Hairy-Footed Dunnart, Delicate Mouse, Yellow-bellied Sheath Tailed Bat and Northern Mastiff Bat.
The invertebrate, *Metacyclops mortoni,* distribution is only NW Australia
The Pacific Black Duck (*Anas superciliosa*), which is rare was surveyed on Eil Eil spring. The Darter (*Anhinga melanogaster*), which is uncommon and breeding was recorded on the springs. Graham, G (1999), recorded a Gastropoda species which is new to science and endemic to these mound springs.

What is the Tenure of the suite? - Crown Lease.

What IBRA does the suite belong to? - Great Sandy Desert (one of two mound springs within that IBRA).

What Climatic Region does the suite to? - Summer Dominant (350 – 650mm).

Is it inundated? - Yes. The mound springs are generally surrounded by inundated moats.

What type of water is in the suite? - Fresh to Brackish; brackish springs tend to be closer to the main lake and as a result are lower in the landscape. Salinity is 1.27. The Suite is at the interface of marine and terrestrial zones.

Is it a raised Tumulus spring (mound spring)? – Yes, raised; 2-3 meters.

Geology - The suite is on Canning Basin, on an alluvial (sandy silt and clay) plain that is underlain by undulating plains of groundwater calcretes and bounded to the north and south by red sand-dunes (to 15 m, parallel, trending west north-west). The plain is the lower reaches and mouth of a Holocene palaeoriver that formerly drained from the East Kimberley to Eighty Mile Beach. Mandora Soak, is a raised peat bog c. 7000 years old, standing c. 2 m above the plain and surrounded by a moat; peat deposits at the other mound springs are less developed.

What is the lithology of the suite? - Surficial Sediments (clay, silt, sand).

What is the geological age of the suite? - Tertiary (65 million years ago).

Is the suite listed on the state TEC List? - Yes (Endangered).

Is it listed on state PEC list? - N/A.

Range of community? - Very narrow endemic community, total range <50 square km or <20 km linear.

Comments on suite:
There is aerial photography for the majority of mound springs but not entire suite.

Does this Site meet the Criteria for inclusion as a HCVAE?
Yes – International Criteria

Which mound spring within the suite should be prioritized?
All springs, all are covered by Ramsar convention

Name of Suite: Dragon Tree Soak

Details of available information on the suite:

1. Watkins, D. Brennan, K., Lange, C., Jaensch, R. and Finlayson, M. (1997) *Management Planning for Ramsar Sites in the Kimberly region of Western Australia : Report to the Dept. of Conservation and Land Management*
2. TEC Database
3. GIS System
4. Register of the National Estate
5. DIWA Site Description

Accuracy of GIS site:
Dragon Tree soak was plotted with the aid of TEC polygons. The accuracy of its boundary is described as poor.

Number of mound springs known to occur within the suite: 1

International Recognition: No
Is this suite listed under any of the three international conventions? - No.

Is it a proposed site for any of the three international conventions? - No.

Representativeness: No
What type of aquifer is the suite on? - Shallow aquifer – surficial sediments.

How many other suites are on this type of aquifer? - 4.

How many other criteria does the suite meet? - 2.

Does this site meet more other criteria that any other site on this aquifer? - No; the suite on the Swan Coastal Plain, which is also on a shallow aquifer is a better representative suite as it meets more criteria.

Diversity: No
Does the suite have a species diversity (specify index) that exceeds the expected diversity or is more than 2 standard deviations from the mean? - Not enough information.

Does the suite have a higher diversity of taxa at higher taxonomic levels (genus, family)? - Not enough information.

Distinctiveness: Yes
Is the suite on the national TEC List? - No.

Has the suite any rare fauna protected under the EPBC Act? - Yes, the endangered Southern Marsupial Mole *Notoryctes typhlops* is on Dragon Tree Soak.

Has the suite any rare flora protected under the EPBC ACT? - No.

Has the suite been lost to a significant degree nation-wide? - No, it is with an IBRA (Australia) region that has the lowest loss of pre-European vegetation. Decline of the occurrence is taught to be small.

Is the suite an uncommon type that is specifically under threat, resulting in decline in occurrence or condition, nation-wide?

- The suite had 4 fires within a ten year period.
- Camels have access to the soak, causing compaction and loss of vegetation cover
- There is pending mining exploration surrounding Dragon Tree Soak, which could become a future threat

Critical Habitat: No
Is the suite important for the life cycle of a species? - Not enough information.

Does the suite support at least 10% of a dependant species suite or community? - Not enough information.

Is the suite providing habitats to species in time of stress? - Not enough information.

Evolutionary History: Yes
Is the suite a habitat for unusually high diversity of endemic taxa with limited geographical distribution? - Not enough Information.

Is the suite habitat for a diversity of taxa endemic at higher taxonomic levels (genus or above)? - Not enough Information.

Is the suite habitat for a group of endemic species suggesting a centre of speciation? - Not enough Information.

Is the suite habitat for a sequence of related taxa indicative of evolutionary process? - Not enough Information.

Is the suite habitat for iconic species recognized as “living fossils”, relictual species that appear as key links in evolution? - Dragon Tree Soak regarded as a relict of the riverine vegetation found along the palaeo-river in the wetter climates of the early to mid Holocene. Due to its undisturbed and isolated situation and peaty sediments, for studies of palaeo-climate in North-Western Australia. Carbon dating and pollen records from core samples indicate continued uninterrupted deposition of peat at the site for at least the last 6000 years, pointing to general climatic stability. There is the relict species*Typha domingensis* (bullrush) and *Sesbania formosa* (dragon tree).

Naturalness

No human use, indigenous or otherwise, occurs at the place other than occasional visits including visits by research staff.

Other relevant Information:
Size? - 5ha.

Interesting Flora surveyed? - The place supports a wetland plant community of dragon tree, *Sesbania formosa*, over jointed twig-rush *Baumea articulata* and cumbungi, *Typha domingensis* which is rare in the bioregion and in WA. Outliers of *Baumea articulate* and *Sesbania formosa* : An oasis within a major desert supporting plants and animals that are absent or scarce elsewhere in the desert.

Interesting Fauna surveyed (including invertebrates)? - Two water bird species are known from the suite: Clamorous Reed-Warbler, *Acrocephalus stentoreus* and Australian Crake, *Porzana fluminea*. Non-wetland birds present include Pheasant Coucal, *Centropus phasianinus*. Other fauna at the place include the frog, *Cyclorana australis*; also at least two bats, lesser long-eared bat, *Nyctophilus geoffroyi* and red flying fox, *Pteropus scapulatus*, which feed in the dragon trees. There are two priority (P4) bird species. Species not recorded elsewhere in the region but present in the *Typha* beds were the Clamorous Reed-Warbler, *Acrocephalus stentoreus* and the Australian crake, *Porzana fluminea* (Jaensch and Lane 1993). The Dragon tree soak also provides a refuge for a frog species, *Cyclorana australis* and the lesser long-eared bat *Nyctophilus geoffroyi* and the flying fox, *Pteropus scapulatus*. (Morton, *et. al.*1995).

What is the Tenure of the suite? - Crown Reserve.

What IBRA does the suite belong to? - Great Sandy Desert.

What Climatic Region does the suite to? - Summer Dominant (350 – 650mm).

What is the lithology of the suite? - Surficial Sediments.

What is the geological age of the aquifer of the suite? - Tertiary.

Is the suite listed on the state TEC List? - Yes.

Is it listed on state PEC list? - N/A.

What type of water is in the suite? - Fresh – brackish.

Is a raised Tumulus spring (mound spring)? - Yes.

Is the suite on a tidal flat? - No.

Is the suite consisting of both raised and flat mounds? - No.

Comments on suite:
There is no aerial photography for this suite

Does this Site meet the Criteria for inclusion as a HCVAE?
Yes

Which mound spring should be listed as HCVAE and Why?
Just one mound spring- Dragon Tree Soak, because it has endangered EPBC fauna on it and is representative of evolutionary history.

Name of Suite: Willie Wetland Springs

Details of available information on the suite:

- GIS System.
- DIWA
- May, J.E. and McKenzie, N.L. (2002) *A Biodiversity Audit of Western Australia's 53 Biogeographical Sub regions in 2002*. Calm

Accuracy of GIS site:
Willie Creek Springs was plotted with the use of co-ordinates given in DIWA site description and with aerial photography. As the co-ordinates only give a specific point the boundary was estimated though the aerial photograph, therefore the accuracy of this boundary is poor.

Number of mound springs known to occur within the suite: 2

International Recognition: No
Is this suite listed under any of the three international conventions? - No.

Is it a proposed site for any of the three international conventions? - No.

Representativeness: No
What type of aquifer is the suite on? - Deep and Extensive – Rocks of low permeability, fractured and weathered rock.

How many other suites are on this type of aquifer? - There a 3 other whole suites on deep and extensive aquifers, and part of Three Springs suites also.

How many other criteria does the suite meet? - 3.

Does this site meet more other criteria that any other site on this aquifer? - No.

