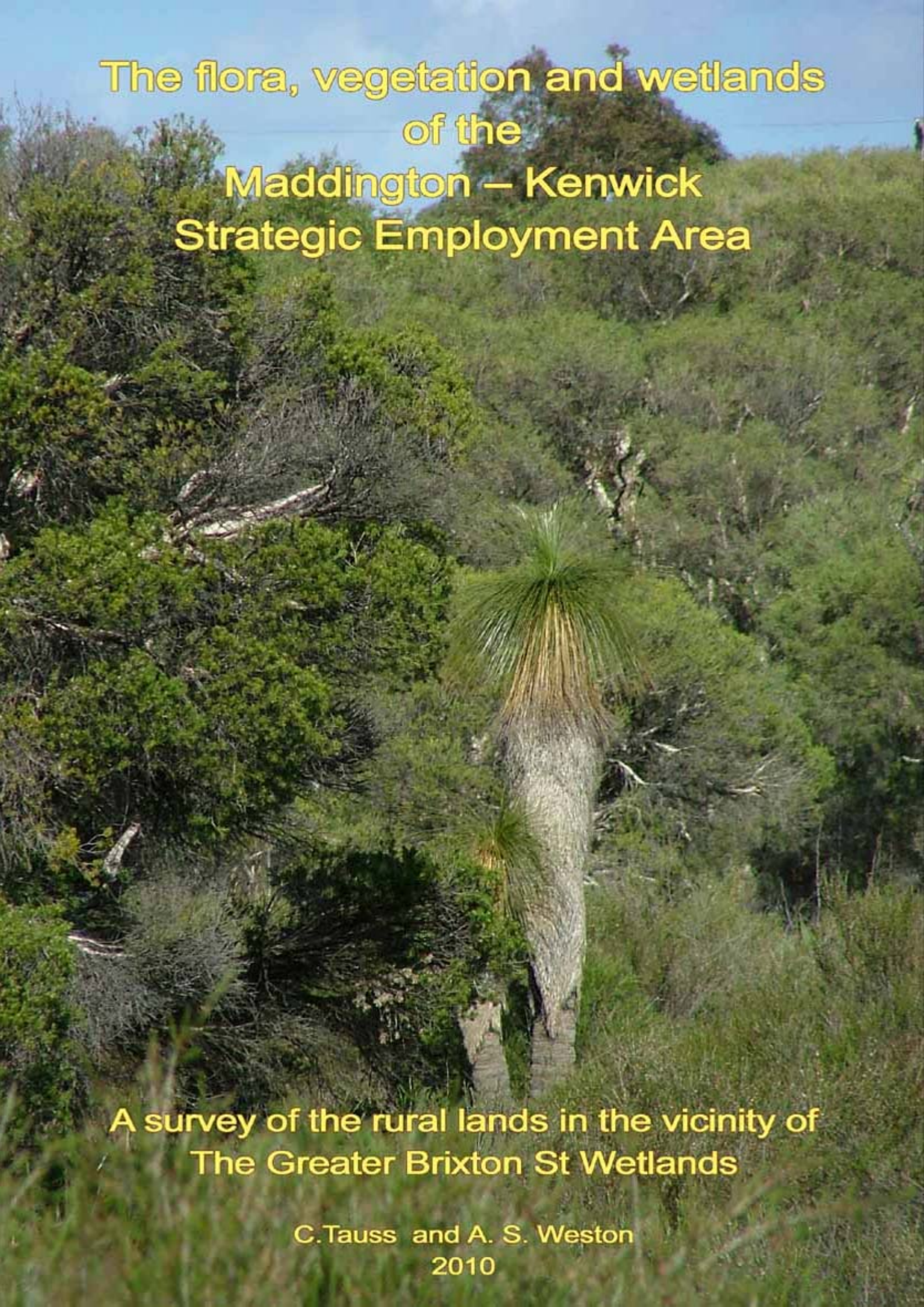

The flora, vegetation and wetlands of the Maddington – Kenwick Strategic Employment Area

A survey of the rural lands in the vicinity of The Greater Brixton St Wetlands

C.Tauss and A. S. Weston

2010

18 April 2010

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Report to the City of Gosnells, Western Australia

C. Tauss and A.S. Weston

DISCLAIMER

The information contained in this report is solely for the use of the City of Gosnells and relevant government stakeholders, such as the Department of Environment and Conservation (DEC), for the purposes of planning and environmental regulation as identified in the report. This report is not intended to be used by parties other than the above (or for commercial purposes), and no responsibility is undertaken to any such parties.

In accordance with the policies of the DEC, the locations of Rare and Priority Flora and Threatened Ecological Communities have been supplied to the DEC but are withheld from publication.

Summary

The City of Gosnells is currently involved in investigating, and planning for, future industrial development within a 585 ha area of rural land (that is known as the Maddington Kenwick Strategic Employment Area or MKSEA), in the north-east of its jurisdiction. The area proposed for development (City of Gosnells, 2007a) is located on the eastern side of the Swan Coastal Plain (SCP) and has been shown to include values of national conservation significance listed under the Federal Environmental Protection and Biodiversity Conservation (EPBC) Act (Cardno BSD, 2005). Within the boundary of the MKSEA, but not proposed for development, there are two Bush Forever sites (BFS 387, the Greater Brixton Street Wetlands, and BFS 53, the Clifford Street Bushland). The Bush Forever sites include multiple conservation values that are listed as nationally significant (Government of Western Australia, 2000). BFS 387, the most species-rich Bush Forever site on the SCP and one of the most important conservation reserves on the SCP, is located downslope from much of the MKSEA and is influenced by groundwater and surface water drainage from the MKSEA. BFS 387 is currently subject to high levels of stress from threats within its boundaries and from the surrounding MKSEA. These threats are not addressed currently by any coordinated management efforts and will require considerable effort to resolve. The local Bush Forever sites are closely coupled with the adjoining MKSEA rural areas via ecological and biological processes and the proposed development is likely to impact, at least indirectly, on their important conservation values.

Environmental and engineering studies of the MKSEA (Cardno BSD, 2005; GHD, 2005) found that, apart from some areas of dunes in the south east, most of the area proposed for development is an extensive, gently sloping, seasonally-waterlogged plain (palusplain) that is part of the Bickley Brook and Yule Brook catchments. These preliminary reports also indicated that the legislation and policies of Federal and State environmental regulatory agencies with regard to the high conservation values found in parts of the proposed development area would significantly constrain the extent of industrial development in the MKSEA. The current Level 2 flora, vegetation and wetlands survey of the MKSEA was commissioned by the City of Gosnells in early September 2007 to provide more detailed guidance to the MKSEA planning process. Pending the outcomes of this study, and the results of other investigations (such as an Aboriginal heritage study), the City of Gosnells has issued two modified Concept Plans for the MKSEA (City of Gosnells, 2007b, 2008).

The current flora, vegetation and wetlands survey found numerous conservation values of national, state and regional significance within the MKSEA (Table A). Some of the values found in the current survey were not identified in the MKSEA in previous studies (Government of Western Australia, 2000b; Cardno BSD, 2005; Trudgen and Keighery, 1995) and are not represented in the Greater Brixton Street Wetlands or the Clifford Street Bushland (Government of Western Australia, 2000b). In accord with Western Australian State Government and Local Government criteria regarding the conservation value of natural areas (Government of Western Australia, 2000; Lamond, 2009) all areas of remnant vegetation assessed as being in good or better condition within the MKSEA in this study were considered to be of, at least, regional conservation significance. These areas of eastern Swan Coastal Plain remnant native vegetation in the MKSEA are considered to be rare biodiversity resources that are poorly represented in the conservation estate and are thus eligible for protection.

Most of the flora and vegetation of high conservation significance found in the MKSEA in the current survey are highly dependent on surface waters and/or groundwater. However, the extensive wetland ecosystem of the alluvial fan system that encompasses most of the MKSEA and the two Bush Forever sites of the area has been somewhat compromised by existing development. There is now reduced recharge of rainfall into groundwater and increased surface run-off due to the clearing of vegetation and the compaction of soils. There is also localised dewatering of wetlands by excavated drains that intersect superficial aquifers and export groundwater, along with run-off, to Yule Brook and Bickley Brook. Yule Brook and Bickley Brook have been converted from high quality water sources (that previously sustained the rich biodiversity of the adjoining floodplains, including BFS 387, by annual flooding and sediment deposition) to water sinks that convey polluted, nutrient-enriched water out of the local wetlands and into the Swan-Canning River system. The complex hydrogeology of the MKSEA and the Bush Forever lands needs to be more fully understood so that any proposed development does not reinforce the current problems (locally and downstream in the Swan

Canning River system) and exacerbate adverse environmental impacts. The importance of the restoration of the hydrological regime of the area is particularly highlighted by predictions of continuing rainfall decline in the region and the threat that this poses to regional biodiversity.

Recommendations

This survey provided significant new information about the natural values of the MKSEA that should be considered in the planning process. However, there are major shortfalls in the current understanding of the biological, ecological and physical processes (such as the hydrological maintenance of wetlands; the reproductive strategies, demography and genetics of threatened flora species; and the use of the area by fauna and their migration patterns) and in the definition of the basic habitat requirements of the Threatened Flora and the Threatened Ecological Communities of the area. There have been no threshold values defined for key variables (such as the ecological water requirements of Threatened Flora Species and Threatened Ecological Communities) that should form the basis of any assessment of the potential effects of various planning scenarios on the important conservation values of the area. Further study into these aspects would be required to ensure that the proposed rezoning and development of the MKSEA will not contribute to the further degradation and loss of environmental values in the MKSEA, BFS 387 and BFS 53.

The current survey identified and mapped areas of high conservation significance that should be excluded from development and proposed a number of general recommendations to assist in the prevention of some of the ongoing current and anticipated degradation and loss of conservation values in the MKSEA, BFS 387 and BFS 53. These recommendations (Section 7.1) include the urgent need to implement recovery actions for most of the Threatened Flora Species populations in the MKSEA and the Bush Forever Sites; the enforcement of native vegetation clearing regulations and wetland conservation measures; and the identification and control of existing land uses that are currently impacting on groundwater quality. A number of changes to the management categories of wetlands in the MKSEA are recommended. Appropriate buffer zones around Conservation and Resource Enhancement Category Wetlands and Ecological Linkage Corridors between high conservation value areas within the MKSEA, BFS 387, BFS 53, the Darling Range and Canning River are also proposed and mapped.

Three major recommendations are presented below that summarise the most important conclusions of the current survey with regard to the proposed development in the MKSEA.

Recommendation 1

Given the significant conservation values within and adjacent to the proposed MKSEA and the potential for these values to be adversely impacted by the proposal, the City of Gosnells is advised of its obligation to refer, for assessment, the proposal to re-zone and develop these rural lands to:

- The Federal Department of Environment, Water, Heritage and the Arts (DEWHA) under the statutory requirements of the Federal Environmental Protection and Biodiversity Conservation Act, 1999; and
- The Western Australian Environmental Protection Authority under the statutory requirements of the Western Australian Environmental Protection Act, 1986.

Recommendation 2

The City of Gosnells is advised that further detailed studies are required to understand the hydrogeology of the highly water-dependent ecosystems of the MKSEA and the Greater Brixton Street Wetlands and to provide the data required to remediate the hydrological regime of the area. The scope, methods and low intensity of the current wetlands survey and the water monitoring programme recently commissioned by the City of Gosnells are considered insufficient to adequately map the major wetland boundaries, to characterise the factors that maintain important conservation wetlands in the area and to define the environmental water requirements of the remnant native vegetation. Detailed mapping of the Muchea Limestone aquifers of the area and an invertebrate study of the active Muchea Limestone mound spring in the MKSEA (and possibly

other areas) are also recommended. These studies are necessary before appropriate planning proposals can be scientifically justified and also to provide a rigorous basis for the long term, ecologically-sustainable management of the water, nutrient and sediment resources of the area and of the biodiversity supported by these resources.

Planning for the MKSEA should be carried out in accordance with a comprehensive plan and specific objectives designed to conserve, restore and manage sustainably (for the long term) the natural and cultural heritage of the Bush Forever sites, the MKSEA and any other areas of high conservation significance in Kenwick - Wattle Grove - Maddington that are part of the local alluvial fan complex. Such objectives should be developed by a scientific panel in consultation with various stakeholders (including the City of Gosnells, Federal Department of Environment, Water, Heritage and the Arts, Western AustralianDepartment of Environment and Conservation, University of Western Australia, Kings Park, Shire of Kalamunda, Swan River Trust and the community.)

Recommendation 3

In the absence of a long-term comprehensive plan to conserve and manage the natural heritage of the area (as above) the City of Gosnells is advised to consider the recommended revisions (below) to the Current Concept Plan for the MKSEA (Figure 3; City of Gosnells, 2008) in order to incorporate, into planning, some of the issues raised by the data obtained in the current survey.

Precinct 1 (southeast of Victoria Rd)

This precinct includes a number of areas of high conservation significance. These areas require reservation, protection from development by revegetated buffer zones that are free of all development or infrastructure and linkage with each other and with the conservation areas in Precinct 2 and BFS 387 via an ecological linkage corridor.

One of the areas indicated as an “Eco-industry Precinct” in the current Concept Plan (City of Gosnells, 2008) is located within REW 8050, a wetland that is recommended in the current survey as eligible for CCW status. The second Eco-industry Precinct in the amended plan is located within the buffer zone of Bush Forever Site 53 (City of Gosnells, 2008). The City of Gosnells is advised that development of any type is not appropriate in CCW or other areas of high biodiversity and in the buffer zones of CCW wetlands.

Similarly, as wetland 8050 and BFS 53 are of high conservation significance, and they (and their buffer zones) should not be used for drainage purposes. These wetlands should be protected from industrial development by buffer zones about 200 m in width that are revegetated and do not include drainage facilities or other infrastructure.

Development in Precinct 1 should be confined to the areas of deep Bassendean Sands, in the eastern part of the precinct, where run-off can be successfully infiltrated (at source) into the adjoining deep sands (above any wetland buffer zones). Such infiltration will support the natural recharge of the high conservation significance wetlands along the Bassendean Sands/Guildford Formation interface.

Precinct 2 (Brook Rd to Victoria Rd)

A number of nationally significant conservation values (that are linked ecologically with the Greater Brixton Street Wetlands) were found in the current survey in the extensive wetland between Boundary Rd and Victoria Rd. Nationally significant areas of high biodiversity, including EPBC listed flora, TECs and CCW wetlands, are located in this wetland. Wetlands listed on the Register of the National Estate (with similar values as the MKSEA areas above) are located in BFS 387 between Brook Rd and Boundary Rd. The City of Gosnells is advised that most of Precinct 2 will need to be managed in such a way as to reserve important conservation values and to protect these values.

Precinct 2 is linked to BFS 387 by the flow of groundwater and superficial aquifers. The areas of high conservation significance in this precinct found in the current survey are mostly unrepresented in BFS 387; they should be reserved as part of BFS 387 and managed for conservation. The remainder of Precinct 2 should be managed as part of a groundwater control area and buffer zone for BFS 387.

Most of Precinct 2 (including some areas in BFS 387) is currently very poorly managed. Some unregulated problems in the area include the dewatering of superficial aquifers and the salinisation of land by the excavated drainage system; the dumping of fill, refuse and hazardous materials in wetlands; the over-stocking of paddocks with horses and other animals; the incursion of stock into BFS 387; groundwater and surface water pollution and nutrient enrichment; excavation of wetlands; unregulated clearing and burning of native vegetation, and weed proliferation.

The existing land uses within this precinct should be audited to determine the activities that are currently incompatible with the objectives of conservation and restoration of native vegetation, the improvement of groundwater quality and the maximum infiltration of rainfall into groundwater. There should be no additional development in Precinct 2, and existing land uses that are incompatible with conservation and resource enhancement wetland management (and acceptable landuses in wetland buffer zones) should be regulated and phased out.

Precinct 3A and Precinct 3B (Yule Brook)

The City of Gosnells is supported in its Concept Plan (City of Gosnells, 2008) to exclude Precinct 3B from development. Yule Brook was fundamental to the development of the complex natural habitats of the alluvial fans of the area and the biodiversity they support. The natural history of Yule Brook parallels the indigenous cultural beliefs that are held about this wetland ecosystem. The areas bordering Yule Brook (in or near to the southwest part of Precinct 3A) were found in this survey to include significant conservation values.

The Concept Plan for the south west end of Precinct 3A and for Precinct 3B should be revised to allow for the protection of these values, the restoration of the floodplains of Yule Brook, the improved linkage of Yule Brook with BFS 387 and initiatives related to the general remediation of the hydrological regime of the MKSEA and BFS 387 that will contribute to the reinstatement of Yule Brook as a living stream. This area represents an important opportunity to fulfil objectives of the Swan-Canning River system Water Quality Improvement Plan (Swan River Trust, 2009) in this regard and to improve the ecological connectivity between conservation reserves of the Darling Range, the Swan-Canning River system and other conservation reserves (including, most importantly, BFS 387) as envisioned by the Perth Biodiversity Project (Del Marco *et al.*, 2004).

Table A: A Summary of the Conservation Values in the MKSEA

Values	Description of Values
National Significance Threatened Flora Species (listed under the Federal EPBC Act)	*Calytrix breviseta* subsp. *breviseta* (Endangered), *Conospermum undulatum* (Vulnerable) and *Lepidosperma rostratum* (Endangered)
National Significance Threatened Ecological Communities (listed under the Federal EPBC Act)	1. Shrublands and Woodlands on Muchea Limestone of the Swan Coastal Plain (Endangered). This TEC is not currently represented in the Greater Brixton Street Wetlands conservation estate. 2. *Corymbia calophylla – Kingia australis* Woodlands on Heavy Soils of the Swan Coastal Plain (Endangered) (FCT 3a).
State Significance Declared Rare Flora & Priority Flora (listed under WA Wildlife Act or by WA Department of Environment and Conservation)	*Eremophila glabra* subsp. *chlorella* (DRF), *Schoenus pennisetis* (P1), *Lepyrodia curvescens* (P2), *Trichocline* sp. Treeton (B.J. Keighery & N. Gibson 564) (P2), *Baeckea* sp. Perth Region (R.J. Cranfield 444) (P3), *Cyathochaeta teretifolia* (P3), *Calothamnus rupestris* (P4), *Grevillea thelemanniana* (P4) and *Verticordia lindleyi* subsp. *lindleyi* (P4). [Note: *Grevillea thelemanniana* is considered eligible for DRF status by B.J. Keighery, B. Makinson, and P. Olde pers. comms.]
State Significance Threatened Ecological Communities (listed by the WA Department of Environment and Conservation)	Herb-rich Saline Shrublands in Claypans (FCT 7) (Vulnerable) Herb-rich Shrublands in Claypans (FCT 8) (Vulnerable) Shrublands on Dry Clay Flats (FCT 10a) (Endangered) Eastern Banksia Woodlands (FCT 20a) (Endangered)
Significant Vegetation of the Eastern SCP in Good Condition and other significant flora (Government of Western Australia, 2000)	Riparian vegetation adjacent to the Yule Brook and ALL other native vegetation in good condition in the MKSEA.

Values	Description of Values
Conservation Wetlands (CCW) and Resource Enhancement Wetlands (REW) listed by the WA Department of Environment and Conservation	There are about 70 wetland areas in the MKSEA (including four CCWs) that are currently identified under Unique Function Identifiers (UFIs) in the WA DEC SCP Wetlands Dataset. In the current survey, 17 of the wetlands in the MKSEA were assessed as CCWs. There were also 17 wetlands in the MKSEA that were assessed as REWs. Parts of UFI 13362 adjacent to Yule Brook that are currently MUW were recommended for REW status in this survey (as part of a restoration of the Yule Brook floodplain, local hydrological regime amelioration and to support catchment management objectives of the Swan-Canning River system).
Ecological linkages including waterways and their buffers that connect high conservation areas (EPA, 2008). Linkages that connect National Parks, Bush Forever sites (BFS) and Regional Parks of the Eastern Swan Coastal Plain and Darling Range as proposed by the Bush Forever Project (Government of Western Australia, 2000) and the Perth Biodiversity Project (Del Marco *et al*., 2004).	1. Yule Brook – BFS 387 Greenway The Yule Brook and its buffer zone (some of which was found to retain significant native flora and vegetation) forms a natural ecological linkage between the Canning River Regional Park, The Greater Brixton Street Wetlands (BFS 387), Hartfield Park (BFS 320), Welshpool Road Bushland (BFS 50), the Darling Range Regional Park and the Lesmurdie Falls National Park. There is sufficient undeveloped land flanking Yule Brook west of Welshpool Rd to reserve a substantial foreshore buffer and to restore some of the Yule Brook floodplains. This will increase the connectivity of BFS 387 to Yule Brook and other reserves, maintain and restore some of the ecological processes of the alluvial fan complex that are important in maintaining long term viability of BFS 387, allow for the protection of indigenous heritage areas and support catchment management objectives of the Swan-Canning River Water Quality Improvement Plan. 2. BFS 387 – BFS 53 Greenway The Yule Brook – BFS 387 Greenway (as above) can also be linked, to wetlands of high conservation significance (including Muchea Limestone springs) along the interface of the Bassendean Sands and Pinjarra Plain in the MKSEA, to the Clifford Street Bushland (BFS 53), the White Road Bushland (BFS 51) and the Darling Range Regional Park. This will require the revegetation of wetland buffer zones along the interface of the dunes and the plain in Precincts 1 and 2 of the MKSEA.
Significant trees and other natural resources not classed as 'bushland'	Stands of native trees or scrub with little or no native understorey such as Flooded Gum (*Eucalyptus rudis*), Marri (*Corymbia calophylla*), Modong (*Melaleuca preissiana*), Tuart (*Eucalyptus gomphocephala*), Freshwater Paperbark (*Melaleuca rhaphiophylla*) and the conifer *Actinostrobus pyramidalis*), seasonally flooded paddocks and some dams within the MKSEA, whilst not classed as 'bushland', have important ecological functions and augment regionally scarce native fauna habitat.

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APPENDICES

1. Introduction

The City of Gosnells is planning the subdivision and industrial development of an area in the north east of its jurisdiction that is currently known (for planning purposes) as the Maddington Kenwick Strategic Employment Area (MKSEA). The MKSEA comprises 585 ha of land currently zoned as rural. It is bounded by Bickley Rd in the south west, Roe Highway in the west and Tonkin Highway in the east and by the City of Gosnells – City of Kalamunda boundary in the north-east (Figure 1).

The MKSEA was first identified for future industrial development in Metroplan, the 1990 planning strategy for the Perth metropolitan region (DPUD, 1990). Subsequent to Metroplan, an altered perspective of the MKSEA has developed from the rapid pace of environmental degradation worldwide, the enactment of Federal and State government environmental legislation and policies and changes in community attitudes to climate change, the deterioration of water resources, and the resultant heightened awareness of the need to conserve wetlands and biodiversity. At the Federal level, the Australian Government Environment Protection and Biodiversity Conservation Act (EPBC Act) was passed in 1999. A large body of scientific data of the biodiversity values and the uniqueness of the Swan Coastal Plain (SCP) Bioregion and data of the eastern side of the SCP (including Speck and Baird, 1984; Semeniuk, 1987; Keighery and Keighery,1991; Keighery and Trudgen, 1992; Gibson *et. al*., 1994; Balla, 1994; Hill *et al.,* 1996; IBRA, 2000 and many others) were drawn together into various Western Australian Government conservation policies for bushlands and the protection of SCP wetlands (Government of Western Australia, 2000; WRC, 2001; EPA, 2004a). Stronger restrictions on native vegetation clearance (amendments made to the Western Australian Environmental Protection Act in 2004) and more focused recommendations of the Swan Canning Water Quality Improvement Plan (Swan River Trust, 2009) have also contributed to changed attitudes and practices in natural resource planning and management.

From consultation with relevant State Government Departments and preliminary technical reports for the MKSEA (GHD, 2005; Cardno BSD, 2005), the City of Gosnells identified some of the important planning issues pertinent to the MKSEA proposal (City of Gosnells, 2007a, 2007b, 2008). These issues included the presence of highly significant conservation values and indigenous heritage values within, and adjacent to, the project footprint; the interactions between the local and district water regimes; the interactions between the groundwater and surface waters; the fragmented land ownership (with an excess of 200 landowners currently in the MKSEA, see Figure 2) and the potential delays and costs in providing the infrastructure to service the MKSEA. In 2005, the City of Gosnells engaged Cardno BSD to survey the flora, vegetation and wetlands of the MKSEA at a level "to provide a sufficient level of information to satisfy the development's likely formal Environmental Impact Assessment by the EPA". However, it became evident from the resultant environmental study and the engineering feasibility study conducted by GHD (2005) that the potential for industrial development in the MKSEA (particularly between Coldwell Rd and Victoria Road) was significantly constrained. The constraints on the MKSEA development included the wetland nature of most of the land, the high conservation values found in and around the project footprint and the environment protection and the biodiversity conservation legislation and policies applicable to these values at both the State and Federal levels.

In September 2007, the City of Gosnells commissioned the current flora, vegetation and wetlands survey of the MKSEA. A Level 2 detailed survey (as defined by the EPA, 2004b) was required for this survey because of the extent of the development proposal, the location of the proposal on the Eastern Swan Coastal Plain (a region of very high stress on scarce and irreplaceable conservation values) and the potential environmental impacts of the development. Similarly, the wetlands survey was required to be conducted at a high level, according to the protocol of DEC (2007). The objectives of the current study, as indicated by the City of Gosnells, were to further assess the potential for industrial development in the MKSEA and to provide additional guidance to the City of Gosnells in the land use planning and approval processes (particularly in the area between Yule Brook and Victoria Rd). The need to adopt a **"**total water cycle management**"** approach to the development of the MKSEA was a key element of the planning process expressed by the City of Gosnells in the brief for this survey.

Two modified Concept Plans for the MKSEA were produced by the City of Gosnells, in November 2007 and July 2008, prior to the completion of the detailed flora, vegetation and wetlands study described in this report. The July 2008 Concept Plan (Figure 3) shows three precincts: Precinct 1 (the Kelvin Road Precinct) south of Victoria Rd; Precinct 2 between Brook Rd and Victoria Rd, and Precinct 3A and Precinct 3B (the Yule Brook Precinct) in the north of the MKSEA. Drainage in this plan conforms generally with the existing scheme, in which water resources (comprising stormwater run-off and water drained from shallow groundwater aquifers by drains that intersect them) are exported away from areas of highly water-dependent, high biodiversity natural ecosystems. The issue of water cycle management in the MKSEA and BFS 387 remains one of the main environmental problems facing the MKSEA development. Other important issues in the MKSEA include the fragmentation of the environmental values and the need to reserve appropriate buffer zones and greenways in the MKSEA in order to increase the connectivity of these values with other reserves nearby.

1. **Precinct 1** (the Kelvin Road Precinct) in the 2008 Concept Plan (Figure 3) shows two "Eco-industry" Precincts. The first "Eco-industry Precinct" is located just south of Victoria Rd. It coincides with the wetland currently mapped as Resource Enhancement Wetland (REW) 8050 in the DEC Wetland Atlas (2008). The second "Eco-industry Precinct" is located in the buffer zone of Conservation Category Wetland (CCW) 12116 and CCW 12114 of the Clifford Street Bushland Bush Forever Site 53 and coincides with REW 12117 and REW 12115. The remaining area of Precinct 1 (except for the Clifford Street Bushland) is shown as industrial.

   About half of the area proposed for development in Precinct 1 is low-lying MUW wetland (where the natural water table in winter is at ground level or less than about 50cm below ground level). Large quantities of imported fill would be required to raise the areas proposed for development above the water table (as shown in GHD, 2005). The soils of much of the proposed development area have low infiltration capacity and most of the native vegetation of these heavy soils has been cleared. Drainage in the Concept Plan conforms largely to the existing scheme and would continue the modification of the original hydrological cycle. Stormwater run-off (and water drained from shallow groundwater aquifers by drains that intersect them) is shown as being exported out of the area rather than being infiltrated in Precinct 1. Any basins excavated in the western part of Precinct 1 would be underlain by the natural clay of the area and would be expected to simply retain water rather than infiltrate it into the groundwater.

2. **Precinct 2** (Victoria Rd to Brook Rd) in the 2008 Concept Plan (Figure 3) shows no development, pending the outcomes of environmental studies, the identification of appropriate wetland buffer zones and the outcomes of district drainage planning. The engineering report (GHD, 2005) shows plans for infrastructure such as a mains water line and a large drainage facility known as a Multiple Use Corridor (MUC) in Precinct 2.

   Precinct 2 is located immediately upslope from BFS 387 (The Greater Brixton Street Wetlands) and forms much of the groundwater catchment area for some of the highest conservation significance wetlands of the Swan Coastal Plain. Therefore, Precinct 2 is an ecologically sensitive zone where the priority management objectives should include groundwater pollution control and revegetation to increase the infiltration of rainfall into groundwater.

3. **Precinct 3B** (the Yule Brook Precinct), between Coldwell Rd and Brook Rd, is shown in the 2008 Concept Plan (Figure 3) with no proposed development due to the "Aboriginal heritage, conservation significance and drainage function" of Yule Brook.

4. **Precinct 3A**, northwest of Coldwell Rd, is shown in the 2008 Concept Plan (Figure 3) as fully developed for industry. This is an area that has been mostly cleared of native vegetation and has low infiltration capacity soils. Most of the area proposed for development is low-lying MUW wetland (where the natural water table in winter is at ground level or less than 50cm below ground level). Large quantities of imported fill would be required to raise the areas proposed for development above the water table (as shown in GHD, 2005). Drainage in this Concept Plan conforms generally with the existing scheme, in which the original hydrological cycle was highly modified; stormwater run-off and

water drained from shallow groundwater aquifers by drains that intersect them would be exported out of the area via Yule Brook rather than being infiltrated at their source in Precinct 3.

The current study reviewed the literature of the flora, vegetation and wetlands of the MKSEA and carried out detailed field surveys (from spring 2007 to winter 2009) of the flora and vegetation in the area. It also ground-truthed the geomorphic classifications, management categories and boundaries of the wetlands currently mapped in the DEC SCP Wetland Dataset within the MKSEA. It also investigated the bushland remnants in the MKSEA and the proposed greenway links through the MKSEA that had been prioritised by the Western Australian Local Government Association Perth Biodiversity Project (Figure 4). The field survey found a species-rich flora and numerous conservation values of national, state and regional significance within the remnant wetlands and bushlands of the MKSEA. Some of the important values found in the MKSEA in this survey are not currently represented in the conservation reserves of the area. A number of recommendations are provided to the City of Gosnells based on the findings of this survey.

1.1 Project Scope and Objectives

The scope and objectives of the current flora, vegetation and wetlands survey are outlined in the City of Gosnells brief of late August 2007 (City of Gosnells, 2007c).

The current survey area is defined as the Maddington Kenwick Strategic Employment Area (MKSEA) (Figures 1, 2, 3), not including Bush Forever Sites 53 and 387 (with the exception of two discrete portions of Site 387 that are located on the south-eastern side of Boundary Rd). However, the survey brief states that "the context of the [MKSEA] area in the district, located between the Canning River and the Darling Range foothills, will need to be recognised", a statement consistent with the intent of the WA Local Government Association Perth Biodiversity Project (Del Marco *et al.,* 2004) in envisioning greenway links through the MKSEA and the local Bush Forever Sites to improve the regional connectivity between areas of high conservation significance in the region (Figure 4). It also indicates that the task include an assessment of the conservation values within the MKSEA footprint and a description of the interaction between the wetlands of the study area and their surrounds.

It was anticipated that some examination of areas surrounding the MKSEA (particularly of the Bush Forever sites) would also be required. This examination would be conducted largely at a desktop level as reliable data of the Bush Forever sites, especially BFS 387, were already available in the literature.

1.1.1 Flora and Vegetation Survey

The current flora and vegetation survey was required to be a Level 2 Detailed Flora and Vegetation Survey, as per EPA Guidance Statement No. 51 (EPA, 2004b), consisting of three or more stages. The specific objectives of the survey that were specified in the brief were to:

- Identify, describe and map each vegetation unit in the study area at a fine scale;
- Assess and map vegetation condition;
- Establish and sample permanent 10 m by 10 m quadrats adequate in number to provide samples sufficient for assigning Floristic Community Types (FCTs) [after Gibson *et al.,* 1994] to them with the help of PATN® [multivariate] analyses;
- Carry out the PATN analyses of the quadrat samples and interpret the results of the analyses;
- Identify and delineate Threatened Ecological Communities (TECs);
- Search for Declared Rare Flora (DRF) and other significant taxa at appropriate times (generally during spring and summer);
- Compile one or more lists of flora recorded during the vegetation surveys and the searches for significant flora;

- Comment on the conservation significance of the flora and vegetation in the study area; and
- Provide additional guidance to the City of Gosnells in the land use planning and approval processes (particularly in the area between Yule Brook and Victoria Rd).

