Gnangara Sustainability Strategy

An across-government initiative

Groundwater – Biodiversity – Land use

STATUS OF VEGETATION COMPLEXES IN THE GNANGARA SUSTAINABILITY STRATEGY STUDY AREA

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Department of Environment and Conservation

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Report to the Department of Environment and Conservation and Gnangara Sustainbility Strategy

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Introduction

As part of the GSS Biodiversity Project, priority areas within the GSS study area will be identified to aid future management decisions. If these priority areas are currently un-protected they could potentially be considered for future inclusion in the conservation estate. An essential component of determining priority areas was to evaluate the levels of remnant vegetation retention and fragmentation across the GSS study area. Additionally identifying the broad levels of representation of vegetation complexes within the GSS study area and across the Swan Coastal Plain also provides valuable information when determining priority areas.

The objectives of the study were to:

1. Quantify the current extent of remnant vegetation within the GSS study area.
2. Evaluate the size and shape of remnant vegetation patches across the GSS study area.
3. Quantify the level of protection and retention of vegetation complexes that occur in the GSS study area, at both the regional (Swan Coastal Plain IBRA region and Perth Metropolitan Region portion of the Swan Coastal Plain) and GSS study area scale.
4. Identify what vegetation complexes require additional areas to be retained, protected and rehabilitated within the GSS study area.

Background

Habitat loss from clearing is recognised as a major threat to biodiversity in Australia and throughout the world (Saunders *et al.* 1991). Destruction of native vegetation is not only associated with the removal of habitat, but with the loss of species (Fahrig 2002). When the amount of habitat within a landscape declines, species richness similarly declines (Fahrig 2002; Lindenmayer and Luck 2005). In addition, the population size of remaining species decreases until many species exist only in small, isolated populations (Huggett 2005). Once habitat loss crosses a 'threshold' a substantial number of species are then lost from the landscape (Hugget 2005; Fahrig 2002; Radford *et al.* 2005; Andren 1994),

potentially leading to an ecological change in state (Lawton *et al.* 1994). Although the concept of an ecological threshold is predominantly driven by theoretical models, there is an increasing amount of research that supports the theory of such a threshold (Radford *et al.* 2005). Modelled simulation studies suggest a major ecological change of state occurs when habitat cover declines to approximately 10-30% of the landscape (Andren 1994), and empirical studies have shown very strong evidence for sharp decline in species richness in landscapes with less than 10% habitat cover (Radford *et al.* 2005). However, the threshold level will undoubtedly vary according to community type, configuration and condition of remnant vegetation and the extent of additional disturbances (Fahrig 2002; Lindenmayer and Luck 2005).

The use of ecological thresholds in land use policy is gaining popularity (Lindemayer and Luck 2005). For example, in semi-arid regions in Queensland, a reduction in remnant vegetation to 30%, at a regional scale, will potentially result in the loss of 25-35% of the vertebrate fauna (McAlpine *et al.* 2002). This finding lead to the proposal of minimum vegetation retention thresholds of a) 50% at a regional scale; b) 30% at a regional ecosystem scale (McAlpine *et al.* 2002). In addition, the 30% minimum retention threshold has been adopted in the National Objectives and Targets for Biodiversity Conservation 2001 to 2005 (Commonwealth of Australia 2001). The retention and protection of ecological communities also contributes to the establishment of a comprehensive, adequate and representative (CAR) system of protected areas, as required under the National Strategy for the Conservation of Australia's Biological Diversity (Commonwealth of Australia 1996).

In the Perth Metropolitan region, the representation and retention of vegetation complexes were key criteria in identifying significant sites as part of the Bush Forever process. In this planning process, a 10% threshold was used due to the considerable constraints associated with protecting areas in a heavily populated urban region (Government of Western Australia 2000a and b). Inherent in the Bush Forever process was the general presumption against clearing any vegetation complex with less than 10% remaining in the Perth Metropolitan Region portion of the Swan Coastal Plain (Government of Western Australia 2000a).

Although the use of ecological thresholds in land use policy is increasing (Lindenmayer and Luck 2005), land use decision makers need to be aware of issues associated with the use of thresholds, including:

a) Above the threshold, species richness will still decline with habitat loss, as the threshold represents the point at which species loss is *exacerbated* (Andren 1994) or an *end point* of species decline (Radford *et al.* 2005).
b) The *configuration* of remaining vegetation in the landscape will play a very important role in determining the threshold level as the degree of fragmentation strongly influences species loss (Fahrig 2002).
c) Retention of habitat needs to be *representative* of the vegetation communities in the landscape, and the *condition* of remnant vegetation is very important in minimising species loss (Lindenmayer and Luck 2005).

The size of remnant habitat is a critical determinant of species richness and population abundance (MacArthur and Wilson 1963; Rosenzweig 1995). The bigger an area the greater its capacity to maintain ecological functioning, retain biodiversity and resist disturbing and threatening factors (Del Marco *et al.* 2004). Therefore small remnant patches may be at greater risk from disturbance and degradation via increasingly frequent, or high intensity fires, weed invasions and fragmentation caused by human use (Hobbs 1993).

In addition, the shape of remnant vegetation areas is important in determining impacts from edge effects (e.g. spread of weeds, altered light levels, increased predation, grazing, rubbish dumping) and influences the diversity and integrity of remaining biota (Rosenzweig 1995). Areas with a compact shape, such as a circle or square have the greatest viability, as their core areas are the largest possible for a given size (Del Marco *et al.* 2004). In contrast, long, thin shapes have the lowest viability as the majority of their area is impacted by edge effects. The perimeter to area ratio is a tool which can provide an indication of which of these categories a patch falls into and therefore the level of impact threatening processes may have. Additionally, the management of reserves with a high perimeter to area ratio is often very difficult (Panetta and Hopkins 1991).

Databases and methods used

Retention and fragmentation of remnant vegetation

Remnant vegetation mapping was compiled from two sources Remnant Vegetation Mapping for the DEC Swan Region and Mapping of Remnant Vegetation Patches in Pine Plantations on the Gnangara Mound (see Table 1 for further details of datasets). Remnant vegetation data was compiled for the GSS study area plus a 10 km buffer. The buffer area was included so that the full extent of remnant vegetation patches within the GSS boundary could be included in the dataset, thus ensuring that the fragmentation measures would be accurate for those patches that straddle the GSS boundary. The compiled data was then modified and cleaned in the following ways:

1. Small non-remnant areas, from the Remnant Vegetation Mapping for the DEC Swan Region datasource, were removed. These were artefacts of the mapping derived from Landsat TM satellite imagery and were restricted to the northern part of GSS only. This was done by visually inspecting the data against the latest aerial photography and deleting artefact polygons that were not overlaying remnant vegetation.
2. Tenure and other lines bisecting remnant vegetation patches were removed. This was done so that the boundaries of the polygons represented the perimeter of intact remnant vegetation areas (patches). A unique identifier was then assigned to each remnant patch.

Areas associated with linear infrastructure that are cleared of remnant vegetation were removed from the large arc of remnant vegetation in the centre of the GSS (see Figure 1 and Table 1 for details of datasets used). The size of buffer areas removed around linear infrastructure (half of stated amount either side) are as follows:

a. 20 m buffer around sealed roads and 10 m buffer around unsealed roads;
b. 10 m buffer around gas pipelines;
c. 10 m buffer around overhead transmission (power) lines.

For each remnant vegetation patch the fragmentation measures of patch area (ha), perimeter (m) and perimeter to area ratio (perimeter (m) divided by patch area (m^2)) were calculated using tools available within ArcView 9.1. Patch area and perimeter to area ratio classes were identified following a visual inspection of the data.

Tenure and Conservation Plan information was also compiled to ascertain the protection status of each of the remnant vegetation patches. The total area of remnant vegetation was then calculated for the following protection categories:

1. Protected (National Parks, reserves in Regional Parks, Whiteman Park, Kings and Bold Park, Nature Reserves, 5(1)(h) Reserves, Other Reserves vested in the Conservation Commission under the CALM Act and Bush Forever – implemented);
2. Some level of Protection (State Forest, State Forest that is proposed excision to Conservation Reserve, Unallocated Crown Land, Misc and 5 (1)(g) reserves and Bush Forever – nominated);
3. Not Protected (Crown Reserves in the Shires of Gingin and Chittering and all other tenures not covered in categories 1 and 2 above).