Diversity: No
Does the suite have a species diversity (specify index) that exceeds the expected diversity or is more than 2 standard deviations from the mean? - Not enough Information.

Does the suite have a higher diversity of taxa at higher taxonomic levels (genus, family)? - Not enough Information.

Distinctiveness: Yes
Is the suite on the national TEC List? - No.

Has the suite any rare fauna protected under the EPBC Act? - No.

Has the suite any rare flora protected under the EPBC ACT? - No.

Has the suite been lost to a significant degree nation-wide? - No – it is within the IBRA region that has the lowest loss of pre-European vegetation.

Is the suite an uncommon type that is specifically under threat, resulting in decline in occurrence or condition, nation-wide?

- Urban expansion - land clearing.
- No serious fire threat
- Feral foxes Vulpes vulpes and cats Felis catus may be affecting bird numbers.
- Potential groundwater extraction associated with Broome expansion. There are operational bores on this aquifer.
- On a leasehold Waterbank pastoral station

Critical Habitat: No
Is the suite important for the life cycle of a species? - The whole Willie Wetland is reported to be an important bird (and perhaps fish) breeding area.

Does the suite support at least 10% of a dependant species suite or community? - Not enough Information.

Is the suite providing habitats to species in time of stress? - Not enough Information.

Evolutionary History: No
Is the suite a habitat for unusually high diversity of endemic taxa with limited geographical distribution? - Not enough Information.

Is the suite habitat for a diversity of taxa endemic at higher taxonomic levels (genus or above)? - Not enough Information.

Is the suite habitat for a group of endemic species suggesting a centre of speciation? - Not enough Information.

Is the suite habitat for a sequence of related taxa indicative of evolutionary process? - Not enough Information.

Is the suite habitat for iconic species recognized as “living fossils”, relictual species that appear as key links in evolution? - Research: Nimalaica Swamp appears to have existed for up to 15 000 years and, as one of few permanent freshwater peat environments in the Kimberley, is potentially of great value for palaeoclimatic reconstructions using pollens preserved in the peat (J. Harman pers. comm. 2008).

Other relevant Information:
Size? - 19ha.

Interesting Flora surveyed? - Mound springs and seeps on the east side of the swamp are notable for the herb *Philydrum lanuginosum* and one of the most southern occurrences of the mangrove fern *Acrostichum speciosum*.

Interesting Fauna surveyed (including invertebrates)? - Composition: 36 species have been recorded, including nine herons and allies, five ducks and allies and 12 shorebirds. This is for the whole wetland system and not just the two mound springs. There is a priority fauna within 2kmof the mound springs.

What is the Tenure of the suite? - Unallocated Crown Land.

What IBRA does the suite belong to? - Dampierland.

What Climatic Region does the suite to? - Summer Dominant (350 – 650).

Is the suite listed on the state TEC List? - No.

Is it listed on state PEC list? - No.

Range of Community? – N/A.

What is the lithology of the suite? - Sand and Sandstone.

Is the suite on a tidal flat? - Yes.

Is the suite consisting of both raised and flat mounds? - No.

What is the geological age of the aquifer of the suite? - Cretaceous over Jurassic.

What type of water is in the suite? - Fresh to brackish.

Is the suite a raised Tumulus spring (mound spring)? - Yes.

Comments on suite:
There is full aerial photographic coverage for this suite.

Does this Site meet the Criteria for inclusion as a HCVAE?
Yes

Which mound spring should be listed as HCVAE and Why?
There is three threatening processes effecting it

Name of Suite: Bunda Bunda

Details of available information on the suite:

- TEC Database
- GIS System.
- DIWA Site Description
- Pinder, A. (2002) *Report on December 2002 sampling on Gnangara Mound Springs.*
- May, J.E. and McKenzie, N.L. (2002) *A Biodiversity Audit of Western Australia's 53 Biogeographical Sub regions in 2002*. Calm

Accuracy of GIS site:
The mound springs were plotted with the aid of TEC polygons. The accuracy of their boundary is defined as good.

Number of mound springs known to occur within the suite: 2

International Recognition: No
Is this suite listed under any of the three international conventions? - No.

Is it a proposed site for any of the three international conventions? - No.

Representativeness: No
What type of aquifer is the suite on? - Shallow –Surficial Sediments. From a major unconfined freshwater aquifer in the Broome Sandstone which meets a saltwater wedge along the coast.

How many other suites are on this type of aquifer? - There are four other suites on shallow aquifers.

How many other criteria does the suite meet? - 0.

Does this site meet more other criteria that any other site on this aquifer? - No.

Diversity: No
Does the suite have a species diversity (specify index) that exceeds the expected diversity or is more than 2 standard deviations from the mean? - No; the species count for Bunda Bunda is lower than the average.

Does the suite have a higher diversity of taxa at higher taxonomic levels (genus, family)? - No, it has only 9 different genus and it would need at least 55 to be captured.

Distinctiveness: No
Is the suite on the national TEC List? - No.

Has the suite any rare fauna protected under the EPBC Act? - No.

Has the suite any rare flora protected under the EPBC ACT? - No.

Has the suite been lost to a significant degree nation-wide? - No; the suite is in an IBRA region that is classified to have the lowest level of loss with pre-European vegetation.

Is the suite an uncommon type that is specifically under threat, resulting in decline in occurrence or condition, nation-wide?

- Soil compaction and erosion
- Grazing pressure – especially larger mound
- Weeds
- Bunda Bunda is not under severe threat from fire.
- No bores on aquifer

Critical Habitat: No
Is the suite important for the life cycle of a species? – Unknown.

Does the suite support at least 10% of a dependant species suite or community? - No.

Is the suite providing habitats to species in time of stress? - Not enough information.

Evolutionary History: No
Is the suite a habitat for unusually high diversity of endemic taxa with limited geographical distribution? - No.

Is the suite habitat for a diversity of taxa endemic at higher taxonomic levels (genus or above)? - No.

Is the suite habitat for a group of endemic species suggesting a centre of speciation? - No.

Is the suite habitat for a sequence of related taxa indicative of evolutionary process? - Not enough information.

Is the suite habitat for iconic species recognized as “living fossils”, relictual species that appear as key links in evolution? - Not enough information.

Other relevant Information:
Size? - Large mound area: 20 ha; small mound area: 2 ha.

Interesting Flora surveyed? - One of the most southerly and best conditioned Rainforest, unusual in the arid climate. An endemic (Kimberley) mistletoe, *Ameba dolichopodum* also occurs on the site. Small mound area: Tall shrublands over grassland, closed forest, mangroves in concentriform arrangement. Large mound area: Closed forest, mangrove in concentriform arrangement. Occurrence of the uncommon mangrove, *Lumnitzera racemosa* on the eastern side.

Interesting Fauna surveyed (including invertebrates)? - At least 26 species recorded, including three darters and cormorants, seven herons and allies, three ducks and allies and 12 shorebirds. Notable species are Black- necked Stork, *Ephippiorhynchus asiaticus*, Marsh Sandpiper, *Tringa stagnatilis* and Long-toed Stint *C. subminuta*. A Red-necked Stint *Calidris ruficollis* leg-flagged (blue) in Hokkaido, Japan, was seen at Bunda Bunda on 29 Oct 1994 (G. Swann pers. comm. 2008). Water birds can often be seen in low numbers at the small permanent lake on the north side of the larger island (G.P.J. Swann pers. comm. 2008).

What is the Tenure of the suite? - Unallocated Crown Land.

What IBRA does the suite belong to? - Dampierland.

What Climatic Region does the suite to? - Summer Dominant (650 – 1200mm).

Is the suite listed on the state TEC List? - Yes.

Is it listed on state PEC list? - N/A.

Range of Community? - Very narrow endemic community, total range <50 square km or <20 km linear.

What is the lithology of the suite? - Surficial Sediments.

What is the geological age of the aquifer of this suite? - Quaternary.

What type of water is in the suite? - Fresh.

Is the suite a raised Tumulus spring (mound spring)? - Yes.

Is the suite on a tidal flat? - Yes, 300 m of the shore.

Is the suite consisting of both raised and flat mounds? - No.

Comments on suite:
There is no aerial photography or GIS layer for this suite.

Does this Site meet the Criteria for inclusion as a HCVAE?
No

Which mound spring should be listed as HCVAE and Why?

Name of Suite: Lollywell Springs

Details of available information on the suite:

- TEC Database
- PEC Site Description
- GIS System.
- Macro-invertebrate survey data – Adrian Pinder

Accuracy of GIS layer:
The GIS data for Lollywell Springs was plotted with the aid of TEC polygons. As the mound springs in Lollywell are extremely close they are also captured within the one polygon. The accuracy of this polygon is good.

Number of mound springs known to occur within the suite: 6 - 12

International Recognition: No
Is this suite listed under any of the three international conventions? - No.

Is it a proposed site for any of the three international conventions? - No.

Representativeness: No
What type of aquifer is the suite on? - Deep and Extensive – Rocks of low permeability, fractured and weathered rock.