1.1.2 MKSEA Wetlands Survey

The current wetlands survey was required "to provide information and mapping that would allow ongoing land use planning to work with well-informed likely future scenarios regarding wetland management classifications, boundaries and buffers." The specific objectives of this survey were to:

- Review the wetland geomorphic classifications and management categories of the wetlands of the MKSEA with reference to the DEC (2008a, 2008b) Wetland Datasets and the recommendations of Cardno BSD (2005);
- If appropriate, recommend and map likely modifications to the geomorphic classifications and/or management categories of wetlands in the MKSEA that may be followed up later in a separate consultancy in accordance with the protocol for proposing modifications to the Geomorphic Wetlands Swan Coastal Plain Dataset (DEC, 2007b);
- Identify and delineate wetland boundaries and boundaries of the wetland buffer zones required to protect these wetlands from adjoining industrial development. The Western Australian Environmental Protection Authority's Guidance Statement No 33 for planning and development (EPA, 2008) provides the principles to consider in this issue; and
- Provide additional guidance to the City of Gosnells in the land use planning and approval processes (particularly in the area between Yule Brook and Victoria Rd) particularly with regard to adopting a "total water cycle management" approach to the development of the MKSEA.

2. Regional Setting

2.1 Climate

Weather records for the Gosnells City weather station taken over the past 17 years can be used to gain an understanding of the climate of the MKSEA (Table 2.1: adapted from Bureau of Meteorology, 2009). The major factors in the rainfall and wind patterns of the Maddington-Kenwick area are the eastwardly migrating, anti-cyclonic pressure cells that bring rain-bearing fronts over the region in a seasonal pattern (Gentilli, 1972). In general, the climate in the MKSEA can be described as warm, subhumid and Mediterranean with a pronounced annual drought for 4-5 months each year and cool, wet winters. Over the period 1961-2008, the temperature at Gosnells City ranged from a mean daily minimum of 8.8°C in August to a mean daily maximum of 32.7°C in January and February. The mean annual rainfall at Gosnells City over the same period was 835.4 mm. On average, approximately 85% of the annual rainfall over this period fell between May and October. In 2006, the year prior to the beginning of the current survey, the total rainfall recorded at the Gosnells City weather station was only 553.1 mm, i.e. approximately 66% of the *mean* annual rainfall for the period 1961-2008. Therefore, in spring 2007, when most of the current flora survey was conducted, the MKSEA was recovering from the worst drought the region has experienced since the beginning of detailed weather records 46 years ago.

The annual rainfall in south-west Western Australia has shown a steady decline over the past three decades (Bureau of Meteorology, 2009). Further rainfall decline and rising temperatures are predicted for the region in the future. These anticipated climatic changes are acknowledged as posing a serious threat to the biodiversity of south-west Western Australia (Pittock, 2003).

The continuation of the trend towards drier conditions in this region indicates that a much greater effort and innovative solutions will be required in the future to manage dwindling water resources in a more sustainable manner in the MKSEA and the Greater Brixton Street Wetlands to support biodiversity and human activities.

Table 2.1: Climatic Data from Gosnells City Weather Station (1991-2008)

Temperature (°C) (1991-2008)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily max	32.7	32.7	30.3	26.2	22.6	19.5	18.7	19.1	20.6	23.5	27.4	30.1
Mean daily min	18.1	18.5	17.1	14.6	12.1	9.8	9.0	8.8	10.0	11.3	14.4	16.0

Mean rainfall (mm) (1961-2008) compared to rainfall in 2006, 2007 & 2008														
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total	Years
Mean rainfall (1961-2008)	11.9	16.2	15.4	45.4	106.9	177.9	164.6	129.2	80.8	48.2	27.8	10.7	837.7	46
Rainfall in 2006	27.0	34.6	9.4	32.5	29.2	42.0	86.8	160.0	63.4	35.9	23.3	9.0	553.1	1
Rainfall in 2007	18.3	17.7	11.6	79.3	89.6	90.4	192.1	126.4	109.1	59.8	3.7	18.8	816.8	1
Rainfall in 2008	0	31.6	12.9	170.8	103.9	142.5	195	21.5	85.2	47.8	59.0	14.2	884.4	1

(Bureau of Meteorology, 2009)

2.2 Landforms

The MKSEA is located about 15 km south-east of the centre of the City of Perth on the eastern Swan Coastal Plain (ESCP) and about 3-4 km west of the Darling Plateau. The Swan Coastal Plain (SCP) comprises a series of landform units of regional scale that are orientated more or less parallel to the coast (McArthur and Bettenay, 1960). The regional scale landforms of the SCP that are represented in the MKSEA comprise the Ridge Hill Shelf (Foothills), the Pinjarra Plain and the Bassendean Dunes (Figure 5).

The Ridge Hill Shelf geomorphic unit (the Forrestfield mapping unit of Churchward and McArthur, 1980) is a more or less continuous ramp of about 1-3 km in width that lies immediately to the west of the scarp of the Darling Plateau. It includes Quaternary-aged sand, clay, conglomerate and laterite of the Yoganup Formation which, in the Perth area, correlates with the Forrestfield soil association (Biggs and Wilde, 1980; Churchward and McArthur, 1980).

The Ridge Hill Shelf is dissected by many channel wetlands (including Yule Brook, Woodlupine Brook and Bickley Brook in the vicinity of the MKSEA and the main channel of the Canning River, south of the MKSEA). These streams have their headwaters on the Darling Plateau and flow west towards the SCP. The smaller streams terminate within the Ridge Hill Shelf, the Pinjarra Plain or the Bassendean Dunes, whilst the larger streams (such as Yule Brook) discharge further west into the Swan-Canning Rivers system (Perth Groundwater Atlas, 2004).

The Pinjarra Plain geomorphic unit adjoins the western margin of the Ridge Hill Shelf and forms a flat to gently undulating landscape. This unit comprises Quaternary age sediments of the Guildford Formation (Churchward and McArthur, 1980) that originated on the Darling Plateau and were deposited on the ESCP as alluvial fans. The Guildford Formation includes layers of gravels, sands, muds and clays in sequences that have been complicated by aeolian reworking and by channel migration. Other sediments materials that were formed *in situ* by precipitation (such as ferricrete and, less commonly, Muchea Limestone) are also present within the Pinjarra Plain. The Greater Brixton Street Wetlands and the MKSEA are part of a Pinjarra Plain alluvial fan complex that was formed over many thousands of years in association with watercourses (that are now represented by Yule Brook and Bickley Brook) draining from the Darling Range. The Kenwick – Wattle Grove alluvial fan complex has been shown to include a varied array of stratigraphic sequences and hydrological patterns that is correlated with a rich mosaic of fine-scale vegetation assemblages (V & C Semeniuk Research Group, 2001). This very high habitat heterogeneity is, undoubtedly, a major factor underpinning the high biodiversity of the area.

The Bassendean Dunes geomorphic unit is an undulating plain of low-relief dunes composed of Bassendean Sands (Churchward and McArthur, 1980). The Bassendean Dunes generally comprise well-drained, deep, aeolian, quartz sands with few drainage channels. However, basins filled with shallow peat, peaty sand or humic sand are often present between the dunes, and these may be seasonally inundated or seasonally waterlogged, most commonly due to the surface expression of the regional watertable (Semeniuk, 1987; Semeniuk and Semeniuk, 2004). The Bassendean Dunes setting is stratigraphically simple compared to the Pinjarra Plain. Although the Bassendean Dunes provide a range of plant habitats (Semeniuk and Glassford, 1989), these habitats are much less varied and more similar to habitats of the other coastal dune systems of the SCP rather than those of the Pinjarra Plain.

There is a transitional zone (the Southern River geomorphic unit) between the Bassendean Dunes and the Pinjarra Plain where Bassendean Sands encroach over the clays of the Guildford Formation. In the Southern River unit, dunes alternate with low lying wetlands. The Southern River wetlands differ from the main suite of wetlands found in the Bassendean Dunes in that they are, in general, formed by water perched by the clay soils of the underlying Guildford Formation (Hill *et al*, 1996). In the southeast of the MKSEA, the Pinjarra Plain surface is overridden by Bassendean Sands which are outliers from the larger area of Bassendean Dunes that is located south of the Canning River. The Bassendean Sands in this area of the MKSEA have piled up as low dunes against the colluvial sands of the Ridge Hill Shelf that abut the eastern boundary of the MKSEA near the Clifford Street Bushland (BFS 53).

2.3 Superficial Sediments (Soils)

Most of the MKSEA was mapped by Jordan (1986), at a scale of 1:50,000, as shallow Bassendean Sands over the sandy clay of the Guildford Formation (S10) (Table 2.2; Figures 6, 11). Although Figure 6 is at a scale that is too broad to assist in the interpretation of wetlands or fine-scale vegetation assemblages it is useful in illustrating the location and extent of some of the general landforms in the area. The natural course of Yule Brook is evident in this mapping as sandy silt (Ms4). The extensive palusplain that extends below about 11 m AHD southwest of Edward St, Grove Rd and Brook Rd in Precinct 3A of the MKSEA was

mapped as clayey sand of the Guildford Formation (Sc). In the lower catchment of Yule Brook, southwest of Brixton St (and below about 7m AHD) the clayey sand (Sc) was mapped as grading into Guildford Formation sandy clay (Cs). The same sandy clay (Cs) was also mapped over much of the MKSEA in the area south of Victoria Rd (in the lower catchment of Bickley Brook). [Note the term 'mud', as defined in Section 3.3 below, is equivalent to the term 'clay' as used in Jordan (1986).]

The Deep Bassendean Sands (S8) unit is mapped by Jordan (1986) as prevalent in the east of the MKSEA. However, the Guildford Formation underlying this area was evident in several areas where sandy clay (S10) was exposed in slightly lower lying areas amongst the dunes. The dune sands (S8) extended to the yellow sand of the Ridge Hill Shelf (S12) at an elevation of about 26 m AHD at the eastern boundary of the MKSEA, south of Victoria Rd. Apart from these dunes in the east of the MKSEA, there was a roughly circular, quartz sand dune (S8) at the corner of Bickley and Victoria Rds and two low, linear sand ridges (S8) in the centre of the Greater Brixton Street Wetlands between Brook and Boundary Rds.

A small basin of peaty sand (Sp1) was mapped by Jordan (1986) at the base of one of the low sand ridges at the corner of Boundary and Bickley Rds. Peaty sediments were not recorded elsewhere in the MKSEA or the Greater Brixton Street Wetlands (Jordan, 1986; V & C Semeniuk Research Group, 2001). This occurrence was, therefore, unusual for this area.

The MKSEA and BFS 387 are located in an alluvial fan complex (V & C Semeniuk Research Group, 2001). This is evident in the topography of the area; it is a series of flat to gently undulating alluvial terraces (floodplains and palusplains) that gently grade down to the Canning River and are dissected by Yule Brook and its tributaries (Figure 7). The regional stratigraphy in this system is linked to the geographic position in the landscape (V & C Semeniuk Research Group, 2001) as the structure of the alluvial fan has been created by the gradation from a large to small sedimentary load and gradation from coarse to fine sediments with increasing distance from the Darling Scarp. This gradation can be seen superficially in the soils (Jordan, 1986) (Figure 6) where the finest soils (Cs) of the area are distributed in the downslope, western areas of BFS 387. The stratigraphic style of the various zones of the alluvial fan also has implications with regard to the characteristic hydrological processes that operate in each of these zones along this gradient (V. Semeniuk pers. comm.). The variation in habitat in the BFS 387 and the MKSEA (topography, soils, stratigraphy and hydrology) is reflected in the subtle variation in vegetation assemblages that have been noted as occurring along the topographical gradient from east to west in the Greater Brixton Street Wetlands (Goble-Garratt, 1991). Thus, the alluvial fan complex can be seen as a series of habitat zones created by the variation in the physical environment along the topographical gradient (Figures 6, 7). The habitat zones created by the variation in the physical environment along the topographical gradient of the alluvial fan complex in Wattle Grove-Kenwick-Maddington are important features that underlie the resilience, connectivity and sustainability of the biodiversity values in the area and should be considered with regard to the conservation values and the management opportunities in the area.

Table 2.2: Soils of the MKSEA (adapted from Jordan, 1986)

Soil unit	Descriptors applicable to soil unit	Landform
Sand over sandy clay (Qpb/Qpa: S10)	Shallow (Pleistocene) Bassendean Sands over Pleistocene alluvium of the Guildford Formation	Palusplain (Pinjarra Plain) at 10-14 m AHD approx.
Sandy silt (Qha: Ms4)	Holocene alluvium	Valley floor of Yule Brook
Clayey sand (Qpa: Sc)	Pleistocene alluvium of the Guildford Formation	Palusplain-floodplain (Pinjarra Plain) <11 m AHD approx.
Sandy clay (Qpa: Cs)	Pleistocene alluvium of the Guildford Formation	Palusplain-floodplain (Pinjarra Plain) adjacent to: Lower Yule Brook at <7 m AHD approx; or Lower Bickley Brook at <14 m AHD approx.
Deep Bassendean Sands (Qpb: S8)	Deep (Pleistocene) Bassendean Sands	Dunes at 16-26 m AHD approx.
Sand (Qpr: S12)	Structure-less yellow sands of the Yoganup Formation	Foothills of Darling Range at >26 m AHD approx.
Peaty sand (Qrw: Sp 1)	Holocene swamp deposit	Basin wetland within Pinjarra Plain

2.4 Hydrology and Wetlands

The hydrology and wetlands issues in the MKSEA and the Greater Brixton Street Wetlands are complex and integral to the conservation of the important biodiversity values of the area. However, many of these issues are not fully understood by regulators and stakeholders and, hence, are poorly managed. Important issues in the area include the relationships between the topography, stratigraphy and hydrology in the local alluvial fan system; the impact of changes in the hydrological cycle that have been brought about by existing development on the Yule Brook – Bickley Brook catchments; the relationship of the local wetlands to the Swan-Canning Rivers system; the hydrological interactions between the MKSEA and the Greater Brixton Street Wetlands (BFS 387); the mapping, classification and management category of the wetlands and unusual wetland types in the area; and artificial drainage and stormwater management issues involved in potential further development.

The MKSEA and the Greater Brixton Street Wetlands are located between Yule Brook and Bickley Brook, a short distance upstream from where these two watercourses drain into the Canning River (Figure 6). Yule Brook traverses the northern precinct of the MKSEA. Downstream from the MKSEA, Woodlupine Brook and Binley Brook converge with Yule Brook before it discharges into the Canning River.

The groundwater in the vicinity of the MKSEA has been mapped in the Perth Groundwater Atlas (2004) at a scale of 1:20,000. Although the wetlands of the MKSEA, the Greater Brixton Street Wetlands and the Clifford Street Bush Forever Site (BFS 53) have been mapped as discrete areas, it is important to understand that most of them are a part of a continuous, extensive wetland ecosystem in which the individual components are connected by groundwater flow, subsurface water flows along impermeable layers and channelled surface water flows (V & C Semeniuk Research Group, 2001; Perth Groundwater Atlas, 2004). The groundwater from the MKSEA discharges to the southwest, through the Greater Brixton Street Wetlands and downslope towards the Canning River. The groundwater contour lines in the area between Yule Brook and Bickley Brook (that includes the MKSEA and the Greater Brixton Street Wetlands) are orientated almost parallel to the surface topography contour lines (Figures 6, 7).

The wetlands of the MKSEA were classified and mapped at a scale of 1:25,000 by Hill *et al*. (1996), and these data are stored and updated in the Swan Coastal Plain Wetland Dataset of the Western Australian Department of Environment and Conservation (DEC, 2008b). The wetlands in the vicinity of the Greater Brixton Street Wetlands and the MKSEA are part of the Keysbrook (P.1) and the Mungala (B/P.2) Consanguineous Wetland Suites (Hill *et al*., 1996, Volume 2A, Figure 4.4). The occurrence in Kenwick of the Keysbrook Consanguineous Wetland Suite is notable as it is the most northerly area of this suite. There are currently about 70 wetland areas (palusplains, sumplands and damplands) within the MKSEA that have been identified and mapped in the SCP Wetland Dataset of the Western Australian Department of Environment and Conservation (DEC, 2008b). Many of the wetlands in the MKSEA that have been mapped in the SCP Wetland Dataset have been assessed as Conservation Category Wetlands (CCW) or Resource Enhancement Wetlands (REW). There is a group of wetlands in the area known as the Greater Brixton Street Wetlands (that corresponds with Bush Forever Site 387) that are of very high conservation value and have been listed on the Register of the National Estate (Government of Western Australia, 2000).

The fine-scale stratigraphic and hydrological study of the Greater Brixton Street Wetlands carried out by the V & C Semeniuk Research Group (2001) provides a basis for understanding the relationship between the native vegetation of the area and its habitat and the long term hydrological regime of the area prior to anthropogenic modification. In this study, a ground and surface water monitoring system (at a scale appropriate to the environmental water requirements of the vegetation of the area) was established throughout the Greater Brixton Street Wetlands.

The complex natural hydrogeology of the area is over-printed by a grid of excavated drainage channels, firebreaks and tracks. V & C Semeniuk Research Group (2001) found that these soil disturbances can influence the hydrological variables of the area (such as soil moisture, depth to groundwater and surface drainage patterns) during the wet season. The initial conclusions and hydrological management recommendations from the study of V & C Semeniuk Research Group (2001) were released in 2001, but the monitoring of some of the bores in this system is ongoing.

Most of the rivers and creeks of the SCP (including Yule Brook and Bickley Brook) are heavily modified by the deepening and straightening of existing channels and the construction of drains to increase conveyance capacity and to lower superficial groundwater levels (Swan River Trust, 2009). The Yule Brook and Bickley Brook catchments in the MKSEA include a number of small creeks, but few of these have retained their natural form; most have been excavated and diverted to facilitate drainage (Figure 7). The area also has a number of small-scale, discontinuous channel segments (that are evident in the stratigraphic sequences and vegetation of the area) that indicate the locations of natural surface drainage channels that in the past had similar attributes to the currently active channel of Yule Brook (V & C Semeniuk Research Group, 2001).

The Swan River Trust (2009) has prepared a Water Quality Improvement Plan (WQIP) for the Swan and Canning Rivers. The flow rates and nutrient levels of numerous watercourses (including Bickley Brook and Yule Brook) that contribute to the Swan and Canning River system are regularly monitored (Swan River Trust, 2008a, 2008b). One of the main aims of the WQIP is 'to set environmental flow objectives, protect wetlands and floodplains (mimic natural inundation and drying patterns) and to minimise the effects of dams and extraction of water on water quality' (Swan River Trust, 2009).

The environmental flow objectives for aquatic and riparian vegetation for watercourses on the SCP were identified in GHD (2008) and these are relevant to the MKSEA. These objectives were:

- 'Maintenance and restoration of wetland/riparian vegetation in winter-wet, pastured, floodplain regions and along the periphery of drainage channels;
- Inundation of wetland/riparian vegetation to restore and maintain these areas; and
- Seasonal inundation of emergent and mid bank vegetation (for survival, germination and recruitment).'

In the MKSEA there are some areas where deep and water-permeable Bassendean Sands overlie, or are emergent from, the Guildford Formation. These dunes and low ridges occur mainly in the southeast of the MKSEA, where they generally form localised perched water mounds. Rainwater infiltrates the Bassendean Sands and is slowly discharged laterally (along the contacts of the dunes with the adjacent, largely impermeable, Guildford Formation clay layers) onto the adjacent palusplains. The hydrology of the small-scale, seasonally-waterlogged slopes (paluslopes) that are maintained by such seepages from low ridges in the Greater Brixton Street Wetlands, and the artesian pressure heads in some aquifers associated with the Bassendean Sands/Guildford Formation interfaces in this area, were described in V & C Semeniuk Research Group (2001). These areas in the Greater Brixton Street Wetlands are the only examples of paluslope wetlands that have been described to date on the SCP. The general principles of paluslope formation are illustrated in Hill *et al*. (1996, Volume 2A, Figure 2.13).

The boundaries between the Pinjarra Plain landscapes (that occur mainly in the northern and central area of the MKSEA) and the Bassendean Dunes landscapes (that occur mainly in the southeast of the MKSEA) are often subtle and irregular. These boundaries effectively divide the wetland landscapes from the upland landscapes. In simple terms, one of the major boundaries of this type in the MKSEA in the vicinity of Victoria Rd has been described as 'a watershed' (GHD, 2005). However, it is not simply the crest of a ridge that sheds water uniformly down the surfaces of both of its slopes. This boundary is marked by a subtle topographical gradient but also complex stratigraphy and hydrology (where water recharge, storage and discharge can be influenced by factors such as groundwater flow, seepage from perched aquifers, artesian springs, and channelled surface flow). Thus an array of wetland types (including paluslopes, palusplains, floodplains, sumplands and damplands) has developed along this boundary. A number of small dams have also been excavated along this boundary and this has further complicated the hydrological features of the area. The boundary between the Bassendean Sands and the Pinjarra Plain in this area is also significant in terms of biological values. The remnant native vegetation along this boundary is often atypical or uncommon in terms of other vegetation on the SCP and thus of high conservation significance and both the natural wetlands and excavated dams in the area are significant habitats for waterbirds and probably other native fauna. To achieve optimum environmental outcomes for the Greater Brixton Street Wetlands and the MKSEA, it is important that the Pinjarra Plain to Bassendean Dunes interfaces of the area are mapped accurately at a fine scale. Decisions about development in the area (such as the determination of buffer zones to protect the wetlands adjoining the Pinjarra Plain to Bassendean Dunes interfaces) should be based on detailed field studies of topography, stratigraphy and hydrology that have been conducted over an

appropriate length of time to develop a good understanding of the complex wetland dynamics across these boundaries.

2.5 Drainage Issues

There is no doubt that the hydrological processes in the Yule and Bickley Brooks catchment have been significantly altered due to rural, urban and industrial development of much of this area. One of the major hydrological effects of development in such catchments is that the clearing of perennial native vegetation and the introduction of large areas of compacted soil and built surfaces (including roads, tracks, firebreaks, buildings and car parks) typically produces a large decrease in the volume of rain that infiltrates locally into groundwater, a large increase in the volume and speed of surface water run-off and a deterioration in the quality of this run-off water. To prevent the flooding of property and infrastructure by this increase in run-off, it is common practice to excavate the existing channel wetlands and to construct new drains where necessary to increase conveyance capacity. These drains can also intersect superficial aquifers and thus act to lower ground water levels in wetland areas and so facilitate development. However, this type of water management typically produces poor outcomes with regard to water quality in the Swan and Canning Rivers, the loss of valuable groundwater resources and the further degradation and loss of wetlands and groundwater-dependant native vegetation. The current Swan River Trust WQIP initiative (Swan River Trust, 2009) is a response to the cumulative negative environmental effects of such practices in the past over the SCP that have produced critical levels of environmental degradation in the Swan and Canning Rivers.

Currently in the Yule-Bickley Brooks catchments, it is evident that a large proportion of the rainfall that previously infiltrated into the groundwater locally and supported native vegetation is now intercepted by compacted soil and built surfaces and is exported, as polluted stormwater, out of the wetlands via an artificial drainage system into Yule Brook and Bickley Brook and from there into the Canning River. This decreases the water available to the highly water-dependent ecosystems of high conservation value that remain in the catchment and contributes to the nutrient and pollutant load of the Canning and Swan Rivers. The changes to the hydrological regime brought about by the constructed drainage network in the City of Gosnells and the Greater Brixton Street Wetlands have been linked with changes observed in remnant native vegetation and the decline of threatened flora (Trudgen and Keighery, 1995; Luu and English, 2004). The de-watering of shallow aquifers in the Greater Brixton Street Wetlands by some of the drainage channels and the negative impact of some of the tracks and firebreaks on surface water resources, have been demonstrated by V & C Semeniuk Research Group (2001). The MKSEA is predominantly a wetland landscape and it includes a number of poorly-regulated and potentially polluting land uses. Thus there are also likely to be significant water and soil pollution issues in the area (including the exposure of acid sulphate soils to oxidation) that could be exacerbated by further drainage and earth moving associated with additional development.

The drainage plan proposed for the MKSEA (GHD, 2005) did not show significant changes to the current method of dealing with run-off in the area. It correctly stated that one of the main issues in the proposed industrial development was ‘the management of an increased quantity and poorer quality of stormwater’. However, the GHD drainage plan did not acknowledge that the increased stormwater (surface flow) that is expected to occur in the area after further development in the MKSEA will be at the expense of decreased groundwater recharge in the catchment and that it will probably impact adversely on the water requirements of the high conservation-significance, groundwater-dependent ecosystems of the area. The wetland management objectives adopted for the development of the stormwater management plan (GHD, 2005) included the aim that ‘existing drains located within the conservation and resource enhancement wetlands should be retained to maintain the existing hydrological regime’. It is important, however, to be aware that the ‘existing hydrological regime’ is a highly modified regime with respect to the original conditions in the catchment and is not necessarily desirable with regard to the sustainability of biodiversity in many areas of the MKSEA and the Greater Brixton Street Wetlands. Industrial development in the MKSEA using the existing drains in the CCW and REW wetlands of the area (and thus basically the same methods of stormwater disposal as are currently used) with the creation of additional conveyance capacity that will be needed to cope with increased stormwater from the development, can be expected to move the hydrological regime further from that which is optimal for the local groundwater dependant ecosystems. After all, there is only a finite amount of rainwater available to recharge groundwater locally and this rainwater is decreasing

due to climate change. In perpetuating the same methods of dealing with run-off as are currently used in the MKSEA and increasing the conveyance capacity in the area, the negative local effects (dewatering and degradation of valuable plant and animal habitats) and negative downstream effects (pollution of the Swan River) will be exacerbated.

Central to this issue are the predominantly muddy or clay soils and the low-lying topography of the MKSEA (Figures 6, 7, 11). The opportunities for both development and the environmentally sustainable treatment of run-off water are significantly constrained by such landscapes. Three main methods that are used currently to manage stormwater on the SCP (that could be used in the MKSEA) and problems associated with them are summarised below.

1. In areas of deep sand, the cheapest (and most common) method of artificial drainage that is currently used on the SCP to prevent the flooding of property and infrastructure by the increased volume of surface flow produced by development, is to gravity feed this water to the lowest points in the landscape (which are usually existing wetlands or constructed swales). To reduce expenses, the run-off from a large area is concentrated into the least number of basins possible and the receiving basins are excavated to accommodate the required volumes. If the basins are located in deep sand, the periodic flooding of these by large volumes of nutrient-enriched, polluted run-off is a practical and cheap method of disposal of excess water as this water readily infiltrates into the regional groundwater table.

   However, to disperse the pollution carried in stormwater and to reduce environmental impacts, water sensitive urban design in areas of deep sand dictates that excess run-off is not concentrated into a few, large basins but is infiltrated into the groundwater as close as possible to the source of the run-off in many small basins (Monk and Chalmers, 2006). Such infiltration basins, according to best practice, also require regular maintenance to remove gross refuse, sediment, nutrient and pollutant build up and nutrient-stripping vegetation. However, the best practice model for drainage is costly as it requires that valuable land be devoted to drainage measures.

   In the MKSEA, the area of the deep sands that could be used for (water sensitive urban design) run-off infiltration areas is limited to a narrow corridor of dunes adjacent to Tonkin Highway in Precinct 1 and a smaller area in Precinct 2 at the east end of Victoria Rd. There are few, if any, sandy areas suitable for water sensitive urban design infiltration sites in Precinct 3 of the MKSEA.

2. The second option for dealing with run-off from development (and this method is most commonly used in areas of clay and mud on the eastern SCP where drainage water will not infiltrate the groundwater) is to direct this run-off into a drains or natural creeks. If creeks are used for this purpose it becomes necessary to regularly excavate their channels, keep the banks clear of natural fringing vegetation and often straighten these channels and line them with concrete to enable large volumes of nutrient enriched and polluted run-off to be rapidly exported into major watercourses such as the Swan River. These practices contribute to the degradation of native fringing vegetation, the destruction of native fauna habitat, the spread of weeds, and the deterioration in the water quality of the creeks and downstream pollution and algal blooms in the Swan River.

   This type of drainage system is currently used throughout Kenwick and Maddington; polluted stormwater run-off and water from the shallow aquifers intersected by excavated drains are channelled into Yule Brook and Bickley Brook and hence into the Canning River.

3. A third drainage option that has been used on the eastern side of the SCP is the excavation of large basins in clay soils to retain the stormwater run-off close to the areas where it was produced. In such retention basins the stored water evaporates slowly or, in peak rainfall events, some of it overflows into the Swan-Canning River system. Such a drainage basin was excavated in the Woodlupine Brook just west of the MKSEA to receive the run-off from Roe Highway. In seasons of peak rainfall, the overflow from this system flows downstream to the Canning River. In the best examples of such drainage options, the water storage basins are vegetated and subsequently provide habitat for water birds and some natural nutrient stripping by the vegetation.

   This drainage option does not address the problem of reduced groundwater recharge in such catchments that usually impacts adversely on the water requirements of groundwater dependent ecosystems. In the MKSEA, as most of the land proposed for development lies in the groundwater catchment for BFS 387

(Figures 6, 7), this is an important issue. This option is also not an appropriate offset as it involves the substitution of a constructed lake or sumpland (common wetland types of the SCP) for one of the previously characteristic and now uncommon wetlands (such as palusplains and floodplains) of the eastern SCP.

The infiltration of run-off into the groundwater at the point of source as suggested by (GHD, 2005) is not expected to be very effective in the clay sediments, ferricrete and other materials that form shallow aquitards in much of BFS 387 and the MKSEA. The infiltration of run-off into the groundwater is anticipated to only be effective in a limited area along Tonkin Highway in the southeast of the MKSEA where development can occur on sandy soils and run-off can be infiltrated into dunes. Elsewhere, it is predicted that the treatment of the run-off will essentially be limited to a combination of:

a) Storage of water from small or medium rainfall events in basins, or Multiple Use Corridors (MUCs) to allow some of it to evaporate; and

b) Discharge of overflow from MUCs during peak rainfall events via the existing drainage channels into the Yule Brook and Bickley Brook.

Without a comprehensive and innovative plan to restore the hydrological cycle of the area to a more sustainable system (including the restoration of Yule Brook to a natural stream and the restoration of extensive areas of floodplain adjacent to Yule Brook) the proposed measures are anticipated to continue to dewater the groundwater of the catchment at the same time that the local groundwater and surface water dependant ecosystems are also stressed by the drier climatic conditions that are forecast for the area.

It must be acknowledged that in areas such as the MKSEA (that are dominated by muddy/clay soils and low-lying topography) the opportunities for combining development with environmentally sustainable treatment of run-off water are significantly constrained. It is expensive to develop these wetland areas as large quantities of fill are usually required to raise the development above the high natural water table. It is also expensive to attempt to conform with the aims of the Swan-Canning WQIP (i.e. to protect wetlands and mimic natural inundation and drying patterns) or implement water sensitive design when dealing with the excessive run-off, post development, in such landscapes. The restoration of natural hydrological regimes and floodplains in such areas subsequent to developments requires the extensive appropriation of land (that could otherwise be most profitably sold for urban and industrial development) to these environmental protection measures. In practice it is much cheaper and easier in the short term, to continue to excavate existing creeks and build new drains to increase conveyance and enable greater volumes of run-off to move into the Swan-Canning River system than to institute improvements in catchment management. However, the potential negative effects on environmental values of the three traditional forms of run-off disposal in the MKSEA and the cost in terms of wasting the opportunity to implement positive changes in this catchment, if water management is not improved, are unacceptably high.

The MKSEA straddles the Greater Brixton Street Wetlands (BFS 387), which is nationally significant on multiple counts and is, probably, the most important biodiversity and wetland conservation reserve of the SCP. Much of MKSEA is located directly upslope from BFS 387 in the groundwater catchment area for this reserve. BFS 387 is already stressed by inadequate water management in the catchment. Further actions that would prejudice the sustainability of the ground and surface water dependant ecosystems in this catchment will not be acceptable to Federal and State regulators and a number of other stakeholders.