Derived spatial layers were created in the GIS application ArcView 9.1 and Microsoft Excel was used to calculate summary statistics.

Table 1: Datasets used in assessment of the current extent of remnant vegetation

Dataset	Source
Remnant Vegetation Extent	
Swan Region Remnant Vegetation mapping (1:20,000)	Department of Agriculture and Food WA (April 2006). Derived from Landsat data and corrected using digital ortho-photos; PMR June 2005.
Remnant Vegetation Patches in Pine Plantations on the Gnangara Mound	DEC (see Brown *et al.* 2009 for details).
Linear Infrastructure	
CALM Operational Graphics (COG) Roads Digital Acquisition Program Dataset (Sealed and Unsealed Roads)	Department of Environment and Conservation (October 2008)
GEODATA Pipelines dataset (Gas Pipelines)	Geoscience Australia (08/10/2003)
Overhead Transmission Lines dataset (powerlines)	Western Power (October 2008)
Protection Status	
GSS Conservation Reserves and other DEC managed land	This dataset was derived from • Existing DEC Managed Lands and Waters dataset (from DEC Tenure Information Systems 2007) • Landgate Cadastre and Tenure (extracted 2007). • 2004 Forest Management Plan (DEC) See Sonneman and Brown (2008) for more details
Regional Parks	Department of Environment and Conservation 2008
Bush Forever Sites	Department for Planning and Infrastructure 2000

Levels of retention and protection of vegetation complexes

There are a number of ways to classify vegetation communities within the Swan Coastal Plain. For our purposes, we used the vegetation complexes defined by Heddle *et al.* (1980), to quantify and interpret representation of biodiversity (see Appendix A for a list and description of vegetation complexes that occur in the GSS study area). Although the vegetation complex data only delineates broad vegetation classes, the benefits of using these data are numerous, including: 1) it depicts the pre-European extent of vegetation complexes across the GSS area; 2) it describes the extent of vegetation complexes for most of the Swan Coastal Plain, enabling the level of representation of each complex to be assessed over its natural extent (Appendix B). However, it is likely that some of the vegetation complexes found within the GSS study area occur in the unmapped areas, and hence the level of representation may be underestimated (Appendix B). More recently mapping of site-vegetation types has been completed by Mattiske (2003), however this mapping has only been completed for a proportion of the GSS area.

In addition to the vegetation complex mapping, information from a number of other spatial datasets (Table 2) were used to calculate statistics on the level of retention and protection of vegetation complexes within the Swan Coastal Plain (SCP), the Swan Coastal Plain portion of the Perth Metropolitan Region and GSS study area (Appendix B). At the time the analysis was undertaken the only digital mapping of the remnant vegetation extent was based on December 2005 – January 2006 ortho-photos for the Perth Metropolitan Region portion of the SCP (Damian Shepherd, DAFWA pers. comm.). The date of the ortho-photos used for the other areas of the SCP is unknown. Henceforth, the current remnant vegetation extent and vegetation complex extent refers to the extent in 2005 – 2006. The cleaned remnant vegetation mapping for GSS described under 'Retention and Fragmentation of Remnant Vegetation' was not used in this analysis as similar cleaned data was not available for the rest of the SCP. The level of protection of vegetation complexes was ascertained using Tenure and Conservation Plan information (see Table 1 for details). Then the total area of remnant vegetation, for each vegetation complex, was calculated for the protection categories listed under 'Retention and Fragmentation of Remnant Vegetation'. Derived spatial layers were created in the GIS application ArcView 9.1 and Microsoft Excel was used to calculate summary statistics.

Table 2: Datasets used in assessment of the level of retention and protection of vegetation complexes

Dataset	Source
Regional Boundaries	
Interim Biogeographic Regionalisation for Australia (IBRA), Version 6.1 (used IBRA boundary as the boundary of the Swan Coastal Plain)	Australian Government Department of the Environment and Heritage
Metropolitan Region Scheme Boundary (boundary of PMR)	Department for Planning and Infrastructure (2007)
GSS Study Area Boundary	Department of Water (2008)
Remnant Vegetation Extent	
Swan Coastal Plain Remnant Vegetation mapping (1:20,000)	Department of Agriculture and Food WA (April 2006). Derived from Landsat data and corrected using digital ortho-photos; PMR June 2005.
Vegetation Complexes	
Vegetation Complex (1:250,000)	Department of Environment and Conservation; mapped by Heddle *et al.* (1980)
Protection Status	
GSS Conservation Reserves and other DEC managed land	This dataset was derived from • Existing DEC Managed Lands and Waters dataset (from DEC Tenure Information Systems 2007) • Landgate Cadastre and Tenure (extracted 2007) • 2004 Forest Management Plan (DEC)
Regional Parks	Department of Environment and Conservation 2008
Bush Forever Sites	Department for Planning and Infrastructure 2000)

Vegetation complexes were then ranked using criteria listed in Table 3. This ranking was undertaken to identify priority vegetation complexes for retention, protection and rehabilitation, and was based on current levels of retention across several regional boundaries, pre-European extent in the GSS and levels of protection in the GSS.

Table 3: Criteria for the ranking of vegetation complexes and management objectives for each rank.

Rank	Criteria	Management Objectives
1	< 10% retained SCP, or < 10% in the SCP portion of the PMR	Retention and protection of remaining areas is a high priority. Since less than 10% remains rehabilitation should be considered especially along ecological linkages.
2	< 30% retained SCP, or < 400 ha retained SCP, or > 60% of pre-European extent is within the GSS	Retention and protection of remaining areas is a priority. If rehabilitation is going to be undertaken ecological linkages should be targeted.
3	< 30% protected GSS	Retention and protection of remaining areas is a priority.
4	do not meet any of above criterion	No additional protection is required.

Results and discussion

Retention and fragmentation of remnant vegetation

Current extent and levels of protection of remnant vegetation

Clearing of remnant vegetation for urban and agricultural development has been extensive in the south west, eastern and far northern sections of the GSS study area (Figure 1). Portions of the central areas have also been cleared for urban, agricultural and pine forestry development. In 2005 – 2006, just over half of remnant vegetation had been cleared in the GSS study area with just over 100,000 ha of remnant vegetation remaining (Table 4). The majority of remnant vegetation patches are small and highly fragmented except a few large intact areas in the north and central areas of the GSS study area. The area of remnant vegetation comprising Yeal Nature Reserve, sections of State Forest and Unallocated Crown Land north and east of the pine plantations and Whiteman Park represent one of the largest contiguous areas of remnant vegetation on the Swan Coastal Plain (Figure 1).