How many other suites are on this type of aquifer? - There are 3 other whole suites on deep and extensive aquifers and part of another suite.

How many other criteria does the suite meet? - 1.

Does this site meet more other criteria that any other site on this aquifer? - No; Willie Wetland Springs are a better representation of mound springs on deep and extensive aquifers.

Diversity: No
Does the suite have a species diversity (specify index) that exceeds the expected diversity or is more than 2 standard deviations from the mean? - The available invertebrate species count is below the mean, there is no other species survey of this site.

Does the suite have a higher diversity of taxa at higher taxonomic levels (genus, family)? - No, it has only 34 different genus.

Distinctiveness: No
Is the suite on the national TEC List? - No.

Has the suite any rare fauna protected under the EPBC Act? - No.

Has the suite any rare flora protected under the EPBC ACT? - No.

Has the suite been lost to a significant degree nation-wide? - No, it is with an IBRA region that has the lowest loss of pre-European vegetation. Decline of the occurrence is taught to be small.

Is the suite an uncommon type that is specifically under threat, resulting in decline in occurrence or condition, nation-wide?

- Lollywell springs is under constant threat from fire, there has been 6 fires over a 10 year period on the 42ha site.
- No grazing
- No mining tenements

Critical Habitat: No
Is the suite important for the life cycle of a species? - Not enough information.

Does the suite support at least 10% of a dependant species suite or community? - Not enough information.

Is the suite providing habitats to species in time of stress? - Not enough information.

Evolutionary History: No
Is the suite a habitat for unusually high diversity of endemic taxa with limited geographical distribution? - Not enough information.

Is the suite habitat for a diversity of taxa endemic at higher taxonomic levels (genus or above)? - No.

Is the suite habitat for a group of endemic species suggesting a centre of speciation? - Not enough information.

Is the suite habitat for a sequence of related taxa indicative of evolutionary process? - Not enough information.

Is the suite habitat for iconic species recognized as “living fossils”, relictual species that appear as key links in evolution? - Not enough information.

Other relevant Information:
Size? - 42ha.

Interesting Flora surveyed? - *Lygodium microphyllum, Ceratopteris thalictroides, Cyclosorus interruptus, Marsilea hirsute, Pandanus spiralis, Eleocharis dulcis, Philydrum lanuginosum, Ceratophyllum demersum, Macroptilium atropurpureum, Melaleuca viridiflora, Merremia gemella, Merremia hederacea, Lantana camara,*

Timonius timon, Goodenia lamprosperma, Acacia neurocarpa, Melaleuca cajuputi subsp. Cajuputi, Cyanthillium cinereum, Nymphaea macrosperma, Phragmites vallatoria Some weeds.

Interesting Fauna surveyed (including invertebrates)? - No other survey except on invertebrates.

What is the Tenure of the suite? - Crown Reserve.

What IBRA does the suite belong to? - Dampierland.

What Climatic Region does the suite to? - Summer Dominant (650 – 1200).

Is the suite listed on the state TEC List? - No.

Is it listed on state PEC list? - Yes: Priority 3 (ii); A community that is known from a few widespread occurences, which are either large or within significant remaining areas of habitat in which other occurrence may occur, much of it not under imminent threat.

Range of community? - Very narrow endemic community, total range <50 square km or <20 km linear.

What is the lithology of the suite? - Sand and Sandstone.

What is the geological age of the aquifer of this suite? - Cretaceous over Jurassic.

What type of water is in the suite? - fresh.

Is the suite a raised Tumulus spring (mound spring)? - Yes.

Comments on suite:
There is no aerial photography or GIS layer for this suite.

Does this Site meet the Criteria for inclusion as a HCVAE?
No

Name of Suite: Disaster Bay

Details of available information on the suite:

- TEC Database
- PEC Site Description
- GIS System.
- May, J.E. and McKenzie, N.L. (2002) *A Biodiversity Audit of Western Australia's 53 Biogeographical Sub regions in 2002*. Calm

Accuracy of GIS site:
The Disaster Bay suite was plotted with the aid of TEC shapefiles, the boundary is accurate of +/- 10ha.

Number of mound springs known to occur within the suite: 1

International Recognition: No
Is this suite listed under any of the three international conventions? - No.

Is it a proposed site for any of the three international conventions? - No.

Representativeness: No
What type of aquifer is the suite on? - Deep and Extensive aquifer – Rock of low permeability, weathered and fractured rock.

How many other suites are on this type of aquifer? - There are 2 other whole suites on this type of aquifer and part of 2 other suites also.

How many other criteria does the suite meet? - 0.

Does this site meet more other criteria that any other site on this aquifer? - No.

Diversity: No
Does the suite have a species diversity (specify index) that exceeds the expected diversity or is more than 2 standard deviations from the mean? - Not enough information; no biological survey data available from this suite.

Does the suite have a higher diversity of taxa at higher taxonomic levels (genus, family)?-Not enough information; no biological survey data available from this suite.

Distinctiveness: Yes
Is the suite on the national TEC List? - No.

Has the suite any rare fauna protected under the EPBC Act? - No.

Has the suite any rare flora protected under the EPBC ACT? - No.

Is the suite on a tidal flat? - Yes.

Is the suite consisting of both raised and flat mounds? - No.

Has the suite been lost to a significant degree nation-wide? - No, it is with an IBRA region that has the lowest loss of pre-European vegetation. Decline of the occurrence is thought to be small.

Is the suite an uncommon type that is specifically under threat, resulting in decline in occurrence or condition, nation-wide?

- This small suite is under threat from fire. Within its 27ha boundary, there are 5 fire scars from a 10 year period.
- No mining tenement on the suite
- It is not on active pastoral land.
- There is soil compaction by cattle
- There is a potential sea level change due to Climate Change.

Critical Habitat: No
Is the suite important for the life cycle of a species? - Not enough information, no biological data from this suite.

Does the suite support at least 10% of a dependant species suite or community? - Not enough information, no biological data from this suite.

Is the suite providing habitats to species in time of stress? - Not enough information, no biological data from this suite.

Evolutionary History: No
Is the suite a habitat for unusually high diversity of endemic taxa with limited geographical distribution? - Not enough information, no biological data from this suite.

Is the suite habitat for a diversity of taxa endemic at higher taxonomic levels (genus or above)? - Not enough information, no biological data from this suite.

Is the suite habitat for a group of endemic species suggesting a centre of speciation? - Not enough information, no biological data from this suite.

Is the suite habitat for a sequence of related taxa indicative of evolutionary process? - Not enough information, no biological data fromthis suite.

Is the suite habitat for iconic species recognized as “living fossils”, relictual species that appear as key links in evolution? - Not enough information, no biological data from this suite.

Other relevant Information:
Size? - 27.04ha.

Interesting Flora surveyed? - Forest and sedgeland communities*, Melaleuca acacioides, Timonius timon, Pandanus spiralus, Melaleuca viridiflora, Acacia neurocarpa and Lumnitzera racemosa* (mangrove) woodland with *Typha domingensis* and sedges, including *Schoenoplectus lilitoralis*.

Interesting Fauna surveyed (including invertebrates)? - no biological data from this suite.

What is the Tenure of the suite? - Freehold / Lease Reserve.

What IBRA does the suite belong to? - Dampierland.

What Climatic Region does the suite to? - Summer Dominant (650 – 1200).

Is the suite listed on the state TEC List? - No.

Is it listed on state PEC list?Yes, it is a P (iii); Community that is made up of large, and / or widespread occurrences, that may or may no be represented in the reserve system, but are under threat of modification across much of their range from processes such as grazing by domestic and/or feral stock, and inappropriate fire regimes.

Range of Community? - Very narrow endemic community, total range <50 square km or <20 km linear.

What is the lithology of the suite? - Sand and Sandstone.

What is the geological age of the aquifer of this suite? - Cretaceous over Jurassic (oldest geological age of any suite).

What type of water is in the suite? - Fresh with saline influence.

Comment on suite.
There is no aerial photography or GIS layer for this suite.

Does this Site meet the Criteria for inclusion as a HCVAE?
No

Name of Suite: Big springs

Details of available information on the suite:

- TEC Database
- GIS System.
- Macro-Invertebrate Survey Data – Adrian Pinder
- DIWA Site description
- May, J.E. and McKenzie, N.L. (2002) *A Biodiversity Audit of Western Australia's 53 Biogeographical Sub regions in 2002*. Calm

Accuracy of GIS layer:
Big Springs mound springs were plotted with the aid of TEC shapefiles. The boundary information of these shapefiles for Big Springs is good and reliable.

Number of mound springs known to occur within the suite: 23

International Recognition: No
Is this suite listed under any of the three international conventions? - No.

Is it a proposed site for any of the three international conventions? - No.

Representativeness: No
What type of aquifer is the suite on? - Shallow aquifer – Surficial Sediments.

How many other suites are on this type of aquifer? - 4.

How many other criteria does the suite meet? - 1.

Does this site meet more other criteria that any other site on this aquifer? - No, the Swan Coastal Plain is a better representation of mound springs on shallow aquifer.