2.6 Biogeography

The Eastern Swan Coastal Plain (ESCP) is defined as the land encompassed by the McArthur and Bettenay (1960) Foothills and Pinjarra Plain geomorphic units (Government of Western Australia, 2000a). Less than 7% of the original extent of the vegetation of the ESCP now remains after the intensive agricultural use of the area and developments such as housing, industry and transport infrastructure (Government of Western Australia, 2000a, 2000b). All areas of the ESCP (including the MKSEA) where the flora, vegetation and wetlands are still in good condition are ranked as being of, at least, regional conservation significance

(Keighery and Trudgen, 1992; Government of Western Australia, 2000a). These areas are specifically protected by the Bush Forever policy (Government of Western Australia, 2000a, p. xiv) that states:

> 'There will be a general presumption against clearing bushland containing threatened ecological communities or representation of vegetation complexes of which less than 10 per cent currently remains on the Swan Coastal Plain portion of the Perth Metropolitan Region (generally involving the eastern side of the Swan Coastal Plain).'

Bush Forever Site 387 (The Greater Brixton Street Wetlands) is the most species-rich area of all the Bush Forever sites described in the Bush Forever report (Government of Western Australia, 2000a, 2000b) and, as such, is one of the most important conservation reserves in the Swan Coastal Plain Bioregion of Western Australia. Currently more than 555 native plant taxa are known from the 127 ha of the Greater Brixton Street Wetlands (Keighery and Keighery, 2000). This represents over 26% of the total native flora of the Perth Floristic District, about 20% of the total native flora of the species-rich Swan Coastal Plain (SCP) Bioregion and about 12% of the total native flora of the South West Australian Botanical Province (the latter area being the only globally-significant biodiversity 'hot spot' in Australia) (Conservation International, 2008; Western Australian Herbarium, 2009). The Greater Brixton Street Wetlands contain nearly five times the species-richness of native flora per unit area that is found in Kings Park, which has only 293 native taxa in 321 ha of bushland according to Government of Western Australia (2000b). Factors that are likely to have contributed to the very high biodiversity values exhibited in remnant bush and wetlands in the vicinity of the Greater Brixton Street Wetlands include:

- The great habitat heterogeneity provided by the complex hydrogeology in the alluvial fans of the Pinjarra Plain (V & C Semeniuk Research Group, 2001);
- The inclusion, in BFS 387, of a substantial sample of the topographical series of landforms and soils (catena) that occur within the Wattle Grove-Kenwick alluvial fan (due to the orientation of this Bush Forever Site parallel to the topographical gradient down the alluvial fan - Figure 7);
- The very species-rich pool of flora available in the southwest Western Australia Floristic Province that was available to colonise the ESCP via the natural corridors; and
- The repeated fluctuations in climatic and edaphic conditions that were experienced in the region during the Quaternary era. Whilst there was good connectivity between the habitats of the ESCP and the Darling Range and its hinterland, plants adapted to both semi-arid and humid conditions were able to colonise the ESCP during climatic fluctuations. This connectivity of habitats between the Darling Range and the Canning River along the Yule Brook is still functioning currently to a certain extent.

2.6.1 Regional Scale Vegetation Units of the Eastern Swan Coastal Plain

There have been numerous studies that have aimed to characterise, classify and/or map the vegetation units that are present within the Swan Coastal Plain Bioregion to investigate the land-use capability of land that was covered with the native vegetation and to assess the conservation significance and reservation status of this vegetation. The terms Vegetation Systems, Vegetation Complexes and Vegetation Associations have been used by various authors to designate vegetation units mapped at various scales. All of these units are regional scale, high order units.

2.6.1.1 Vegetation Systems (Beard, 1979a)

Beard (1979a, 1979b, 1981) mapped the vegetation of the Swan Coastal Plain as broadscale Vegetation Systems based on the structures of the dominant vegetation layers. In this mapping, the vegetation of most of the MKSEA and neighbouring area is indicated as Marri (*Corymbia calophylla*) Woodland (e_3Mi), of the Pinjarra Plain Vegetation System (as defined by Smith 1974). Beard's Pinjarra Plain Vegetation System extended from about Gingin to Dunsborough and was located between the Bassendean Vegetation System to the west and the Ridge Hill Shelf Vegetation System to the east. The Pinjarra Plain Vegetation System inhabited the most fertile soils of the coastal plain, which were preferentially developed for pasture and irrigation systems. Because Beard (1979a) considered that very little (if any) virgin Marri Woodland of the

Pinjarra Plain Vegetation System remained he mapped this vegetation from relic trees or shrubs over pasture grasses and ungrazed road verges that gave some idea of the nature and extent of the original vegetation.

The south-eastern part of the MKSEA was mapped by Beard (1979a) as Jarrah-Marri Forest ($e_{2,3}$Mc), which is in the Ridge Hill Shelf Vegetation System, a narrow band at the foot of the Darling Scarp.

2.6.1.2 Vegetation Complexes (Heddle *et al*. 1980)

Heddle *et al*. (1980) characterised a number of vegetation units that are called Vegetation Complexes in the Perth Region. The Vegetation Complexes were mapped on the assumption that the distribution of distinctive vegetation complexes (each complex comprising a number of plant communities aggregated in proportions characteristic of that complex) was correlated with the major geomorphic systems and soil units of the region (McArthur and Bettenay, 1960; Churchward and McArthur, 1980).

In the vicinity of the MKSEA (where the Ridge Hill Shelf, Pinjarra Plain and the Bassendean Dunes geomorphic systems are present) Heddle *et al*. (1980) mapped six Vegetation Complexes (Figure 8). The relevant geomorphic units, the vegetation complexes associated with these geomorphic units and the percentage of native vegetation remaining within each vegetation complex in the Perth Metropolitan Area (as determined in Government of Western Australia, 2000b) are listed below.

FOOTHILLS (Ridge Hill Shelf) VEGETATION COMPLEXES

Forrestfield Vegetation Complex (9% remaining)
Open forest of *Corymbia calophylla – Eucalyptus wandoo - E. marginata* to open forest of *E. marginata - Corymbia calophylla – Allocasuarina fraseriana - Banksia* spp. Fringing *Eucalyptus rudis* low forest in the gullies that dissect this landform.

PINJARRA PLAIN VEGETATION COMPLEXES

Guildford Vegetation Complex (6% remaining)
A mosaic of open forest to tall open forest of *Corymbia calophylla - Eucalyptus wandoo - E. marginata* and woodland of *E. wandoo* (with rare occurrences of *E. lane-poolei*). Minor components include *E. rudis - Melaleuca rhaphiophylla*.

Swan Vegetation Complex (11% remaining)
Fringing woodland of *Eucalyptus rudis - Melaleuca rhaphiophylla* with localised occurrences of low open forest of *Casuarina obesa* and *Melaleuca cuticularis*.

Cannington Vegetation Complex (1% remaining)
A mosaic of the vegetation of the Bassendean, Karrakatta, Southern River and Vasse vegetation complexes.

BASSENDEAN DUNES VEGETATION COMPLEXES

Southern River Vegetation Complex (17% remaining)
Open woodland of *Corymbia calophylla - Eucalyptus marginata - Banksia* spp. with fringing woodlands of *E. rudis - Melaleuca rhaphiophylla* along creek banks.

Bassendean Central and South Vegetation Complex (24% remaining)
Woodland of *Eucalyptus marginata - Allocasuarina fraseriana - Banksia* spp. to low woodland of *Melaleuca* spp. and sedgelands on the moister sites.

2.6.1.3 Vegetation Associations (Keighery and Trudgen, 1992)

In a study of the vegetation of the Eastern Swan Coastal Plain, Keighery and Trudgen (1992) identified several main Vegetation Associations within the Pinjarra Plain landform. These are listed below.

1. *Corymbia calophylla* Woodland to Open Forest
2. *Casuarina obesa* Woodland to Open Forest
3. *Corymbia calophylla* and *Eucalyptus wandoo* Woodland to Open Forest
4. *Eucalyptus wandoo* Woodland to Open Forest
5. *Eucalyptus rudis* Woodland to Open Forest

6. Ephemeral Wetlands, a complex mosaic of shrublands, heaths, sedgelands and herblands

The *Corymbia calophylla* and the *Casuarina obesa* woodlands and open forests and the wetland vegetation mosaic were considered to be the most common units prior to the large-scale clearing of the Pinjarra Plain.

2.6.1.4 Floristic Community Types (FCTs)

Early work to classify the vegetation of the Swan Coastal Plain using numerical classification of floristic data was carried out by Havel (1968) and, later, by Heddle *et al*. (1980). More comprehensive survey and analysis of the vegetation of the SCP was carried out by Gibson *et al*. (1994) to define finer-scale vegetation units than those of the regional-scale Vegetation Systems of Beard (1979) and the Vegetation Complexes of Heddle *et al*. (1980). The vegetation units derived by Gibson *et al.* (1994; Government of Western Australia 2000) are known as the Floristic Community Types of the Swan Coastal Plain (SCP FCTs).

As there were only 43 FCTs identified for the entire SCP by Gibson *et al*. (1994), it is a fair assumption to consider that these FCTs represent relatively high order units (as discussed by Trudgen, 1999, and by Griffin, Appendix C). In the current survey, the FCTs are therefore considered as *sub-regional* scale vegetation units to differentiate them from the *local* scale vegetation units that were mapped in the current study (and in other studies of the Greater Brixton Street Wetlands, including Mattiske and Associates, 1992) at a scale of approximately 1:5,000 or finer.

The derivation of Floristic Community Types, after Gibson *et al.* (1994), is an example of a purely-floristic method of vegetation classification. In floristic classification, vegetation classes are defined by the grouping of standard-sized, sample plots of native vegetation (on the basis of the similarity matrices of the floristic composition of these plots) with the aid of software such as PATN®. In the case of the FCTs of the Swan Coastal Plain defined by Gibson *et al*. (1994) and in subsequent update studies, the standard size of the vegetation sample plot from which floristic data are recorded for the purposes of FCT definition is a 10 m by 10 m quadrat. It is important to note that the definition of FCTs on the SCP by this method does not include vegetation structure data or individual taxa abundance data from the vegetation sample plots in the analysis. Only presence/absence data of all vascular flora taxa (regardless of height and cover class) are included in the analysis.

In Gibson *et al.* (1994), 509 standard quadrats were surveyed on public lands throughout the SCP to record floristic data. A numerical classification of these vegetation samples resulted in the identification of four supergroups of sites. These supergroups were correlated with three of the major geomorphic units of the SCP (Foothills/Pinjarra Plain, Bassendean Dunes and Spearwood/Quindalup Dunes) and seasonal wetlands. The Gibson et al. 1994 supergroups can thus be considered as showing regional scale patterning of the vegetation at approximately the same scale as the Vegetation Complexes of Heddle *et al.* (1980).

Within the four supergroups of Gibson *et al.* (1994) there were a total of 43 clusters of sites. Each of these 43 clusters of sites was designated by Gibson *et al.* (1994) as a Floristic Community Type (FCT). The Seasonal Wetlands supergroup contained the largest number of FCTs. However, the mean number of quadrats that were sampled per FCT in this supergroup was the lowest of all the supergroups, i.e. the seasonal wetlands were relatively poorly sampled in this study.

Numerous attempts have been made (e.g. Trudgen, 1999) to numerically compare the floristics of the vegetation units derived by fine scale mapping on the SCP with the data obtained in Gibson *et al.* 1994. The vegetation units recorded in environmental assessment projects, such as the current survey, that, on analysis, show affinity with the Gibson *et al.* (1994) FCTs that are recognised as Threatened Ecological Communities (DEC, 2007 and DEWHA, 2008) have very high conservation value. However, because most of the Threatened Ecological Communities (TECs) of the SCP are defined exclusively by their statistical similarity with the FCTs found by Gibson *et al.* (1994), vegetation that does not show floristic affinity to these FCTs, is often, in practice, automatically deemed to be of low conservation significance. The results of such analyses have often failed to recognise vegetation that is known to be genuinely rare and threatened on the SCP by the most experienced botanists and environmental scientists working in Western Australia (Trudgen, 1999 being the best documented example of this).

The floristic classification of the vegetation of the SCP of Gibson *et al.* (1994) was later updated by the addition of floristic data from a further 613 quadrats surveyed on both private and public lands of the SCP

(Keighery, 1997). These data supplemented the data available for some of the previously poorly-sampled landforms, such as seasonal wetlands and the Quindalup Dunes, and included data (for the first time) of vegetation on the Dandaragan Plateau and Muchea Limestone (Muchea Limestone was thought to be entirely cleared of vegetation at the time of the Gibson *et al.* survey). The updated analysis resulted in a new classification that added 20 new vegetation units (S1 to S20) to the original list of FCTs of the SCP. This vegetation classification for the SCP was adopted in Government of Western Australia (2000) as a baseline for the assessment of the conservation status of native vegetation throughout the Perth Metropolitan Region. It is important to note that the urgency of the task to conserve the globally-significant biodiversity of the Perth Region and the lack of resources available for biological research in Western Australia justifies, to some extent, the methods used. However, it is unfortunate that the additional data used to supplement Gibson *et al.* (1994) remain unpublished and inaccessible for use in assessing the conservation value of vegetation in surveys such as that currently conducted in the MKSEA.

It may be concluded that the FCTs derived from Gibson *et al.* 1994 and subsequent updates should be cautiously interpreted as showing valuable indications of the sub-regional scale patterning and conservation values of the vegetation on the SCP but not as a rigorous standard (especially in the absence of critical discussion) for determining the conservation value of *all* vegetation in subsequent surveys.

Nevertheless, in the absence of more suitable methods and a greater amount of contextual data that would add scientific rigour to the process of assessing the conservation value of vegetation on the SCP, there are significant records of vegetation units at the sub-regional scale of the FCTs in the vicinity of Kenwick and Maddington. At least 15 Floristic Community Types (FCTs) have been identified in the City of Gosnells by Trudgen and Keighery (1995) and in the Bush Forever sites of Cannington, Forrestfield, Kenwick, Maddington, Orange Grove, Queens Park, Southern River, Welshpool and Wattle Grove by various workers (Government of Western Australia, 2000b). Some of these FCTs were identified by inference rather than by multivariate analysis. The FCTs that have been listed in the vicinity of the MKSEA are listed below.

Supergroup 1: Foothills and Pinjarra Plain FCTs
- FCT 2: Southern wet shrublands.
- FCT 3a: *Eucalyptus (Corymbia) calophylla – Kingia australis* woodlands on heavy soils.
- FCT 3b: *Corymbia calophylla – Eucalyptus marginata* woodlands on sandy clay soils.

Supergroup 2: Seasonal Wetlands FCTs
- FCT 4: *Melaleuca preissiana* damplands.
- FCT 7: Herb rich saline shrublands in claypans.
- FCT 8: Herb rich shrublands in claypans.
- FCT 10a: Shrublands on dry clay flats.
- FCT 12: *Melaleuca teretifolia/Astartea* shrublands.
- FCT 13: Deeper wetlands on heavy soils.
- S2: Northern *Pericalymma ellipticum* dense low shrublands.

Supergroup 3: Uplands centred on Bassendean Dunes (or Dandaragan Plateau) FCTs
- FCT 20a: *Banksia attenuata* woodlands over species-rich dense shrublands.
- FCT 20b: Eastern *Banksia attenuata* and/or *Eucalyptus marginata* woodlands.
- FCT 21c: Low lying *Banksia* woodlands or shrublands.
- FCT 23a: Central *Banksia attenuata – B. menziesii* woodlands.

Restricted Floristic Community Type Mosaic
- Shrublands and woodlands on Muchea Limestone.

2.6.2 Local scale vegetation units and habitats previously recorded in the Greater Brixton Street Wetlands

The flora of the Greater Brixton Street Wetlands (BFS 387) has been extensively collected. Most of the collections of the area are held by the Western Australian Herbarium and the Herbarium of the School of

Plant Biology, University of Western Australia. The Greater Brixton Street Wetlands and nearby areas have been the subject of numerous studies, including some detailed, quadrat-based vegetation studies (Speck and Baird, 1984; Gibson *et al.* 1994; Keighery and Tauss, 2008; Tauss, 2009) and other brief, reconnaissance-level surveys (Goble-Garratt, 1991; Mattiske & Associates, 1992; Keighery, 1995a, 1995b; Koch, 2004).

A study of the plant habitats of the Greater Brixton Street Wetlands was conducted by VCSRG (2001). This study attempted to sample the entire area recommended for BFS 387 in Government of Western Australia (2000) and provided very detailed data of plant habitats, defined on the basis of several years of monitoring of surface and groundwater levels, soil moisture and water chemistry. However, the vegetation of many areas of BFS 387 remains relatively poorly known. Many of the flora collections from this area were made many years ago and were not annotated with detailed locations or habitat details. There are also a large number of taxa that have been recorded in the area that have not been formally described and remain listed by the Western Australian Herbarium under informal phrase names.

Marshall (2000) summarised 26 vegetation units mapped within the Greater Brixton Street Wetlands in Speck and Baird (1984), Goble-Garratt (1991), Mattiske & Associates (1992), Keighery (1995a, 1995b) and Gibson *et al.* (1994) at scales of approximately 1:5,000. The vegetation units in the studies included in this summary were associated with four, loosely-defined vegetation habitats: (1) water filled depressions; (2) seasonally waterlogged or inundated flats, (3) dry or occasionally waterlogged flats and (4) uplands. To try to understand the local context of the vegetation of the MKSEA, some of the more detailed previous accounts of the vegetation and habitats of BFS 387 (Marshall, 2000; VCSRG, 2001; Keighery and Tauss, 2008; and Tauss, 2009) were compared (Table 2.3).

The taxonomic and vegetation description data available from BFS 387 were found to be quite variable. To collate the information from the numerous authors and to compare the data (Table 2.3) a list of synonymous terms is suggested below.

- The terms ‘claypan’ or ‘water filled depression’ (Marshall, 2000) are equivalent to ‘sumpland’ (VCSRG, 2001; Keighery and Tauss, 2008; Tauss, 2009).
- The terms ‘seasonally or occasionally waterlogged flat’ (Marshall, 2000) are equivalent to ‘palusplain’, ‘sandy flat’ and ‘sandy palusplain’ (VCSRG, 2001; Keighery and Tauss, 2008; Tauss, 2009).
- The term ‘seasonally inundated flat’ (Marshall, 2000) is equivalent to ‘floodplain’ (VCSRG, 2001).
- The term ‘paluslope’ (VCSRG, 2001) that was used to denote a seasonally waterlogged slope in BFS 387 has no equivalent in the other literature of BFS 387. Paluslopes are uncommon on the SCP and the characterisation of these landforms requires detailed stratigraphic and hydrological data.
- The term ‘dry flats’ (Marshall, 2000) are presumed to be equivalent to ‘low sand ridges’ (VCSRG, 2001).
- The term ‘dry clay flats’ as per Floristic Community Type 10a (Gibson *et. al.* 1994) were equivalent to ‘mud palusplain’ (VCSRG, 2001). The use of the term ‘dry clay flats’ to denote the habitat of this TEC can be confusing as in the eastern SCP setting, most clay or mud flats are actually wetlands, albeit with a shorter hydroperiod than sumplands in this setting.

Table 2.3: A broad comparison of local scale vegetation units and associated habitats recorded in the Greater Brixton Street Wetlands (1984-2009). [Note: each row in table compares similar vegetation units from similar habitats as recorded in disparate studies]

BFS 387 (Marshall, 2000; Government of Western Australia, 2000)	BFS 387 (VCSRG, 2001)	Lot 106 Wanaping Rd in BFS 387 (Keighery and Tauss, 2008)	Lots 28 and 32 Brook Rd in BFS 387 (Tauss, 2009)
Melaleuca lateritia shrubland - *Amphibromus nervosus* grassland (water filled depressions).	*M. lateritia - Meeboldina cana* (sumplands).	*M. rhaphiophylla* tall open shrubland over *M. lateritia* open heath (sumpland).	-
M. rhaphiophylla low woodland (water filled depressions).	*M. rhaphiophylla, M. viminea* (sumplands).	*M. rhaphiophylla - Viminaria juncea* open scrub over very open sedges (sumpland).	*M. rhaphiophylla* low open forest over open sedges (sumplands).
Eucalyptus rudis - M. rhaphiophylla open woodland to	-	-	-

BFS 387 (Marshall, 2000; Government of Western Australia, 2000)	BFS 387 (VCSRG, 2001)	Lot 106 Wanaping Rd in BFS 387 (Keighery and Tauss, 2008)	Lots 28 and 32 Brook Rd in BFS 387 (Tauss, 2009)
low open woodland (water filled depressions).			
Pericalymma open heath (water filled depressions)/*Pericalymma - Tremulina* scrub (seasonally waterlogged or inundated flats)/*Pericalymma* shrubs (dry or occasionally waterlogged flats).	*Pericalymma ellipticum, Tremulina tremula;* or *Viminaria juncea* (paluslopes, sandy palusplains, gradation between basin and paluslope).	*V. juncea t*all open shrubland over *P. ellipticum* var. *floridum* open heath over *T. tremula* rushes and sedges.	-
Halophytic complex of *Sarcocornia quinqueflora* and sedges (water filled depressions).	*Halosarcia* (transitional area between two vegetation units).	-	-
Chaetanthus flats (water filled depressions). Sedgelands (water filled depressions).	*Meeboldina cana* (muddy palusplains-transitional area between two vegetation units).	-	-
-	*M. uncinata* (partly = *M. osullivanii*) (channels).	-	-
Myrtaceae spp. mixed open heath. *Hypocalymma angustifolium* – Myrtaceae spp. open heath (seasonally waterlogged or inundated flats).	-	*M. lateriflora – M. brevifolia* open heath over *Chaetanthus aristatus - Gahnia trifida* sedgeland (palusplain).	*Actinostrobus - M. lateriflora- M. brevifolia scrub over C. aristatus –G. trifida* rushes (palusplain).
Viminaria juncea tall shrubland (seasonally waterlogged or inundated flats).	*Viminaria juncea* (wet mounds).	*V. juncea* tall open shrubs over *B. telmatiaea - Acacia lasiocarpa* closed heath (palusplain).	-
Actinostrobus scrub (seas. waterlogged or inundated flats)/Mixed scrub/Tall scrub (dry or occ. waterlogged flats)	-	*Actinostrobus - M. viminea - Hakea varia* closed tall scrub (palusplain).	*M. viminea – A. pyramidalis* scrub to heath (palusplain).
Myrtaceae spp. – Proteaceae spp. - *Actinostrobus* closed heath (seasonally waterlogged or inundated flats, dry or occasionally waterlogged flats).	*Banksia telmatiaea, A. pyramidalis* (mud flats).		*Actinostrobus - B. telmatiaea- M. seriata* dense heath over *C. aristatus* rushes, sedges and herbs (palusplain).
-	-	*Banksia telmatiaea* closed heath (sandy palusplain).	-
Acacia saligna tall shrubland (seasonally waterlogged or inundated flats).	-	*A. saligna - V. juncea - M. rhaphiophylla* scrub over very open sedges (palusplain).	-
Verticordia plumosa – V. spp. closed heath/Mixed low shrubland (dry/seasonally waterlogged/inundated flats).	*Acacia lasiocarpa, Calytrix breviseta* (sandy palusplains).	*Acacia lasiocarpa. - Verticordia acerosa* open heath over open herbs (palusplain).	-
-	-	*A. pyramidalis* tall open shrubs, *M. seriata - Stirlingia latifolia* heath (sand palusplain).	-
Eremaea low shrubland (upland).	*Eremaea pauciflora* (low sand ridges).	*E. pauciflora - Hibbertia hypericoides* low open shrubland (low dune).	-
Banksia woodland or low open woodland (upland).	*Banksia menziesii* (high sand ridges).	-	-
Corymbia calophylla woodlands (upland).	*Corymbia calophylla* woodland, dry sand.	-	*Corymbia calophylla* (low dune).

3. Methods

3.1 Guiding Principles

The survey and analysis methods adopted in the current MKSEA flora and vegetation survey, the wetlands survey and the assessment of the natural values in the MKSEA were based on:

- *The Western Australian Environmental Protection Authority's position paper with regard to terrestrial biological surveys as an element of biodiversity protection* (EPA, 2002);
- *The Western Australian Environmental Protection Authority's Guidance Statement No. 51 for terrestrial flora and vegetation surveys for environmental impact assessment* (EPA, 2004b);
- *The Department of Environment and Conservation protocol for proposing modifications to the Geomorphic Wetlands Swan Coastal Plain Dataset* (DEC, 2007);
- *The Western Australian Environmental Protection Authority's Guidance Statement No. 10 for the level of assessment for proposals affecting natural areas within the System 6 Region and Swan Coastal Plain portion of the System 1 Region* (EPA, 2006); and
- *The Western Australian Environmental Protection Authority's Guidance Statement No. 33 for planning and development* (EPA, 2008).

The MKSEA is located on the Eastern Swan Coastal Plain, in the Swan Coastal Plain Bioregion (IBRA, 2004) of the South West Botanical Province of Western Australia. Based on the existing regional modification and loss of biodiversity, degree of threat and high sensitivity of this bioregion to further loss, a Level 2 survey (including background research, reconnaissance survey and comprehensive survey) was required (EPA, 2004b). With regard to the current regional survey project, the three components of the Level 2 search were fulfilled as below.

1. **Background Research**. A literature review and a search of the rare flora, threatened ecological communities and wetland values were carried out including relevant Federal and Western Australian Government databases. Advice and information was also sought from a number of relevant experts and stakeholders in government, scientific institutions and the community regarding the known conservation values and other environmental issues applicable to the target area.

2. **Reconnaissance Survey**. A reconnaissance field survey was carried out in early spring 2007 to verify the accuracy of the background information and to obtain an overview of the range of flora, vegetation and wetland values in the area. Transects were walked through areas that were identified from aerial photographs as retaining natural vegetation. This allowed opportunistic sampling and recording of the flora and vegetation in the more degraded areas, targeted searches of habitat that could potentially harbour rare flora and the selection of suitable sites to install quadrats for detailed sampling.

3. **Comprehensive Field Survey**. The level of knowledge of the flora and vegetation of the target area was enhanced by a detailed quadrat-based flora and vegetation field survey.

The wetlands within the MKSEA that are mapped in the DEC Wetlands Database were ground-truthed and re-evaluated with regard to geomorphic classification and management category using the additional fine-scale data obtained during the flora and vegetation field survey and data collected by manual augering of the sediments in selected wetlands, the logging of the stratigraphy of these pits and the measurement of the depth to watertable(s) on the day of the augering.

3.2 Flora Sampling, Vegetation Description and Classification

The flora, vegetation and wetlands field survey was carried out from September 2007 to July 2009. Colour aerial photography, stereo pairs of contact prints and topographic maps were used to interpret the vegetation patterns of the survey area prior to the reconnaissance survey. These interpretations were then verified using ground traverses to record dominant species and vegetation structure and to search for flora of conservation significance. Quadrat sites were selected to be representative of the vegetation units as interpreted above. One or more quadrats or relevés were surveyed, where possible, in each vegetation type encountered in the project footprint.

A total of 32 study sites were surveyed in the study. They are listed in Tables 5.5 and 6.2.

Fourteen sampling quadrats (each of area 100 m^2) were established in species-rich native vegetation that was in good to very good condition. The quadrat size in this survey was determined by that used in the previous surveys that contributed to the SCP dataset of Gibson *et al.* (1994). The quadrats were marked with galvanised steel fence droppers, and all of the vascular plant taxa in these quadrats were recorded. Voucher specimens were collected, where necessary, and identified with reference to the Western Australian Herbarium collections. At each quadrat the following were also recorded: location (including GPS coordinates), landform, shallow stratigraphy (by manual augering), vegetation structure of the site's dominant vascular flora taxa (in terms of the life-form, height and canopy cover classes given in Table 3.1), presence and cover class of all vascular flora taxa in the quadrat (including naturalised alien taxa), assessment of vegetation condition (using the scale shown in Table 3.2, which is a slight modification of the Keighery (1994) scale used in the Bush Forever study (Government of Western Australia, 2000b), and estimated time since the last fire. Overstorey abundance was estimated over a larger area (approx. 400 m^2), which encompassed the marked quadrat in each case.

In addition to the 14 marked quadrats, a further 18 relevés (of varying size) were surveyed in vegetation that was less species-rich and in good to degraded condition. The relevé method was to compile a comprehensive inventory list of the vascular plant taxa in a particular vegetation unit during traverses through it.

In order to establish the Floristic Community Types of the vegetation of the MKSEA, a multivariate analysis of the floristic data obtained in the current survey was carried out against the SCP floristic dataset of Gibson *et al*. (1994). This provided an indication of the similarity of the community types within the MKSEA with previously defined Floristic Community Types (FCTs) in the context of the Swan Coastal Plain Bioregion. The classification assisted in the objective evaluation of the conservation significance of the vegetation assemblages found in the MKSEA.

The classification of the vegetation in the MKSEA footprint via multivariate analysis was also useful in verifying the patterns derived intuitively in the field in this complex and species-rich vegetation. The boundaries of the major vegetation units derived from the field observations and the detailed site data analysis were mapped onto colour aerial photography of the area at a scale of 1:2,000.

Table 3.1: Vegetation Structure Classification (adapted from Government of Western Australia, 2000)

Life Form and Height	Canopy Cover			
	Dense 70% - 100%	Mid Dense 30% - 70%	Open 10% - 30%	Sparse 2% - 10%
Trees 10-30 m Trees <10 m	Closed forest Low closed forest	Open forest Low open forest	Woodland Low woodland	Open woodland Low open woodland
Mallee [1]	Closed mallee	Mallee	Open mallee	Very open mallee
Shrubs >2 m Shrubs <2 m	Closed scrub Closed heath	Scrub Heath	Open scrub Open heath	Tall open shrubs Low open shrubs
Grasses, Herbs Rushes or Sedges	Closed grasses, herbs, rushes or sedges	Grasses, herbs, rushes or sedges	Open grasses, herbs, rushes or sedges	Sparse grasses, herbs, rushes or sedges

[1] The mallee life-form is used for eucalypts that are multi-stemmed at ground level and usually less than 10 m in height.

Table 3.2: Bush and Wetland Vegetation Condition (adapted from Government of Western Australia, 2000)

Code	Condition	Description of Vegetation
P	Pristine	No obvious signs of disturbance.
E	Excellent	Vegetation structure characteristic of the vegetation type remains intact, disturbance affects individual species only, and weeds are non-aggressive species.
VG	Very good	Vegetation structure altered somewhat; obvious signs of disturbance, but recovering. Some highly invasive weeds may be present at low abundance.
G	Good	Vegetation structure modified significantly (and/or floristic composition somewhat altered) by very obvious multiple disturbances but ability to regenerate is retained (by, e.g. recruitment of native species from abundant soil seed bank).
D	Degraded	Vegetation structure and floristic composition severely impacted by disturbance; scope for regeneration but not to a state approaching good (sic) condition without intensive management
CD	Completely degraded	Vegetation structure no longer intact; the area almost completely without native species, e.g. isolated native trees or shrubs over pasture ('parkland cleared').
TC	Totally cleared	No native vegetation remaining on site.

3.3 Wetland Assessment

The term 'wetland' is defined under the Western Australian Environmental Protection Act, 1986 as 'an area of seasonally, intermittently or permanently waterlogged or inundated land, whether natural or otherwise, and includes a lake, swamp, marsh, spring, dampland, tidal flat or estuary'.

Wetlands of the Swan Coastal Plain, from Wedge Island in the north to Dunsborough in the south, have been comprehensively surveyed at a broad scale in Hill *et al.* (1996). In this survey work (covering approximately 362,000 ha of wetlands) the wetlands were classified according to the geomorphic wetlands classification system of Semeniuk (1987) and Semeniuk and Semeniuk (1995), mapped and evaluated for management category. This survey forms the basis of the current Department of Environment and Conservation Swan Coastal Plain Wetlands Datasets and Atlas (DEC, 2008a, 2008b, 2008c). In this electronic dataset, each wetland has been:

- classified and allocated to a Consanguineous Suite (after Semeniuk, 1987);
- given a unique number that is known as a Unique Function Identifier (UFI); and
- allocated to a management category *viz*. Conservation Category Wetland (CCW), Resource Enhancement Wetland (REW) or Multiple Use Wetland (MUW). These management categories are defined in the evaluation section (3.3.3) below.

The Swan Coastal Plain Wetlands Dataset is recognised and endorsed as a guide to planning and decision making by all relevant agencies in Western Australia, including representatives of the Western Australian Department of Environment and Conservation, Western Australian Department of Planning and Infrastructure, Western Australian Department of Agriculture and Food, local government and community conservation groups.