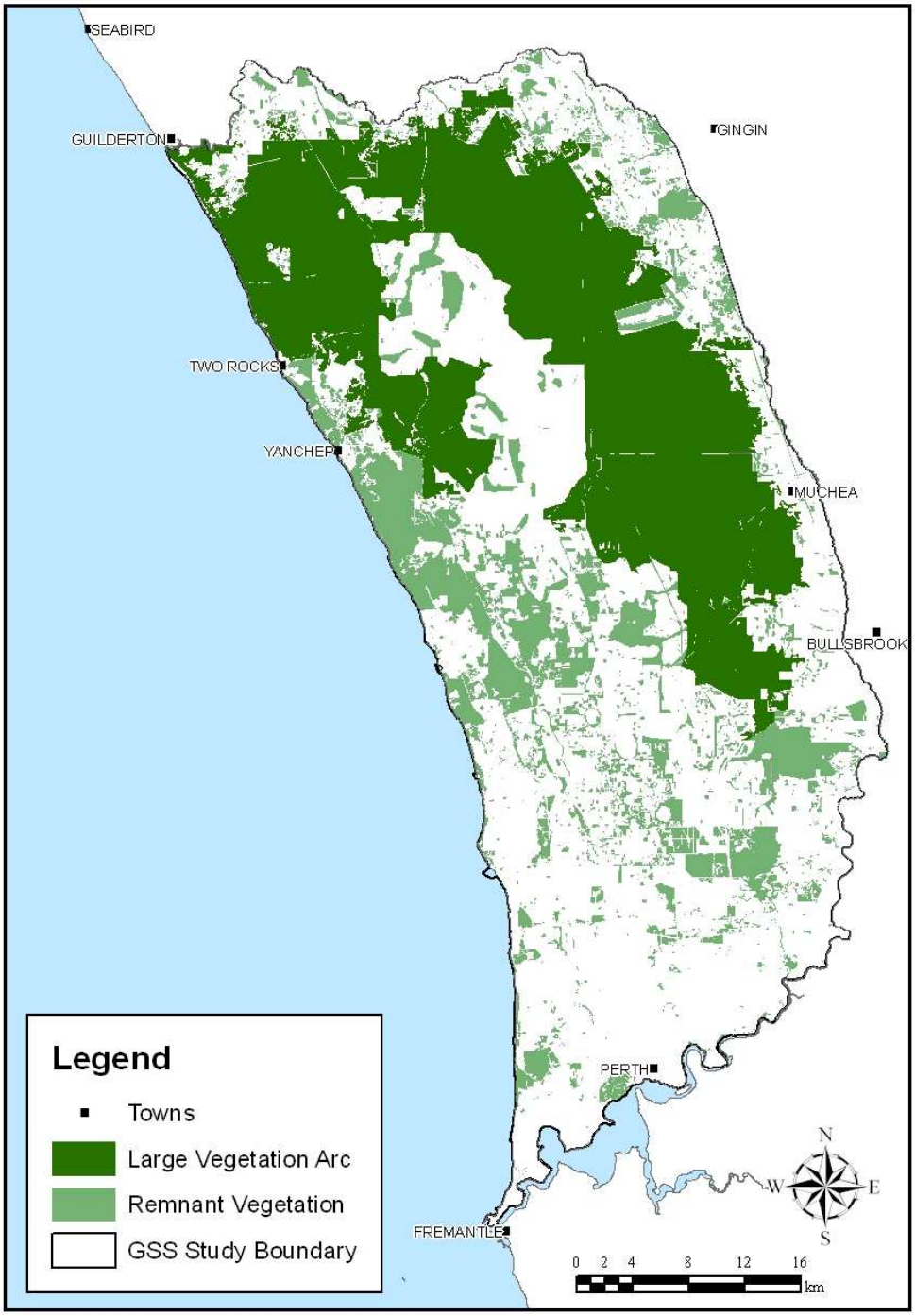

Figure 1: Current extent of remnant vegetation across the GSS study area.

Approximately 34% of the remaining remnant vegetation in the GSS study area is protected with an additional 42% which is either proposed to be protected or within tenure that precludes large scale clearing (State Forest and Unallocated Crown Land, Table 4). Of the areas that are protected the majority are managed by DEC. Bush Forever identified over 8,000 ha of remnant vegetation, occurring outside existing protected areas, as being

regionally significant (Table 4, Government of Western Australia 2000a). These Bush Forever sites are on public and private land and the protection status for a small amount is yet to be finalised. A similar assessment of regional significance of remnants in the portion of the GSS covered by the Shires of Gingin and Chittering is yet to be undertaken. In these Shires large areas of remnant vegetation are on unallocated crown land and within crown reserves (Table 4) which are not currently protected for conservation purposes.

Table 4: The extent of remnant vegetation and protection status in the GSS study area in 2005 – 2006.

Level of protection	Tenure	Total area of remnant vegetation (ha)	Proportion of remnant vegetation (%)	Proportion of total area of GSS (%)
Protected for conservation	Major parks, nature reserves, other reserves vested in the Conservation Commission (CALM Act)	25 950	25.6	12.1
	Bush Forever – additional to above	8195	8.1	3.8
	Sub-total	**34 145**	**33.6**	**15.9**
Some level of protection	Bush Forever (additional nominations)	69	0.1	0.0
	State forest and other DEC managed lands (vesting purpose not conservation)	11 809	11.6	5.5
	Proposed for vesting as a conservation reserve (currently state forest)	11 490	11.3	5.3
	Unallocated Crown Land	19 218	18.9	8.9
	Sub-total	**42 586**	**41.9**	**19.8**
Not protected for conservation	Other Crown reserves outside Metropolitan Regional Scheme	670	0.7	0.3
	All other tenures (not protected through Bush Forever)	24 143	23.8	11.2
	Sub-total	**24 813**	**24.4**	**11.5**
Total area of remaining remnant vegetation		**101 544**[+]	**100.0**	**47.3**
Total area cleared		**113 352**		**52.7**

[+] Total area of remnant vegetation is slightly higher than that reported in Table 5 as this total is based on data which has been cleaned and incorporates more accurate mapping of remnant vegetation patches within the pine plantations.

Level of fragmentation – patch size and shape

Analysis of remnant vegetation patches revealed that most remnants in the south-west and east of the GSS are small and highly fragmented, whereas large intact areas remain in the north and central areas with the largest patches within the arc to the north and east of the pine plantations (Figure 1 and Figure 3). The areas and shapes of the remnant vegetation patches varied greatly and hence their perimeter to area ratios did too. Many of the very small patches which appear in Figure 2 (very small area and very high perimeter to area ratio) are actually artefacts of the spatial analysis. Figure 2 shows the distribution of remnant vegetation patches by area and by perimeter to area ratio classes, while Figure 3 illustrates this for the area classes (see Appendix C for the same illustration for perimeter to area classes).

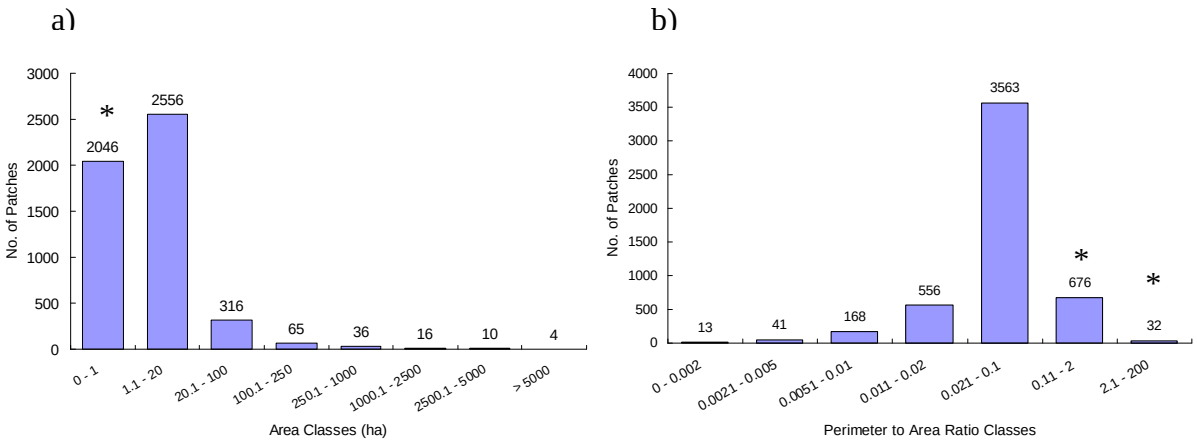

Figure 2: Distribution of remnant vegetation patches within area (ha) classes and perimeter to area ratio classes (* majority are artefacts of the spatial analysis).