Diversity: No
Does the suite have a species diversity (specify index) that exceeds the expected diversity or is more than 2 standard deviations from the mean? - No; Big Springs has a species count of 43, which is just above the average of 40. It is not 2 standard deviations form the mean.

Does the suite have a higher diversity of taxa at higher taxonomic levels (genus, family)? - No; Big Spring has 38 different genus which is not up to the specified 55.

Distinctiveness: No
Is the suite on the national TEC List? - No.

Has the suite any rare fauna protected under the EPBC Act? - No.

Has the suite any rare flora protected under the EPBC ACT? - No.

Has the suite been lost to a significant degree nation-wide? - No; the suite is within an IBRA region that has the lowest percentage of pre-European vegetation loss.

Is the suite an uncommon type that is specifically under threat, resulting in decline in occurrence or condition, nation-wide?

- No; Big Spring in relative terms is not under threat by fire. It has only had two fires over the last 12 years.
- There is a pending mining tenement on the mound springs for exploration
- It is not on active pastoral land
- There is grazing on the mound springs
- There is a capped bore 1.5 km north-west of the main seepage feature, on the upper saltmarsh, with a hydrant-type valve.

Critical Habitat: No
Is the suite important for the life cycle of a species? - Not enough information.

Does the suite support at least 10% of a dependant species suite or community? - Not enough information.

Is the suite providing habitats to species in time of stress? - Not enough information.

Evolutionary History: No
Is the suite a habitat for unusually high diversity of endemic taxa with limited geographical distribution? - Not enough information.

Is the suite habitat for a diversity of taxa endemic at higher taxonomic levels (genus or above)? - Not enough information.

Is the suite habitat for a group of endemic species suggesting a centre of speciation? Not enough information

Is the suite habitat for a sequence of related taxa indicative of evolutionary process? - Not enough information.

Is the suite habitat for iconic species recognized as “living fossils”, relictual species that appear as key links in evolution? - Not enough information.

Other relevant Information:
Size? - Total area of mound springs approximately 80ha, is comprised of one large seepage area (Bigs 01a, 01b) and surrounded by smaller mound springs.

- BigS 01a, 01b – 58ha (+/- 10ha)
- BigS 02 - 0.695ha
- BigS 03 - 0.499ha
- BigS 04 - 0.183ha
- BigS 05 - 1.143ha

- BigS 06 - 0.472ha
- BigS 07 - 0.023ha
- BigS 08 - 0.022ha
- BigS 09 - 0.023ha
- BigS 10 - 0.021ha
- BigS 11 - 0.022ha
- BigS 12 - 0.023ha
- BigS 13 - 0.024ha
- BigS 14 - 0.62ha
- BigS 15 - 0.023ha
- BigS 16 - 0.023ha
- BigS 17 - 0.023ha
- BigS 18 - 0.023ha
- BigS 19 - 0.059ha
- BigS 20 - 0.863ha
- BigS 21 - 0.025ha
- BigS 22 - 0.03ha
- BigS 23 - 0.024

Interesting Flora surveyed? - Well developed rainforest vegetation. A further feature is the scattered clusters of outlying, densely-vegetated mound spring islands. The visual impact of these mound springs is enhanced as the trees that grow upon them arise out of a vast mudflat landscape. Toward the landward side of these mudflats the main vegetation is grass and toward King Sound the flats are saline and devoid of vegetation. The main seepage area is dominated by forests of *Terminalia microcarpa*, a species not otherwise known south of Walcott Inlet, 90 km NE. One population of climbing swamp fern *Stenochlaena palustris* was noted.

Interesting Fauna surveyed (including invertebrates)? - No other fauna information other that on invertebrates.

What is the Tenure of the suite? - Unallocated Crown Land.

What IBRA does the suite belong to? - Dampierland.

What Climatic Region does the suite to? - Summer Dominant (650 – 1200mm).

Is the suite listed on the state TEC List? - Yes.

Is it listed on state PEC list? - N/A.

Range of Community? - Very narrow endemic community, total range <50 square km or <20 km linear.

What is the lithology of the suite? - Surficial sediments.

What is the geological age of the suite? - Quaternary – young, modern times.

What type of water is in the suite? - Fresh and Saline.

Is the suite a raised Tumulus spring (mound spring)? - Yes with seepage areas.

Is the suite on a tidal flat? - Yes.

Is the suite consisting of both raised and flat mounds? - Yes.

Comments on suite:
There is no aerial photography or GIS layer for this suite.

Does this Site meet the Criteria for inclusion as a HCVAE?
No

Name of Suite: Black Springs

Details of available information on the suite:

- TEC Database
- GIS System.
- Macro-Invertebrate Survey Data – Adrian Pinder
- May, J.E. and McKenzie, N.L. (2002) *A Biodiversity Audit of Western Australia's 53 Biogeographical Sub regions in 2002*. Calm

Accuracy of GIS site:
The GIS site for Black Springs was plotted with the aid of TEC shapefiles, the boundary for the TEC is poor.

Number of mound springs known to occur within the suite: 1

International Recognition: No
Is this suite listed under any of the three international conventions? - No.

Is it a proposed site for any of the three international conventions? - No.

Representativeness: No
What type of aquifer is the suite on? - Local Aquifer – Rocks of low permeability fractured and weathered rocks. It is made up of two different local aquifers.

How many other suites are on this type of aquifer? - There are 2 other suites fully reliant on local aquifers. There are also parts of 2 other suites occurring on local aquifers.

How many other criteria does the suite meet? - 1.

Does this site meet more other criteria that any other site on this aquifer? - No.

Diversity: No
Does the suite have a species diversity (specify index) that exceeds the expected diversity or is more than 2 standard deviations from the mean? - No; the species count for Black Springs is below the mean.

Does the suite have a higher diversity of taxa at higher taxonomic levels (genus, family)? - No.

Distinctiveness: YES
Is the suite on the national TEC List? - No.

Has the suite any rare fauna protected under the EPBC Act? - No.

Has the suite any rare flora protected under the EPBC ACT? - No.

Has the suite been lost to a significant degree nation-wide? - No. Black Springs in an IBRA that is classifies as having the lowest loss of pre-European vegetation extent.

Is the suite an uncommon type that is specifically under threat, resulting in decline in occurrence or condition, nation-wide?

- Black springs are under constant threat from fire. In the period 1998 – 2006, there were 6 fires on the mound spring.
- The northern end of the mound spring suite has a live mining tenement for exploration.

Critical Habitat: No
Is the suite important for the life cycle of a species? - Not enough information.

Does the suite support at least 10% of a dependant species suite or community? - Not enough information.

Is the suite providing habitats to species in time of stress? - Not enough information.

Evolutionary History: No
Is the suite a habitat for unusually high diversity of endemic taxa with limited geographical distribution? - No.

Is the suite habitat for a diversity of taxa endemic at higher taxonomic levels (genus or above)? - No.

Is the suite habitat for a group of endemic species suggesting a centre of speciation? - No.

Is the suite habitat for a sequence of related taxa indicative of evolutionary process? - No.

Is the suite habitat for iconic species recognized as “living fossils”, relictual species that appear as key links in evolution? - No.

Other relevant Information:
Size? - 3.98ha.

Interesting Flora surveyed? - A raised central mound supports a forest of *Melaleuca viridiflora, Ficus spp., Timonius timon*, and *Pandanus spiralis* over taro lilies, *Colocasia esculenta* and ferns, *Cyclosorus interruptus*. The very tall cane grass *Phragmites karka* dominates the outer edge of the mound and the entire mound is ringed by a moat of water supporting sedges and grasses.

Interesting Fauna surveyed (including invertebrates)? - Oligochaeta, Acarina, Crustacea (Ostracoda), Crustacea (Copepoda), Gastropoda, Insecta (Coleoptera), Insecta (Diptera - Culicidae), Insecta (Diptera - Tabanidae), Insecta (Diptera - Ceratopogonidae), Insecta

(Diptera - Chironomidae) Insecta (Ephemeroptera), Insecta (Hemiptera), Insecta (Odonata) and Insecta (Trichoptera).

What is the Tenure of the suite? - Unallocated Crown Land.

What IBRA does the suite belong to? - North Kimberly.

What Climatic Region does the suite to? - Summer Dominant (650 – 1200).

Is the suite listed on the state TEC List? - Yes.

Is it listed on state PEC list? - N/A.

Range of Community? - Very narrow endemic community, total range <50 square km or <20 km linear.

What is the lithology of the suite? - Basalt, Intermediate and Acid Volcanic and Sandstone.

What is the geological age of the suite? - Lower Proterozoic – Youngest geological age of all suites.

Is the suite on a tidal flat? - No.

Is the suite consisting of both raised and flat mounds? - No; just raised.

Comment on suite.
There is no aerial photography or GIS layer for this suite.