The SCP Wetlands Dataset is maintained and updated, when required, by the Western Australian Department of Environment and Conservation. These updates are only carried out after rigorous assessments based on well-documented, scientific evidence and are usually related to the scale of the mapping and the provision of additional biological data (DEC, 2007). The wetland mapping carried out by Hill *et al* (1996), and other data contributing to the SCP Wetlands Dataset, was at a scale of about 1:25,000. In this mapping, small elevation differences were beyond the scale of the mapping but may contribute to the reclassification of wetlands (or parts of wetlands) as reliable data become available at finer scales. There are also sometimes small discrepancies between the broad scale at which the dataset was originally captured and the finer scales at which this dataset can now be viewed. Biological data are often valuable in recognising additional conservation values in the wetlands mapped in the SCP Wetlands Dataset.

DEC (2007) outlines some of the information required to assess requests to modify the dataset. Essentially the collection of such information requires wetland identification, wetland delineation, wetland classification

and wetland evaluation. These processes and how they were applied in the current study of the MKSEA are described below. It is important to note that wetlands are complicated ecosystems and that they are subject to change due to climatic fluctuation and anthropogenic disturbances. The collection of data, at appropriate scales, may require extended periods of field- and laboratory-based research in both biological and earth sciences. This applies particularly to areas of complex stratigraphy and hydrology such as the eastern Swan Coastal Plain, where a broad overview of the biodiversity has only recently been defined (Government of Western Australia, 2000) and wetland types and ecological processes are poorly known.

The wetland study conducted in the MKSEA in the current survey was, of necessity, a limited and preliminary approach intended mainly to assess the conservation values of the wetlands within the proposed industrial footprint, given the additional detailed biological data that were obtained in the current flora and vegetation survey. The MKSEA wetlands assessment was intended to detect any additional and important values that were not recorded in the broadscale survey of Hill *et al.* (1996) that would require special protection in the planning process rather than as a formal proposal to amend the DEC Swan Coastal Plain Wetlands Dataset (DEC, 2008a).

As the alluvial fan wetlands in the MKSEA are complex environments, it is anticipated that additional information would be required, above the data provided in the current report, for any formal proposals to DEC to amend the Swan Coastal Plain Wetlands Dataset.

3.3.1 Wetland Identification and Delineation

Identification and delineation of a wetland relies on evidence from hydrology, soils and vegetation (Hill *et al*. 1996; Tiner, 1999). An introductory guide to some basic requirements in the identification and delineation of wetlands is provided in DEC (2007).

Because hydrological systems maintaining a wetland are dynamic, hydrological variables at any one site – such as soil moisture, depth to water table and depth of standing surface water – may vary considerably over time due to such factors as climatic fluctuations, variations in vegetation cover and human use of both the wetland and its catchment area. Thus, a single groundwater or surface water measurement in one part of a wetland is seldom sufficient to characterise the hydrology of a wetland. A detailed survey of the wetland topography is also usually needed to accurately assess its hydrology.

The soils that are formed in wetlands due to prevailing inundation or waterlogging (e.g. peat, peaty or humic sands and some types of carbonate mud), the biochemical evidence of waterlogging or inundation (such as mottling of sediments) and the biogenesis associated with wetland conditions (such as algal or invertebrate remains) provide evidence of the presence of wetland conditions. Semeniuk and Semeniuk (2004) provide a detailed description and discussion of the hydric soils of the SCP. Soil data are very reliable and valuable sources of information as hydric soils persist even when wetlands have been cleared of their original vegetation. Soil data can also provide indications of past hydrological conditions in a wetland.

The inundated and/or waterlogged (anoxic) conditions in wetlands and the characteristics of the hydric soils of wetlands provide specific habitats for plants. The presence of obligate wetland plant species (Tiner, 1999) that have structural and functional anatomical adaptations to wetland conditions (such as well-developed aerenchyma tissue; Pate and Delfs, 1999) is a reliable, mid-to-long term indicator of wetland conditions. There are also many facultative wetland plant species (those plants that can occur in both wetland and upland habitats) that are commonly associated with damplands, palusplains and the wetland zones around the periphery of lakes and sumplands on the SCP.

A limited field survey of the hydrology and shallow stratigraphy of the wetlands in the MKSEA was undertaken using manual augering in spring 2007 (in addition to detailed flora and vegetation survey) to identify wetlands (i.e. to distinguish between putative wetland and upland zones) and to delineate wetlands in the study area, in accordance with the guidelines of DEC (2007). Sixteen study sites were selected to sample the hydrology and stratigraphy of the survey area.

To determine the depth to the water table and the stratigraphic sequence at each of these 16 study sites, holes were augered manually down to the water table (where possible). In some sites, the low moisture levels of shallow materials such as laterite or mud prevented augering down to the water table. Surface sediments and the presence of waterlogging or inundation of surface sediments were recorded opportunistically elsewhere throughout the survey area. The observations of the surface perching of rainwater (early in the wet season) in areas where shallow, relatively impermeable layers were encountered later during the augering were valuable.

Due to the time constraints of the survey it was not practical to install piezometers at the study sites to monitor watertable change over time. Thus the depth to the watertable was measured only once (immediately after augering) in the holes where the watertable was reached. This method, when augering in sediments that have low hydraulic conductivity, sometimes does not allow enough time for the groundwater level to rise to its full equilibrium height before measurement. Thus all of the 'one-off' watertable levels recorded in this study in situations where there were peaty or muddy sediments should be viewed as being an underestimate of the true height of the water table at each location on the date of measurement.

The sediments from the auger holes were sampled at 10 cm intervals, labelled and then examined via a low power stereoscopic microscope to assess grain size and sediment fabric. The presence of calcareous materials in the samples was determined after application of several drops of 10% hydrochloric acid to each sample. The sediments obtained from the augered holes were classified and described using terms consistent with Semeniuk and Semeniuk (2004) (Tables 3.3 and 3.4).

Table 3.3: Wetland Sediment Classification (adapted from Semeniuk and Semeniuk, 2004)

Descriptor	Diameter of Grains
gravel	>2 mm
coarse to very coarse sand	0.5-2 mm
fine to medium sand	0.125-0.5 mm
very fine sand	0.063-0.125 mm
mud or peat	<0.063 mm

Table 3.4: Wetland Sediment Definitions (adapted from Semeniuk and Semeniuk, 1995)

Sediment	Definition
sand	Sand grain supported sediment with minor or no interstitial mud
humic sand	Sand grains coated with a thin layer of fine organic particles
muddy sand or peaty sand	Sand grain supported sediment with interstitial mud, or peat
sandy mud or sandy peat	Mud (or peat) supported sediment with floating sand grains
mud (or peat)	Mud (or peat) dominant (i.e. <10% sand)

The habitat preferences of each of the native flora species recorded at each of the hydrology/stratigraphy study sites, and at each flora quadrat, in the survey area were investigated by checking the habitat notes of all occurrences of these species (across the known geographical range for each of these species) in Paczkowska and Chapman (2000), in Keighery and Keighery (2000) and in Marchant *et al.* (1987) and as recorded on herbarium voucher labels in FloraBase (Western Australian Herbarium, 2008), as required. A list of the obligate wetland flora species (those plants generally restricted to wetland habitats) and the facultative wetland flora species (those plants that can occur in either wetland or upland habitats) that were present within the survey area was then assembled on the basis of these desk-top investigations and the personal experience of the authors (Appendix D).

3.3.2 Geomorphic Classification of Wetlands

The geomorphic classification of wetlands in the MKSEA as detailed in the DEC Wetlands Dataset was examined using the water level data obtained in the current study and observations of landforms present. The wetlands were classified according to the system of Semeniuk (1987), which is applicable to the Darling System of Western Australia, and of Semeniuk and Semeniuk (1995), which is applicable globally (Table 3.5). The following wetland types have been documented in the Kenwick area: creeks, sumplands, damplands, palusplains, floodplains and paluslopes (V & C Semeniuk Research Group, 2000; DEC, 2008b,

2008c). Due to the time constraints of the survey, the wetlands in the current study area were not topographically surveyed to accurately determine the landforms present. Also, the hydroperiod assessment of the wetlands was based on a single water table measurement taken in spring 2007 (at the time of augering) and usually from only one hole per wetland. Observations of surface water in the wetlands, however, spanned the period September 2007 to December 2008.

Table 3.5: Geomorphic Classification of Wetlands (adapted from Semeniuk and Semeniuk, 1995)

	Channel	Basin	Flat	Slope	Hill
Permanent inundation	river	lake	-	-	-
Seasonal inundation	creek	sumpland	floodplain	-	-
Seasonal waterlogging	trough	dampland	palusplain	paluslope	palusmont
Intermittent inundation	wadi	playa	balkarra	-	-

3.3.3 The Evaluation of Wetland Management Categories

The **Conservation Category** indicates that the wetland should be managed for conservation to protect its high value attributes and functions. Alteration to wetlands in this category is strongly discouraged by State and Federal environmental regulatory agencies. These wetlands are usually recommended for reservation into various classes of conservation reserve to protect them from any human-induced deterioration.

The **Resource Enhancement Category** indicates that the priority management objective for the wetland should be to maintain the wetland's natural attributes and functions and, wherever possible, to enhance the ecological status of the wetland by such activities as improving water quality or revegetating cleared areas with endemic, site-appropriate species.

The **Multiple Use Category** indicates that the priority management objective for the wetland should be to maintain multiple uses of the wetland, including its ecological functions. This necessitates maintaining the geomorphic integrity of the wetland. It excludes destruction of the wetland through processes such as infilling, excavation, mining or emplacing urban structures such as roads or buildings.

The methods for evaluating wetlands on the Swan Coastal Plain are currently under revision. In the interim, three methods are recommended by DEC (2007) to evaluate the management category of wetlands.

The first of the methods recommended to evaluate the management category of wetlands is a questionnaire, commonly referred to as Bulletin 686 (EPA, 1993), that was designed before the SCP wetlands were comprehensively mapped by Hill *et al.* (1996). The acknowledged drawback of this questionnaire is that it tends to allot the highest scores to wetlands with standing water (such as lakes and sumplands) and those wetlands that include optimum waterbird habitats (such as open water, dense vegetation, roosting trees and mud flats adjacent to open water). Bulletin 686 does not adequately score wetland condition, floristic complexity, the presence of habitat of less conspicuous fauna and the functions and values of wetlands such as damplands and palusplains (DEC, 2007). The exceptional biodiversity, scarcity and conservation values of some of the these wetland types on the SCP have only recently become apparent, through initiatives such as Hill *et al.* (1996) and Bush Forever (Government of Western Australia, 2000). Methods of wetland evaluation other than, or supplementary to, EPA (1993) are required to assist in the adequate evaluation of all types of wetlands on the SCP.

The second method for wetland management category evaluation that is currently recognised by DEC (2007) is a questionnaire that was designed for the Western Australian Water and Rivers Commission (VCSRG, 1998). This method enables wetland attributes to be assessed from first principles, irrespective of wetland type.

The third method for wetland management category evaluation involves wetland vegetation condition. The vegetation condition scale of Government of Western Australia (2000) and guidelines regarding wetland vegetation in Hill *et al.* (1996) are recommended for use in this evaluation (DEC, 2007).

All three methods were used to evaluate the management categories of the wetlands in the current survey. The features of each of these methods are summarised below.

3.3.3.1 V & C Semeniuk Research Group (1998) method of wetland evaluation

The Water and Rivers Commission instrument designed by VCSRG (1998) supplements Hill *et al.* (1996) and takes into account all types of wetlands (including palusplains) that have been mapped within the Southern Swan Coastal Plain. This system recognises that evaluation demands an approach to capture the recognised natural values of all wetland types.

In this evaluation system, six classes of wetland values (wetland type, wetland processes, wetland habitats, wetland functions, biodiversity and scientific value) are examined and scored for the wetland in question (Table 3.6). Essentially, each of these values is graded as high, moderate or low for the wetland being evaluated; then this is translated to the management categories of CCW, REW or MUW, respectively. The six wetland values are first checked against the criteria that are appropriate at the level of CCW (Table 3.7). If the wetland does not meet the CCW criteria for at least one question in any of the six values, the wetland is then checked for these values again at the level of REW (Table 3.8). Then, if necessary, any values that do not meet the REW criteria are checked against the criteria at the level of MUW (Table 3.9). The wetland is then allocated to a management category (CCW, REW or REW) according to the score achieved (Table 3.6).

Table 3.6: A Score Sheet for Wetland Evaluation (after VCSRG, 1998)

Wetland values	Criteria met at the level of CCW	Criteria met at the level of REW	Criteria met at the level of MUW
Wetland type	Yes/No	Yes/No	Yes/No
Wetland processes	Yes/No	Yes/No	Yes/No
Wetland habitats	Yes/No	Yes/No	Yes/No
Wetland functions	Yes/No	Yes/No	Yes/No
Biodiversity of wetland	Yes/No	Yes/No	Yes/No
Scientific value of wetland	Yes/No	n/a	n/a
Total Score	Best score = 6/6	Best score = 5/6	Best score = 5/6

Table 3.7: Conservation Category Wetlands Criteria (VCSRG, 1998)

Wetland type: *A wetland may be classed as* **Conservation** *if it satisfies one or more of the following criteria*
1. It is an anthropogenically unaltered wetland type (i.e. river, creek, paluslope, palusplain, floodplain, lake, sumpland, dampland)
2. It is a scarce wetland type
3. It is a representative wetland type (i.e. representative of its consanguineous suite)

Wetland processes: *A wetland may be classed as* **Conservation** *if it satisfies one or more of the following criteria*
1. The wetland is subject to anthropogenically unaltered wetland processes (i.e. recharge and discharge mechanisms, hydroperiod, sedimentary processes)
2. The wetland exhibits unusual wetland processes
3. The wetland exhibits representative wetland processes (i.e. representative of its consanguineous suite and geomorphic setting)

Wetland habitats: *A wetland may be classed as* **Conservation** *if it satisfies one or more of the following criteria*
1. The wetland is a habitat for rare and endangered fauna
2. The wetland is a habitat for rare and endangered flora
3. The wetland exhibits a high diversity of habitats

Wetland functions: *A wetland may be classed as* **Conservation** *if it satisfies one or more of the following criteria*
1. The wetland is necessary for maintenance of large faunal populations
2. The wetland is a refuge for resident fauna
3. The wetland is an important breeding, feeding or watering site for migratory populations (local and international)
4. The wetland is a significant regional component of the hydrological cycle (has an important hydrological storage, recharge or discharge function; or an hydrochemical function)

Wetland Biodiversity: *A wetland may be classed as* **Conservation** *if it satisfies one or more of the following criteria*
1. The wetland exhibits unaltered wetland vegetation and fauna
2. The wetland has a scarce vegetation association or faunal association
3. The wetland has a highly diverse wetland flora or fauna

Wetland Scientific value: *A wetland may be classed as* **Conservation** *if it satisfies one or more of the following criteria*
1. The wetland contains scientifically significant pollen records
2. The wetland is underlain by unusual wetland sediments (indicators of wetland history)
3. The wetland has unusual geomorphology (i.e. it is situated in an unusual geomorphic setting or contains unusual geomorphic features within it)

Table 3.8: Resource Enhancement Category Wetlands Criteria (VCSRG, 1998)

Wetland type: *A wetland may be classed as* **Resource Enhancement** *if it satisfies the following criterion*
It is an anthropogenically altered wetland type (i.e. river, creek, paluslope, palusplain, floodplain, lake, sumpland, dampland) but retains its natural geomorphology and natural, if modified, hydrological mechanisms

Wetland processes: *A wetland may be classed as* **Resource Enhancement** *if it satisfies the following criterion*
The wetland is subject to anthropogenically altered wetland processes (i.e. recharge and discharge mechanisms, hydroperiod, sedimentary processes) but not to the degree that habitats cannot still be identified and rehabilitated

Wetland habitats: *A wetland may be classed as* **Resource Enhancement** *if it satisfies the following criterion*
The wetland habitats are disturbed but the wetland is a habitat for rare and endangered fauna or flora, or the wetland exhibits a high diversity of habitats and for these reasons should be rehabilitated (i.e. water quality addressed, water levels naturalised, revegetation of communities undertaken, and re-establishment of ecological links with surrounding areas via corridors and/or buffer zones)

Wetland functions: *A wetland may be classed as* **Resource Enhancement** *if it satisfies one or more of the following criteria*
1. The wetland is necessary for maintenance of specific faunal populations
2. The wetland is a breeding, feeding or watering site for migratory faunal populations (local)
3. The wetland is a fauna refuge but is degraded and requires revegetation or improvement of water quality
4. The wetland is a significant local component of the hydrological cycle (has an hydrological storage, recharge or discharge function; or an hydrochemical function)
5. The wetland is a regionally important hydrological or ecological link in a system
6. Portion of extended wetlands is vegetated and therefore functions as an ecological corridor

Wetland Biodiversity: *A wetland may be classed as* **Resource Enhancement** *if it satisfies the following criterion*
The wetland exhibits some unaltered wetland vegetation and fauna which may be extended through revegetation programs

Table 3.9: Multiple Use Category Wetlands Criteria (VCSRG, 1998)

Wetland type: *A wetland may be classed as* **Multiple Use** *if it satisfies the following criterion*
It is an anthropogenically altered wetland type and retains its natural geomorphology but has highly modified, hydrological mechanisms

Wetland processes: *A wetland may be classed as* **Multiple Use** *if it satisfies the following criterion*
The wetland is subject to anthropogenically altered wetland processes (i.e. recharge and discharge mechanisms, hydroperiod, sedimentary processes) to the degree that habitats can no longer be identified and rehabilitated

Wetland habitats: *A wetland may be classed as* **Multiple Use** *if it satisfies the following criterion*
The wetland habitats are disturbed such that revegetation is possible but not rehabilitation (i.e. sediments, water quality and water levels, are altered so that re-establishment of original flora and fauna communities is not possible)

Wetland functions: *A wetland may be classed as* **Multiple Use** *if it satisfies one or more of the following criteria*
1. The wetland is necessary for maintenance of low numbers of faunal populations
2. The wetland is a feeding or watering site for local migratory faunal populations (usually in association with a number of other wetlands as no single wetland is sufficient to maintain species)
3. The wetland is a component of the hydrological cycle and therefore to catchment management (has an hydrological storage, recharge or discharge function; or an hydrochemical function, albeit a minor function)

Biodiversity: *A wetland may be classed as* **Multiple Use** *if it satisfies the following criterion*
The wetland has minor biodiversity, but does have ecosystem diversity and landscape diversity

3.3.3.2 Bulletin 686 (EPA, 1993) method of wetland evaluation

Bulletin 686 EPA (1993) was designed to allocate wetlands to five categories: High Conservation, Conservation, Conservation and Recreation, Resource Enhancement and Multiple Use, according to the graphs in the bulletin. These management categories were updated in Hill *et al.* (1996) (Table 3.10) to the system now recognised on the SCP (DEC, 2007; EPA, 2008).

Table 3.10: Management categories of wetlands from EPA Bulletin 686 as updated in Hill *et al.* (1996)

Management category	General description	Management objective
H – High Conservation (incorporates EPA Bulletin 686 categories H and C)	Wetlands which support a high level of attributes and functions.	To preserve wetland attributes and functions through reservation in national parks, crown reserves and state owned land and protection under Environmental Protection Policies.
R – Resource Enhancement (incorporates EPA Bulletin 686 categories O and R)	Wetlands which may have been partly modified but still support substantial attributes and functions.	To restore wetlands through maintenance and enhancement of wetland attributes and functions by protection in crown reserves and state or local government owned land and by Environmental Protection Policies or in private property by sustainable management.
M – Multiple Use (aligned with EPA Bulletin 686 category M)	Wetlands with few attributes which still provide important wetland functions.	Use, development and management should be considered in the context of water, town (land use) and environmental planning through land care.

In EPA Bulletin 686, wetland basins are evaluated as isolated units (either with well-defined boundaries or with diffuse boundaries). It is well-acknowledged that palusplains and damplands are not adequately evaluated by the use of Bulletin 686 (DEC, 2007) and that other methods, such as VSCRG (1998) and vegetation condition assessment, are more relevant to the assessment of these wetlands.

Bulletin 686 consists of a questionnaire that includes several parts, as briefly listed below (Table 3.11).

Table 3.11: Bulletin 686 Questionnaire for Wetland Management Category Evaluation

Part I: Presence of Rare Species
If the wetland includes gazetted rare flora or fauna species then the wetland is automatically allocated to CCW.

Part II Natural Attributes

Part IIA: For permanent and seasonal wetlands with well defined boundaries

i. Environmental geology classification: wetlands in the Quindalup Dunes or in river/estuary floodplain receive the highest score.

ii. Adjacent wetlands. Wetlands that have no other wetlands within a 2 km radius of them receive the highest score.

iii. Habitat diversity. If the composition and structure of the vegetation of the wetland under evaluation is significantly different to that found at other nearby wetlands, the wetland receives the highest score.

iv. Drought refuge. Wetlands that are major drought refuges for birds receive the highest score.

v. Area of wetland. Wetlands greater the 100 ha in area receive the highest score.

vi. Habitat type. Habitat types scored in this question include vegetation and landforms typical of lakes and sumplands such as fringing rushes and sedges, extensive in lake beds of rushes and sedges, large paperbark trees, islands, flooded grassland, permanent or seasonal open water, low thickets and samphires. Waterlogged areas are not considered in the scoring.

vii. Emergent vegetation. Wetlands with a moderate cover (40-60%) of emergent vegetation receive the highest score compared to very high or very low cover of vegetation as both open water and vegetation are considered desirable for waterbirds.

viii. Adverse water quality. Oil slicks, algal blooms or botulism that have been observed or reported from the wetland in the last two years lower the score received by the wetland.

ix. Drainage. This deals with drains into and/or out of the wetland that can alter water levels or water quality. Wetlands with fewer drains entering the wetland receive the highest score as this lowers the chances of nutrient enrichment and artificial elevation of water levels. Wetlands with outlet drains constructed to maintain water levels receive the highest score, whilst outlet drains constructed to dry out the wetland receive the lowest score.

x. Adjacent nutrient scores. Wetlands with more than one nutrient source lower the score received by the wetland.

xi. Area of wetland modified. Wetlands with 0-10% of area modified receive the highest score.

xii. Reserve Area. The ratio of the area of wetland to the area of reserve around the wetland is considered in this question. The lowest wetland to reserve ratio (<0.1) receives the highest score.

xiii. Native vegetation buffer. Wetlands with 90-100% of the wetland perimeter of at least 50 m of buffer vegetation receive the highest score.

Part IIB: For seasonal and episodic wetlands with poorly defined boundaries.
Note: each zone of the wetland is usually scored as a separate assessment.
The questions above for environmental geology classification, adjacent wetlands, habitat diversity, habitat type, drainage, area of wetland modified are scored as above. Wetland size is also considered, and wetlands >100 ha in area receive the highest score in the latter question.

Part III: Human Use Questionnaire
Wetlands that have attributes such as aesthetic values, historical and archaeological features, reserve status and community group involvement and uses such as passive and active recreation, agriculture, mining or water supply receive the highest scores.

Part IV: Supplementary Questions
These questions concern the occurrence of rare, but ungazetted, flora and fauna species, the effect of wetlands on nearby land values, the frequency of human use of wetlands and the importance of the wetland to the owner. This section is usually only evaluated if the management category obtained by the uses of Parts I, II and III falls in one of the transitional zones between categories on the EPA (1993) graph.

In Bulletin 686, wetlands that have gazetted rare species are automatically allocated to the High Conservation Category (=CCW in the wetland management categories currently in use by the EPA, 2008). If a wetland includes gazetted rare species, it is recommended that the questions in Part I and Part II of the questionnaire should still be answered to provide additional management information. However, the scores arrived at in Parts II and III of the Bulletin 686 questionnaire for a wetland that includes rare species do not alter the allocation of the CCW category to such wetlands.

If the wetland undergoing the evaluation does not include gazetted rare species, two graphs are provided at the end of the Bulletin 686 questionnaire to determine management category. These graphs display the total Part II scores received by the wetlands that were evaluated in the process of designing this evaluation instrument versus their total Part III scores. The first graph applies to 'permanent and seasonal wetlands with well defined boundaries'. The second graph applies to 'seasonal and episodic wetlands with poorly defined boundaries'. The two dimensional space in both of the graphs provided in Bulletin 686 is divided up in both graphs into five areas. Each of these areas delineates one of the five wetland management categories recognised by the EPA in 1993.

The appropriate graph from Bulletin 686 is used to plot Part I scores versus Part II scores for each wetland that is evaluated by this method to arrive at a final management category for the wetland.

3.3.3.3 Vegetation condition in the evaluation of wetland management category

The extent and condition of remnant native vegetation in a wetland is a good guide to which management category is appropriate for the wetland (Hill *et al.* 1996; EPA, 2008). In the survey of the MKSEA, the evaluation of wetland vegetation condition is of particular relevance due to the very high conservation significance of any remnant vegetation of the Guildford Vegetation Complex.

For extensive wetlands over 70 ha in area (usually palusplains and damplands on the eastern SCP) all areas with remnant vegetation were assigned to the management category of Conservation Category Wetland (EPA, 2008) in recognition of the widespread clearing that has occurred in the past in this type of wetland. The assessment by Hill *et al.* (1996) of what constituted wetland vegetation for extensive wetlands over 70 ha in area differed from the bushland condition scale used in Government of Western Australia (2000). The definition of remnant vegetation for this process in Hill *et al.* (1996) includes:

- Complete native vegetation cover;
- Partial disturbance of either canopy or understorey; or
- Canopy (tree or shrub) cover with understorey removed.

For lakes, sumplands and damplands under 70 ha in area, an assessment was made as to the 'naturalness' of the wetland (EPA, 2008), i.e. the percentage of vegetation that remains undisturbed in a wetland. This measure provided a second tier assessment method of determining the management category for a wetland (Table 3.12).

Table 3.12: Vegetation status assessment in the evaluation of the management category of wetlands (adapted from Hill *et al.* 1996, Table 3)

Management Category	General Description	Vegetation Status Assessment
C – Conservation	Wetlands which support a high level of attributes and functions.	>50% vegetation undisturbed
R – Resource Enhancement	Wetlands which may have been partly modified but still support substantial attributes and functions.	10-50% vegetation undisturbed
M – Multiple Use	Wetlands with few attributes which still provide important wetland functions.	<10% vegetation undisturbed

The pattern of vegetation distribution that is present in many palusplains on the SCP presents some specific difficulties in wetland management category evaluation and in wetland management. Palusplains are laterally extensive, and on the SCP they are largely cleared of native vegetation and often accommodate a plethora of poorly-planned and poorly-managed land uses. The MKSEA is not an exception in being a patchwork of small native vegetation remnants, paddocks, vacant derelict dwellings, dams and drains, areas of dumped fill, roads, houses, factories, poultry sheds, truck yards, mechanical workshops, warehouses, quarries and private refuse dumps. If the vegetation of a 'patchwork' palusplain is evaluated over its entire area, the vegetation condition is, effectively, averaged over the large area involved. This method of evaluation would be likely to result in a MUW or REW category, regardless of the high conservation significance of remnants of vegetation that may be present. The alternative method of evaluation, which is more commonly used, is to evaluate parts of an extensive palusplain as several, separate entities (after defining the boundaries that are to be used in the assessment). In this case, the evaluation is likely to result in a MUW or REW category for the unvegetated units and CCW for the small vegetated units.

Although the process of splitting an extensive wetland into several management units may be the most objective way of recognising small areas of high conservation value vegetation, it serves to reinforce the fragmentation of ecological units that are already critically small. Such splitting up of a palusplain into several management units does little to recognise that ecological functions and processes, such as groundwater flow, unify parts of a palusplain into a single unit and help to maintain areas of valuable vegetation. It also prompts the further loss of scarce palusplain habitat on the SCP. Palusplains that are classed as 'degraded' or 'completely degraded' in terms of native vegetation often retain their geomorphic integrity, soils or other attributes. Some can be restored and replanted, and can also be recolonised by native flora and fauna from adjacent native vegetation. If managed appropriately, such areas can provide additional habitat suitable for the reintroduction of flora that is currently threatened because its former range has contracted to a small fraction of its previous size due to development.

The approach taken in the current evaluations of wetlands in the MKSEA was to initially split extensive areas of palusplain/floodplain into separate units based on vegetation condition. The wetland management categories of these wetlands were then evaluated separately via two questionnaire methods (VCSRG, 1998 and EPA, 1993) and according to vegetation condition. Subsequently, the opportunities for maintenance and enhancement of conservation values and ecological functions were considered in the discussion of linkage of areas with high conservation values via buffer zones and ecological corridors.

3.4 Survey Limitations

EPA Guidance Statement for Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia (EPA, 2004b) identify the main factors that can limit and constrain such surveys. The current project was evaluated against these factors (Table 3.4) and several significant limitations were found to be present. These constraints are addressed below.

1. Completeness and intensity of the survey

An appropriate level of survey was used for the high conservation value flora and vegetation of the area in accordance with EPA recommendations. The only aspect of this survey that was not completed was the investigation of several blocks that clearly had remnant vegetation but to which landowners withdrew or did not grant access (see below).

Some investigations into the stratigraphy and hydrology of a sample of sites were made during the current field survey and hydrological features of high conservation significance were found that were not known previously in the MKSEA or in the Greater Brixton Street Wetlands. However, the current survey of the MKSEA was primarily a biological survey, not a detailed hydrological study. The intensity of the hydrological study was below that required to characterise the essential features of the hydrological cycle in the MKSEA and the hydrological interactions between the MKSEA and the Greater Brixton Street Wetlands. The hydrogeology of the Greater Brixton Street Wetlands is relatively well-known thanks to a detailed, fine-scale hydrological field study by the V & C Semeniuk Research Group (2001). The results of this study and the ongoing monitoring of the bores after 2001 by the V &

C Semeniuk Research Group provide a large baseline database, which will provide a rigorous context for monitoring the effects of proposed development in the MKSEA on the Greater Brixton Street Wetlands. A study of the same intensity is required to characterise (in detail) the hydrogeology of MKSEA, to determine baseline data and to quantify the variables in the hydrological cycle that will be, potentially, affected by development. Some of the issues that require specific investigation include:

- The dewatering of native vegetation by the existing drainage schemes and issues that are related to this, such as salinity, acid sulphate soils and the surface and groundwater requirements of various flora species and ecosystems in the area;
- The formulation of specific guidelines for the management of Yule Brook as a living stream rather than a drainage conduit that effectively wastes the water that is needed to maintain the wetland ecosystems of the area;
- Investigation of nutrient enrichment and other contamination of the ground and surface waters in the area due to current land uses;
- A full survey to determine the location of artesian springs in the area and the identification of the management issues associated with the springs that are found (including the effect of dam excavation on these springs); and
- The identification of catchment areas and catchment management issues for the MKSEA and the Greater Brixton Street Wetlands (including an investigation of the hydrological relationship between the dunes in the southeast of the MKSEA and the wetlands of the area).

Such studies will require more than one year to adequately capture seasonal variations. There is thus a significant shortfall in the data available to design the measures required to ensure that the management of the total water cycle for the MKSEA is compatible with the maintenance and enhancement of the conservation values of the area.

A number of recommendations for changes to the management categories of wetlands within the MKSEA were made in this report. Due to the number of changes recommended, the full documentation that the current protocol for proposing such changes (DEC, 2007) requires is beyond the scope of this survey. Some further survey of these wetlands is needed to complete the data collection to support these recommendations.

2. Remoteness and/or access problems

Access to a number of the private lands in the MKSEA was not granted for the purposes of this survey. This was a significant limitation as some of the lands where access was denied were known from the Cardno BSD (2005) reconnaissance survey to include vegetation in very good condition, EPBC-listed and DRF flora, and other high conservation values. Because botanical survey is usually a prerequisite in the process of obtaining permits and exemptions for the clearing of native vegetation and for developing land, the lands where access was not granted will still be required to be surveyed at some stage during the MKSEA planning process.

3. Disturbances that affected the results of the survey

At least five blocks of land within the MKSEA or in BFS 387 that had high conservation value flora and vegetation were either burnt, cleared of native vegetation or had livestock grazing on them during the current survey or in the year before it. One of these blocks was known, from the Cardno BSD (2005) reconnaissance survey, to have an EPBC-listed flora species and vegetation in very good condition. Part of BFS 387, which is known to include listed high conservation significance values (Government of Western Australia, 2000), was being grazed by horses at the time of the current survey and had temporary fencing set up by the landowners to facilitate this.