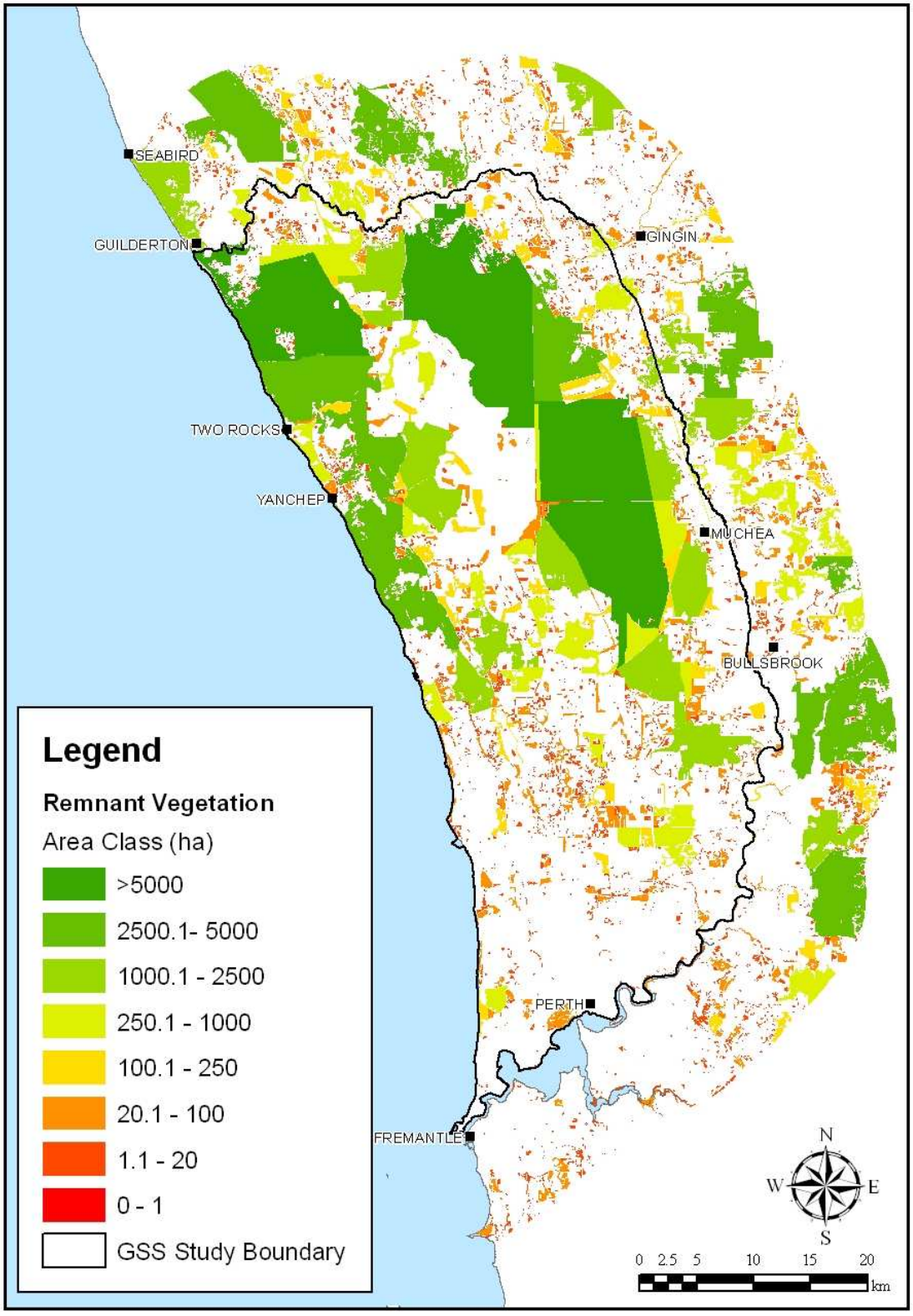

Figure 3: Ranking of remnant vegetation patches, according to area class, within the GSS study area and additional 10 km buffer.

Levels of retention and protection of vegetation complexes

Swan Coastal Plain

An assessment of the level of *retention* across the original extent (Swan Coastal Plain) of the 21 vegetation complexes that occur in the GSS study area, showed that two complexes (Beermullah and Guilford) have less than 10% retained and an additional seven (Bassendean Central and South, Herdsman, Karakatta Central and South, Pinjar, Southern River, Swan and Yanga) have less than 30% retained (Table 5). To prevent an exponential loss of species within these ecological communities and to meet the requirements of current policy, all of these vegetation complexes should be priorities for additional protection across the Swan Coastal Plain including within the GSS study area. Of particular importance for retention and protection in the GSS study area are those vegetation complexes which have < 30% retained across the Swan Coastal Plain and that have a good proportion (> 40%) of their pre-European extent within the GSS study area boundary (Herdsman, Karrakatta Central and South, Pinjar and Yanga complexes). It should be noted that very small amounts (<10 ha) of the heavily cleared Beermullah and Guilford complexes are unprotected in the GSS (Table 5) therefore rehabilitation would need to be undertaken to increase the levels of retention and protection of these complexes.

Perth Metropolitan Region portion of the Swan Coastal Plain

One of the Bush Forever Policy Measures for Implementation was a general presumption against clearing of any vegetation complex with less than 10% remaining (retention) in the Perth Metropolitan Region portion of the Swan Coastal Plain (Government of Western Australia 2000a). Four of the 19 GSS vegetation complexes that occur in the Perth Metropolitan Region have less than 10 % retention across this regional boundary (Beermullah, Guilford and Vasse, Coonambidgee). A fifth complex, Swan, is worthy of mention as its current level of retention (11 %) is only just above the 10 % threshold. On a more positive note, comparison of the levels of retention based on 2005 – 2006 remnant vegetation extent (this study) with the levels of retention based on 1997 extent (Bush Forever study, Government of Western Australia 2000b) has revealed that the level of retention has not changed in the intervening years for those complexes identified as having less than 10% in Bush Forever.

GSS study area

Although nearly 50% of remnant vegetation remains within the GSS study area, the degree of *retention* varies considerably between vegetation complexes. In the GSS study area, 11 vegetation complexes have less than 30% remaining, and typically occur in areas that have been heavily cleared for urban and agricultural development (e.g. Pinjarra Plain, southern Bassendean Dunes and central Wetlands; Table 5; Figure 4). Not surprisingly, nine of these 11 vegetation complexes have inadequate levels of retention at the Swan Coastal Plain scale (see above) and four have less than 10% retained in the Swan Coastal Plain portion of the Perth Metropolitan Region (see above). Additionally three have less than 10% remaining in the GSS (Vasse Complex, Beermullah Complex and Swan Complex). These communities require protection of all, or as much as possible of the remaining remnant vegetation within the GSS.

Only three of the 21 GSS vegetation complexes have greater than 30% of their remnant vegetation *protected* (Table 5). These are Bassendean Central and South Transition, Bassendean North Transition and Karakatta North Transition complexes. Of the remaining vegetation complexes, levels of current protection and opportunities to protect additional areas vary considerably (summarised in Table 5).

Table 5: Current (2005 – 2006) and pre-European extent of vegetation complexes in the Swan Coastal Plain and GSS study area (hectares). Values in brackets are proportions (%) of the pre-European extent for each category.