Does this Site meet the Criteria for inclusion as a HCVAE?
No

Name of Suite: North Kimberly Mounds

Details of available information on the suite:

- TEC Report
- TEC Database
- GIS System
- Halse, S.A. (2001) *Comments on Kimberley Springs sampled by Sally Black.* Unpublished report, CALM.
- May, J.E. and McKenzie, N.L. (2002) *A Biodiversity Audit of Western Australia's 53 Biogeographical Sub regions in 2002*. Calm

Accuracy of GIS site:
This suite was plotted with the aid of the TEC site polygons. According to the TEC boundary accuracy for each site is as follows:

- Drysdale 1a – Good
- Drysdale 2a, 2b – Poor
- Drysdale 3a, 3b – Poor
- GibbR1 – Good
- Mt Elizabeth 1a, 1b, 1c, 1d – Poor
- Mt Elizabeth 2a, 2b – Good.
- Mt Elizabeth 3a, 3b - Good
- Mt Elizabeth 4 - Good

Number of mound springs known to occur within the suite: 8

International Recognition: No
Is this suite listed under any of the three international conventions? - No.

Is it a proposed site for any of the three international conventions? - There is a World Heritage Area proposed for the Kimberly but its location is not known at time of writing.

Representativeness: No
What type of aquifer is the suite on? - Rocks of low permeability fractured and weathered rocks – Local Aquifer.

How many other criteria does the suite meet? - 1.

Does this site meet more other criteria than any other site on this aquifer? - No.

Diversity: No
Does the suite have a species diversity (specify index) that exceeds the expected diversity or is more than 2 standard deviations from the mean? - No; the species count from Drysdale is less than 2 standard deviations from the mean.

Does the suite have a higher diversity of taxa at higher taxonomic levels (genus, family)? - No; there were only 26 different genus surveyed, which is well below the amount required under this specification.

Distinctiveness: Yes
Is the suite on the national TEC List? - No.

Has the suite any rare fauna protected under the EPBC Act? - No.

Has the suite any rare flora protected under the EPBC ACT? - No.

Has the suite been lost to a significant degree nation-wide? - No, occupies most or all of former extent. It is in the IBRA region that is classified as having the lowest loss of pre-European vegetation.

Is the suite an uncommon type that is specifically under threat, resulting in decline in occurrence or condition, nation-wide?

- Yes; The North Kimberly Suite is severely under threat from fire. The number of fire scars over the last 12 years on each mound spring is as follows:
- Drysdale 1a – 8 fire scars
- Drysdale 2a, 2b and Drysdale 3a,3b – 7 fire scars
- GibbR1 – 7 fire scars
- Mt. Elizabeth 4 – 6 fire scars
- Mt Elizabeth 1a, 1b, 1c, 1d – 4 fire scars
- Mt. Elizabeth 2a, 2b and Mt Elizabeth 3a, 3b – 2 fire scars (not considered under significant threat)

Critical Habitat: No
Is the suite important for the life cycle of a species? - Not enough information.

Does the suite support at least 10% of a dependant species suite or community? - Not enough information.

Is the suite providing habitats to species in time of stress? - Not enough information.

Evolutionary History:
Is the suite a habitat for unusually high diversity of endemic taxa with limited geographical distribution? - Not enough information.

Is the suite habitat for a diversity of taxa endemic at higher taxonomic levels (genus or above)? - Not enough information.

Is the suite habitat for a group of endemic species suggesting a centre of speciation? - No.

Is the suite habitat for a sequence of related taxa indicative of evolutionary process? - Not enough information.

Is the suite habitat for iconic species recognized as “living fossils”, relictual species that appear as key links in evolution? - Not enough information.

Other relevant Information:

Size?

- Drysdale 1a; 3.2 +/- 2ha
- Drysdale 2a, 2b; 7.7 +/-3ha
- Drysdale 3a, 3b; 6.9 +/- 3ha
- GibbR1; 38.9 +/- 20 ha
- Mt Elizabeth 1a, 1b, 1c, 1d; 2.4 +/-0.2ha
- Mt Elizabeth 2a, 2b; 8.9 +/- 5ha.
- Mt Elizabeth 3a, 3b; 16.7 +/- 8ha
- Mt Elizabeth 4; 1.1 +/- 1ha

Interesting Flora surveyed? - Black, S (2001) survey of the suite. It supports a mound spring sedge land community with sparse *Melaleuca nervosa, Pandanus spiralis* and/or *Banksia dentate*. *Eriocaulon inapertum* was a new record for the state and was previously only recorded in the Northern Territory.
Other mound springs in the Kimberly are vegetated by forest/woodland. Most sedges present on this suite are restricted to the periphery of wetlands and creeks.

Interesting Fauna surveyed (including invertebrates)? - In 1999, aquatic invertebrates were surveyed. Halse (2001) described this suite as conservation value due the particular taxa present and their importance.

What is the Tenure of the suite? - Pastoral lease.

What IBRA does the suite belong to? - North Kimberly.

What Climatic Region does the suite to? - Summer Dominant (650 – 1200mm).

Has the suite been lost to a significant degree (of it pre-European vegetation)? - No, it is in an IBRA region that has had the least loss of native vegetation post 1790.

What are the threats to the suite?

- All of the mound springs within this suite are on pastoral land. They are being affected by cattle grazing. Three of the eight mound springs are fenced, however these fenced are not being properly maintained and a site reports describes one as “completely ineffective”
- bores on aquifers

Is the suite listed on the state TEC List? - Yes.

Is it listed on state PEC list? - N/A.

Range of Community? - Very narrow endemic community, total range <50 square km or <20 km linear.

What is the lithology / Geology of the suite? - There are two different lithological classifications on this suite of mounds. The majority of mound springs (Mt Elizabeth 1a, 1b, 1c, 1d, Mt Elizabeth 2a, 2b, Mt Elizabeth 3a 3b, Mt Elizabeth 4 and a fraction of GibbR1 is on sandstone. However the rest of GibbR1 is on basalt, intermediate and acid volcanic.

What is the geological age of the aquifer of the suite? - Lower Proterozic. This is the youngest geological age of all of the aquifers of the suites.

How many other suites are on this type of aquifer? - 3; The only other suite wholly on this aquifer is Black springs, which is very close to the North Kimberly Suite. Kachana Station and part of the SCP plain suite are also on a local aquifer.

Is the suite on a tidal flat? - No.

Is the suite consisting of both raised and flat mounds? - No.

Comments on suite:
There is no aerial photography or GIS layer for this suite.

Does this suite meet the Criteria for inclusion as a HCVAE
No

Name of Suite: Kachana springs

Details of available information on the suite:

- TEC Database
- PEC Site Description
- Macro-Invertebrate Survey Data – Adrian Pinder
- GIS Tools
- http://www.kachana.com/menu/about_us.php
- May, J.E. and McKenzie, N.L. (2002) *A Biodiversity Audit of Western Australia's 53 Biogeographical Sub regions in 2002*. Calm

Accuracy of GIS site:
The exact amount of mound springs within this suite is unknown. In order to capture the suite within the GIS work for this project, the general property boundary of where the suite is located has been used. This is a large station in the Kimberly and is only used as indication for the location of the suite.
As the mound springs occur on the slopes of the Durack Range, they are on the west side of the property boundary.

Number of mound springs known to occur within the suite: Unknown

International Recognition: No
Is this suite listed under any of the three international conventions? - No.

Is it a proposed site for any of the three international conventions? - No.

Representativeness: Yes
What type of aquifer is the suite on? - Local Aquifer – Rocks of low permeability, fractured and weathered rocks.

How many other assembles are on this type of aquifer? - There are 2 other suites fully reliant on local aquifers. There are also parts of 2 other suites occurring on local aquifers.

How many other criteria does the suite meet? - 2.

Does this site meet more other criteria that any other site on this aquifer? - Yes.

Diversity: Yes
Does the suite have a species diversity (specify index) that exceeds the expected diversity or is more than 2 standard deviations from the mean? - Using the standard deviation for the mound springs in the Kimberly only, Kachana has a diversity that is more than two standard deviations from the mean. However, when using available data from all suites, Kachana is not captured under this specification, as it would need a species count of 100 and it species count is 89. It should also be noted though, that two

families (Crustacea (Cladocera) and Crustacea (Ostracoda)) have not yet been identified so could increase the species count for Kachana considerably.

Does the suite have a higher diversity of taxa at higher taxonomic levels (genus, family)? - Yes, the 89 species count that was surveyed, comprised of species from the majority of family groups (Protozoa, Rotifera, Nematoda, Oligochaeta, Acarina, Crustacea (Copepoda), Insecta (Coleoptera), Insecta (Diptera - Culicidae), Insecta (Diptera - Simulidae), Insecta (Diptera - Dolichopodidae), Insecta (Diptera - Empididae), Insecta (Diptera - Stratiomyidae), Insecta (Diptera - Tabanidae), Insecta (Diptera - Tipulidae), Insecta (Diptera - Ceratopogonidae), Insecta (Diptera - Chironomidae), Insecta (Ephemeroptera), Insecta (Hemiptera), Insecta (Odonata) and Insecta (Trichoptera)).