The disturbance of areas of native vegetation and the taking of DRF or EPBC-listed flora without a permit via activities such as the above is subject to very high penalties under Western Australian and Federal legislation. Also, under the changes to the Western Australian Environmental Protection Act 1986 regarding the protection of native vegetation (that came into effect in 2004), it is illegal to clear any native vegetation in Western Australia without a permit or an exemption. Under these changes to

the Act, 'clearing' is defined as any act that substantially damages native vegetation ('(a) the killing or destruction of; (b) the removal of; (c) the severing or ring-barking of trunks or stems of; or (d) the doing of any other substantial damage to, some or all of the native vegetation in an area, and includes the draining or flooding of land, the burning of vegetation, the grazing of stock, or any other act or activity, that causes – (e) the killing or destruction of; (f) the severing of trunks or stems of; or (g) any other substantial damage to, some or all of the native vegetation in an area; and includes ringbarking, draining or flooding of land, burning and grazing of stock').

These disturbances did not greatly affect the survey results. The good regrowth of native vegetation in the burnt sites enabled an adequate assessment to be made; it was possible to identify most plants.

4. Availability of contextual information for the survey data

The Swan Coastal Plain (SCP) is a bioregion that has undergone great climatic and edaphic change in the past and is renowned for the species-richness of its flora and the complexity of its native vegetation. However, the description of the native vegetation and the processes used to analyse the conservation significance of native vegetation on the SCP are complicated by many factors. These factors include the range of methods that have been used in the literature to classify the vegetation (structural vs. floristic; qualitative vs. numerical, etc.); the various scales at which the vegetation has been recorded and mapped; the taxonomic unreliability of many of the floristic datasets that have been collected as unpublished reports by environmental consultants and have not been subjected to peer review; the lack of a single, publicly-available, peer-reviewed database that includes all of the more reliable (DEC-collected) floristic data of the SCP, and the low intensity of the survey effort that, to date, has contributed to the best-available DEC database.

Part of the process described by Government of Western Australia (2000) to determine the conservation values of remnant vegetation in a survey area on the SCP such as the MKSEA involves the comparison of floristic data from a survey area (the survey dataset) with that of Gibson *et al*. (1994) (the SCP dataset) using appropriate software to define clusters of sites called Floristic Community Types (FCTs) on the basis of similarity of floristic composition. However, the identification of FCTs and Threatened Ecological Communities (TECs) of the SCP (TECs based largely on the FCTs originally identified by Gibson *et al*. 1994) by this method has well-acknowledged limitations (see, for example, Appendix C).

The 'SCP dataset' included data from a larger number of sites than any previous study and it provided a significant documentation of the variation present in the native vegetation of the SCP. However, although the 'SCP dataset' was collected from a very large area (that is renowned for the multiplicity of the fine-scale vegetation types that are clearly evident in the field at a scale of 1:25,000 or finer), it resulted in the definition of a relatively small number of Floristic Community Types. Trudgen (1999) and Griffin (Appendix C) maintain that the relatively small size of the sample of the vegetation captured by Gibson *et al* (1994), and the fact that Gibson *et al.* did not consider vegetation structure and floristic species abundance variation, resulted in an underestimation of the true variation that is present in the vegetation of the SCP. The sample size of Gibson *et al.* (1994) was later augmented by additional data, which resulted in the identification of supplementary FCTs (Government of Western Australia, 2000). However, the additional data have not been published in sufficient detail or in a format that would allow comparison with other survey datasets (Griffin, Appendix C). Most of the Threatened Ecological Communities (TECs) of the SCP currently listed by DEC (2008d) and by DEWHA (2008b) are FCTs that were identified in the initial cluster analysis of the 'SCP dataset'. Trudgen (1999) has argued that the FCTs of the 'SCP dataset' should be regarded as being of a *very high rank* in the classificatory hierarchy. A more comprehensive baseline database than that of Gibson *et al.* (1994) used in cluster analysis with survey datasets would undoubtedly confirm the TEC status of the FCTs currently recognised as TECs. It would also probably identify additional FCTs that would be eligible for TEC status.

Table 3.13: MKSEA Survey Limitations

Aspects	Constraints	Comments
Scope	None	The scope of the current study was very wide as was appropriate to an area that is known to include significant values, wetland types that have attributes that are often poorly understood by the general public and many agencies, and complex ecological processes that have been poorly managed in the past. The values within the Bush Forever conservation lands were relatively well-known and were not surveyed. However, some recommendations of Cardno BSD (2005) regarding wetlands in BFS 387 required review in the current survey.
Proportion of flora identified, recorded and/or collected	Negligible	The vascular flora inventory for the MKSEA in this survey recorded more than 425 taxa, including three potentially new species. It recorded a large proportion of the total native flora known from BFS 387 and BFS 53 from many past surveys and also found many additional taxa. Most sites were visited at least 3 times to ensure a comprehensive floristic inventory of the target area.
Availability of contextual information of background information	Significant	Abundant existing data of flora and vegetation were available from the literature. Deficit existed with regard to the regional data and the methods available to classify floristic community types on the SCP (see Appendix C). This deficit is considered to sometimes contribute to an under-estimation of the conservation value of vegetation types that may in fact be rare or uncommon on the SCP.
Completeness and further work which might be needed	Significant	Access was not granted to survey some of the private lands in the MKSEA. Some of these blocks will require survey if any change to zoning or if development is proposed. Detailed study to investigate the total hydrological cycle and hydrological linkages between proposed development lands and conservation areas was beyond the time and resources allocated for this survey. Excellent baseline data for the Greater Brixton Street Wetlands (BFS 387) is available (VCSRG, 2001) and subsequent monitoring of bores established that baseline study should be used as a basis for further studies of the area. A number of changes to the DEC SCP Wetlands Dataset (DEC, 2008a, 2008b) are proposed in this report and will require further survey to complete the documentation required by DEC for formal changes to datasets. In particular, the upland boundary of the palusplain wetlands mapped in this study in Precinct 2 will require formal documentation to DEC.
Timing/weather/ season/cycle	Negligible	Much of the survey was conducted in fine spring weather in 2007 (after the record low rainfall year of 2006). The vegetation was still recovering from drought at this time. Subsequent visits to various survey areas were made in spring 2008 (and at other times during 2007, 2008 and 2009) after heavier, more typical rainfall.
Disturbances which affected results of survey	Small	At least five blocks of land within the MKSEA were burnt, grazed and/or cleared of native vegetation just before or after the current botanical survey was conducted. The grazing of horses was also observed within BFS 387. All of these actions contravene the Western Australian Environmental Protection Act clearing regulations relating to high conservation value native vegetation of the eastern SCP. These disturbances did not alter the outcomes of the survey significantly.
Intensity (in retrospect, was the intensity adequate?)	Significant	An appropriate level of survey was used for the high conservation value flora and vegetation of the area in accordance with EPA recommendations (see above). The intensity of the wetlands study was below that required to examine the crucial variables of the total water cycle in the target area and to characterise the hydrological interactions between the conservation lands and the MKSEA lands (see 'completeness' above).
Resources	None	The study required more time than anticipated but this was accommodated by the City of Gosnells.
Remoteness and/or access problems	Significant	Access was not granted to survey a number of the private lands in the MKSEA. If re-zoning or development is proposed for these areas, full access and detailed field surveys will be required.
Competency and experience of the consultants who carried out the survey	None	Two very experienced and qualified botanists carried out the survey. Additional input was received from a number of specialists in various issues and these are listed in the acknowledgments.

4. Flora

4.1 Flora Desktop Study

A comprehensive search of the flora taxa of conservation significance (at the national, state and regional levels) that are known to have distributions that may include the MKSEA (or habitats similar to those found in the MKSEA) was conducted in the literature and the databases of rare flora maintained by relevant agencies. The main aim of this search was to predict the occurrence of the taxa of conservation significance most likely to occur within the study area and so assist the targeted search and recognition of these taxa in the field survey. Apart from the names of these taxa and their listed conservation significance codes, other relevant information (where available), such as geographic distribution, locality records, growth form, habitat and flowering time, was also included in the list compiled (Appendix A: Table A.1). The sources of these data are listed below.

1. The list of Flora of National Conservation Significance was compiled from the Threatened Flora Database of the DEWHA (2008a).

2. The list of Flora of State Significance (the taxa listed as Declared Rare Flora and Priority Flora in Western Australia) was compiled from searches of three Western Australian DEC Flora Databases by DEC staff. The parameters for each search are shown below.

   a. *The Threatened (Declared Rare) Flora Database*, for records in the rectangle defined by the coordinates 32^0 00’ 00” - 32^0 02’20” S and 115^0 58’ 00” - 116^0 00’ 10” E.

   b. *The Western Australian Herbarium Specimen Database* (WAHERB) for records in the rectangle defined by the coordinates above; and

   c. *The Declared Rare and Priority Flora List Database* for the locations Beckenham, Brixton, Cannington, Forrestfield, Gosnells, High Wycombe, Kenwick, Kewdale, Maddington, Maida Vale, Orange Grove, Perth Airport, Wattle Grove and Welshpool.

   There is doubt (based on discrepancies between specimen collection coordinates and stated location in Western Australian Herbarium [WAH], in 2008, on recorded habitats or on examination of WAH collections) that none of the eight Priority taxa - *Acacia lasiocarpa* var. *bracteolata* long peduncle variant (G.J. Keighery 5026), *Acacia oncinophylla* subsp. *patulifolia, Aotus cordifolia, Banksia pteridifolia* subsp. *vernalis*, (syn. *Dryandra pteridifolia* subsp. *vernalis*), *Lasiopetalum bracteatum, Templetonia drummondii, Tetratheca* sp. Granite (S. Patrick 1224) [aff. *hirsuta*] and *Thysanotus anceps* - has been recorded previously within the Swan Coastal Plain part of the DEC database search area.

3. The list of Flora of Regional Significance was compiled from the records of other field surveys conducted in the vicinity of the MKSEA, including Keighery and Trudgen (1992), Keighery and Keighery (2000); Government of Western Australian (2000); Cardno BSD (2005), Tauss (2007a), Keighery and Tauss (2008) and Tauss (2009). All geographical distributions were checked on FloraBase (Western Australian Herbarium, 2008, 2009).

4. Much of the data about localities, distributions and flowering times of many of these taxa were provided by the Western Australian DEC database search result and Atkins (2006, 2008). Other data of form, features and habitats were added from Paczkowska and Chapman (2000) and Western Australian Herbarium (2007, 2008, 2009). Additional data were compiled from examination of herbarium specimens and their labels in the Western Australian Herbarium, consultations with other botanists, Marchant *et al.* (1987), Hoffman and Brown (1998) and relevant parts of the *Flora of Australia* and *How to Know Western Australian Wildflowers* series.

4.1.1 Flora of Conservation Significance

4.1.1.1 Flora of National Significance

Federal Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act).

Flora taxa (species, subspecies or varieties) that are listed as being of National Conservation Significance under the EPBC Act are designated one of the six categories (Critically Endangered, Endangered, Vulnerable, Conservation Dependent, Extinct, Extinct in the Wild) defined by the Australian Government Department of Environment, Water, Heritage and the Arts (DEWHA, 2008a). (See Appendix A for definitions of the EPBC Act categories.)

A search of the Threatened Species Database of the Australian Government Department of Environment, Water, Heritage and the Arts (DEWHA, 2008a) for the local government areas of Gosnells, Kalamunda and Canning yielded records of 14 Flora Taxa of National Conservation Significance listed under the EPBC Act, *viz. Acacia anomala* (Vulnerable), *Acacia aphylla* (Endangered), *Andersonia gracilis* (Endangered), *Anthocercis gracilis* (Endangered), *Caladenia huegelii* (Endangered), *Conospermum undulatum* (Vulnerable), *Darwinia apiculata* (Endangered), *Diuris drummondii* (Vulnerable), *Drakaea elastica* (Endangered), *Dryandra mimica* (Endangered: now *Banksia mimica*), *Lasiopetalum pterocarpum* (syn. *Lasiopetalum* sp. Serpentine S. Paust 1103A), *Lepidosperma rostratum* (Endangered), *Macarthuria keigheryi* (Endangered) and *Thelymitra stellata* (Endangered) (Appendix A, Table A1). Six of the EPBC listed species that were found in this desktop search (*Acacia anomala, Acacia aphylla*, *Anthocercis gracilis, Darwinia apiculata*, *Lasiopetalum pterocarpum* and *Thelymitra stellata*) are typically restricted to rocky habitats of the Darling Scarp and the Yilgarn Plateau and, consequently, are unlikely to occur within the predominantly wetland and sand dune settings of the MKSEA.

Further searches of the literature and the databases of the Western Australian Department of Environment and Conservation showed that the following six nationally significant flora species have been recorded in BFS 387 (Government of Western Australia, 2000): *Andersonia gracilis* (Endangered), *Calytrix breviseta* subsp. *breviseta* (Endangered), *Diuris purdiei* (Endangered), *Eleocharis keigheryi* (Vulnerable), *Hydatella dioica* (Endangered) and *Lepidosperma rostratum* (Endangered). Additionally, there are records of *Caladenia huegelii* (Endangered), *Macarthuria keigheryi* (Endangered) and *Tetraria australis* (Vulnerable) from Kenwick or nearby (Western Australian Herbarium, 2007) (Appendix A, Table A1).

Two of the Nationally Significant Flora Taxa above (*Calytrix breviseta* subsp. *breviseta* and *Conospermum undulatum*) were recorded by Cardno BSD (2005) in Lot 138 Brentwood Rd and Lot 25 Victoria Rd, respectively. *Calytrix breviseta* var. *breviseta* was also recorded from Lot 138 Brentwood Rd in DEC field searches for this species (Western Australian Herbarium, 2009). *Conospermum undulatum* was also known from the Clifford Street Bushland (BFS 53) in Precinct 1 of the MKSEA (Government of Western Australian, 2000).

Thus the most likely Flora Taxa of National Conservation Significance that may occur in the vicinity of the MKSEA survey area can be reduced to a total of twelve taxa (Appendix A, Table A1). These are: *Andersonia gracilis*, *Caladenia huegelii*, *Calytrix breviseta* subsp. *breviseta, Conospermum undulatum*, *Diuris purdiei*, *Drakaea elastica*, *Banksia* (=*Dryandra*) *mimica*, *Eleocharis keigheryi, Hydatella dioica*, *Lepidosperma rostratum, Macarthuria keigheryi* and *Tetraria australis.* Of these taxa, five are shrubs (*Andersonia gracilis*, *Calytrix breviseta* subsp. *breviseta, Conospermum undulatum, Banksia mimica* and *Macarthuria keigheryi*) that are either very conspicuous in flower during spring or are clearly distinguishable from other species in a vegetative state. The four EPBC-listed sedge or sedge-like taxa in this list (*Eleocharis keigheryi*, *Hydatella dioica*, *Lepidosperma rostratum* and *Tetraria australis*) all occur in claypans, are difficult to distinguish from similar-appearing taxa in the field and are generally located only during intensive quadrat-based surveys by experienced botanists. One of the orchids is conspicuous in flower (*Caladenia huegelii)*, and another has distinctive vegetative features (*Drakaea elastica*). The donkey orchid *Diuris purdiei* (which only flowers after fire and is inconspicuous at other times) is probably the most cryptic of the rare species that could be present in the MKSEA.

4.1.1.2 Flora of State Significance

***Western Australian Wildlife Conservation Act 1950 (WA Conservation Act)* and *Western Australian Department of Environment and Conservation (WA DEC) Priority Flora Taxa*.**

Declared Rare Flora (DRF) taxa are protected under the Western Australia Conservation Act. The list of taxa currently protected under this Act was gazetted in Government Gazette, WA (2008). DRF taxa are assessed under the same international criteria as EPBC listed species. Therefore, if a species is listed as DRF in Western Australia, it is also eligible for listing under the EPBC Act and should be listed as such as soon as the required administrative process is completed.

The Western Australian DEC has also defined four classes of Priority Flora Taxa that are considered to be of conservation significance (Atkins, 2008). These taxa are grouped into four categories (Priority One, Priority Two, Priority Three and Priority Four) depending on the perceived urgency of determining their formal conservation status as indicated by the degree of threat to these taxa. (See Appendix A for the definitions of Declared Rare Flora and the four categories of Priority Flora.)

Ten Declared Rare Flora taxa are known from the vicinity of the MKSEA survey area (Appendix A, Table A1). These species are the same as the EPBC listed species for this area. Forty-five Priority Species are known from the same area, of which 24 have been recorded from BFS 387.

One species that is currently listed as Priority 4 by DEC, *Grevillea thelemanniana*, has recently been confirmed as being restricted entirely to the Kenwick-Wattle Grove area, an extremely small range for any species (B. Makinson, 2009, pers. comm; P. Olde, 2009, pers. comm.). When this narrow range is considered in the context of the level of threat that is experienced by native flora in this setting, *Grevillea thelemanniana* is eligible for Declared Rare Flora status and, at least, Endangered status under the EPBC Act.

Trudgen and Keighery (1995, Table 1) list 41 taxa of Declared Rare and Priority Flora recorded in the part of the City of Gosnells west of the Darling scarp and another 11 that may occur there. Fifteen of these 52 taxa are listed as endemic to alluvial soils on the eastern side of the SCP.

4.1.1.3 Flora of Regional Significance

EPA (2004b) and (Government of Western Australian, 2000) have nominated a number of other criteria (apart from the Federal and Western Australian State criteria of Threatened Flora, Declared Rare Flora and Priority Species) under which flora taxa (i.e. species, sub-species and varieties) may have conservation significance. In EPA (2004b) such taxa are termed ‘other taxa of conservation significance’. These criteria are not explained well in EPA (2004b) and can be somewhat difficult to understand without further explanation. Essentially, the conservation significance of such taxa is assessed primarily by considering their status *in the context of a single region* (i.e. the Swan Coastal Plain Bioregion when examining the MKSEA), rather than in the context of the whole of Western Australia or Australia. Thus in the MKSEA study, such taxa were termed ‘regionally significant’ rather than ‘other taxa of conservation significance’ because the former term was thought to be more descriptive and easier to understand. The criteria for the conservation significance of these taxa (from EPA, 2004b) and how they apply to the Maddington-Kenwick area in the context of the SCP are briefly explained below.

1. *Taxa with populations in Maddington-Kenwick that are significant (with reference to the SCP).* Significant populations in this context are populations that are important in maintaining the survival of these taxa on the eastern SCP (or, more generally, on the SCP). There are potentially many reasons that may ensure that one population is of higher conservation significance than other populations of the same species in the region. For example, a large population may be of high regional significance if the other populations in the region are very small. A mature population of obligate re-seeding plants with an abundant soil seed bank may be of high regional significance if most other populations in the region have been burnt recently and could be extirpated by another fire. A population that occurs in a wetland reserve with an adequate buffer zone and has good connectivity to suitable habitat in other wetland reserves nearby can be of higher regional significance than a population that is confined to the edges of drains along road verges. Other factors to consider in assessing regional significance of populations

include such things as the occurrence of valuable genotypes or phenotypes in some populations, the relative abundance of pollinators in some populations and the levels of threat (e.g. weeds, dieback, and water abstraction) operating in populations.

2. *Taxa with populations in Maddington-Kenwick that are disjunct from their main geographic range* (i.e. they are isolated outliers from other populations of the same taxon) *or are at the limit of their geographic range* (i.e. they are at the range end of the taxon). These populations may have developed valuable genetic resources that are not present in populations within the main range of the taxon.

3. *Narrowly endemic taxa that occur in Maddington-Kenwick.* These are taxa that are entirely confined to a relatively small area (in this case, the eastern SCP or the part of the eastern SCP that is in the Perth Metropolitan Region). These taxa are very vulnerable to relatively small (local or regional-scale) disturbances. Disturbances of the eastern SCP on these scales have included the clearing for farming of most of the Guildford Formation habitat, urban development on almost all sandy habitat, the development of major roads along a particular topographic-habitat zone of the foothills, the increased frequency of fire, the alteration of hydrological regimes by district drainage schemes and changes to groundwater and surface water quantity and quality on the eastern SCP due to vegetation clearing in Darling Range catchment areas.

4. *Taxa occurring in Maddington Kenwick that are poorly reserved* (but not already listed as DRF or Priority Taxa).

5. *Taxa that are regionally extinct elsewhere in the SCP Bioregion but still occur in Maddington-Kenwick* (and maybe in other Bioregions of south-west Western Australia).

6. *Taxa of taxonomic significance in Maddington-Kenwick that are potentially new to science and need to be formally described prior to their distribution being fully documented*.

7. *Taxa occurring in Maddington-Kenwick that are confined to scarce or refugial habitats on the SCP*. These taxa may have been common on the eastern SCP in the past when their habitats were widespread. Currently, these taxa have contracted to ‘islands’ of remnant habitat on the eastern SCP (such as palusplains and creek banks that have not been cleared of native vegetation) that are separated from other native vegetation by developed or degraded lands (although some of the taxa may still be more widespread and common in other regions).

8. *Keystone taxa occurring in Maddington-Kenwick.* These are taxa that may have important ecological functions and which make special contributions to supporting the biodiversity of the area. For example, *Banksia ilicifolia* (one of the few species that flowers throughout the year in some bushland) may be considered as a keystone species when it occurs in large populations in areas of the Bassendean Dunes where honey possums are still prevalent. The pollen and nectar of *Banksia ilicifolia* maintain populations of honey possums through the autumn months when few other native plants are flowering and thus enables the possums to be available to pollinate other species that flower in spring and summer.

Knowledge of the taxonomy and geographical distributions of flora taxa on the Swan Coastal Plain has grown considerably over the last 20 years. This process has been facilitated by the development of FloraBase, an authoritative electronic database of the flora records of the Western Australian Herbarium (2009), and by numerous flora surveys of the region during this period. As a result of this growth in knowledge, various lists of flora considered to be of national, state or regional significance on the eastern SCP have been compiled, lists which have changed over time as taxa have been added to (or subtracted from) the DRF and Priority lists maintained by the Department of Environment and Conservation.

For example, a study of the eastern Swan Coastal Plain between Gingin and Pinjarra (Keighery and Trudgen, 1992) identified 36 regionally significant taxa. These taxa are *Acanthocarpus canaliculatus*, *Agrostocrinum scabrum*, *Andersonia aristata*, *Anigozanthos bicolor*, *Banksia telmatiaea*, *Burchardia bairdiae*, *Calandrinia composita*, *Calothamnus hirsutus*, *Conostylis festucacea*, *Daviesia physodes*, *Drosera heterophylla*, *Eryngium pinnatifidum* subsp. 'palustris’, *Eryngium* 'subdecumbens', *Grevillea bipinnatifida*, *Hakea auriculata*, *Hakea erinacea*, *Hydrocotyle lemnoides*, *Isotoma scapigera*, *Jacksonia alata*, *Melaleuca lateritia*, *Melaleuca osullivanii* (syn. *Melaleuca uncinata* in part), *Patersonia juncea*, *Petrophile juncifolia* (syn. *Petrophile media* var. *juncifolia*), *Philydrella drummondii*, *Prasophyllum drummondii, Scaevola*

lanceolata, *Schoenus andrewsii*, *Stylidium dichotomum*, *Stylidium divaricatum*, *Stylidium ecorne*, *Stylidium utricularioides*, *Tribonanthes brachypetala*, *Tricoryne humilis*, *Tremulina tremula* (syn. *Restio tremulus)*, *Verticordia acerosa* and *Verticordia plumosa.*

However, Government of Western Australian (2000) identified over 60 taxa that occur in the Foothills and Pinjarra Plain (in the Perth Metropolitan Area) as having regional significance. Over 40 of these taxa are known to occur in the Greater Brixton Street Wetlands. Apart from a number of taxa in the Keighery and Trudgen (1992) list, the following taxa were also included as species of regional significance on the eastern SCP in Government of Western Australia (2000): *Caesia micrantha* Large Swamp Form (B.J. Keighery & N. Gibson 094), *Calandrinia* sp. Kenwick (aff. *composita*; G.J. Keighery 10905, *Conospermum huegelii*, *Conospermum incurvum, Conospermum triplinervium, Cyathochaeta equitans, Cyclosorus interruptus, Darwinia* sp. Muchea (B.J. Keighery 2006), *Dasypogon obliquifolius, Dielsia stenostachya, Drosera bulbigena, Drosera gigantea* subsp. *geniculata, Drosera macrantha* Swan Coastal Plain form (B.J. Keighery & N. Gibson 228), *Dryandra kippistiana, Dysphania glomulifera* subsp. *glomulifera, Epaltes australis*, *Eremaea purpurea, Eucalyptus lanepoolei, Glischrocaryon aureum, Grevillea althoferum, Grevillea obtusifolia*, *Hakea conchifolia, Hakea myrtoides, Hakea* aff. *lasiantha*, *Haloragis cordiger, Jacksonia gracilis, Johnsonia pubescens* subsp. *cygnorum, Kennedia coccinea, Isopogon asper, Kunzea* aff. *recurva* (G.J. Keighery 12828), *Melaleuca brevifolia, Pimelea imbricata* var. *major, Stylidium roseoalatum* and *Stylidium utricularioides.*

In the current desktop survey, taxa listed as occurring in the Greater Brixton St Wetlands (Keighery and Keighery, 2000; Western Australian Herbarium, 2007, 2008, 2009) the Clifford St bushland (Government of Western Australia, 2000) or the Wattle Grove-Kenwick-Maddington area (Western Australian Herbarium, 2007, 2008, 2009) and considered as regionally significant in studies of the eastern Swan Coastal Plain (including Keighery and Trudgen, 1992; Gibson *et al*., 1994; Keighery and Keighery, 2000; Government of Western Australia, 2000; Tauss, 2007a, 2009; Keighery and Tauss, 2008) were reviewed against their current distributions as given in FloraBase (Western Australian Herbarium, 2007, 2008, 2009). It was concluded that, currently, about 109 regionally significant taxa are known from the Wattle Grove-Kenwick-Maddington area (Appendix A, Table A2). Moreover, in this review, some of these taxa (e.g. *Schoenus elegans* and *Drosera tubaestylis*) were found to be poorly reserved and have very limited distributions; thus they require review by DEC in order to determine if they are currently eligible for DRF or Priority listing.

The regionally significant species that are known to occur in the vicinity of BFS 387 or BFS 53 (Appendix A, Table A2) were each usually significant for more than one reason. The main categories that were applicable to them are listed below.

1. Scarce or refugial habitats

Most of these taxa are significant in this area because their habitats on the SCP have been reduced to the status of remnants or small refuges. These habitats include the wetlands underlain by the alluvial sediments of the Pinjarra Plain (e.g. palusplains, clay sumplands, i.e. claypans, floodplains and creeks) and uplands underlain by the colluvial sediments of the Foothills of the Darling Range. The habitats of these species on the SCP are now very limited compared to their former extent, and they have continued decreasing and degrading in recent years due to development, illegal clearing and poor management. Some of these species are significant in this area because their distribution is limited *entirely* to the eastern SCP in these habitats. An example of such a species is *Drosera tubaestylis.* However, some of these species may be significant on the SCP but not in other regions (such as the Jarrah Forest or Warren) where there is more continuous habitat and, possibly, fewer threatening processes.

Some other examples of such species and their habitats include *Acanthocarpus canaliculatus* (palusplains), *Conospermum huegelii* (palusplains), *Thomasia macrocarpa* (riparian zone of creeks draining from the Darling Range onto the Pinjarra Plain), *Schoenus elegans* (palusplains and floodplains) and *Utricularia inaequalis* (claypans and floodplains).

These taxa are indicated by labels such as ‘h (wetlands, PP)’ or ‘h (F)’ in Appendix A.

2. Significant Populations

A group of taxa form *significant populations* in the Wattle Grove-Kenwick-Maddington area (i.e. populations that are important in maintaining the survival of these taxa on the eastern SCP) due to factors such as the size of the local population, the genetic resources in the population, the viability of the population due to the security of the reserve it occurs in, the lack of dieback or other threats to the population and many other factors. Examples of taxa that form significant populations in the MKSEA include *Banksia telmatiaea*, which occurs in large, healthy populations that are free of dieback in the area and *Actinostrobus pyramidalis*, which also forms large populations in the area and including very tall, mature stands as well as younger cohorts in some areas

Some of the factors that contribute to high viability of plant populations in the Wattle Grove-Kenwick-Maddington area include:

- The relatively large area of alluvial fan habitat still remaining in BFS 387 and the adjoining MKSEA and the compact shape of the reserve area;
- The orientation of the BFS 387 lands and the MKSEA (along the topographic and groundwater flow gradient of the area) is favourable with regard to potentially permitting the expansion and contraction of populations with changing climatic conditions.
- The connectivity between BFS 387, the MKSEA and the Darling Range and Canning River. Yule Brook and Bush Forever Sites such as Hartfield Park currently provide a degree of connectivity between BFS 387, the MKSEA and other conservation reserves in the Darling Range and the Canning River. Moreover this connectivity can be improved with restoration and better management of this corridor.
- The muddy and clay soils that prevail in the area are relatively resilient (compared with sandy habitats on the SCP) to disturbances such as weed invasion. Significant natural regeneration has been demonstrated after well-targeted weed control in the Brixton Street Reserve and other areas on the eastern SCP, such as Meelon Reserve, that were previously weed infested (R. Drummond, Friends of the Brixton Street Wetlands; K. Brown, DEC, pers. comm.). Thus the long term viability of relatively small areas of remnant native vegetation in these habitats is higher than in the sandy soils that prevail over much of the SCP.

These taxa are indicated by the label ‘s’ in Appendix A.

3. Geographical Range

Another large group of regionally significant taxa is significant in the Wattle Grove-Kenwick-Maddington area because this area is at, or near to, the end of the natural geographical ranges of these taxa or because populations in this area are disjunct from their main ranges.

Examples of such species include *Anarthria laevis, Anigozanthos bicolor* subsp. *bicolor, Boronia crenulata* subsp. *viminea, Hakea ceratophylla, Lawrencia squamata* and *Prasophyllum drummondii.*

These taxa are indicated by labels such as ‘r (S, Kenwick SWA)’ in Appendix A. In this case, the bracketed symbols indicate that the southern end of the taxon’s range in the Swan Coastal Plain Bioregion is at Kenwick.

4. Taxonomic variants

A fourth notable group of regionally significant taxa in the Wattle Grove-Kenwick-Maddington area is significant because they require taxonomic study and formal description/publication.

An example of such taxa is *Calectasia grandiflora* subsp. *grandiflora* R.L. Barrett ms. It requires formal description to demonstrate how it differs from other taxa in the *Calectasia grandiflora* complex. Such a description will include an assessment of the geographical distribution of this taxon based on the existing collections held by the Western Australian Herbarium. It will also provide the basis for further field surveys to more fully determine the extent of its distribution.

It is anticipated that some of the taxa in the category of 'taxonomic variants' in Wattle Grove-Kenwick-Maddington, when fully described in the above manner, may prove to have a very restricted distribution and may be eligible for Priority Flora or DRF/Threatened Flora status.

These taxa are indicated by the label 't' in Appendix A.

4.2 Flora Field Survey

The native flora of the remnant vegetation of the MKSEA was found to be very species-rich. A total of 435 taxa (330 taxa of native vascular flora and 105 taxa of naturalised alien flora) (Appendix B) were recorded in reconnaissance transects, in 32 sampling sites (quadrats and relevés), and opportunistically within the MKSEA footprint. Most sampling sites were visited at least three times between 2007and 2009 (including winter, spring and early summer); therefore, it is considered that a high proportion of the existing MKSEA flora was recorded.

Three Threatened Flora Taxa (listed under the Federal EPBC Act as having national conservation significance), four Declared Rare Flora taxa and eight listed Priority Species (listed under the Western Australian State Wildlife Act and Western Australian Department of Environment and Conservation, respectively) were recorded in the MKSEA in the current survey.

Approximately a third of the native flora recorded in the MKSEA in the current survey was considered to be of regional conservation significance according the criteria of EPA (2004b) and Government of Western Australian (2000).

In the current survey, the MKSEA was found to include a number of dune and wetland habitats that did not occur in BFS 387 or BFS 53. However, the native vegetation of the MKSEA was fragmented amongst many small remnants, whereas most of the vegetation of the BFS 387 was mainly concentrated in a single polygon (although one dissected by a number of roads).