Landform	Vegetation Complex	Pre-European extent in the SCP	Current extent in the SCP	Pre-European extent in the PMR	Current extent in the PMR	Pre-European extent in the GSS	Current extent in the GSS	Current extent protected in the GSS	Current extent with some level of protection in the GSS	Current extent not protected in the GSS	Extent Proposed for formal conservation protection in FMP[(1)]
Quindalup Dunes	Quindalup	52251	30129 (58)	24470	11514 (47)	15843 (30)	9614 (61)	1804 (11)	1973 (12)	5837 (37)	0
Spearwood Dunes	Cottesloe Central and South	45300	17529 (39)	34702	11863 (34)	21593 (48)	8381 (39)	3575 (17)	889 (4)	3917 (18)	0
	Cottesloe North	43474	25304 (58)	8717	6537 (75)	21399 (49)	15461 (72)	5038 (24)	8802 (41)	1621 (8)	5644
	Karrakatta Central and South	49912	12791 (26)	34597	5848 (17)	24284 (49)	3484 (14)	1348 (6)	323 (1)	1813 (7)	0
	Karrakatta – North	44273	19586 (44)	5155	1071 (21)	15365 (35)	5868 (38)	778 (5)	4050 (26)	1040 (7)	411
	Karrakatta – North Transition	5260	4751 (90)	2345	1850 (79)	5260 (100)	4751 (90)	2102 (40)	2648 (50)	0 (0)	0
Marine (Estuarine and Lagoonal) Deposits	Vasse	11196	3778 (34)	763	7 (1)	549 (5)	6 (1)	5 (1)	0 (0)	1 (0)	0
Wetlands	Herdsman	9665	2559 (26)	6509	1979 (30)	4144 (43)	996 (24)	770 (19)	0 (0)	226 (5)	0
	Pinjar	4893	1140 (23)	4893	1140 (23)	4893 (100)	1140 (23)	905 (18)	63 (1)	172 (4)	0
Combinations of Quindalup/Spearwood/ Bassendean Dunes	Moore River	8462	2979 (35)	not in PMR	not in PMR	797 (9)	267 (34)	0 (0)	0 (0)	267 (34)	0
Bassendean Dunes	Bassendean – Central and South	87476	24678 (28)	46279	10826 (23)	10437 (12)	1923 (18)	1566 (15)	97 (1)	260 (2)	0
	Bassendean – Central and South Transition	2178	2176 (100)	623	623 (100)	2178 (100)	2176 (100)	2175 (100)	1 (0)	0 (0)	0
	Bassendean – North	79057	57054 (72)	22933	12476 (54)	51920 (66)	34705 (67)	10194 (20)	18878 (36)	5633 (11)	4738
	Bassendean – North Transition	20856	18510 (89)	3116	2164 (69)	7789 (37)	6687 (86)	2845 (37)	3643 (47)	199 (3)	6
	Caladenia	9660	5309 (55)	not in PMR	not in PMR	277 (3)	49 (18)	0 (0)	0 (0)	49 (18)	0
Combinations of Bassendean Dunes / Pinjarra Plain	Southern River	57172	12238 (21)	31150	5144 (17)	7490 (13)	1429 (19)	1047 (14)	0 (0)	382 (5)	0
Pinjarra Plain	Beermullah	6707	436 (6)	6707	436 (6)	1000 (15)	87 (9)	81 (8)	0 (0)	6 (1)	0
	Guildford	92497	4870 (5)	24432	1370 (6)	486 (1)	91 (19)	83 (17)	0 (0)	8 (2)	0
	Swan	16590	2239 (13)	6054	665 (11)	1741 (10)	83 (5)	48 (3)	0 (0)	34 (2)	0
	Yanga	26176	5164 (20)	5775	1025 (18)	16321 (62)	3680 (23)	482 (3)	73 (0)	3125 (19)	36
Gingin Scarp	Coonambidgee	6272	2865 (46)	40	3 (7)	448 (7)	336 (75)	0 (0)	0 (0)	336 (75)	0
	Total	**679329**	**256085**	**269257**	**76539**	**214214**	**101212**	**34846**	**41441**	**24925**	**10835**

[(1)] Extent of State Forest proposed for formal conservation protection in the Forest Management Plan (Conservation Commission of Western Australia 2004)

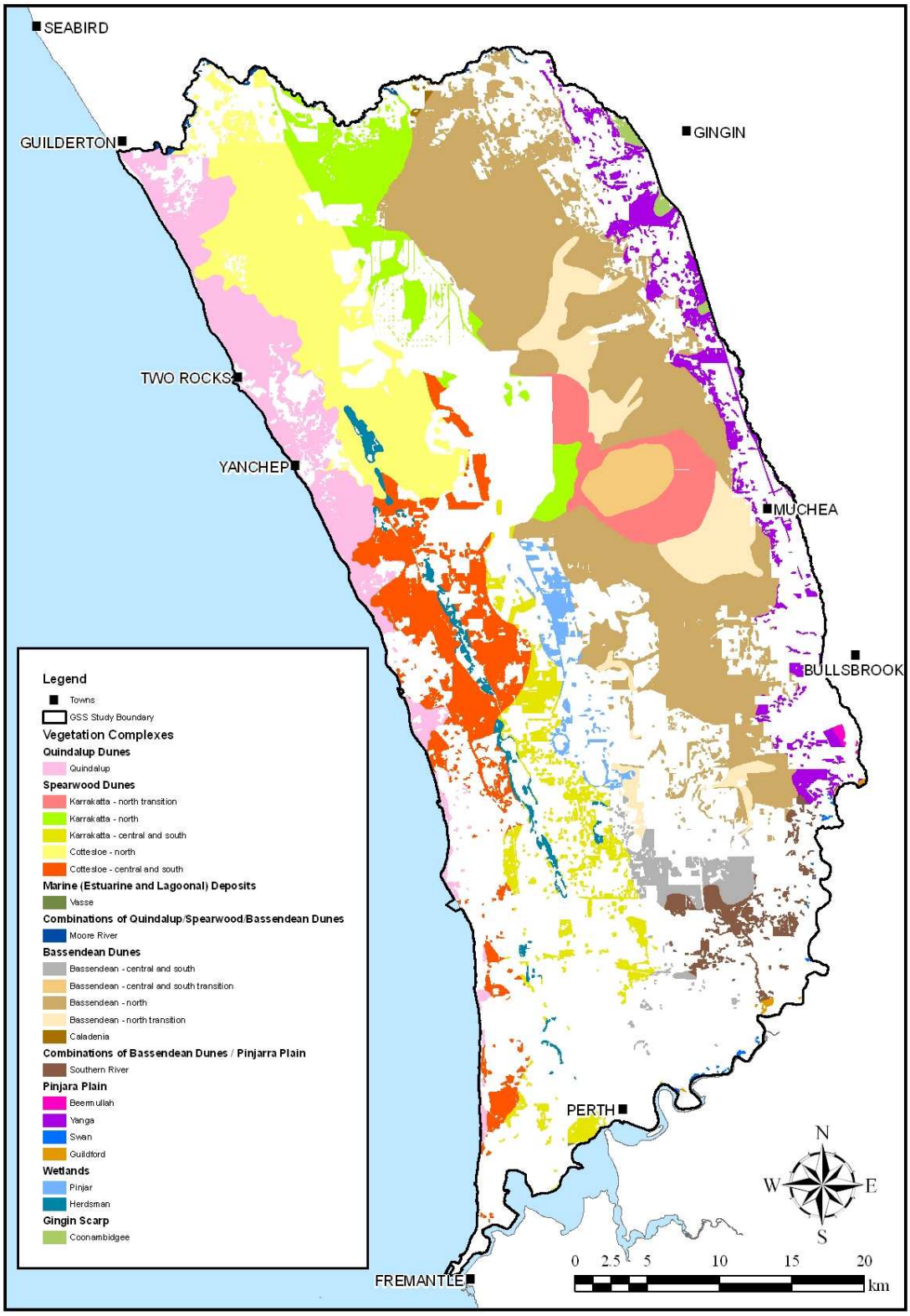

Figure 4: Current extent of remnant vegetation and vegetation complexes in the GSS study area.

Priorities for additional protection and rehabilitation

Based on the levels of retention and protection, vegetation complexes were ranked, indicating priority complexes for retention, protection and rehabilitation (Table 6). All four of the vegetation complexes ranked 1 (Beermullah, Guilford and Vasse, Coonambidgee) have very low or low levels of retention across one or more of the regional boundaries assessed (Table 5 and Table 6). These four vegetation complexes occur in the extensively cleared areas in the east or south east of the study area on the Pinjarra Plain, Gingin Scarp or the Marine deposits of the Swan River (Figure 4). For the Coonambidgee complex the lack of protected areas within the GSS is reflecting that no assessment of regionally significant biodiversity assets has been undertaken in the Shires of Gingin and Chittering. The majority of remaining remnant vegetation for this complex lies on rural land and additional protection is vital to maintain ecological linkages to the existing conservation estate to the west and east. For the other three vegetation complexes ranked 1 (Beermullah, Guilford and Vasse) the majority of existing areas are protected within the GSS study area so opportunities to rehabilitate along ecological linkages (along Ellen Brook and the Swan River) could be investigated. Rehabilitation should only be considered if it is assessed that no better outcomes can achieved in spending the money protecting existing areas that occur outside the GSS.