It has 70 different genus, which is above the specified amount of 55, it has 20 different family surveyed which is above 20 and has 7 different orders which is above 6.

Distinctiveness: YES
Is the suite on the national TEC List? - No.

Has the suite any rare fauna protected under the EPBC Act? - No.

Has the suite any rare flora protected under the EPBC ACT? - No.

Is the suite on a tidal flat? - No.

Is the suite consisting of both raised and flat mounds? - No.

Has the suite been lost to a significant degree nation-wide? - No, it is on the IBRA region that is classified as having the lowest loss of pre-European native vegetation. Its occurrence decline is unknown but taught to be small.

Is the suite an uncommon type that is specifically under threat, resulting in decline in occurrence or condition, nation-wide?

- Kachana Station is under continuous threat from fire. There have been 10 fires in 11 years on the station and nine of these occur in the west of the station where the Durak Range is.
- Is also a threat from cattle grazing, soil compaction and weeds.
- There is a mining exploration license for a small area down the south of the station. This is close to the Durak Range.

Critical Habitat: No
Is the suite important for the life cycle of a species? - Not enough information.

Does the suite support at least 10% of a dependant species suite or community? - Not enough Information.

Is the suite providing habitats to species in time of stress? - Not enough Information.

Evolutionary History:
Is the suite a habitat for unusually high diversity of endemic taxa with limited geographical distribution? - Not enough information.

Is the suite habitat for a diversity of taxa endemic at higher taxonomic levels (genus or above)? - Not enough information.

Is the suite habitat for a group of endemic species suggesting a centre of speciation? - Not enough information.

Is the suite habitat for a sequence of related taxa indicative of evolutionary process? - Not enough information.

Is the suite habitat for iconic species recognized as “living fossils”, relictual species that appear as key links in evolution? - No.

Other relevant Information:
Size? - The whole station is 423’000 km², the area of mound springs unknown.

Interesting Flora surveyed? - Drainage lines are vegetated with a forest of *Corymbia ptychocarpa* (swamp bloodwood), *Grevillea pteridifolia, Melaleuca* spp, *Pandanus spiralis*, and some *Livistona* spp. over the fern *Cyclosorus interruptus* and the climbing fern *Lygodium microphyllum*. Sedges occur in the understorey and clumps of Reed Grass *Arundinella nepalensis* are dominant in the understorey where the canopy is more open. Also associated with the drainage lines are swamps vegetated by dense sedgelands with grasses and herbs.

Interesting Fauna surveyed (including invertebrates)? - Details of invertebrates above, no other fauna survey conducted.

What is the Tenure of the suite? - Crown Lease – to a land care pastoral company.
What IBRA does the suite belong to? - Central Kimberly.

What Climatic Region does the suite to? - Summer Dominant (650 – 1200).

Is the suite listed on the state TEC List? - No.

Is it listed on state PEC list? - Yes, it is a Priority 1 TEC. This means it is a “poorly known ecological community with apparently few, small occurrences, all or most not actively managed for conservation (e.g. Within Agricultural or pastoral lands, urban area, active mineral leases) and for which current threats exist. Communities may be included if they are comparatively well-known from one or more localities but do not meet adequacy requirements, and/or are not well defined, and appear to be under immediate threat from known threatening processes across their range”

Range of Community? - Narrow endemic, total range < 500 square km or 100 km linear
What is the lithology of the suite? - Sandstone and Basalt, intermediate and Acid Volcanic.

What is the geological age of the aquifer of this suite? - Lower Proterozoic – youngest age from all suites.

What type of water is in the suite? - Fresh.

Is the suite a raised Tumulus spring (mound spring)? - Yes.

Comments on suite:
The station is being actively managed by a land care group.
There is no aerial photography or GIS layer for this suite.

Does this Site meet the Criteria for inclusion as a HCVAE?
Yes

Which mound spring should be listed as HCVAE and Why?
Spring surveyed by Adrian Pinder, due to its diversity and threat from fire.

Name of Suite: Carlton Hill Suite

Details of available information on the suite:

- PEC Brief Site Listing
- GIS System.
- Geoff Warriner, Manager, Carlton Hill Station Aerial burning in the North East Kimberly: Dry-season wildfires are a real risk for WA's Carlton Hill Station. A fire-management plan that incorporates aerial and ground burning has more than halved the number of wildfires occurring over the past six years.

Accuracy of GIS site:
The exact amount of mound springs within this suite is unknown. Of the three mound springs that are known, the location of one is only known (Brolga Spring). Even the accuracy of this location is not very good. In order to capture the suite within the GIS work for this project, the general property boundary of where it is located has been used. This is a large station in the Kimberly and is only used as indication for the location of the suite. It is thought that the mound springs are in the north of the station as they are on tidal flats and that is where Brolga spring is located.

Number of mound springs known to occur within the suite: 4 or more.

International Recognition: No
Is this suite listed under any of the three international conventions? - No.

Is it a proposed site for any of the three international conventions? - No. The northern boundary of the station is shared by the Ord River Floodplains Ramsar listed site. Brolga Spring is approximately 4.5km from the Ramsar site border.

Representativeness:
What type of aquifer is the suite on? - Carlton Hill sits on three different types of Aquifers – Local (Rocks of Low Permeability, Fractured and Weathered Rocks), Shallow (Surficial Sediments) and Deep and Extensive (Sedimentary Rocks). Most of the Northern end of the station is on a deep and extensive aquifer, as is Brolga Spring.

How many other suites are on this type of aquifer? - There are 5 other suites on Deep and extensive Aquifers.

How many other criteria does the suite meet? - 1.

Does this site meet more other criteria that any other site on this aquifer? - No.

Diversity: No
Does the suite have a species diversity (specify index) that exceeds the expected diversity or is more than 2 standard deviations from the mean? - Not enough information; No species survey has been done on this site.

Does the suite have a higher diversity of taxa at higher taxonomic levels (genus, family)? - Not Enough Information; No species survey has been done on the site.

Distinctiveness: Yes
Is the suite on the national TEC List? - No.

Has the suite any rare fauna protected under the EPBC Act? - Yes, there is a threatened molluscs with in 1km of Brolga spring. There are also numerous other records of threatened mollusks up the north of Carlton Hill Station, where the rest of mound springs are thought to be.

Has the suite any rare flora protected under the EPBC ACT? - No.

Is the suite on a tidal flat? - Yes.

Is the suite consisting of both raised and flat mounds? - No.

Has the suite been lost to a significant degree nation-wide? - No. Carlton hill Station is in an IBRA that has the lowest loss of pre-European vegetation extent.

Is the suite an uncommon type that is specifically under threat, resulting in decline in occurrence or condition, nation-wide?

- Carlton Hill Station is an active cattle station. There are approximately 45,000 cattle present on the station. Cattle use mound springs as a water source.
- The Carlton Hill Suite is under threat from fire. The number of fire scars over the last 12 years is as follows
- Brolga spring – 2 fire scars
- Whole Property – 12 fire scars.

However, this property is being actively managed for fire minimization.

- All bores present are for monitoring purposes but are down south of the property.

Critical Habitat: No
Is the suite important for the life cycle of a species? - Not enough information; No species survey has been done on this site.

Does the suite support at least 10% of a dependant species suite or community? - Not enough information; No biological survey data for this site.

Is the suite providing habitats to species in time of stress? - Not enough information; No biological survey data for this site.

Evolutionary History: No
Is the suite a habitat for unusually high diversity of endemic taxa with limited geographical distribution? - Not enough information; No biological survey data for this site.

Is the suite habitat for a diversity of taxa endemic at higher taxonomic levels (genus or above)? - Not enough information; No biological survey data for this site.

Is the suite habitat for a group of endemic species suggesting a centre of speciation? Not enough information; No biological survey data for this site.

Is the suite habitat for a sequence of related taxa indicative of evolutionary process? Not enough information; No biological survey data for this site.

Is the suite habitat for iconic species recognized as “living fossils”, relictual species that appear as key links in evolution? - Not enough information; No biological survey data for this site.

Other relevant Information:
Size? - Brolga spring – 5.9ha

Interesting Flora surveyed? – Rainforest.

Interesting Fauna surveyed (including invertebrates)? - No other information available on fauna besides that information on mollusks.

What is the Tenure of the suite? - Pastoral Lease.

What IBRA does the suite belong to? - Victoria Bonaparte.

What Climatic Region does the suite to? - Summer Dominant (650 – 1200mm).

Is the suite listed on the state TEC List? – No.

Is it listed on state PEC list? - Yes, it is a Priority 1 TEC. It is a poorly known ecological community with apparently few, small occurrences, all or most not actively managed for conservation (e.g. Within Agricultural or pastoral lands, urban area, active mineral leases) and for which current threats exist. Communities may be included if they are comparatively well-known from one or more localities but do not meet adequacy requirements, and/or are not well defined, and appear to be under immediate threat from known threatening processes across their range.

Range of Community? – Narrow.

What is the lithology of the suite? - Sand, Sandstone.

What is the geological age of the aquifer of this suite? - Devonian – the 2nd youngest geogolical age of all suites.