The family composition of the native flora of the MKSEA was similar to that recorded in the Greater Brixton Street Wetlands (Table 4.1) although the MKSEA had a greater proportion of perennial taxa in the families Myrtaceae and Papilionaceae than BFS 387 did. Naturalised alien taxa (weeds) formed a larger percentage of the total flora in the MKSEA than in the total flora of the Greater Brixton Street Wetlands (Table 4.2). The percentage of native annuals in the total native flora of the MKSEA was low compared to the total for BFS 387 but in excess of that found in some surveys of areas in BFS 387. The total number of native flora taxa and rare species and the percentage of native annuals recorded in the MKSEA in the current survey was considerably in excess of that found in the same area by Cardno BSD (2005) (Tables 4.1 and 4.2).

There was a mean of 42 taxa recorded per 10 m x 10 m quadrat in the MKSEA (range 9-67 taxa). The most species-rich community types and habitats in the MKSEA (all of which are recognised by authorities at either State or Federal level as Threatened Ecological Communities) were:

1. *Banksia* woodlands on well-drained Bassendean Sands over the Guildford Formation (mean species-richness of 62 taxa per 100 m^2); and
2. Shrublands on seasonally-waterlogged shallow muddy sand of the Guildford Formation (mean species-richness of 51 taxa per 100 m^2).

The previously known flora of the Greater Brixton Street Wetlands (BFS 387), as compiled by Keighery and Keighery (2000) from numerous sources included at least 555 native taxa. More recent surveys (Keighery and Tauss, 2008; Tauss, 2009) added an additional seven taxa to the tally for BFS 387. The current survey found 32 native taxa within the MKSEA (including at least three Priority Flora species) that have not been recorded previously in BFS 387 or BFS 53. One of the Declared Rare Flora Species found in the MKSEA in the current survey (*Eremophila glabra* subsp. *chlorella*) is probably no longer extant in BFS 387.

The total number of native flora taxa in Kenwick-Wattle Grove (i.e. in BFS 387 and MKSEA, which together include about 174 ha. of native vegetation) is thus at least 594 taxa. Despite the long history of settlement in the district and the extensive clearing that has taken place locally, it can be seen that the area remains a *remarkably* species-rich component of the globally significant flora biodiversity of the Swan Coastal Plain and is comparable in this respect with species-rich national parks in south west Western Australia.

Table 4.1: The most species-rich native plant families of the Greater Brixton Street Wetlands (BFS 387) compared to the MKSEA

Family	Native Taxa (and % of total native taxa) in the richest families of native taxa in BFS 387 (Keighery and Keighery, 2000)	Native Taxa (and % of total native taxa) in the same families of native taxa in MKSEA (Cardno BSD, 2005)	Native Taxa (and % of total native taxa) in the same families of native taxa in the current MKSEA survey
Cyperaceae	53 (9.5%)	9 (6.5%)	33 (10%)
Myrtaceae	43 (7.8%)	27 (19.4%)	38 (11.5%)
Proteaceae	39 (7.0%)	19 (13.7%)	21 (6.4%)
Asteraceae	32 (5.8%)	4 (2.9%)	12 (3.6%)
Papilionaceae	22 (4.0%)	11 (7.9%)	18 (5.5%)
Poaceae	17 (3.1%)	2 (1.4%)	10 (3%)
Total natives	555 (100%)	139 (100%)	330 (100%)

Table 4.2: Species-richness of native flora in the MKSEA compared with other areas of high conservation significance flora nearby

Survey Area (native vegetation only)	Total Area of Bushland	Total Native Taxa	Total Weeds (% of total flora)	Total Native Annual Taxa (% of total natives)	Total Current EPBC/ DRF Taxa	Total Current Priority Taxa
Greater Brixton Street Wetlands (BFS 387) (Keighery and Keighery, 2000)	126.7 ha	555+	120 (17.8%)	140 (25.2%)	7	26
MKSEA (current survey, Tauss and Weston)	45.6 ha	330	105 (24.1%)	47 (14.2%)	4	8
Lot 106 Wanaping Rd, Kenwick (BFS 387) (Keighery and Tauss, 2008)	8 ha	220	67 (23.4%)	44 (19.9%)	2	6
Lot 48 & Pt Lot 35 Brixton St (BFS 387) Goble-Garratt (1991)	30.29 ha	163	48 (22.6%)	36 (21.9%)	1	2
MKSEA (Cardno BSD, 2005)	45.6 ha	139	60 (30.2%)	7 (5.7%)	2	2
Lots 28 and 32 Brook Rd, Wattle Grove (BFS 387) (Tauss, 2009)	4.5 ha	97	54 (36%)	25 (17.9%)	2	6
Lots 17-33, 36, 340, 341 Brook–Boundary Rds (BFS 387) including Lots 28, 32 Brook Rd (Mattiske & Associates, 1992)	<40 ha	97	-n/a	11 (11.3%)	1	1
Lots 105A Brixton St and 107 Kenwick Rd (Koch, 2003)	4 ha	67	16 (19.3%)	8 (11.9%)	1	2

4.2.1 Flora of National Conservation Significance found in the MKSEA

Three flora taxa of national conservation significance (that are listed under the EPBC Act) were found within the MKSEA survey area (Table 4.3). Another taxon that is also eligible for listing as flora of national conservation significance, but which has only recently been listed as Declared Rare Flora in Western Australia (and for which the nomination process for EPBC listing has not yet been completed) was also found there. These species are described below. (N.B.: In accordance with current practices of the Western Australian Department of Environment and Conservation to protect Threatened, Rare and Priority Flora, the locations and maps of such flora found in the current MKSEA survey have been supplied to DEC and other relevant government authorities but are withheld from the general public).

1. *Calytrix breviseta* subsp. *breviseta* (Myrtaceae).

This small shrub is currently listed as Endangered under the EPBC Act (DEWHA, 2008d).

A small population comprising about 20 plants was found in the current survey. *Calytrix breviseta* subsp. *breviseta* is endemic to the eastern side of the Swan Coastal Plain in the Perth Metropolitan Region (Kelly *et al*., 1993), where it is only known from two populations. One of these populations is centred on BFS 387 in Kenwick. The other population is at Bellevue. There has been a decline in the habitat of this species at Kenwick that is probably due to falling groundwater levels and increased salinity resulting from local drainage practices (Luu and English, 2004). Efforts to translocate this species into nearby blocks at BFS 387 have not been successful, probably due to lack of information about the specific habitat requirements of this shrub.

2. *Conospermum undulatum* (Proteaceae).

The current status of this species under the EPBC Act (DEWHA, 2008d) is Vulnerable. A previously unrecorded population of this species was found in the MKSEA during the current survey. Another population in the MKSEA that was reported by Cardno BSD (2005) was also confirmed in this survey.

This species is endemic to the foothills of the Darling Range, where it occurs in a number of small fragmented bushland remnants from about Muchea to Maddington (Western Australian Herbarium, 2009). Much of its previous habitat has been cleared.

The two populations of *Conospermum undulatum* in the MKSEA are close to the southern range end of the species. The small sizes and fragmented distributions of *Conospermum undulatum* populations may be threats to the long-term survival of the species.

3. *Lepidosperma rostratum* (Cyperaceae).

This rather inconspicuous perennial sedge is currently listed as Endangered under the EPBC Act (DEWHA, 2008d). It was found on three palusplain blocks in the current survey.

Prior to the current MKSEA survey, *Lepidosperma rostratum* was known from one site within BFS 387 and at Forrestdale Lake Nature Reserve (Western Australian Herbarium, 2009). One of the areas where *Lepidosperma rostratum* was found in the current MKSEA survey coincided with an occurrence of *Calytrix breviseta* var. *breviseta*. *Lepidosperma rostratum* has also been reported from two other Kenwick/Wattle Grove areas (Koch, 2003; Tauss, 2009).

Many of the *Lepidosperma rostratum* plants observed in the MKSEA in early September 2007 (after the driest year on record, 2006) appeared to be drought-stressed. Many, but not all, of these moribund *Lepidosperma rostratum* plants recovered as the rainfall increased later in 2007. There is no data about the reproductive biology of *Lepidosperma rostratum*. However, as this sedge lacks extensive rhizomes, it is likely to be an obligate re-seeding species. Based on the observations of this species in the MKSEA survey, the threatening processes that endanger *Calytrix breviseta* var. *breviseta* also appear to be threatening *Lepidosperma rostratum*. Further intensive survey of this species in the area after favourable rainfall is required to establish a baseline for efforts to conserve it in the area.

4.2.2 Flora of State Conservation Significance found in the MKSEA

Apart from the three taxa of national significance above, which are also listed as Declared Rare Flora (DRF) under the Western Australian Wildlife Conservation Act, there are nine flora taxa of State Conservation Significance (one listed as DRF and eight as Priority Flora by the Western Australian Department of Environment and Conservation) (Atkins, 2008; Smith 2009; FloraBase, 2009) that were found in the current field survey of the MKSEA (Table 4.3). These taxa are described below.

1. *Eremophila glabra* subsp. *chlorella* (Myoporaceae) (Declared Rare Flora).

This low shrub is listed as Declared Rare Flora in Western Australia (Atkins, 2008; Western Australian Herbarium, 2009). The most recent information available about this taxon indicates that it is extremely rare (G.J. Keighery and R.J. Chinnock, pers. comms.).

Eremophila glabra subsp. *chlorella* was previously confused with another subspecies of, but *Eremophila glabra* subsp. *chlorella* is now known to be extremely rare (R.J. Chinnock and G.J. Keighery, pers. comms.). Apart from the occurrence in the MKSEA, the only other occurrence of *Eremophila glabra* subsp. *chlorella* on the SCP appears to be in one small suburban degraded bush remnant (B.J. & G.J. Keighery pers. comms.).

Active recovery measures are urgently needed to prevent the extirpation of *Eremophila glabra* subsp. *chlorella* on the SCP.

2. ***Schoenus pennisetis*** **(Cyperaceae) (Priority 1).** This is inconspicuous annual sedge that is usually less than 10 cm in height. This sedge was present in a number of blocks in scrub, heath and sedgelands on palusplain and in sumplands.

3. ***Lepyrodia curvescens*** **ms (Restionaceae) (Priority 2).** This is a dioecious, tufted, shortly rhizomatous rush 0.24–0.4 m in height. The rhizomes are at, or very near, the soil surface and are glabrous and pale brown. This species is poorly known and probably poorly collected. It is most similar to *Lepyrodia hermaphrodita* and *L. monoica* but is dioecious, has appressed culm sheaths and a longer leaf lamina. It can be distinguished from *L. macra* by its sparser inflorescence and appressed culm sheaths. *Lepyrodia curvescens* is infrequent on peaty sand and shallow sand over 'laterite' (Western Australian Herbarium, 2009) on the margins of wetlands and in seasonally waterlogged basins. It flowers between September and November. It has been recorded previously in Marri woodland near Jurien, wetland heath near Mogumber and in *Eucalyptus todtiana* woodland and Marri-*Kingia* woodland at Hazelmere in the Darling Range Foothills. The occurrence in the MKSEA (in Marri-*Kingia* woodland) is a southern range extension for this species. From FloraBase descriptions (Western Australian Herbarium, 2009) it appears that occurrences of *Lepyrodia curvescens* in Hazelmere were recorded from habitats (Bassendean Sands overlying the Guildford Formation in close proximity to the Darling Range Foothills) similar to some of those in the MKSEA.

4. ***Trichocline*** **sp. Treeton (B.J. Keighery & N. Gibson 564) (Asteraceae) (Priority 2).** This perennial herb has narrow glabrous leaves and a large inflorescence of white and pink ray florets, similar to the more common *Trichocline spathulata*. It was recorded on two blocks in the MKSEA, amongst shrubs on palusplain.

5. ***Baeckea*** **sp. Perth Region R.J. Cranfield 444 (Myrtaceae) (Priority 3).** This wispy shrub, less than about 1 m in height, is often overlooked or mistaken for a species of *Astartea* or *Verticordia*. It was recorded on five blocks in the MKSEA on palusplain in dense heath or sedgelands.

6. ***Cyathochaeta teretifolia*** **(Cyperaceae) (Priority 3).** This rhizomatous perennial sedge grows to about 1 m or more in height and has culms that are round to broadly elliptical in cross-section. It is generally found in peaty sumplands that are maintained by uncommon hydrological factors. *Cyathochaeta teretifolia* inhabits a number of locations in the Warren and Jarrah Forest Bioregions, including the fringes of tributaries of the Blackwood River that are maintained by the deep Yarragadee and Leederville aquifers. However, the habitat of *Cyathochaeta teretifolia* is very uncommon on the SCP. Records of this species on the SCP are predominantly from collections made many decades ago from wetlands where the hydrological conditions and vegetation are now completely degraded.

   A closed sedgeland of *Cyathochaeta teretifolia* was recorded in this survey in a wetland that was assessed as having very high conservation significance. It is probably the only permnanently waterlogged wetland in the vicinity of the Greater Brixton Street Wetlands where the vegetation remains more or less intact.

7. ***Calothamnus rupestris*** **(Myrtaceae) (Priority 4).** This is a tall shrub with red flowers and needle-like, pungent leaves. It also appeared to have been planted in an additional site adjacent to Yule Brook. *Calothamnus rupestris* is uncommon on the Swan Coastal Plain; it is generally confined to granite and laterite habitats along creeks in the Darling Range and the Darling Scarp (mainly in the Perth Region).

8. ***Grevillea thelemanniana*** **(Proteaceae) (Priority 4).** This attractive low or prostrate shrub was recorded on palusplain in several blocks in the MKSEA. Although this shrub is relatively common in the Greater Brixton Street Wetlands it is a very narrowly-endemic species entirely confined to the Kenwick area.

The continued existence of *Grevillea thelemanniana* in its natural habitat is dependent on the conservation and appropriate management of the fragmented populations in this area. As it appears to be a bird-pollinated species, its reproduction is probably also dependent on the maintenance of local bird habitats. This species is eligible for listing as Threatened Flora (B.J. Keighery, P. Olde, R. Makinson, pers. comm.).

9. ***Verticordia lindleyi* subsp. *lindleyi* (Myrtaceae) (Priority 4).** This small shrub is endemic to the eastern SCP; but most of its previous habitat has been cleared. Kenwick has significant populations in the Greater Brixton Street Wetlands. Several plants were recorded in two blocks in the MKSEA.

Notes:

1. *Isopogon drummondii* (P3) was recorded by Cardno BSD (2005) in the MKSEA, but that record was not confirmed in the current survey, probably due to lack of access to the block where Cardno BSD (2005) recorded it. This block will require full survey at a later date if development is proposed for it.
2. *Acacia lasiocarpa* var. *bracteolata* (long peduncle variant) (P2) was was also recorded by Cardno BSD (2005) in the MKSEA, but not in the current survey. *Acacia lasiocarpa* var. *lasiocarpa* sens. strict. was the only *Acacia* recorded in the current survey in the area where *Acacia lasiocarpa* var. *bracteolata* (long peduncle variant) was recorded by Cardno BSD. It is probable that the Cardno BSD (2005) record is this variety.

Table 4.3: Summary of the Flora of National and State Significance recorded in the MKSEA Field Survey

Species	Status
1. *Calytrix breviseta* var. *breviseta*	Endangered (EPBC Act); DRF (WA Wildlife Act)
2. *Conospermum undulatum*	Vulnerable (EPBC Act); DRF (WA Wildlife Act)
3. *Lepidosperma rostratum*	Endangered (EPBC Act); DRF (WA Wildlife Act)
4. *Eremophila glabra* subsp. *chlorella*	DRF (WA Wildlife Act)
5. *Schoenus pennisetis*	P1
6. *Lepyrodia curvescens* ms	P2
7. *Trichocline* sp. Treeton (B.J.Keighery & N.Gibson 564)	P2
8. *Baeckea* sp. Perth Region (R.J.Cranfield 444)	P3
9. *Cyathochaeta teretifolia*	P3
10. *Calothamnus rupestris*	P4
11. *Grevillea thelemanniana*	P4
12. *Verticordia lindleyi* subsp. *lindleyi*	P4

4.2.3 Flora of Regional Conservation Significance found in the MKSEA

Apart from EPBC-listed, DRF and Priority Species, EPA Guidance Statement 51 (EPA, 2004b) and Government of Western Australia (2000b) define a third set of criteria under which flora taxa (i.e. species, sub-species or varieties) may have conservation significance. This set of criteria is referred to in this report as 'regional conservation significance' (see Section 4.1.1 above).

The MKSEA was found to have about 97 flora taxa that can be considered as regionally significant under these criteria (Appendix B). Most of these are also in BFS 387 and/or BFS 53 (Appendix A). The regionally significant taxa that are in the MKSEA and not in BFS 387 or BFS 53 are *Dielsia stenostachya, Eucalyptus decipiens* subsp*. decipiens, Eucalyptus gomphocephala, Gastrolobium ebracteolatum, Lepidosperma* sp. Kenwick (C.Tauss 2598), *Leucopogon strictus, Schoenus subflavus* subsp. *subflavus, Schoenus unispiculatus, Tricoryne* aff. *elatior* (C. Tauss 1905) and *Trymalium odoratissimum* subsp. *odoratissimum.*

The most numerous regionally significant taxa in the MKSEA could be grouped under the following criteria.

1. Taxa of scarce or refugial habitats

Most of the regionally significant taxa in the MKSEA are plants whose habitats on the SCP have been reduced to the status of remnants or small refuges. These habitats in the MKSEA include:

a. Muchea Limestone habitats in Precincts 2 and 3B. These habitats had the following species: *Burchardia bairdiae, Comesperma* cf. *polygaloides, Dielsia stenostachya, Dodonaea ceratocarpa, Eucalyptus decipiens, Eucalyptus gomphocephala, Gahnia trifida, Gastrolobium ebracteolatum, Hakea ceratophylla, Lawrencia squamata, Melaleuca brevifolia, Prasophyllum drummondii, Samolus junceus, Sphaerolobium vimineum, Thysanotus arenarius, Tricoryne* aff. e*latior* and *Wilsonia backhousei*.

b. Floodplains of Yule Brook. Although these wetlands have been degraded in many areas and their ecological functions have been somewhat disturbed, a number of regionally significant taxa have persisted on the levee banks and floodplains of this watercourse in the MKSEA. These taxa include *Melaleuca osullivanii*, *Thysanotus dichotomus* and *Trymalium odoratissimum* subsp. *odoratissimum.*

c. Muddy sand palusplains were most prevalent in Precinct 2 of the MKSEA and were host to the largest group of regionally significant taxa in the MKSEA. These taxa include *Acanthocarpus canaliculatus, Anigozanthos viridis* subsp*. viridis, Borya scirpoidea, Burchardia multiflora, Calothamnus hirsutus, Chaetanthus aristatus, Conostylis festucacea* subsp. *festucacea, Cytogonidium leptocarpoides, Dichopogon preissii, Drosera bulbosa* subsp. *bulbosa, Drosera menziesii* subsp*. menziesii, Drosera tubaestylis, Gastrolobium capitatum, Isotoma scapigera, Grevillea bipinnatifida* subsp*. bipinnatifida, Hypocalymma angustifolium* Mud Habitats Variant, *Kunzea micrantha* subsp. *micrantha, Melaleuca lateriflora* subsp*. acutifolia, Mesomelaena tetragona, Neurachne alopecuroidea, Hakea sulcata, Petrophile juncifolia, Philydrella pygmaea* subsp. *pygmaea, Pimelea imbricata* var. *major, Pogonolepis stricta, Scaevola lanceolata, Schoenus asperocarpus, Schoenus elegans, Schoenus odontocarpus, Schoenus plumosus, Schoenus variicellae, Schoenolaena juncea, Stylidium roseoalatum, Thelymitra antennifera, Tremulina tremula, Tribonanthes brachypetala, Triglochin muelleri, Verticordia acerosa* var*. preissii, Verticordia plumosa* var. *brachyphylla* and *Wurmbea dioica* subsp. *alba.*

d. Muddy sumplands (claypans) and floodplains were located in Precincts 2 and 3B and had a number of aquatic or emergent taxa that are regionally significant, including *Amphibromus nervosus, Chorizandra enodis, Melaleuca lateritia, Utricularia inaequalis, Utricularia multifida, Villarsia capitata* and *Wurmbea dioica* subsp. Brixton (G.J. Keighery 12803).

e. Dunes of Bassendean Sands over the Guildford Formation were located in Precincts 1 and 2. Regionally significant taxa in these habitats are *Cyathochaeta equitans* and *Dasypogon obliquifolius*.

2. Significant Populations

Many of the taxa in the MKSEA that are regionally significant for other reasons also formed large, healthy, resilient populations in this area despite the stresses on these small wetland remnants. These taxa include *Acacia lasiocarpa* var*. lasiocarpa* sens. strict., *Actinostrobus pyramidalis*, *Banksia telmatiaea*, *Gahnia trifida, Goodenia pulchella* subsp. Coastal Plain B (M.Hislop 634) p.n., *Hypocalymma angustifolium* Mud Habitat Variant (C. Tauss 1850), *Melaleuca brevifolia, Melaleuca lateriflora* subsp*. acutifolia, Pimelea imbricata* var. *major* and *Thysanotus arenarius*.

3. Geographical Range

The MKSEA has a large group of taxa that are at, or near to, the ends of their natural geographical ranges or have populations in this area disjunct from their main ranges. These taxa are *Anarthria laevis, Anigozanthos manglesii x bicolor, Banksia telmatiaea, Boronia crenulata* subsp*. viminea, Cytogonidium leptocarpoides, Hakea ceratophylla, Lawrencia squamata*, *Leucopogon strictus*, *Pimelea imbricata* var. *major, Podolepis capillaris*, *Prasophyllum drummondii, Schoenus elegans* and *Schoenus subflavus* subsp. *subflavus.*

4. Taxonomic variants

Taxa in the MKSEA that are significant because they differ morphologically from currently accepted descriptions and forms, and which require taxonomic study and possibly recognition as distinct taxa, include *Calectasia grandiflora* subsp*. grandiflora* R.L. Barrett ms, *Comesperma* cf. *polygaloides* (C. Tauss 2541), *Hypocalymma angustifolium* Mud Habitat Variant (C. Tauss 1850), *Lepidosperma* sp. Kenwick (C. Tauss 2598), *Podolepis gracilis* Swamp Form (G.J. Keighery 13255), *Tricoryne* aff. *elatior* (C. Tauss 1905), *Velleia* aff. *trinervis* (G.J. Keighery 10429) and *Wurmbea dioica* subsp. Brixton (G.J. Keighery 12803).

4.2.3.1 Descriptions of the some taxa of regional conservation significance recorded in the current field survey of the MKSEA

Some of the regionally significant taxa that occur in the MKSEA are described below. For further taxonomic notes, particularly for cross-referencing other names of taxa listed below, see Appendix B, Table B1. For other information about them, see Appendix A, Table A2.

Family Anthericaceae

1. *Tricoryne* aff. *elatior* (C. Tauss 1905). This perennial herb was found in the MKSEA in several palusplain sites where Muchea Limestone was present. It had a tall, lax, tangled habit to about 1 m in height and very scabrous stems. The form of *Tricoryne elatior* that is more prevalent on the SCP also occurred in the MKSEA, but it was recorded only in sandy, upland sites.
2. *Thysanotus arenarius.* This fringe lily species is a calcicole that is common in sandy, upland habitats overlying Tamala Limestone of the Spearwood Dunes. In the MKSEA it was very abundant in some Muchea Limestone sites. It has also been noted in other sites on the eastern SCP associated with Muchea Limestone (Keighery and Keighery, 1995).
3. *Thysanotus dichotomus.* This striking perennial fringe lily has large mauve flowers and forms thick, intricate clumps up to a height of about 1.2 m. It was on the floodplain of Yule Brook. The main range of this species is in the Jarrah Forest, Avon and Warren Bioregions. There are no previous Swan Coastal Plain collections of this species in the Western Australian Herbarium (2009). The species has been noted several times on the SCP; near BFS 65 at Oakford adjacent to Beenyup Brook (Tauss, 2007b), at Lot 61 Welshpool Rd adjacent to Yule Brook (Tauss, 2007a) and at the Greater Brixton Street Wetlands (Keighery and Keighery, 1991). *Thysanotus dichotomus,* as currently circumscribed, appears to include several taxa (T. MacPharlane, pers. comm.), and the very robust form found at Yule Brook is in need of further taxonomic study.

Family Asteraceae

1. *Podolepis capillaris.* BFS 387 and the MKSEA are the only areas on the SCP where this daisy has been recorded. It is otherwise widespread in the semi-arid regions of the Southwest and Eremaean Botanical Provinces of Western Australia. Further taxonomic studies on this form are required to establish the differences between it and the common, dry inland habitat form of *Podolepis capillaris.*
2. *Podolepis gracilis* Swamp Form (G.J. Keighery 13255). This is a robust, glabrous form of *Podolepis gracilis*, with large pink or white flowers, that is known from the seasonally inundated heavy soils of the Pinjarra Plain from Gingin to Busselton. Further taxonomic studies on this form are required to establish whether it can be distinguished taxonomically from the common, upland form of *Podolepis gracilis*.

Family Colchicaceae

1. *Burchardia bairdiae.* This is generally a species of the Pinjarra Plain wetlands. However, populations have recently been recorded at Piney Lake Reserve (BFS 339), at Alfred Cove Nature Reserve and at the Serpentine River (its most southern location). In the current survey this robust geophytic herb was found to be very abundant in one of the Muchea Limestone areas.
2. *Wurmbea dioica* subsp. Brixton (G.J. Keighery 12803). This is a tall hermaphrodite form of *Wurmbea dioica* subsp. *alba* that grows in sumplands (claypans) on the Swan Coastal Plain and in the Jarrah Forest (from Cervantes to Beaufort River and Lake Muir). This taxon is common in BFS 387. In the MKSEA it

was recorded in a small claypan adjacent to Yule Brook. The small, more common, dioecious form of *Wurmbea dioica* subsp. *alba* was also recorded in the MKSEA and BFS 387 but in seasonally waterlogged sites rather than in sumplands. This complex of taxa requires further taxonomic study.

Family Cupressaceae

Actinostrobus pyramidalis. This conifer (Swamp Cypress) is typical of wetland communities on shallow sand over Pinjarra Plain sediments. Most of the former habitat of this species on the Swan Coastal Plain has been cleared of native vegetation, and this species is vulnerable because it recruits from seed after fire and has a long establishment phase. The MKSEA and BFS 387 population of this species is significant because it is quite large and includes stands of tall mature trees. And there is additional habitat in the MKSEA where this species can recruit, given appropriate management.

Family Cyperaceae

1. *Gahnia trifida.* On the SCP, this large sedge is associated with calcareous habitats and samphires in the Quindalup and Spearwood Dunes and with Muchea Limestone on the Pinjarra Plain. The MKSEA and BFS 387 population of this species is significant because it is quite large and it often indicates a rare habitat and an EPBC listed TEC.
2. *Lepidosperma* sp. Kenwick (C. Tauss 2598). This taxon has not been recognized previously in the current revision of *Lepidosperma* by R.L. Barrett. The full distribution of this taxon is not known, but it probably is a short range endemic species that is confined to muddy palusplains of the eastern SCP in the Perth Metropolitan Region.
3. *Schoenus elegans.* This is a tufted annual sedge to 30 cm tall that grows on loam, sand and granite on seasonally waterlogged sites and along streams. It has been recorded in only seven locations in the Swan Coastal Plain, Jarrah Forest and Warren Bioregions. Further study and probably an upgrade to Priority Flora are required for this species. *Schoenus elegans* is quite abundant in parts of BFS 387 but it was only encountered once in the current survey of the MKSEA. It appears to be a species that is vulnerable to disturbance that is soon lost from small wetland remnants.
4. *Schoenus rigens.* This perennial sedge grows in sandy clay wetlands from Leeman to Tuart Forest Reserve - Ludlow State Forest (Simmonds Wetland) on the Swan Coastal Plain and is considered to be endemic to the Swan Coastal Plain. *Schoenus rigens* was quite abundant in most palusplain sites in the current survey of the MKSEA.
5. *Schoenus subflavus* subsp. *subflavus.* This is a tufted perennial sedge to 30 cm in height that grows on loam, sandy clay and sand in seasonally waterlogged areas. It is widespread throughout the Southwest Botanical Province but is rare on the southern Swan Coastal Plain. Apart from the MKSEA occurrence, it has previously been recorded on the SCP near Mandurah and at Ruabon (Western Australian Herbarium, 2009).
6. *Schoenus unispiculatus.* This tufted perennial sedge to 45 cm in height grows on sand, lateritic sand, gravel and loam. It is widespread in the western Southwest Botanical Province, where it is most common on Darling Range and scarp sites. It is relatively uncommon on the Swan Coastal Plain (Western Australian Herbarium, 2009).

Family Dasypogonaceae

Acanthocarpus canaliculatus. On the Swan Coastal Plain this is an uncommon low shrubby species that is associated with clay-based wetlands on the Pinjarra Plain. Its southernmost occurrence is near Kemerton (north-east of Bunbury).

Family Epacridaceae

Leucopogon strictus. This small (<70 cm tall), pale pink to white flowered, erect, dense shrub has been recorded on sandy soils on granite outcrops and rocks, and their drainage areas, mainly in the Jarrah Forest Bioregion. It is very uncommon on the SCP.

Family Haemodoraceae

Conostylis festucacea subsp. *festucacea.* On the Swan Coastal Plain this perennial herb occurs in Pinjarra Plain clay-based wetlands from the Anstey/Keane Dampland and Adjacent Bushland (BFS 342) in Forrestdale and extends north to the southern end of the Geraldton Sandplains Bioregion. The populations in the Perth area are disjunct from other occurrences.

Family Juncaginaceae

Triglochin muelleri. This annual herb is endemic to the SCP region and is associated with claypans from Cooljarloo to Busselton (B.J. Keighery, pers. comm.). Near Busselton it is found in Tuart Forest Reserve - Ludlow State Forest (Simpson Wetland) and at Fish Road, Yoongarillup and Ruabon Bushlands.

Family Malvaceae

Lawrencia squamata. This is a spinescent shrub that can grow to about 1 m in height and grows in sandy, saline, gypsum and limestone soils on wetland flats and depressions. It occurs in only two, disjunct areas on the Swan Coastal Plain; both (Bullsbrook and Cannington-Kenwick) are near Perth. Otherwise, the species is widespread in semi-arid and arid regions, especially northern and eastern parts of the Southwest Botanical Province and the south-western quarter of the Eremaean Botanical Province.

Family Mimosaceae

Acacia lasiocarpa var. *lasiocarpa* sens. strict. Of the several forms of *Acacia lasiocarpa* that are currently informally grouped under the name of *Acacia lasiocarpa* var. *lasiocarpa* and occur on the Swan Coastal Plain, the form that was recorded in the current survey of the MKSEA most closely matches the type concept of *Acacia lasiocarpa* var. *lasiocarpa* (Maslin, 1975; B. Maslin, pers. comm.).

Family Myrtaceae

1. *Eucalyptus decipiens* subsp. *decipiens.* The main habitat of this mallee on the SCP is sand over Tamala Limestone in near-coastal areas of the SCP. However, it also occurs (much more rarely) as disjunct populations on the Pinjarra Plain on the eastern side of the SCP, where it is an indicator of Muchea Limestone (Keighery and Keighery, 1995). The occurrence in the current survey of the MKSEA is very significant as this species and Muchea Limestone were not known previously from the vicinity of BFS 387.
2. *Eucalyptus gomphocephala* (Tuart). The main habitat of this large tree on the SCP is sand over Tamala Limestone in near-coastal areas. Some of the occurrences of this species that were recorded in the current survey of the MKSEA at Victoria Rd, although large mature trees, were obviously trees that have been planted by landowners. However, some of the Tuarts in the MKSEA occur in areas where there is calcareous material (that may be Muchea Limestone) in adjacent drainage channels. All of the occurrences of Tuart in the MKSEA require detailed assessment to determine if they are natural occurrences associated with Muchea Limestone (and thus of very high conservation significance) or not.
3. *Hypocalymma angustifolium* Mud Habitat Variant (C. Tauss 1850). The MKSEA and BFS 387 populations of this undescribed taxon are significant because this species is a dominant component of many vegetation units in these areas. This taxon inhabits muddy palusplains, in contrast to the form of *Hypocalymma angustifolium* that is prevalent on the SCP (but is relatively uncommon in Kenwick) and inhabits peaty to humic sand on the margins of sumplands and damplands.
4. *Melaleuca brevifolia.* This species is widespread in the south-west of Western Australian including the Geraldton Sandplains, Swan Coastal Plain, Avon Wheatbelt, Mallee and Esperance Plains Bioregions. It is uncommon on the Swan Coastal Plain where it occurs in a small number of disjunct populations in wetlands of the Pinjarra Plain. The most northerly occurrence of this taxon is at the Bullsbrook Nature Reserve and the adjacent bushland (BFS 292). The most southerly occurrence is at Kemerton Bushland. Several of the wetlands inhabited by *Melaleuca brevifolia* on the SCP are recognised as occurrences of the Muchea Limestone Threatened Ecological Community.