Five of the vegetation complexes ranked 2 have very low or low levels of retention within the GSS study area (Table 5) with limited scope to protect additional areas (Herdsman, Bassendean Central and South, Karrakatta Central and South, Southern River and Swan). Formal protection of unprotected areas is a priority for these complexes and could be achieved by retaining areas for ecological linkages. Targeted rehabilitation within ecological linkages and surrounding existing remnants could also be considered if it is assessed that no better outcomes can be achieved in spending the money protecting existing areas that occur outside the GSS. The Pinjar complex is also ranked 2 and has low levels of retention. This complex only occurs within the GSS and therefore is a high priority for protection. The high conservation significance of this vegetation complex was recognised by Bush Forever and the WAPC have been purchasing land in Lake Pinjar to increase the area protected. Another complex ranked 2 with low levels of retention is the Yanga complex. It also has very low levels of protection reflecting that no assessment of regionally significant biodiversity assets has been undertaken in the Shires of Gingin and

Chittering. The majority of remaining remnant vegetation for this complex lies on rural land and additional protection is vital to maintain ecological linkages to the existing conservation estate to the west and east. The Forest Management Plan is proposing that 36 ha of the Yanga vegetation complex be protected for conservation (Table 5). The Karrakatta North Transition and Bassendean North vegetation complexes are also ranked 2 and both have high levels of retention in the GSS study area and have substantial areas protected. These complexes are still considered a high priority for protection within the GSS study area as they either occur only within the GSS (Karrakatta North Transition) or occur largely within the GSS and are still below the 30% protection threshold (Bassendean North). Additional areas of Bassendean North have been proposed to be protected in the Forest Management Plan (Table 5).

Many of the vegetation complexes ranked 3 are still a priority for further protection. Worthy of mention are the Quindalup and Cottesloe Central and South complexes that currently have respectively moderate to high or moderate levels of retention within the GSS (Table 5) but a significant amount of unprotected areas are zoned for urban development. Therefore the protection of these vegetation complexes should be carefully considered during the development of structure plans. This will ensure that adequate areas are set aside so the 30% protection threshold can be met and that areas are retained in such a way that connectivity of existing protected areas is maintained.

Table 6: Ranking of GSS vegetation complexes, in regards to priority for retention and further protection, and summary of status. For the criteria, the values in brackets indicate the scores used in the ranking.

Vegetation Complex	**Rank**	**Criteria**							**Priorities and opportunities for additional retention, protection, rehabilitation in the GSS**
		< 10% retained SCP (1)	< 10% in the SCP portion of the PMR (1)	< 30% retained SCP (2)	< 400 ha retained SCP (2)	> 60% of pre-European extent is within the GSS (2)	< 30% protected GSS (3)	no additional protection required to meet 30% threshold (4)	
Quindalup	3						x		Current retention levels within GSS moderate to high but majority of the unprotected areas are zoned urban (along the coast Quinns Rocks to Moore River). Therefore it is a priority to protect additional areas to meet 30% protection target before large scale clearing occurs and areas become highly fragmented. Additional protected areas will be vital in providing linkages to other remnants north and south along the coast and to the east.
Cottesloe – Central and South	3						x		Moderate levels of retention within GSS good but a good portion of the unprotected areas are zoned for urban or industrial development (located Quinns Rocks, Eglinton and Carabooda to Neerabup areas). Therefore it is a priority to protect additional areas to meet 30% protection target before areas become highly fragmented. Additional areas being protected will be vital in providing linkages to other remnants.
Cottesloe – North	3						x		High levels of retention in the GSS and good levels of protection. 5644 ha of State Forest is proposed to be protected in the Forest Management Plan (Conservation Commission of WA 2004). This would bring the level of protection to well above 30%.
Karrakatta – Central and South	2			x			x		Low level of retention within the GSS with a good proportion of the remaining unprotected areas small and highly fragmented and largely on land zoned for intensive development. Therefore it is a priority to protect additional areas and to investigate the feasibility of rehabilitation especially around existing remnants and ecological linkages.

Vegetation Complex	Rank	Criteria							Priorities and opportunities for additional retention, protection, rehabilitation in the GSS
		< 10% retained SCP (1)	< 10% in the SCP portion of the PMR (1)	< 30% retained SCP (2)	< 400 ha retained SCP (2)	> 60% of pre-European extent is within the GSS (2)	< 30% protected GSS (3)	no additional protection required to meet 30% threshold (4)	
Karrakatta – North	3						x		Moderate levels of retention in the GSS and very low levels of protection. Remaining areas are largely in State Forest with 411 ha proposed to be protected in the Forest Management Plan (Conservation Commission of WA 2004). Additional retention and protection of areas in ecological linkages in the Yanchep pine plantation would assist in reaching the 30% protection target.
Karrakatta – North Transition	2					x		x	High levels of retention in the GSS and good levels of protection. Since this complex occurs solely within the GSS it is important that the remaining 2648 ha within Unallocated Crown Land and State Forest has its protection status for conservation formalised.
Vasse	1^{+}		x				x		Very low levels of retention and what areas remain are largely protected (along the Swan River in Central Perth). Only 5% of the pre-European extent occurs in the GSS study area. Rehabilitation would be required to increase the level of retention and protection of this complex in the GSS but this should not be done without an assessment of whether better outcomes would be achieved in spending the money on protecting existing remnants that occur outside the GSS.
Herdsman	2			x			x		Low level of retention within the GSS though a good proportion of what remains is protected. Some of the unprotected remnants are of a moderate size and are well connected to other protected areas (Nowergup). Formal protection of these is a priority and this could be achieved by the retaining areas for ecological linkages and targeted rehabilitation.
Pinjar	2			x		x	x		Low level of retention within the GSS. This complex occurs only within the GSS and therefore is a high priority for further protection. The WAPC have been purchasing land in Lake Pinjar to increase the area protected. Highly fragmented unprotected areas also remain on rural and urban land around Mariginup. Rehabilitation around existing protected areas should also be considered.

Vegetation Complex	Rank	Criteria							Priorities and opportunities for additional retention, protection, rehabilitation in the GSS
		< 10% retained SCP (1)	< 10% in the SCP portion of the PMR (1)	< 30% retained SCP (2)	< 400 ha retained SCP (2)	> 60% of pre-European extent is within the GSS (2)	< 30% protected GSS (3)	no additional protection required to meet 30% threshold (4)	
Moore River	3						x		Moderate to low levels of retention in the GSS with no areas formally protected for conservation. Some of the remaining areas are highly fragmented. The low level of protection of this complex reflects that no assessment of regionally significant biodiversity assets has been done in the Shire of Gingin. Significant areas of this complex also occur north of the GSS study area. Opportunities exist to rehabilitate areas as some of the river is within existing crown reserves. Once again this should not be done without an assessment of whether better outcomes would be achieved in spending the money on protecting existing remnants that occur outside the GSS.
Bassendean – Central and South	2			x			x		Low levels of retention and what areas remain are largely protected (Whiteman Park). This complex has less than 30% remaining over the Swan Coastal Plain so is a priority for protection. Unprotected areas are on rural land in East Wanneroo. Additional protection of remnants in this area could help in the establishment of ecological linkages. Targeted rehabilitation around existing protected remnants should also be considered.
Bassendean – Central and South Transition	4					x		x	Full pre-European extent retained and protected within the GSS
Bassendean – North	2					x	x		High levels of retention in the GSS and low levels of protection. 4738 ha of State Forest is proposed to be protected in the Forest Management Plan (Conservation Commission of WA 2004). This additional protection of areas would bring the level of protection to just under 30% and would be welcome since this complex largely occurs within the GSS.
Bassendean – North Transition	4							x	High levels of retention in the GSS and good levels of protection. No additional protection is required to meet 30% threshold.