What type of water is in the suite? – Fresh.

Is the suite a raised Tumulus spring (mound spring)? - Unknown but thought to be likely.

Comments on suite:
The Carlton Hill Suite has very little biological data collected from it. If Brolga spring had not been mapped, then this suite would not have been captured by the HCVAE criteria, although there is aerial photographic coverage for the region.

Does this Site meet the Criteria for inclusion as a HCVAE?
Yes

Which mound spring should be listed as HCVAE and Why?
Brolga, as this is the only mound spring with any information attached and that we know there is EPBC threatened fauna within 1km of it.

Appendix 2: Summary of survey data from Pinder (unpublished), Pinder, A., Stratford, L. and McRae, J. (2006) and Pinder, A. (2002)

Assemblage	No of Genus		No. of Family		No. of Order	
SCP	36		17			
Three Springs	49		18			
Mandora Marsh						
Dragon Tree Soak						
Willie Wetland						
Springs						
Bunda Bunda	9		6		3	
Lollywell Springs	34		11		3	
North Kimberly	26		14		5	
Disaster Bay						
Big Springs	38		12		3	
Black Springs	34		15		4	
Carlton Hill						
Kachana	70		20		7	
mean + stdev	37	17.55807	14.125	4.454131	4.166667	1.602082
sum	**296**		**113**		**25**	

Appendix 3: Summary of specie survey data from Pinder (unpublished), Pinder, A., Stratford, L. and McRae, J. (2006) and Pinder, A. (2002).

Major group	Identification	KMS001 Big Spring	KMS004 Black Spring	KMS005 Drysdale	KMS006 Lollywell	KMS008 Bunda Bunda	KMS009 Kachana	SCP	Three spring (from just one spring)
Protozoa	*Lecquereusia* sp.						**1**		
Protozoa	*Quadrulella* sp.						**1**		
Protozoa	*Euglypha* K1						**1**		
Protozoa	*Cephalodella* sp.						**1**		
Rotifera	*Brachionus urceularis*						**1**		
Rotifera	*Lecane nitida*						**1**		
Nematoda	Nematoda						**1**		
Oligochaeta	*Allonais paraguayensis*		**1**		**1**				
Oligochaeta	*Allonais pectinata*						**1**		
Oligochaeta	*Aulodrilus pigueti*								
Oligochaeta	*Dero flabelliger*						**1**		
Oligochaeta	*Dero furcata*		**1**						
Oligochaeta	*Nais communis*			**1**					
Oligochaeta	*Pristina longiseta*						**1**		
Oligochaeta	*Pristina proboscidea*		**1**		**1**				
Acarina	Acarina sp. 1 (KMS)		**1**						
Acarina	*Aspidiobates* sp.						**1**		
Acarina	*Australiobates nr perplexus*						**1**		
Acarina	*Australiobates* sp. K1 (KMS)						**1**		
Acarina	*Australotiphys* sp. K1 (KMS)						**1**		
Acarina	*Austraturus* sp. K1 (KMS)						**1**		
Acarina	*Coaustraliobates minor*						**1**		
Acarina	*Hygrobates hamatus*						**1**		
Acarina	*Koenikea* sp.						**1**		
Acarina	*Limnesia* sp. K1 (KMS)						**1**		
Acarina	*Neumania* sp.						**1**		
Acarina	Oribatida		**1**	**1**					
Acarina	Oribatida group 1 (PSS)						**1**		
Acarina	Oribatida group 3 (SAP)						**1**		
Acarina	Oribatida group 5 (PSS)						**1**		
Acarina	Oribatida sp. 4 (PSW)						**1**		

Acarina	*Sigthoria nilotica*					**1**
Crustacea (Cladocera)	*Alona* cf. *longinqua* (CB)					
Crustacea (Cladocera)	*Alona* cf. *rigidicaudis* s.l. (CB, but may be multiple spp.)					
Crustacea (Cladocera)	*Ceriodaphnia cornuta*	**1**				**not**
Crustacea (Cladocera)	*Ceriodaphnia* sp.	**1**				**identified**
Crustacea (Cladocera)	*Diaphanosoma* sp.	**1**				**yet**
Crustacea (Cladocera)	*Ilyocryptus* sp.			**1**		
Crustacea (Cladocera)	*Kurzia longirostris*	**1**				
Crustacea (Cladocera)	*Leydigia* sp.	**1**				
Crustacea (Cladocera)	*Macrothrix* sp. a (of RJS) (SAP)					
Crustacea (Cladocera)	*Macrothrix* sp. b (of RJS) (SAP)	**1**				
Crustacea (Cladocera)	*Rak* sp.					
Crustacea (Ostracoda)	*Ampullacypris oblongata*		**1**			
Crustacea (Ostracoda)	*Candonopsis tenuis*			**1**		**not**
Crustacea (Ostracoda)	*Cypretta baylyi*	**1**	**1**			**identified**
Crustacea (Ostracoda)	*Cypretta* sp. 654 (KMS)	**1**				**yet**
Crustacea (Ostracoda)	*Cyprinotus kimberleyensis*				**1**	
Crustacea (Ostracoda)	Herpetocypris sp. 652 (KMS)	**1**	**1**			
Crustacea (Ostracoda)	*Ilyodromus viridulus*	**1**	**1**	**1**		
Crustacea (Ostracoda)	*Stenocypris major*	**1**				
Crustacea (Ostracoda)	*Strandesia* sp. 653 (KMS)	**1**				
Crustacea (Copepoda)	*Ectocyclops rubrescens*	**1**	**1**			
Crustacea (Copepoda)	*Eucyclops australiensis*					
Crustacea (Copepoda)	Harpacticoida sp. 1 (PSS)					**1**
Crustacea (Copepoda)	*Macrocyclops albidus*					**1**
Crustacea (Copepoda)	*Mesocyclops* aff *darwini*					
Crustacea (Copepoda)	*Mesocyclops papuensis*					
Crustacea (Copepoda)	Mesocyclops sp.					**1**
Crustacea (Copepoda)	*Mesocyclops woutersi*	**1**				
Crustacea (Copepoda)	*Microcyclops varicans*			**1**		**1**
Crustacea (Copepoda)	*Paracyclops* sp. 8 (PSW)					**1**
Crustacea (Decapoda)	*Caridina serratirostris*					
Crustacea (Decapoda)	*Holthuisana* sp.				**1**	
Crustacea (Decapoda)	*Macrobrachium australe*					**1**
Gastropoda	*Austropeplea lessoni*		**1**			
Gastropoda	*Ferrissia petterdi*					
Gastropoda	*Glyptophysa* sp	**1**				
Gastropoda	*Gyraulus* sp. 2 (KMS)	**1**	**1**	**1**	**1**	
Gastropoda	*Leichhardtia* sp.					
Insecta (Coleoptera)	*Berosus* sp.				**1**	
Insecta (Coleoptera)	*Copelatus clarki*					

Insecta (Coleoptera)	*Enochrus deserticola*		**1**		**1**	**1**
Insecta (Coleoptera)	*Enochrus esuriens*		**1**			
Insecta (Coleoptera)	*Enochrus eyrensis*			**1**		
Insecta (Coleoptera)	*Hydaticus consanguineus*					**1**
Insecta (Coleoptera)	*Hydaticus quadrivittatus*					**1**
Insecta (Coleoptera)	*Hydraena* sp. K1					**1**
Insecta (Coleoptera)	*Hydrocanthus australasiae*			**1**		
Insecta (Coleoptera)	*Hydrochus decoris*					**1**
Insecta (Coleoptera)	*Hydrochus numerospunctatus*					**1**
Insecta (Coleoptera)	*Hydrochus obscuroaeneus*					**1**
Insecta (Coleoptera)	*Hydrochus* sp.	**1**			**1**	
Insecta (Coleoptera)	*Hydroglyphus godeffroyi*				**1**	
Insecta (Coleoptera)	*Hydroglyphus leai*				**1**	
Insecta (Coleoptera)	Hydrophilidae			**1**		
Insecta (Coleoptera)	*Hydrovatus opacus*					**1**
Insecta (Coleoptera)	*Hydrovatus ovalis*					
Insecta (Coleoptera)	*Laccophilus clarki*	**1**				
Insecta (Coleoptera)	*Laccophilus sharpi*				**1**	
Insecta (Coleoptera)	*Limbodessus compactus*					
Insecta (Coleoptera)	*Megaporus ruficeps*					
Insecta (Coleoptera)	*Nanophyes* sp.				**1**	
Insecta (Coleoptera)	*Neohydrocoptus subfasciatus*		**1**	**1**		
Insecta (Coleoptera)	*Onychohydrus atratus*				**1**	
Insecta (Coleoptera)	*Paracymus pygmaeus*		**1**	**1**	**1**	**1**
Insecta (Coleoptera)	*Paranacaena horni*			**1**		**1**
Insecta (Coleoptera)	*Regimbartia attenuata*	**1**				
Insecta (Coleoptera)	Scirtidae sp.	**1**	**1**		**1**	**1**
Insecta (Coleoptera)	*Sternolophus australis*					**1**
Insecta (Coleoptera)	*Sternolophus marginicollis*		**1**			
Insecta (Coleoptera)	*Sternopriscus* sp.					**1**
Insecta (Diptera - Culicidae)	*Tripteroides atripes*					**1**
Insecta (Diptera - Culicidae)	*Anopheles novaguinesis*		**1**			
Insecta (Diptera - Culicidae)	*Anopheles* sp.				**1**	**1**
Insecta (Diptera - Culicidae)	*Culex* sp.		**1**	**1**		
Insecta (Diptera - Simulidae)	*Cnephia aurantiacum*					**1**
Insecta (Diptera - Dolichopodidae)	Dolichopodidae			**1**		
Insecta (Diptera - Dolichopodidae)	Dolichopodidae sp. K1 (KMS)					**1**
Insecta (Diptera -	Hemerodromia sp.					**1**