5. *Melaleuca osullivanii.* This shrub species occurs in a small number of populations from Augusta to Mogumber and inhabits muddy palusplains of the Pinjarra Pain and riparian/estuarine habitats (Western Australian Herbarium, 2009). It has recently been segregated taxonomically from the large complex of taxa known previously as *Melaleuca uncinata.*

Family Papilionaceae

1. *Gastrolobium ebracteolatum.* This tall sparse shrub is uncommon in the SCP Bioregion where it is generally confined to 'mound springs' (Bullsbrook), riparian zones (Bennett Brook) and a few other locations including Lake Pinjar, Wellard, Piney Lakes and Baldivis (Western Australian Herbarium, 2009). It seems likely that hydrological factors that are uncommon on the SCP (such as seepage from perched aquifers and artesian springs) may determine the occurrence of this species.
2. *Sphaerolobium vimineum.* This small shrub is uncommon in the SCP Bioregion. Records in the Western Australian Herbarium (2009) for this region are confined to a few old collections on the Pinjarra Plain or riparian habitats (at Guildford and Bayswater, where it is probably no longer extant, and scattered occurrences from a few other sites, including Bateman, Bullcreek and Henley Brook). In the MKSEA, this species occurred in a wetland associated with Muchea Limestone.

Family Poaceae

Amphibromus nervosus. This is a tall emergent grass that is characteristic of sumplands on the Pinjarra Plain. It flowers in spring while the water level in these wetlands is still high.

Family Polygalaceae

Comesperma cf. *polygaloides* (C. Tauss 2541). An undescribed taxon of palusplains that is allied to *Comesperma polygaloides* and was first distinguished in the current field survey, this taxon is a sparse sub-shrub with a clonal habit, small glaucous leaves and mauve flowers. It is very inconspicuous except when it is flowering, in summer. It was later found to also occur in BFS 387 (Keighery and Tauss, 2008; Tauss, 2009).

Family Proteaceae

Banksia telmatiaea. This species extends from the southern Geraldton Sandplains onto the SCP as far south as Serpentine. The majority of the collections on the SCP are from wetlands on the Pinjarra Plain in the Perth Metropolitan Region (PMR). While many of these populations are in reserves or proposed reserves (Bush Forever sites) all populations are at risk from water draw down and/or *Phytophthora* dieback. The populations in the BFS 387 are some of the largest and healthiest known in the PMR. The most southern population record is near Serpentine but is uncertain if the later is still extant.

Family Restionaceae

1. *Cytogonidium leptocarpoides.* This small rush occurs occasionally in wetlands of the eastern SCP from Gingin to Busselton, in scattered locations in the Jarrah Forest and on the south coast from Augusta to Albany. The most northern occurrence on SCP is in the Gingin area.
2. *Dielsia stenostachya.* This perennial sedge with horizontal thick, dark-brown hairy rhizomes forms dense mats usually under 20 cm high, on peaty sand (to clayey) damplands, from the southern end of the Geraldton Sandplains Bioregion to south of Mandurah. It is usually in Bassendean Dunes and unusual in Pinjarra Plain habitats and in the Jarrah Forest Bioregion.
3. *Tremulina tremula.* This large rush occurs at Scott River, Albany-Walpole-Rocky Gully and south of the Greater Brixton Street Wetlands on the Swan Coastal Plain and adjacent Darling Range. Some scattered populations near Busselton are the only other known populations on the SCP.

Family Rhamnaceae

Trymalium odoratissimum subsp. *odoratissimum.* This shrub is common and widely distributed in the Darling Range and the Jarrah Forest Bioregion. However, on the SCP it is unusual and confined to small populations (that are outliers from its main range) along a few watercourses, such as Yule Brook, that

traverse the Pinjarra Plain. In the past it is probable that transport of plant propagules of species like *Trymalium odoratissimum* from the Darling Range via waterways such as Yule Brook was an important way in which the large species pool of the Pinjarra Plain was developed. Most of its previous habitat on the SCP has been cleared and degraded.

Family Sapindaceae

Dodonaea ceratocarpa. This shrub is generally confined to granitic habitats in the Darling Range, on the Leeuwin-Naturaliste Block and along the south coast from Cape Leeuwin to Cape Arid. It also inhabits coastal limestone over granite and uncommon basalt habitats in the lower south west and south coastal areas (Western Australian Herbarium, 2009). The MKSEA and BFS 387 (Keighery and Keighery, 2000) appear to be the only locations on the Swan Coastal Plain where this species has been recorded. The form of *Dodonaea ceratocarpa* that occurs in BFS 387 and the MKSEA requires further taxonomic study to determine if it differs from other populations beyond the Swan Coastal Plain.

Family Thymeliaceae

Pimelea imbricata var. *major.* This is a taxon restricted to Pinjarra Plain clay flats and pans. The most southern population known is on the Busselton Plain in the Fish Road Bushland (B.J. Keighery, DEC. pers. comm.) The most northern population is just north of Gingin. This subspecies is endemic to the Swan Coastal Plain.

5. Vegetation

5.1 Vegetation Desktop Study

Rare and threatened vegetation and other Threatened Ecological Communities (TECs) that are listed as being of National Conservation Significance under the EPBC Act are designated as one of the six categories (Critically Endangered, Endangered, Vulnerable, Conservation Dependent, Extinct, Extinct in the Wild) as defined by the Australian Government Department of Environment, Water, Heritage and the Arts (DEWHA, 2008b). (See Appendix A for definitions of the EPBC Act categories relevant to this MKSEA survey.)

The Western Australian Department of Environment and Conservation also maintains a list of Threatened Ecological Communities (TECs) that have been endorsed by the Western Australian Threatened Species and Communities Scientific Committee and the Environment Minister of Western Australia, but some of these are yet to be endorsed at the Federal level. These TECs are defined under the same criteria and are equivalent to the categories of Threatened Ecological Communities under the Federal EPBC Act. The Western Australian Department of Environment and Conservation also maintains a list of Threatened Ecological Communities (TECs) that have been endorsed by the Western Australian Threatened Species and Communities Scientific Committee but are yet to be endorsed by the Environment Minister of Western Australia. These last TECs are designated as Priority Threatened Ecological Communities (PTECs).

5.1.1 Vegetation of National Conservation Significance

A search of the Threatened Ecological Communities Database of the Australian Government Department of Environment, Water, Heritage and the Arts (DEWHA, 2008b) for the local government areas of Gosnells, Kalamunda and Canning yielded records of two TECs listed under the EPBC Act (Table 5.1).

Table 5.1: Vegetation of National and State Conservation Significance known from the vicinity of the MKSEA

SCP FCT	Name of TEC	Occurrences in vicinity of MKSEA	Conservation status (WA) Atkins, 2008	Conservation status (Federal) EPBC Act
3a	*Eucalyptus calophylla – Kingia australis* woodlands on heavy soils	Dundas Road, Forrestfield and Brixton St Reserve (BFS 387).	Critically Endangered CR B) ii)	Endangered
n/a	Shrublands and woodlands on Muchea Limestone (Keighery and Keighery,1995)	Not supplied on EPBC database	Endangered EN B) ii)	Endangered

Further searches of the literature (including Trudgen and Keighery, 1995 and Government of Western Australian, 2000) and the TEC database of the Western Australian Department of Environment and Conservation showed that no other occurrences of other nationally listed TECs had been recorded in Cannington, Forrestfield, Kenwick, Maddington, Orange Grove, Queens Park, Southern River, Welshpool or Wattle Grove.

The two TECS listed under the EPBC Act in the vicinity of the MKSEA are discussed further below.

1. *Corymbia calophylla – Kingia australis* woodlands on heavy soils of the Eastern Swan Coastal Plain (SCP FCT 3a)

The series of Marri (*Corymbia calophylla*) - dominated plant communities (FCTs 3a, 3b and 3c) that occur on the alluvial soils between Waterloo (near Bunbury) and Bullsbrook are considered to have been the most extensive vegetation types on the eastern side of the Swan Coastal Plain (Beard, 1979a). However, all forms of this vegetation unit have undergone extensive clearing and are now rare (Keighery and Trudgen, 1992; Gibson *et al.* 1994; DEP, 1996). The *Corymbia calophylla - Kingia australis* vegetation was found to be subject to the most prolonged waterlogging; whilst the other two units inhabited sites where there was better drainage. The *Corymbia calophylla - Xanthorrhoea preissii* unit was associated with the driest conditions and in Gibson *et al.* (1994) had the lowest species-richness of the three eastern SCP Marri units (48.0 spp.

per 100 m^2). All of these vegetation units have been reduced by at least 90% (as estimated for vegetation of the eastern side of the Swan coastal plain as a whole by Government of Western Australian, 2000). The remaining patches of this vegetation are threatened by clearing, weed invasion and frequent fire.

The *Corymbia calophylla – Kingia australis* woodlands on heavy soils (FCT 3a) occur on a variety of landforms where shallow sand over mud aquitards perch rainwater and contribute to seasonal waterlogging in this vegetation. This FCT had a mean species-richness of 58.9 spp. per 10 m x10 m site in Gibson *et al.* (1994). Plant taxa that were almost always associated with this FCT in Gibson *et al.* (1994) were *Banksia dallanneyi* var. *dallanneyi, Desmocladus fasciculatus, Kingia australis*, *Mesomelaena tetragona*, *Philotheca spicata* and *Xanthorrhoea preissii*. Also present at high consistency levels in this unit were *Borya scirpoidea, Cyathochaeta avenacea, Hakea ceratophylla, Pericalymma ellipticum* and *Synaphea petiolaris.* Although some of the taxa consistently present in FCT 3a may also be present in the two other Marri (*Corymbia calophylla*) units (Table 5.2), each of these FCTs have been shown to have floristic and habitat factors that clearly distinguish them from each other (English and Blyth, 2000a). There are approximately 83 ha of FCT 3a remaining at 10 documented sites that are located at Pinjarra, Waroona, Byford, Mundijong, Wungong, Forrestfield and Kenwick (English and Blyth, 2000a). The Forrestfield occurrences of this TEC total 4.6 ha (4 ha and 0.6 ha in two reserves). The known Kenwick occurrence is 0.75 ha and is located in the Brixton Street Reserve (BFS 387).

Table 5.2: Native taxa recorded in at least 50% of sites in the three *Corymbia calophylla* TECs of the Eastern SCP in Gibson ***et al.*** (1994). (Taxa in 90% or more sites are underlined)

Corymbia calophylla/Kingia australis FCT 3A	***Corymbia calophylla/Eucalyptus marginata*** FCT 3B	***Corymbia calophylla/Xanthorrhoea preissii*** FCT 3C
Trees		
Corymbia calophylla	*Corymbia calophylla* *Eucalyptus marginata*	*Corymbia calophylla* *Eucalyptus wandoo*
Shrubs		
Banksia dallanneyi var. *dallanneyi* *Hakea ceratophylla* *Kingia australis* *Pericalymma ellipticum* *Philotheca spicata* *Synaphea petiolaris* *Xanthorrhoea preissii*	*Acacia willdenowiana* *Baeckea camphorosmae* *Banksia dallanneyi* var. *dallanneyi* *Bossiaea eriocarpa* *Burchardia umbellata* *Gompholobium marginatum* *Hibbertia hypericoides* *Xanthorrhoea preissii*	*Acacia pulchella* *Banksia dallanneyi* var. *dallanneyi* *Burchardia umbellata* *Gompholobium marginatum* *Hypocalymma angustifolium* *Xanthorrhoea preissii*
Herbs		
Borya scirpoidea *Cassytha glabella* *Conostylis setigera* *Cyathochaeta avenacea* *Dampiera linearis* *Desmocladus fasciculatus* *Drosera menziesii* subsp. *menziesii* *Goodenia caerulea* *Haemodorum laxum* *Hypolaena exsulca* *Mesomelaena tetragona* *Neurachne alopecuroidea* *Patersonia occidentalis* *Tetraria octandra* *Thysanotus manglesianus* *Tricoryne elatior* *Xanthosia huegelii.*	*Burchardia umbellata* *Caesia micrantha* *Caladenia flava* *Chamaescilla corymbosa* *Conostylis juncea* *Desmocladus fasciculatus* *Drosera erythrorhiza* *Drosera stolonifera* *Haemodorum laxum* *Homalosciadium homolocarpum* *Hypolaena exsulca* *Kennedia prostrata* *Lagenifera huegelii* *Lepidosperma angustatum* *Lomandra hermaphrodita* *Mesomelaena tetragona* *Pronaya fraseri* *Sowerbaea laxiflora* *Tetraria octandra* *Thysantus thyrsoideus*	*Burchardia umbellata* *Caesia micrantha* *Cyathochaeta avenacea* *Desmocladus flexuous* *Dichopogon capillipes* *Drosera menziesii* subsp. *penicillaris* *Lepidosperma* sp. BJK & NG232 *Mesomelaena tetragona* *Neurachne alopecuroidea* *Opercularia vaginata* *Tetraria octandra*

2. Shrublands and Woodlands on Muchea Limestone of the Swan Coastal Plain

Muchea Limestone (ML), a geological unit also known as Plain Limestone (Gozzard, 1982), occurs on the eastern side of the Swan Coastal Plain. It occurs in a discontinuous distribution from Muchea to Benger along the eastern side of the Swan Coastal Plain.

The known occurrences of the Muchea Limestone TEC currently include a range of wetland and well-drained plant habitats, on a variety of landforms. Unlike many other TECs, that are defined primarily on the basis of floristic composition (e.g. a single Floristic Community Type from Gibson *et al.,*1994), the Muchea Limestone TEC is defined as a range of relatively heterogeneous assemblages that inhabits a rare geological formation. The vegetation that has been recorded on Muchea Limestone includes *Melaleuca huegelii* shrubland, *Eucalyptus decipiens* mallee, *Casuarina obesa* woodland and *Melaleuca* spp. (*M. brevifolia, M. systena,* or *M. viminea*) shrublands (Keighery and Keighery, 1995). Calcicole species such as *Eremophila glabra*, *Eucalyptus decipiens, Eucalyptus gomphocephala*, *Gahnia trifida, Grevillea curviloba, Grevillea evanescens, Melaleuca brevifolia* and *Thysanotus arenarius* can be present (Keighery and Keighery, 1995; English and Blyth, 2000b; B.J. Keighery, pers. comm.). Muchea Limestone vegetation was not sampled by Gibson *et al,* (1994) and/or not identified as a distinct FCT in that study. Floristic analyses of vegetation of the eastern SCP that are conducted against the SCP database of Gibson *et al,* (1994) often group ML vegetation with the FCTs of Tamala Limestone in the Spearwood Dunes or FCT 18 (Shrublands on Calcareous Silts) due to the calicole species common to all of these vegetation types (English and Blyth, 200b).

The range of flora and vegetation that occurs in Muchea Limestone and the habitats of this TEC are, as yet, poorly documented. In addition to the generally high levels (>90%) of loss and degradation of native vegetation on the eastern SCP due to clearing and grazing(Government of Western Australian, 2000a, Table 4, Pinjarra Plain), many occurrences of Muchea Limestone on the SCP have been extirpated by mining (Keighery and Keighery, 1995). There is little known about the aquifers that maintain this vegetation and the development of calcicole vegetation on the eastern SCP. There are no data available about the basic characteristics of these aquifers (e.g. fine scale maps of the aquifers or identification of the catchment areas that maintain them) that could inform in the sustainable management of these ecosystems. The stygofauna that potentially inhabit these aquifers have also not been investigated. Muchea Limestone and the biota associated with it are thus of high scientific and conservation significance.

Muchea Limestone TEC occurrences are, as yet, poorly documented, but available data cite only two occurrences south of the Swan River in the Perth Metropolitan Region. These are in BFS 465, Southern River (Government of Western Australian, 2000) and in Cannington (; B.J. Keighery, pers. comm.).

5.1.2 Vegetation of State Conservation Significance

A search of the Threatened Ecological Communities Database of DEC (2008d) and searches of the literature (including Trudgen and Keighery, 1995 and Government of Western Australian, 2000) showed that, apart from the two EPBC listed TECS (as above), occurrences of another seven TECs that are listed by the Western Australian Department of Environment and Conservation (Table 5.3) have been recorded in Cannington, Forrestfield, Kenwick, Maddington, Orange Grove, Queens Park, Southern River, Welshpool and Wattle Grove. There were no Priority Threatened Ecological Communities (PTECs) listed by DEC (2008d) for this area.

The seven TECS listed by DEC (2008d) have all been assessed and approved by the Western Australian Threatened Species Scientific Committee, under the same international criteria that are used to determine TECS under the EPBC Act and thus they are, in a scientific sense, all of national conservation significance. However, these Western Australian-listed TECs are yet to be endorsed by the Federal Department of Environment, Water, Heritage and the Arts for EPBC listing.

Table 5.3: Vegetation of State Conservation Significance known from Bush Forever Sites (BFSs) in Localities in the vicinity of the MKSEA

SCP FCT	Name of TEC	Occurrences in Localities (BFSs) in vicinity of the MKSEA	Conservation status (WA) Atkins, 2008
2	Southern wet shrublands	Forrestfield (BFS 319)	Endangered EN B) ii)
3b	*Corymbia calophylla- Eucalyptus marginata* woodlands on sandy clay soils	Maddington (BFS 53)	Vulnerable VU B)
7	Herb rich saline shrublands in claypans	Kenwick (BFS 387)	Vulnerable VU B)
8	Herb rich shrublands in claypans	Kenwick (BFS 387)	Vulnerable VU B)
10a	Shrublands on dry clay flats	Kenwick (BFS 387)	Endangered EN B) ii)
20a	*Banksia attenuata* woodlands over species-rich dense shrublands	Wattle Grove (BFS 50, BFS 320); Forrestfield (BFS 319, BFS 320, BFS 401, BFS 440); Queens Park (BFS 283); Orange Grove (BFS 51)	Endangered EN B) ii)
20b	Eastern *Banksia attenuata* and/or *Eucalyptus marginata* woodlands	Maddington (BFS 53)	Endangered EN B) i) EN B) ii)

Some characteristic features of each TEC listed in Table 5.3 as recorded in Gibson *et al.* (1994) are presented below.

FCT 2: Southern Wet Shrublands
(mean species-richness per 100 m^2 =51 spp).

These were shrublands or low open woodlands on seasonally-inundated, or waterlogged, sandy mud. The high species-richness of these sites was due to the number of shrubs recorded, not the annuals and herbs (as in the other species-rich seasonal wetlands of FCTs 7, 8 and 10a on the eastern SCP).

Species that were present in 50% or more of the sites sampled in Gibson *et al.* (1994) in this FCT were *Acacia stenoptera, Astartea affinis, Calothamnus lateralis, Cassytha glabella, Dampiera linearis, Desmocladus fascicularis, Eutaxia virgata, Grevillea brachystylis, Hakea ceratophylla, Hakea sulcata, Hakea varia, Haemodorum sparsiflorum, Hypocalymma angustifolium, Hypolaena exsulca, Isopogon scaber, Kingia australis, Kunzea micrantha, Leptocarpus tenax, Lyginia barbata, Mesomelaena tetragona, Pericalymma ellipticum, Stylidium brunonianum, Stirligia latifolia, Synaphea petiolaris, Thelymitra crinita, Thysanotus multiflorus* and *Xanthorrhoea preissii*.

FCT 3b: *Corymbia calophylla- Eucalyptus marginata* Woodlands on Sandy Clay Soils
(mean species-richness per 100 m^2 =61.2 spp). (Discussed in Section 5.1.1, number 1 above in comparison with FCT 3a.)

FCT 7: Herb Rich Saline Shrublands in Claypans
(mean species-richness per 100 m^2 =46.6 spp).

This vegetation was usually dominated by *Melaleuca viminea, M. osullivanii, M. cuticularis* or *Casuarina obesa* (or a mixture of these species) and it inhabited the more deeply inundated sumplands (with maximum standing water up to about 30cm in depth) that had a long hydroperiod. The species-richness was evident in the many annuals and geophytes that developed over the annual cycle of inundation and gradual drying of these wetlands from winter to early summer. Many annual and geophytic species were present at low frequency in this FCT including aquatic species (in winter and early spring) and emergent species. These included *Amphibromus nervosus, Aponogeton hexatepalus, Baumea arthrophylla, *Callitriche stagnalis*, *Cotula coronopifolia, Crassula natans, Isoetes muelleri* (Keighery and Tauss, 2008), *Schoenus natans, Wurmbea dioica* subsp. aff. *alba* and *Villarsia submersa.*

Species that were present in 50% or more of the sites sampled in Gibson *et al.* (1994) in this FCT were **Briza maxima,*Briza minor, Centrolepis aristata, *Cicendia filiformis, Cotula coronopifolia,*Hypochaeris glabra, Melaleuca viminea, Philydrella pygmaea, Pogonolepis stricta, Schoenus odontocarpus, Thysantus manglesianus* and *Utricularia multifida.*

FCT 8: Herb Rich Shrublands in Claypans
(mean species-richness per 100 m^2 =52 spp).

This vegetation also occurred in seasonally inundated muddy wetlands but the hydroperiod was shorter in these wetlands than in FCT 7. Dominant shrub species included *Viminaria juncea, Melaleuca viminea, M. osullivanii* or *M. lateritia.* Low shrub species such as *Hypocalymma angustifolium, Acacia lasiocarpa* and *Verticordia huegelii* that were not present in FCT 7 occurred in this vegetation type, along with some aquatic species.

Species that were present in 50% or more of the sites sampled in Gibson *et al.* (1994) in this FCT were **Briza maxima,*Briza minor, Centrolepis aristata, *Cicendia filiformis, *Cyperus tenellus, Drosera glanduligera, Drosera menziesii* subsp. *menziesii, Drosera rosulata, Goodenia micrantha, Haemodorum simplex, Hyalosperma cotula, *Hypochaeris glabra, *Juncus capitatus, Meeboldina cana, Melaleuca viminea, *Monopsis debilis, Schoenus odontocarpus, Utricularia multifida* and *Viminaria juncea.*

FCT 10a: Shrublands on Dry Clay Flats
(mean species-richness per 100 m^2 =53.7 spp).

This FCT occurred on muddy palusplains that had a shallow ferricrete layer. The hydroperiod in these wetlands was short compared with the other three species-rich wetland types (FCT 2, 7 and 8) and aquatic species were not present in this FCT.

Species that were present in 50% or more of the sites sampled in Gibson *et al.* (1994) in this FCT were *Aphelia cyperoides,*Briza minor, Burchardia multiflora, Centrolepis aristata, Centrolepis drummondiana,*Cicendia filiformis, *Cyperus tenellus, Drosera menziesii* subsp. *menziesii, Drosera gigantea, Goodenia micrantha, Hakea sulcata, Kunzea micrantha, *Monopsis debilis, *Parentucellia viscosa, Pericalymma ellipticum, Philydrella pygmaea, Schoenus odontocarpus, Siloxerus humifusus, Stylidium calcaratum, Stylidium repens, Thelymitra antennifera, Utricularia multifida* and *Viminaria juncea.*

FCT 20a: *Banksia attenuata* Woodlands over Species-Rich Dense Shrublands
(mean species-richness per 100 m^2 =67.4 spp).

This vegetation type occurred on sandy soils at Koondoola (on Spearwood Dunes) and Forrestfield (on Southern River landforms). The presence of *Cyathochaeta equitans* was a reliable indicator of this type of vegetation (B.J. Keighery, pers. comm.). This was the most species-rich *Banksia* woodland vegetation of the SCP.

Species that were present in 50% or more of the sites sampled in Gibson *et al.* (1994) in this FCT were *Alexgeorgea nitens, Amphipogon turbinatus, Banksia attenuata, Bossiaea eriocarpa, Burchardia umbellata, Allocasuarina humilis, Conostephium pendulum, Dampiera linearis, Daviesia triflora, Drosera menziesii* subsp. *penicillaris, Eremaea pauciflora, Hemiandra pungens, Hibbertia huegelii, Hypolaena exsulca, Lomandra hermaphrodita, Mesomelaena pseudostygia, Monotaxis grandiflora, Patersonia occidentalis, Petrophile linearis, Philotheca spicata, Scaevola repens, Schoenus curvifolius, Stirlingia latifolia, Stylidium brunonianum, Stylidium piliferum, Synaphea spinulosa* and *Xanthosia huegelii.*

FCT 20b: Eastern *Banksia attenuata* and/or *Eucalyptus marginata* Woodlands
(mean species-richness per 100 m^2 =62.7 spp).

This vegetation type occurred on sandy soils at the base of the Darling Scarp on the Guildford and Forrestfield Formations.

Species that were present in 50% or more of the sites sampled in Gibson *et al.* (1994) in this FCT were *Allocasuarina humilis, Amphipogon turbinatus, Banksia attenuata, Banksia dallanneyi* var. *dallanneyi, Bossiaea eriocarpa, Burchardia umbellata, Conostephium pendulum, Conostylis juncea, Dasypogon bromeliifolius, Hibbertia huegelii, Lomandra hermaphrodita, Pyrorchis nigricans, Mesomelaena pseudostygia, Petrophile linearis, Philotheca spicata, Stirlingia latifolia, Stylidium brunonianum, Stylidium piliferum* and *Xanthosia huegelii.*

5.2 Vegetation Field Survey

In order to compare the MKSEA vegetation with the data available from the literature and assess its conservation significance, the floristic, structural and habitat data from the current survey were analysed in a hierarchical manner, as outlined below.

1. **Vegetation units recorded in the current MKSEA Field Survey.**
   The MKSEA data were first classified and mapped using a simple vegetation structure approach. This provided a preliminary (and purely descriptive) overview of the range of fine-scale vegetation units that were recorded in the MKSEA without attempting to relate the vegetation to any previous classifications.

2. **Vegetation of the MKSEA in comparison to vegetation within the local conservation estate.**
   The fine-scale vegetation units above were then compared to units that have been described and/or mapped previously (at a similar scale) within the Greater Brixton Street Wetlands and in the Clifford Street Bush Forever Site (Marshall, 2000; Government of Western Australian, 2000; VCSRG, 2001, Keighery and Tauss, 2008; Tauss, 2009). This comparison was carried out to determine if there were any vegetation types present in the MKSEA that were not represented locally within the conservation estate.

3. **The conservation significance of the vegetation recorded in the current field survey.**
   The floristic data of the MKSEA were then numerically classified in the context of the SCP database of Gibson *et al.* (1994) to examine the statistical similarity between the vegetation of the MKSEA and the FCTs and TECS of the SCP as defined by Gibson *et al.* (1994). The results of this analysis were then critically reviewed (by considering the limitations of the above approach, the total evidence of floristics, vegetation structure and habitat available from the MKSEA and from other studies of the SCP) to assess the conservation values of the MKSEA vegetation and map these values.

5.2.1 Vegetation units recorded in the current MKSEA field Survey

The MKSEA vegetation data were first classified according to the vegetation structure of the tallest layer (i.e. forest, woodland, mallee, tall shrubs, low shrubs or rushes/sedges) and the dominant species of this layer (e.g. *Corymbia calophylla, Melaleuca rhaphiophylla, Actinostrobus pyramidalis, Melaleuca lateriflora, Banksia telmatiaea, Meeboldina cana*). Further division within the above categories was then made when the understorey included distinctive and unusual, dominant species (e.g. dense *Cyathochaeta teretifolia* sedges) or the understorey was degraded and it was not possible to reliably infer original composition. This provided a simple, first pass overview of the range of fine-scale vegetation units that are present in the MKSEA without attempting to relate the vegetation to any previous classifications. From the data collected in the reconnaissance survey and the 32 sampling quadrats and relevés established within the current MKSEA field study it was possible to define and map 28 vegetation units, at a scale of 1: 2,000, within the MKSEA (Table 5.4). These vegetation units are described below.

Vegetation Unit T1: *Corymbia calophylla* low woodland to low open forest over *Xanthorrhoea preissii* and/or *Kingia australis*, low shrubs that often include *Pericalymma ellipticum, Hypocalymma angustifolium* Mud Habitat Variant (C.Tauss 1850) and *Hakea sulcata,* and an open perennial rush and sedge layer with *Cyathochaeta avenacea, Mesomelaena tetragona* and *Tetraria octandra.*

This unit was in good to very good condition and inhabited palusplains of shallow muddy sand over sandy mud and clay between about 13 m and 16 m AHD. The understorey of this vegetation was in very good condition in a block in Precinct 1 of the MKSEA, where it had been carefully managed to control weeds in the understorey and to exclude fire. On two adjacent blocks the canopy of this vegetation unit was intact, but the understorey was dominated by weeds in some places, probably due to frequent burning. However, there were no highly invasive weeds present in theseblocks that could not be controlled successfully with a moderate management regime that would enable natural regeneration and recruitment of native species from the adjoining very good condition bushland. The large *Corymbia calophylla* trees in this vegetation are important native fauna habitat (for native birds, bats and possums); they provide connectivity of habitat between the forest of the Darling Range and the woodlands of the SCP, and they also have high landscape value.

In several blocks in Precinct 2 of the MKSEA, this vegetation was in good to degraded condition and included floristic components that were not present in the Precinct 1 bushland referred to above, such as the perennial herb *Borya scirpoidea* (that was abundant in the ground layer) and the shrub *Baeckea camphorosmae*. This vegetation appeared to have been lightly grazed and had a mid-dense cover of **Ehrharta calycina* in some parts. The *Corymbia calophylla* woodland here graded into two very unusual vegetation types *viz. Eucalyptus decipiens* mallee (Vegetation Unit M1) and an unusual, species-rich heath (Vegetation Unit SL1) that included floristic elements characteristic of the muddy soil of Vegetation Unit T1 understorey (such as *Hakea ceratophylla*) but also *Conospermum undulatum* (which is usually characteristic of deep sand habitats).

Associates of this vegetation included: *Acacia willdenowiana*, *Astartea scoparia, Baeckea camphorosmae, Banksia dallanneyi* var. *dallanneyi, Banksia littoralis*, *Borya scirpoidea, Bossiaea eriocarpa,*Briza maxima, Calothamnus rupestris*, *Conostylis setigera* subsp. *setigera, Dampiera linearis*, *Dasypogon bromeliifolius, Desmocladus fasciculatus, Drosera glanduligera, *Ehrharta calycina, Gahnia trifida, Haemodorum laxum*, *Hakea ceratophylla, Hakea sulcata*, *Hakea varia, Hypocalymma angustifolium* Mud Habitat Variant (C.Tauss 1850), *Hypolaena exsulca, Juncus pallidus, Kingia australis, Lepidosperma pubisquameum* sens. lat*., Lepyrodia curvescens, Lomandra hermaphrodita, Lyginia imberbis, *Melinis repens, Neurachne alopecuroidea*, *Nuytsia floribunda,*Olea europaea*, *Opercularia vaginata*, **Orobanche minor, *Paspalum dilatatum, Patersonia occidentalis* var. *occidentalis, Pericalymma ellipticum* var. *floridum*, *Philotheca spicata,*Romulea rosea* var. *australis, Schoenus pedicellatus, Schoenus rigens, *Sparaxis bulbifera, Tricoryne elatior, Ursinia anthemoides, Verticordia densiflora* subsp. *densiflora and Viminaria juncea.*

Vegetation Unit T2: *Corymbia calophylla* low open forest over open *Xanthorrhoea preissii* and open *Anarthria laevis - Cytogonidium leptocarpoides* rushes and sedges.

This unit was partly in good condition and inhabited a muddy sand palusplain to gentle slope between about 16m and 18m AHD in Precinct 1 of the MKSEA. It was very similar to Vegetation Type T1 in floristic composition except for the dominance of the two rushes *Anarthria laevis - Cytogonidium leptocarpoides* in the understorey. *Anarthria laevis* and *Cytogonidium leptocarpoides* are both wetland species and are very uncommon on the SCP. There are no other documented occurrences of these species on the SCP in association with *Corymbia calophylla*. Vegetation Unit T2 probably represents vegetation closely related to T1 that was more prevalent in the past on the eastern side of the SCP, but has now been cleared. The large *Corymbia calophylla* trees in this vegetation are important native fauna habitat (for native birds, bats and possums); they provide connectivity of habitat between the forest of the Darling Range and the woodlands of the SCP and they also have high landscape value. The thick understorey in part of this unit is also habitat for Quenda and other fauna.