Vegetation Complex	Rank	Criteria							Priorities and opportunities for additional retention, protection, rehabilitation in the GSS
		< 10% retained SCP (1)	< 10% in the SCP portion of the PMR (1)	< 30% retained SCP (2)	< 400 ha retained SCP (2)	> 60% of pre-European extent is within the GSS (2)	< 30% protected GSS (3)	no additional protection required to meet 30% threshold (4)	
Caladenia	3						x		Low levels of retention in the GSS and what areas remain are not protected. This complex occurs over only 3% of the GSS study area (based on pre-European extent) and significant areas are retained to the north of the GSS. The low level of protection of this complex reflects that no assessment of regionally significant biodiversity assets has been done in the Shire of Gingin. Decisions on what areas should be protected should be done at a regional level.
Southern River	2			x			x		Low level of retention within the GSS though a good proportion of what remains is protected (Whiteman Park). The majority of the unprotected remnants are small and highly fragmented and are on urban and rural land. Formal protection of these is a priority and this could be achieved by retaining areas for ecological linkages along which targeted rehabilitation could also be considered.
Beermullah	1	x	x	x			x		Very low level of retention across the SCP and within the GSS though a good proportion of what remains in the GSS is protected (Twin Swamps Nature Reserve). Opportunities exist along ecological linkages for rehabilitation of areas (Ellen Brook). Once again this should not be done without an assessment of whether better outcomes would be achieved in spending the money on protecting existing remnants that occur outside the GSS.
Guildford	1	x	x	x			x		Low level of retention within the GSS though a good proportion of what remains is protected (Swan River and Whiteman Park). Since less than 10% of this complex is retained on the Swan Coastal Plain rehabilitation of areas should be considered. This rehabilitation could be targeted along existing ecological linkages (Swan River). Once again this should not be done without an assessment of whether better outcomes would be achieved in spending the money on protecting existing remnants that occur outside the GSS.

Vegetation Complex	Rank	Criteria							Priorities and opportunities for additional retention, protection, rehabilitation in the GSS
		< 10% retained SCP (1)	< 10% in the SCP portion of the PMR (1)	< 30% retained SCP (2)	< 400 ha retained SCP (2)	> 60% of pre-European extent is within the GSS (2)	< 30% protected GSS (3)	no additional protection required to meet 30% threshold (4)	
Swan	2[+]			x			x		Very low level of retention within the GSS and only half of what remains is protected (Swan River). Since only 13% of this complex is retained over the Swan Coastal Plain, rehabilitation of areas should be considered. This rehabilitation could be targeted along existing ecological linkages (Swan River). Once again this should not be done without an assessment of whether better outcomes would be achieved in spending the money on protecting existing remnants that occur outside the GSS.
Yanga	2[+]			x		x	x		Low level of retention and very low level of protection within the GSS. All remaining areas are on rural land and the majority are fragmented though some remnants are a reasonable size. The low level of protection of this complex reflects that no assessment of regionally significant biodiversity assets has been done in the Shires of Gingin and Chittering. Over 60% of the pre-European extent occurs in the GSS and less than 30% is retained across the Swan Coastal Plain. Therefore it should be a priority for protection in the GSS. Additional areas to be protected will be vital in providing linkages to the Conservation Estate in the west and to the Darling Scarp in the east.
Coonambidgee	1		x				x		High levels of retention in the GSS but very low levels of retention within the Perth Metropolitan Region portion of the Swan Coastal Plain. No areas are protected in the GSS. Remaining areas are largely on rural land. Only 7% of the pre-European extent of this complex occurs in the GSS and significant areas exist to the east of the GSS. Many of the remaining large fragments in the GSS are contiguous with remnants outside of the GSS and for this reason would be priorities for additional protection. Additional areas to be protected will be vital in providing linkages east to the Darling Scarp. The lack of protected areas within the GSS reflects that no assessment of regionally significant biodiversity assets has been undertaken in the Shires of Gingin and Chittering.

[+] A review of the initial GSS assessment of level of retention across the SCP portion of the PMR revealed that Vasse has <10 % retained and the complexes Swan and Yanga have >10% retained within this regional boundary. Therefore the rank for Vasse is now 1 (formerly 3) and rank for Swan and Yanga is now 2 (formerly 1). The 'formerly' ranks have been reported in Wilson *et al.* (2009) and used in analyses in Kinloch *et al.* (2009), Kinloch (2009) and Kinloch and Wilson (2009).

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Appendices

Appendix A: Vegetation Complexes within the GSS study area

Descriptions have been adapted from Heddle et al. 1980.

QUINDALUP DUNES
Quindalup Complex: Coastal dune complex consisting of mainly two alliances – the strand and fore-dune alliance and the mobile and stable dune alliance.
SPEARWOOD DUNES
Cottesloe Complex-Central and South: Mosaic of woodland of tuart (*Eucalyptus gomphocephala)* and open forest of tuart-jarrah-marri (*E. gomphocephala-E. marginata-Corymbia calophylla)*; closed heath on the limestone outcrops (similar in composition to Cottesloe North). **Cottesloe Complex-North**: Predominantly low open forest and low woodland of *Banksia* species and coastal blackbutt (*Banksia attenuata-B.menziesii-Eucalyptus todtiana)*. Characteristic understorey species of the closed heath on limestone outcrops include: *Melaleuca huegelii, M. cardiophylla* and *Acacia heteroclita.* **Karrakatta Complex-Central and South**: Predominantly open forest of tuart-jarrah-marri (*Eucalyptus gomphocephala-E.marginata-Corymbia calophylla)* and woodland of *E. marginata, Banksia attenuata, B. menziesii, B. grandis, Allocasuarina fraseriana,* and to a lesser extent *Agonis flexuosa*. Shrub species include *Jacksonia, Acacia* and *Hibbertia* species. **Karrakatta Complex – North**: Predominantly low open forest and low woodland of *Banksia attenuata, B. menziesii* and coastal blackbutt (*Eucalyptus todtiana)* with the occasional *B. ilicifolia* on the lower slopes. Minor occurrences of open forest of tuart (*E. gomphocephala*), coastal blackbutt and *Banksia* spp. Common understorey species include *Conspermum triplinevium, Hakea trifurcata* and *Mesomelaena stygia.* **Karrakatta Complex-North Transition**: A transition complex of low open forest and low woodland of *Banksia* species and *E. todtiana* on the transition zone of a series of high sand dunes between Bassendean-North and Karrakatta-North. Common understorey species include: *Mesomelaena stygia, Synaphea polymopha* and *Calothamnus sanguineus.*
MARINE (ESTUARINE AND LAGOONAL) DEPOSITS
Vasse Complex: Dominated by a mixture of closed-scrub of *Melaleuca rhaphiophylla, M. pressiana, M. cuticularis and M. lateritia*, fringing woodland of flooded gum (*E. rudis*) and *Melaleuca* spp., and open-forest of tuart-jarrah-marri (*E. gomphocephala-E.marginata-Corymbia calophylla)*. Other species include *Casuarina obesa* and *Acacia saligna*.
WETLANDS
Herdsmen Complex: Dominated by sedgelands and a woodland of flooded gum (*Eucalyptus rudis*) and *Melaleuca* spp., with the species of *Melaleuca* depending on the local drainage and adjacent soils. Other plants include species of *Typha, Baumea, Juncus, Leptocarpus* and *Scirpus.* **Pinjar Complex**: Ranges from a woodland of jarrah (*Eucalyptus marginata*) and *Banksia* spp. on the upper dune slope to a woodland of flooded gum (*E. rudis)* and *Melaleuca preissiana* and sedgelands in the depressions. Other species common in depressions include *Regelia ciliata, Hakea varia* and *Pericalymma ellipticum.*
COMBINATIONS OF QUINDALUP/SPEARWOOD/BASSENDEAN DUNES
Moore Complex: Consists of the fringing vegetation of the Moore River with its woodland of *Eucalyptus rudis* and *Melaleuca rhapiophylla*.
BASSENDEAN DUNES
Bassendean Complex-Central and South: Vegetation ranges from woodland of jarrah (*Eucalyptus marginata), Allocasuarina fraseriana, Banksia attenuata, B. grandis* and *B. menziesii* on the sand dunes to low woodland of *Melaleuca preissiana, B. ilicifolia* and *B. littoralis* and sedgelands on the low-lying moister sites. This area includes the transition of jarrah to coastal blackbutt (*E. todtiana*) in the Perth vicinity and jarrah to marri (*Corymbia calophylla*) on the moister soils. Other plant species include *Kunzea ericifolia, Hypocalymma angustifolium, Adenanthos obovatus* and *Verticordia* spp.

Bassendean Complex-Central and South Transition: Woodland of jarrah (*Eucalyptus marginata*) and marri (*Corymbia calophylla*) with well defined second storey of *Allocasuarina fraseriana* and *Banksia grandis* on the deeper soils and a closed scrub on the moister sites of such species as *Regelia ciliata, Adenanthos obovatus* and *Kunzea ericifolia*.. The understorey reflects similarities with adjacent vegetation complexes.