Empididae)							
Insecta (Diptera - Stratiomyidae)	Stratiomyidae	**1**			**1**		
Insecta (Diptera - Tabanidae)	Tabanidae		**1**				**1**
Insecta (Diptera - Tipulidae)	Tipulidae sp. K1 (KMS)						**1**
Insecta (Diptera - Ceratopogonidae)	*Atrichopogon* sp. 2 (SAP)		**1**				
Insecta (Diptera - Ceratopogonidae)	*Forcypomyia* sp.						
Insecta (Diptera - Ceratopogonidae)	*Bezzia* sp.	**1**	**1**		**1**		**1**
Insecta (Diptera - Ceratopogonidae)	*Nilobezzia* sp.				**1**		**1**
Insecta (Diptera - Ceratopogonidae)	*Culicoides* sp.		**1**				
Insecta (Diptera - Ceratopogonidae)	*Dasyhelea* sp.						**1**
Insecta (Diptera - Ceratopogonidae)	Ceratopogonidae					**1**	
Insecta (Diptera - Chironomidae)	*Chironomus* aff. *alternans* (V24) (CB)	**1**			**1**	**1**	**1**
Insecta (Diptera - Chironomidae)	*Chironomus tepperi*						
Insecta (Diptera - Chironomidae)	*Dicrotendipes jobetus*						**1**
Insecta (Diptera - Chironomidae)	*Dicrotendipes* sp.	**1**					**1**
Insecta (Diptera - Chironomidae)	*Djalmabatista* sp.						**1**
Insecta (Diptera - Chironomidae)	*Ablabesmyia notabilis*						**1**
Insecta (Diptera - Chironomidae)	*Fittkauimyia disparipes*						**1**
Insecta (Diptera - Chironomidae)	*Kiefferulus intertinctus*	**1**			**1**		**1**
Insecta (Diptera - Chironomidae)	*Larsia albiceps*						**1**
Insecta (Diptera - Chironomidae)	*Larsia* sp. K1 (KMS)						**1**
Insecta (Diptera - Chironomidae)	Orthocladiinae S03 sp.			**1**			
Insecta (Diptera - Chironomidae)	*Paraborniella* sp.						
Insecta (Diptera - Chironomidae)	*Parakiefferiella* sp.		**1**				
Insecta (Diptera - Chironomidae)	*Parakiefferiella variegatus* (KMS)						**1**
Insecta (Diptera - Chironomidae)	*Paramerina levidensis*					**1**	

Insecta (Diptera - Chironomidae)	*Paramerina parva*						**1**
Insecta (Diptera - Chironomidae)	*Parametriocnemus ornaticornis*						**1**
Insecta (Diptera - Chironomidae)	*Paratanytarsus* sp.				**1**		
Insecta (Diptera - Chironomidae)	Pentaneurini sp.	**1**	**1**	**1**	**1**		
Insecta (Diptera - Chironomidae)	*Polypedilum* nr *vespertinus* (M2) (SAP)						**1**
Insecta (Diptera - Chironomidae)	*Polypedilum nubifer*		**1**				**1**
Insecta (Diptera - Chironomidae)	Polypedilum sp.						
Insecta (Diptera - Chironomidae)	Polypedilum sp. K1 (PSW)						**1**
Insecta (Diptera - Chironomidae)	*Procladius paludicola*			**1**	**1**		**1**
Insecta (Diptera - Chironomidae)	*Rheocricotopus* sp. K1 (KMS)						**1**
Insecta (Diptera - Chironomidae)	*Stenochironomus* sp.						**1**
Insecta (Diptera - Chironomidae)	*Tanytarsus fuscithorax/semibarbitarsus*						
Insecta (Diptera - Chironomidae)	*Tanytarsus* 'K12' (PSW)						**1**
Insecta (Diptera - Chironomidae)	*Tanytarsus* sp.	**1**					
Insecta (Diptera - Chironomidae)	*Tanytarsus* sp. C (*bispinosus*) (SAP)		**1**			**1**	
Insecta (Diptera - Chironomidae)	*Tanytarsus* sp. P1 (PSW)						**1**
Insecta (Diptera - Chironomidae)	*Zavreliella marmorata*						
Insecta (Ephemeroptera)	*Cloeon* sp.	**1**	**1**	**1**	**1**		**1**
Insecta (Ephemeroptera)	*Tasmanocoenis arcuata*		**1**	**1**			
Insecta (Ephemeroptera)	Tasmanocoenis sp.			**1**			
Insecta (Ephemeroptera)	*Tasmanocoenis tonnoiri*						**1**
Insecta (Ephemeroptera)	*Thraulus* sp AV 3						**1**
Insecta (Hemiptera)	*Agraptocorixa* sp.	**1**					
Insecta (Hemiptera)	*Anisops nasuta*						
Insecta (Hemiptera)	*Anisops* sp.	**1**			**1**		
Insecta (Hemiptera)	*Austronepa angusta*				**1**		
Insecta (Hemiptera)	*Diplonychus eques*				**1**		
Insecta (Hemiptera)	*Enithares loria*				**1**		
Insecta (Hemiptera)	*Hydrometra papuana*				**1**		
Insecta (Hemiptera)	*Laccotrephes tristis*	**1**					
Insecta (Hemiptera)	*Limnogonus fossarum gilguy*					**1**	

Insecta (Hemiptera)	*Limnogonus luctuosus*		**1**				**1**		
Insecta (Hemiptera)	*Merragata hackeri*	**1**							
Insecta (Hemiptera)	*Mesovelia vittigera*				**1**				
Insecta (Hemiptera)	*Micronecta* sp.	**1**		**1**			**1**		
Insecta (Hemiptera)	*Micronecta virgata*				**1**				
Insecta (Hemiptera)	*Microvelia* sp.		**1**	**1**	**1**		**1**		
Insecta (Hemiptera)	*Naucoris australicus*	**1**							
Insecta (Hemiptera)	*Naucoris subaureus*						**1**		
Insecta (Hemiptera)	*Naucoris subopacus*	**1**		**1**					
Insecta (Hemiptera)	*Paranisops endymion*	**1**							
Insecta (Hemiptera)	*Paraplea brunni*	**1**		**1**	**1**				
Insecta (Hemiptera)	*Paraplea liturata*				**1**				
Insecta (Hemiptera)	*Ranatra diminuta*	**1**			**1**				
Insecta (Odonata)	*Agriocnemis* sp.	**1**							
Insecta (Odonata)	*Argiocnemis rubescens*				**1**				
Insecta (Odonata)	*Ceriagrion aeruginosum*	**1**							
Insecta (Odonata)	Coenagrionidae				**1**				
Insecta (Odonata)	*Hemicordulia australiae*								
Insecta (Odonata)	*Hemicordulia* sp.	**1**	**1**						
Insecta (Odonata)	*Ictinogomphus australis*								
Insecta (Odonata)	Libellulidae					**1**			
Insecta (Odonata)	*Nannodiplax rubra*						**1**		
Insecta (Odonata)	*Nososticta koongarra*						**1**		
Insecta (Odonata)	*Orthetrum caledonicum*		**1**				**1**		
Insecta (Odonata)	*Orthetrum pruinosum migratum*						**1**		
Insecta (Odonata)	*Orthetrum villosovittatum villosovittatum*	**1**	**1**			**1**			
Insecta (Odonata)	*Pseudagrion* sp.								
Insecta (Odonata)	*Rhodothemis lieftincki*								
Insecta (Odonata)	*Xanthagrion erythroneurum*		**1**	**1**					
Insecta (Trichoptera)	*Ecnomus pilbarensis*						**1**		
Insecta (Trichoptera)	*Orthotrichia* sp.						**1**		
Insecta (Trichoptera)	*Triaenodes* sp.		**1**				**1**		
Insecta (Trichoptera)	*Triplectides ciuskus seductus*	**1**		**1**			**1**		
Insecta (Trichoptera)	*Triplectides helvolus*				**1**				
Sum		**43**	**37**	**27**	**37**	**9**	**89**	**43**	**49**
Mean + Std Dev	**39.21897 + 22.75177**								