Bassendean Complex-North: Vegetation ranges from a low open forest and low open woodland of *Banksia* species and coastal blackbutt (*Eucalyptus todtiana*) to low woodland of *Melaleuca* species and sedgelands which occupy the moister sites. Understorey species include: *Melaleuca seriata, Adenanthos obovatus, Dasypogon bromeliifolius, Hypocalymma angustifolium, Boronia purdieana,* and *Scholtzia involucrata*. *Banksia laricina* is restricted to this northern area.

Bassendean Complex-North Transition: A transition complex of low open forest and low woodland of *Banksia* species and coastal blackbutt (*Eucalyptus todtiana*) on a series of high sand dunes. The understorey species reflect similarities with both the Bassendean-North and Karrakatta-North vegetation complexes. Understorey species on deep pale grey sands and surface leached deep pale yellow sands include *Boronia purdieana, Scholtzia involucrata, and Leucopogon conostephioides.* Yellow sand patches indicated by species such as *Mesomelaena stygia* and *Synaphea polymorpha*.

Caladenia Complex: Upper dunes support a low open-forest of Banksias and coastal blackbutt (*Eucalyptus todtiana*) with *B. attenuata* and *B. menziesii* being dominant. The understorey species reflect the presence of yellow sands (Karrakatta-North) or grey sands (Bassendean-North). The swamps and depressions support low woodland of *Melaleuca preissiana* and sedgelands. Seasonally inundated wetlands are dominated by *Casuarina obesa* and *M. lateritia, M. hamulosa* and *M. rhaphiophylla*.

COMBINATIONS OF BASSENDEAN DUNES AND PINJARRA PLAIN

Southern River Complex: Open woodland of marri (*Corymbia calophylla*), jarrah (*Eucalyptus marginata*) and *Banksia* species with fringing woodland of flooded gum (*E. rudis*) and *Melaleuca rhaphiophylla* along creek beds.

PINJARRA PLAIN

Beermullah Complex: Mixture of low open forest of swamp sheoak (*Casuarina obesa*) on moister flats with and open woodland of marri (*Corymbia calophylla*), wandoo (*Eucalyptus wandoo*) and jarrah (*E. marginata*). Minor components on wetter soils include closed scrub of *Melaleuca* species and occurrence of *Actinostrobus pyramidalis*. Remnant understorey species include *Hakea* spp., *Hypocalymma angustifolium* and *Pericalymma ellipticum.*

Guildford Complex: A mixture of open forest to tall open forest of marri (*Corymbia calophylla*), wandoo (*Eucalyptus wandoo*) and jarrah (*E. marginata*) and woodland of wandoo (with rare occurrences of *E. lane-poolei*). Minor components include fringing woodland of flooded gm (*E. rudis*) and *Melaleuca rhaphiophylla* along streams. Other remnant plant species include *Banksia grandis*, *Kingia australis* and *Xanthorrhoea preissi.*

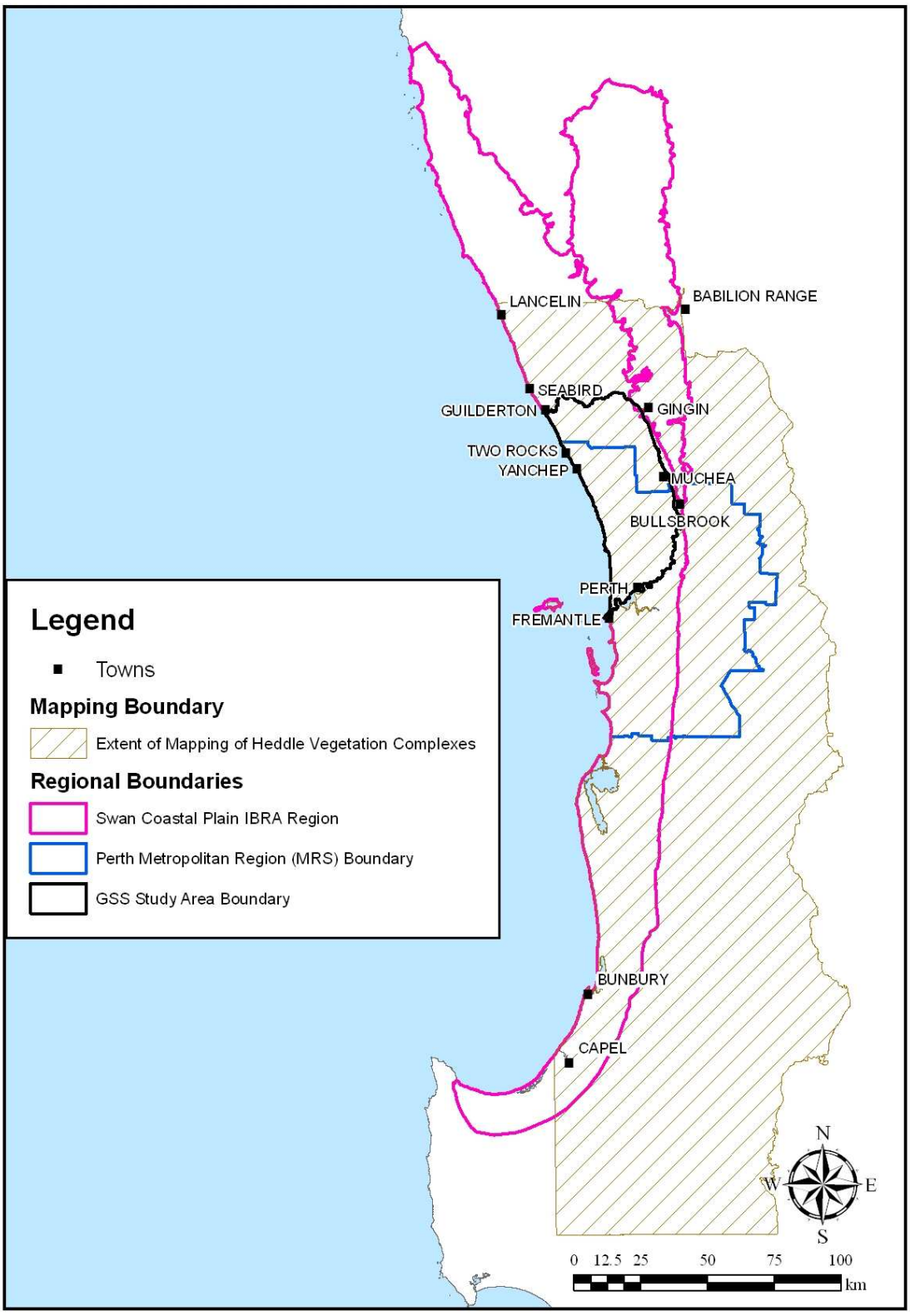
Swan Complex: Fringing woodland of flooded gum (*Eucalyptus rudis*) and *Melaleuca rhaphiophylla* with localized occurrence of low open forest of *Casuarina obesa* and *Melaleuca cuticularis.* Other plants present include species of *Leptocarpus, Juncus, Cyperus, Schoenus* and *Scirpus*.

Yanga Complex: Predominantly a closed scrub of *Melaleuca* species, including *M. lateritia* and *M. hamulosa*, and low open forest of *Allocasuarina obesa* on the flats subject to inundation. On drier sites the vegetation reflects the adjacent complexes of Bassendean and Coonambidgee with a mixture of low open forest of *Banksia* spp. and coastal blackbutt (*Eucalyptus todtiana)* and open woodland of marri (*Corymbia calophylla*) and *Banksia* spp., the latter being on the moister low-lying areas.

GINGIN SCARP

Coonambidgee Complex: Vegetation ranges from low open forest and low woodland of coastal blackbutt (*Eucalyptus todtiana*), *Banksia attenuata, B. menziesii* and *B. ilicifolia* with localized admixtures of *B. prionotes* to open woodland of marri (*Corymbia calophylla*) and *Banksia* species. Common plant species in the understorey include *Persoonia comata, Stirlingia latifolia* and *Nuytsia floribunda.*

Appendix B: Mapping and regional boundaries



Appendix C: Perimeter to Area Ratio of remnant vegetation patches.