Associates of this vegetation included: *Acacia willdenowiana*, *Banksia dallanneyi* var. *dallanneyi,, Burchardia umbellata*, *Calothamnus rupestris, Dasypogon bromeliifolius*, **Ehrharta calycina, Hakea varia, Hypocalymma angustifolium* Mud Habitat Variant (C.Tauss 1850), *Jacksonia furcellata*, *Kingia australis, Lepidosperma pubisquameum* sens. lat., **Leptospermum laevigatum, Lyginia imberbis, * Melinis repens*, *Mesomelaena tetragona*, **Paspalum dilatatum, *Pericalymma ellipticum, Philotheca spicata, Schoenus rigens, Tremulina tremula, Verticordia densiflora* var*. densiflora, Verticordia lindleyi* subsp. *lindleyi* and *Watsonia* sp.

Vegetation Unit T3: *Corymbia calophylla* low woodland to low open forest over largely alien understorey.

This unit was mostly in a completely degraded condition and inhabited palusplain between about 10 m and 12 m AHD in Precincts 1 and 3A. It occurred mainly along the road verges, where it had an understorey of alien species, in some places with occasional *Xanthorrhoea preissii* and *Kingia australis* shrubs, the native sedges *Baumea juncea* and *Mesomelaena tetragona* and few other natives. There were several large groves of fine, mature *Corymbia calophylla* trees in these areas (larger than any of the *Corymbia calophylla* trees in BFS 387) that had an understorey dominated by the naturalised alien grasses **Eragrostis curvula* and **Ehrharta calycina.* Several groves of smaller *Corymbia calophylla* that had regrown after clearing were also present in the MKSEA. The large *Corymbia calophylla* trees in this vegetation are important native fauna habitat (for native birds, bats and possums); they provide connectivity of habitat between the forest of the Darling Range and the woodlands of the SCP and they also have high landscape value.

Vegetation Unit T4: *Melaleuca rhaphiophylla – Eucalyptus rudis - Actinostrobus pyramidalis* low open forest to low open woodland.

Associates of this vegetation also included: *Acacia lasiocarpa* var. *lasiocarpa* sens. strict., *Acacia saligna* var. *saligna*, *Acanthocarpus canaliculatus, Alternanthera nodiflora*, *Amphibromus nervosus, Anarthria laevis, Astartea scoparia, Banksia telmatiaea, Baumea juncea, Bolboschoenus caldwellii, Cassytha racemosa, Casuarina obesa, Chaetanthus aristatus*, *Corymbia calophylla*, *Cyathochaeta avenacea, Dichopogon capillipes, Drosera glanduligera, Gahnia trifida, Grevillea thelemanniana, Hakea varia, Hypocalymma angustifolium* Mud Habitat Variant (C.Tauss 1850), *Jacksonia sternbergiana, Juncus pauciflorus, Lepidosperma longitudinale, Lepyrodia glauca, *Lolium multiflorum, Lomandra micrantha* subsp. *micrantha*, *Meeboldina roycei, Melaleuca osullivanii, Melaleuca viminea* subsp. *viminea, *Pennisetum macrourum, Schoenus asperocarpus, Schoenus efoliatus, Schoenus pennisetis, Tetraria octandra, Thysanotus dichotomus, Tricoryne elatior, Triglochin linearis, Trymalium odoratissimum* subsp. *odoratissimum* and *Viminaria juncea*.

This vegetation was part of a complex mosaic fringing channel wetlands in Precinct 3B. The floristic composition and structure of Vegetation Unit T4 varied according to the level and type of disturbance, and hydroperiod (the depth and persistence of standing water or waterlogging experienced by the site). The canopy of this vegetation was dominated by one or more of the following: *Melaleuca rhaphiophylla, Eucalyptus rudis, Actinostrobus pyramidalis, Acacia saligna* or *Melaleuca viminea* subsp. *viminea.*

Melaleuca rhaphiophylla was most abundant in floodplain areas that were inundated in winter. *Actinostrobus pyramidalis* occurred on seasonally-waterlogged soils and was largely absent from frequently burnt areas. The riparian vegetation included flora species (*Trymalium odoratissimum* subsp. *odoratissimum* and *Thysanotus dichotomus*) that are rare on the SCP but are abundant in the Darling Range; water serves as a means for the dispersal of plant propagules of such species from the Darling Range towards the Canning River.

Much of this area has experienced a number of disturbances (including the clearing of native vegetation, the deepening of the channel of the watercourse, the dumping of fill, frequent burning in some areas, grazing and weed invasion). The more disturbed native vegetation fringing Yule Brook had an open canopy over a degraded understorey dominated by dense stands of the naturalized alien grass **Pennisetum macrourum* or **Watsonia meriana* var. *bulbillifera.* Other invasive weeds in degraded parts of this vegetation included patches of **Acacia podalyriifolia, *Allium triquetrum, *Chamaecytisus palmensis* and **Zantedeschia aethiopica.* All of these weeds are probably spread by machinery involved in the excavation of watercourses to reduce local flooding.

The dense scrub, woody litter and the dense grass weeds along watercourses provide good native fauna habitat and form an important fauna corridor from the Darling Range to the Canning River. There were abundant birds noted in the area at the time of the survey and *Isoodon obesulus* (Quenda) diggings were frequent. The native water rat *Chrysomys melanogaster* (Rakali) may also still use this corridor.

Whilst the course of the Yule Brook may have been somewhat straightened and the channel excavated over part of the MKSEA, it is important to note that the long term position of this waterway is clearly indicated by specific native vegetation (as mapped in this survey) and the *surface sediments* mapped in Jordan (1986; see unit MS4 in Figure 6). This pattern of deposition of floodplain sediments along the natural, long term course of Yule Brook indicate that this watercourse has conformed fairly closely for many years to the vicinity of the current channel. However, an investigation of the *deeper sediments* of the area (VCSRG, 2001) has provided evidence of the more extensive meandering of watercourses draining from the Darling Range in this area (such as the current Yule Brook and Bickley Brook) over much longer, geological time frames.

Vegetation Unit T5: *Melaleuca rhaphiophylla – M preissiana.* - low open forest over *Xanthorrhoea preissii* grass trees and *Lepidosperma longitudinale-Cyathochaeta teretifolia* closed sedges.

Common associates of this unit included: **Acacia longifolia, Acacia saligna* var. *saligna,*Amphipogon setaceus, Aphelia cyperoides,*Anagallis arvensis* var. *caerulea*, *Aotus gracillima, Astartea affinis*, *Centrolepis aristata*, **Cicendia filifolia*,*Cortaderia selloana, ,*Eragrostis curvula, Dampiera linearis, Dielsia stenostachya, Gastrolobium ebracteolatum, Hypocalymma angustifolium* Sand Habitat Variant (C.Tauss 1895), *Lepyrodia glauca, Lobelia anceps*, **Lotus subbiflorus*, *Meeboldina roycei*, *Patersonia occidentalis* var. *angustifolia ,*Ricinus communis, *Schinus terebinthifolius, Senecio pinnatifolius* var.

*latilobus, Sphaerolobium vimineum, *Symphyotrichum squamatum, Thysanotus arenarius, Typha* ?*domingensis, *Watsonia meriana* var. *bulbillifera*, *Xanthorrhoea preissii* and **Zantedeschia aethiopica*

Vegetation Unit T5 inhabited a gentle slope underlain by a well developed peat layer and coarse quartz sand. It was a transitional zone between a deep quartz sand dune and a muddy palusplain (i.e. between about 15 m and 17.5m AHD) in Precinct 2. There was a very high water table in this habitat throughout the year (such that the soil surface was waterlogged for most of the year).

The condition of the vegetation in this area was generally in good to very good condition with an intact vegetation structure. However, a number of invasive woody weeds have invaded the wetland and require management before they become more abundant. These weeds are **Acacia longifolia,*Cortaderia selloana,*Ricinus communis* and **Schinus terebinthifolius.*

Vegetation Unit T6: *Melaleuca preissiana* low open forest over *Lepidosperma longitudinale- Schoenus rigens* open sedges and open herbs.

Vegetation Unit T6 inhabited the base of the slope below about 15 m AHD on shallow sand over mud in Precinct 2. This area was waterlogged and remained damp due to seepage from upslope for most of the year.

Common associates of this unit included: **Acacia longifolia, Aotus gracillima, Banksia littoralis, Burchardia bairdiae, Baumea juncea, *Cortaderia selloana,*Eragrostis curvula, Dampiera linearis, Dielsia stenostachya, Drosera gigantea* subsp. *gigantea, *Ricinus communis, *Schinus terebinthifolius, Senecio pinnatifolius* var. *latilobus, Sphaerolobium vimineum, *Symphyotrichum squamatum, Thysanotus arenarius* and **Zantedeschia aethiopica.*

This vegetation was well developed and in good condition in one block in Precinct 2 despite a few large woody weeds. Another occurrence in Precinct 2 had a degraded understorey.

Vegetation Unit T7: *Melaleuca preissiana* low open forest over *Dielsia stenostachya* mid-dense rushes and open herbs.

Common associates of this unit included: *Beaufortia squarrosa, Chamaescilla corymbosa* var. *corymbosa, *Conyza sumatrensis, Drosera heterophylla, Drosera macrantha* subsp. *macrantha*, **Ehrharta calycina, *Gladiolus undulatus*, *Lomandra micrantha* subsp. *micrantha*, *Melaleuca rhaphiophylla, Schoenus rigens, Thysanotus arenarius, Thysanotus manglesianus, Thysanotus thyrsoideus, *Urospermum picroides.*

This vegetation was an unusual unit that was only recorded from one area in the MKSEA (in Precinct 2). It inhabited a dampland where the sandy soil was waterlogged during the winter and early spring only, probably due to sub-surface seepage. Unfortunately there was insufficient access allowed to this wetland by the landowner to characterise this habitat in more detail.

The condition of the vegetation in this area was good although weedy grass species were abundant in parts of the wetland, probably due to frequent burning.

Vegetation Unit T8: *Melaleuca rhaphiophylla* low woodland to low open forest over degraded understorey.

All of the vegetation in the MKSEA that includes a canopy of low *Melaleuca rhaphiophylla* trees and a degraded understorey is this unit. It occurred in a number of areas in Precincts 3A, 2 and 1. On the SCP, *Melaleuca rhaphiophylla* is a key indicator of the seasonally high water tables. In the MKSEA these wetlands were either sumplands, floodplains or paluslopes.

Vegetation Unit T9: *Casuarina obesa - Eucalyptus rudis* low open woodland over *Melaleuca lateritia – Melaleuca viminea - Astartea affinis* patchy mid-dense scrub with patchy *Casuarina obesa -Eucalyptus rudis* low trees over open herbs, grasses, and sedges including **Romulea rosea, Amphibromus nervosus* and *Chorizandra enodis.*

Common associates of this unit included: *Isolepis cernua* var. *setiformis, *Juncus capitatus, Lepyrodia glauca,*Lolium multiflorum, Meeboldina cana, Meeboldina roycei, *Ranunculus muricatus, Triglochin linearis* and *Wurmbea dioica* subsp. aff. *alba.*

This vegetation inhabited a small clay sumpland in Precinct 3B.

The canopy of this wetland was more or less intact but the understorey was somewhat depauperate and dominated by naturalised alien taxa. The rest of the block was completely degraded with a dense cover of **Watsonia meriana* var. *bulbillifera* and **Watsonia marginata*. The block was grazed by several horses but the thick vegetation in the sumpland tended to exclude the horses.

Vegetation Unit T10: *Allocasuarina fraseriana- Eucalyptus todtiana- Banksia menziesii* low woodland over species-rich low shrubs.

This vegetation was one of the most species-rich vegetation types recorded in the MKSEA; it included more than 62 taxa per 100 m^2. Unlike the other species-rich vegetation in the MKSEA, that inhabited muddy palusplains and sumplands, Vegetation Unit T10 inhabited upland areas of sand dunes in the south east of the MKSEA where deep Bassendean Sands overlie the Guildford Formation. This unit occurred in three blocks in Precinct 1. The occurrences of this vegetation unit two of these blocks were in very good to good condition whilst the occurrence the third block was degraded and dominated by invasive woody and grassy weeds. One of the blocks that was in very good condition had the EPBC Listed Threatened Species *Conospermum undulatum*; it had been burnt about a year before the current survey but was regenerating well. The understorey of this bushland was dominated by *Austrostipa compressa*, an annual, native grass. The recruitment of abundant *Austrostipa compressa* after fire is a characteristic of bushland that includes an abundant soil seed bank of native annual species.

Common associates of this unit included: *Acacia willdenowiana, Adenanthos cygnorum, Alexgeorgea nitens, Allocasuarina humilis, Amphipogon turbinatus, Austrostipa compressa, Austrostipa elegantissima*, *Austrostipa pycnostachya*, *Baeckea camphorosmae, Banksia attenuata, Bossiaea eriocarpa, Briza maxima*, **Briza minor, Burchardia umbellata, Comesperma calymega, Conospermum undulatum, Conostylis aurea, Conostylis juncea*, *Corymbia calophylla, Crassula exserta, Cyathochaeta equitans, Dampiera linearis, Dasypogon bromeliifolius*, *Dasypogon obliquifolius, Desmocladus fasciculatus, *Dischisma arenarium, Drosera macrantha* subsp. *macrantha, Drosera stolonifera, *Ehrharta calycina*, **Ehrharta longiflora, *Eragrostis curvula, Eremaea pauciflora* var. *calyptra, Gastrolobium linearifolium, *Gladiolus caryophyllaceus, Gompholobium confertum, Gompholobium tomentosum, Haemodorum paniculatum, Haemodorum spicatum*, *Hakea ruscifolia, Hemiandra pungens, Hibbertia hypericoides, Hybanthus calycinus, *Hypochaeris glabra, Hypolaena exsulca, Jacksonia angulata, Jacksonia floribunda, Johnsonia pubescens, Kunzea glabrescens, Lechenaultia expansa, Lepidosperma scabrum* Eastern Terete Form (B.J. Keighery & N. Gibson 232), *Lepidosperma squamatum* sens. lat., **Leptospermum laevigatum, Levenhookia pusilla, Levenhookia stipitata*, *Lomandra caespitosa, Lomandra hermaphrodita, Lomandra sericea*, *Lyginia barbata, Lyginia imberbis, Mesomelaena pseudostygia, Mesomelaena tetragona, Microtis media*, *Monotaxis grandiflora* var. *grandiflora, Nuytsia floribunda, Patersonia occidentalis* var. *occidentalis,*Pentaschistis aeroides, Phlebocarya ciliata*, *Phlebocarya filifolia, Philotheca spicata, Pimelea sulphurea, Rhodanthe citrina, Scaevola repens* var. *repens, Schoenus caespititius, Schoenus curvifolius, Senecio pinnatifolius* var. *latilobus*, *Siloxerus filifolius, *Sonchus oleraceus, Stirlingia latifolia, Stylidium calcaratum, Stylidium diuroides* subsp. *diuroides, Stylidium piliferum, Stylidium repens, Stylidium schoenoides, Synaphea spinulosa, Thysanotus manglesianus*, *Thysanotus sparteus, Thysanotus thrysoideus, Trachymene pilosa, Tricoryne elatior, Tricoryne tenella, *Trifolium arvense* var. *arvense, *Ursinia anthemoides, Verticordia densiflora* var. *densiflora,*Vulpia fasciculata, *Wahlenbergia capensis*, *Wahlenbergia gracillenta* and *Xanthorrhoea preissii.*

Vegetation Unit T11: *Allocasuarina fraseriana-Banksia menziesii* low open woodland over a degraded understorey.

This unit occurred in Precinct 1 and, less commonly, in Precinct 2. All of the occurrences of this unit in the MKSEA were in a degraded condition probably due frequent fire with a patchy sparse tree canopy and understorey dominated by a mid-dense to dense cover of invasive weeds such as **Ehrharta calycina*, **Eragrostis curvula* and **Leptospermum laevigatum.*

Common associates of this unit included: *Acacia huegelii, Acacia pulchella* var. *glaberrima, Acacia saligna* var. *saligna, Adenanthos cygnorum, Alexgeorgea nitens, Allocasuarina humilis, Arnocrinum preissii, Banksia ilicifolia, Bossiaea eriocarpa, *Briza maxima*, *Burchardia umbellata, Conostylis juncea*, *Dampiera linearis, Dasypogon bromeliifolius*, *Desmocladus fasciculatus, *Dischisma arenarium, *Ehrharta calycina*, **Eragrostis curvula,, Eremaea pauciflora* var. *pauciflora, Eucalyptus todtiana, *Gladiolus caryophyllaceus, Gompholobium tomentosum, Hakea ruscifolia, Hemiandra pungens, Hibbertia hypericoides, Hibbertia*

*racemosa, *Hypochaeris glabra, Jacksonia floribunda, Kunzea glabrescens, Lechenaultia expansa, *Leptospermum laevigatum, Leucopogon conostephioides, Lomandra hermaphrodita, Lyginia barbata, Macrozamia reidlei, Melaleuca seriata*, *Nuytsia floribunda, Patersonia occidentalis* var. *occidentalis, Phlebocarya ciliata*, *Philotheca spicata, Schoenus curvifolius, Scholtzia involucrata, *Sonchus oleraceus, Stirlingia latifolia, Stylidium repens, Thysanotus manglesianus*, **Ursinia anthemoides* and *Xanthorrhoea preissii.*

Vegetation Unit T12: *Eucalyptus marginata - Allocasuarina fraseriana* low woodland over **Leptospermum laevigatum* tall shrubland over a degraded understorey of **Ehrharta calycina - Mesomelaena pseudostygia* open grasses and sedges.

This unit occurred in two blocks in Precinct 1.

Vegetation Unit T13: *Eucalyptus gomphocephala* scattered trees over alien understorey. .

Four very small populations of *Eucalyptus gomphocephala*, with a total of seven large trees, all well over 10 m tall, were recorded near Coldwell Rd, The trees are in Precinct 3B. Large *Eucalyptus gomphocephala* trees were also noted in other parts of the MKSEA where, judging by the configuration of the groves, they were the result of plantings by landowners. However, the Precinct 3B *Eucalyptus gomphocephala* trees appeared to be a natural occurrence as they were associated with sub-surface calcareous material (in drainage ditches adjacent to these trees). The presence of this material was also strong evidence that this area is natural *Eucalyptus gomphocephala* habitat. As such, the *Eucalyptus gomphocephala* in Precinct 3B should be further investigated as a rare occurrence of *Eucalyptus gomphocephala* on Muchea Limestone and thus possibly of high conservation significance.

Vegetation Unit M1: *Eucalyptus decipiens* subsp. *decipiens* mid-dense mallee over **Olea europaea* tall open shrubs, patchy open sedges and mid-dense naturalised alien grasses.

This unit occurred at one location in Precinct 2, on a palusplain with low, outcropping Muchea Limestone. The artesian spring at this site is no longer active, possibly due to human disturbance. The naturalised alien grass **Ehrharta calycina* and the woody calcicole weed **Olea europaea* dominated the understorey. The canopy of *Eucalyptus decipiens* subsp. *decipiens* was, however, more or less intact. The relatively rich assemblage of native sedges, grasses and herbs that is currently present in the understorey of this vegetation would probably regenerate well if the alien grasses were controlled.

Common associates of this unit included: *Acacia saligna* var. *saligna*, *Austrostipa* sp. ,**Asparagus asparagoides*, *Baumea juncea, Conostylis festucacea* subsp. *festucacea*, *Corymbia calophylla, Cyathochaeta avenacea,*Cynodon dactylon,*Ehrharta calycina, Hakea prostrata*, *Lomandra hermaphrodita, Lepidosperma longitudinale*, *Lepidosperma pubisquameum* sens. lat., *Lyginia imberbis*, **Melinis repens, Neurachne alopecuroidea, Nuytsia floribunda, Patersonia occidentalis* var. *occidentalis, Schinus terebinthifolius, Tetraria octandra, Tricoryne elatior* and *Xanthorrhoea preissii.*

Vegetation Unit ST1: *Actinostrobus pyramidalis* tall open shrubs over *Melaleuca seriata, Jacksonia sternbergiana, Melaleuca viminea* and other shrubs.

This vegetation unit occurred in Precinct 3B just south of Yule Brook. It appeared disturbed due to heavy weed invasion but was considered to have good potential for restoration. This area (and other similar areas in the MKSEA along Yule Brook) were once probably thick scrubs, similar to that still found in the floodplain areas adjacent to a tributary of Yule Brook in the University of Western Australia Allison Baird Flora Reserve in Bush Forever Site 387. They are likely to retain species-rich, native soil seed banks and could be restored to thick scrubs given a moderate management input and remediation of the hydrological regime of Yule Brook. Meanwhile, the dense scrub, woody litter and the dense grass weeds in areas like this along Yule Brook provide good native fauna habitat and form part of an important fauna corridor from the Darling Range to the Canning River.

Associates of this vegetation included: *Acacia lasiocarpa* var. *lasiocarpa* sens. strict., *Acanthocarpus canaliculatus, Astartea scoparia, Cassytha racemosa, Cyathochaeta avenacea, Drosera glanduligera, Gonocarpus nodulosus, Hakea trifurcata, Hakea varia, Hypocalymma angustifolium* Mud Habitat Variant (C.Tauss 1850), *Kunzea micrantha* subsp. *micrantha, Lomandra micrantha* subsp. *micrantha*, *Melaleuca incana* subsp. *incana, Melaleuca lateritia, Melaleuca osullivanii, Neurachne alopecuroidea, Schoenus*

asperocarpus, Schoenus pennisetis, Senecio pinnatifolius var. *latilobus, Trymalium odoratissimum* subsp. *odoratissimum* and *Viminaria juncea*

Vegetation Unit ST2: *Viminaria juncea* open scrub over *Lepidosperma longitudinale* mid-dense sedges and *Burchardia bairdiae - Thysanotus arenarius* open herbs.

This vegetation occupied a small area in Precinct 2 in seasonally waterlogged to shallowly inundated peat and humic sand over a shallow layer of coarse muddy sand. Although this area was small, it was distinctive in having an unusual understorey assemblage of sedges and geophytes that did not occur elsewhere in the MKSEA or BFS 387.

Associates of this vegetation included: **Briza minor, Drosera gigantea* subsp. *gigantea*, *Drosera rosulata*, **Hypochaeris glabra* and *Prasophyllum drummondii.*

Vegetation Unit ST3: *Melaleuca rhaphiophylla - Melaleuca viminea- Melaleuca lateritia* open to mid-dense scrub over sparse rushes, sedges and, mainly naturalised alien, grasses. Alien understorey species usually dominant.

This vegetation inhabited shallowly inundated sumplands in Precincts 2 and 3B .

Associates of this vegetation included: *Amphibromus nervosus*,**Asparagus asparagoides, Baumea arthrophylla, Baumea juncea, Chaetanthus aristatus, Chorizandra enodis, *Crassula natans* var. *minus*, *Eremophila glabra* subsp. *chlorella, Gahnia trifida, Halosarcia lepidosperma, *Hesperantha falcata, Hypocalymma angustifolium* Mud Habitat Variant (C.Tauss 1850), *Isolepis cernua* var. *setiformis, *Lolium multiflorum, *Lotus subbiflorus, Melaleuca lateriflora* subsp. *acutifolia, *Sparaxis bulbillifera, Triglochin linearis*, *Villarsia capitata* and *Viminaria juncea.*

Vegetation Unit ST4: *Melaleuca viminea – M. lateriflora – M. brevifolia* open scrub over *Hypocalymma angustifolium- Acacia lasiocarpa* var. *lasiocarpa* sens strict. over species-rich herbs.

This vegetation was very species-rich and inhabited palusplains of muddy sand over a shallow hardpan in Precincts 2 and 3A. It was generally in good to very good condition except for the presence of a number of old, dumped vehicles. The areas in good condition were, however, quite patchy, with areas of understorey invaded by pasture grasses and herbs interspersed with very species-rich areas of native herbs. This vegetation was very species-rich and was also notable in that it included a number of Declared Rare and Priority Flora Species.

Associates of this vegetation included: *Acacia stenoptera, Actinostrobus pyramidalis, Baeckea* sp. Perth Region (R.J. Cranfield 444), *Baumea juncea, Brachyscome pusilla, *Briza minor, *Briza maxima, Caladenia pectinata, Calandrinia* sp. Kenwick (G.J. Keighery 10905), *Calothamnus hirsutus*, *Calytrix breviseta* subsp. *breviseta, Cassytha glabellla*, *Chaetanthus aristatus*., *Centrolepis aristata*.*Centrolepis polygyna*, *Chorizandra enodis, *Cicendia filifolia, Comesperma* aff. *polygaloides, *Crassula glomerata, Diuris laxiflora, Dodonaea ceratocarpa*, **Disa bracteata, Drosera glanduligera, Drosera heterophylla, Drosera macrantha* subsp. *macrantha, Drosera menziesii* subsp. *menziesii, Gahnia trifida, Goodenia micrantha, Goodenia pulchella* sp. Coastal Plain (M. Hislop 634) p.n.,, *Grevillea thelemanniana*, *Haemodorum laxum, Hakea varia,*Heliophila pusilla*, *Hydrocotyle alata*, **Hypochaeris glabra*, *Isolepis stellata, *Juncus capitatus, Lawrencia squamata, Lepidosperma rostratum, Lepidosperma* sp. Kenwick C.Tauss 2598, *Lomandra micrantha* subsp. *micrantha, *Lotus subbiflorus, Microtis media* ,**Monopsis debilis, *Moraea flaccida *Parentucellia latifolia*, **Parentucellia viscosa*, *Phyllangium paradoxum*, *Philydrella pygmaea* subsp. *pygmaea, Podolepis gracilis* sens. lat., *Pogonolepis strictus, Quinetia urvillei, *Romulea rosea, Samolus junceus, Scaevola lanceolata, Schoenus odontocarpus, Schoenus plumosus, Schoenus subfascicularis, Schoenolaena juncea, *Sparaxis bulbifera, Stylidium divaricatum, Tecticornia lepidosperma*, *Thelymitra antennifera*, *Thelymitra vulgaris, Thysanotus manglesianus, Tribonanthes australis*, *Tribonanthes longipetala, Tribonanthes violacea, Triglochin mucronata, Triglochin muelleri, Trithuria bibracteata, *Ursinia anthemoides, Utricularia multifida, Verticordia densiflora* subsp. *densiflora, Verticordia huegelii* var. *huegelii, Verticordia plumosa* var. *brachyphylla, Viminaria juncea and *Vulpia bromioides.*

Vegetation Unit ST5: *Hakea trifurcata – Xanthorrhoea preissii* open scrub over patchy *Hypocalymma angustifolium - Xanthorrhoea preissii* closed heath over mid-dense *Mesomelaena tetragona - Cyathochaeta avenacea* sedges.

This vegetation was species- rich and it inhabited a palusplain of deep muddy sand in Precinct 2. It was generally in good condition except for some small localized areas of rubbish dumping and excavations that had been made many years ago and had now grown over with thick heath and scrub. There was a dense weed infestation on the periphery and part of the central area of this block (mainly **Eragrostis curvula*, **Hyparrhenia hirta* and **Watsonia meriana* var. *bulbillifera*).

Associates of this vegetation included: *Acacia stenoptera, Anarthria laevis, Aphelia cyperoides, *Asparagus asparagoides, Actinostrobus pyramidalis, Baeckea camphorosmae, Baeckea* sp. Perth Region (R.J. Cranfield 444), *Banksia dallanneyi* var. *dallanneyi, Baumea juncea,*Briza minor, Calytrix aurea, Cheilanthes austrotenuifolia, Chordifex sinuosus, Conostylis aculeata* subsp. *preissii, Centrolepis aristata, Dampiera linearis, Desmocladus fasciculatus, Drosera glanduligera, Drosera heterophylla, Drosera neesii* subsp. *neesii, Drosera rosulata, *Ehrharta calycina, *Ehrharta longiflora, Gastrolobium capitatum, Haemodorum laxum, Hypolaena exsulca, Jacksonia floribunda, Kingia australis, Lepidosperma longitudinale,* Lepidosperma *pubisquameum* sens. lat.., *Lomandra caespitosa, Lomandra micrantha* subsp. *micrantha, *Lotus subbiflorus, Neurachne alopecuroidea, Patersonia occidentalis* var. *angustifolia, Pericalymma ellipticum* var. *floridum, Philotheca spicata, Pimelea imbricata* var. *major, Scaevola lanceolata, Schoenus subflavus* subsp. *subflavus, Schoenolaena juncea, Stylidium dichotomum, Stylidium repens, Thelymitra mucida, Tribolium uniolae, Tribonanthes australis, Tricoryne elatior, Tripterococcus brunonis,*Ursinia anthemoides, Verticordia densiflora* subsp. *densiflora* and **Wahlenbergia capensis.*

Vegetation Unit ST6: *Acacia saligna - Actinostrobus pyramidalis - Melaleuca viminea* closed scrub over sparse rushes and sedges.

This vegetation was in good to very good condition and inhabited a muddy floodplain-palusplain adjacent to Yule Brook in Precinct 3B. It had a dense canopy as it was recovering from a fire that had occurred in the vegetation less than five years before the current survey. The dense scrub and moderate woody litter on the site was observed to be very good fauna habitat for native birds and *Isoodon obesulus* (Quenda). This area was similar floristically to the species-rich vegetation on an adjacent block, but it had a closed, taller vegetation structureand was less species-rich in some places. The ecological attributes of these two blocks are complementary and they should be managed as one unit by replanting the small cleared area between them.

Associates of this vegetation included: *Acacia lasiocarpa* var. *lasiocarpa* sens. strict. *Acanthocarpus canaliculatus, Banksia telmatiaea, Baumea juncea, Cassytha racemosa, Chaetanthus aristatus, Cyathochaeta avenacea, Dichopogon capillipes, *Ehrharta calycina, Gahnia trifida, Grevillea thelemanniana, Hypocalymma angustifolium* Mud Habitat Variant (C.Tauss 1850), *Lepidosperma longitudinale, Lepyrodia glauca, Lomandra micrantha* subsp. *micrantha, *Lolium multiflorum, Meeboldina roycei, Melaleuca brevifolia, Melaleuca lateriflora* subsp. *acutifolia, Melaleuca osullivanii, Samolus junceus, Schoenus asperocarpus, Thysanotus dichotomus, Tricoryne elatior, Triglochin linearis, Viminaria juncea, *Watsonia meriana* var. *bulbillifera* and **Watsonia marginata.*

Vegetation Unit SL1: *Hypocalymma angustifolium – Banksia telmatiaea* mid-dense heath over *Cyathochaeta avenacea- Mesomelaena tetragona* open sedges.

This vegetation inhabited a palusplain of muddy sand over sand over sandy mud and calcareous mud (Muchea Limestone) in Precinct 2. It was an unusual, species-rich heath in very good condition that included some floristic elements characteristic of the muddy soil of the understorey of Vegetation Unit T1 (such as *Hakea ceratophylla*), but also *Conospermum undulatum* (which is usually characteristic of deep sand habitats). The weed cover in this vegetation was very low but there were invasive weeds nearby including **Hyparrhenia hirta*. There are no other known occurrences of this type of vegetation in the MKSEA or BFS 387 nor were any found in the literature for elsewhere on the Swan Coastal Plain.

Associates of this vegetation included: *Acacia stenoptera, Acanthocarpus canaliculatus, Amphipogon turbinatus, Andersonia lehmanniana* subsp. *lehmanniana, Banksia dallanneyi* var. *dallanneyi, Boronia crenulata* subsp. *viminea, *Briza maxima, Calectasia grandiflora* subsp. *grandiflora* R.L. Barrett ms, *Calytrix aurea, Centrolepis aristata, Chaetanthus aristatus, Comesperma* aff. *polygaloides, Conospermum*

undulatum, Conostylis setigera subsp. *setigera, Daviesia physodes, Desmocladus fasciculatus, Drosera glanduligera, Drosera menziesii* subsp. *menziesii*, *Drosera macrantha* subsp. *macrantha*, **Ehrharta calycina*,*Gahnia trifida, Goodenia micrantha, Goodenia pulchella* sp. Coastal Plain (M. Hislop 634) p.n., *Grevillea bipinnatifida* subsp. *bipinnatifida, Grevillea thelemanniana, Haemodorum laxum, Hakea ceratophylla, Hakea sulcata*, *Hakea varia*,**Hesperantha falcata, Hibbertia aurea Hypocalymma angustifolium* Mud Habitat Variant (C.Tauss 1850), **Hypochaeris glabra, Laxmannia ramosa* var. *ramosa, Lomandra suaveolens, Lyginia imberbis, Melaleuca seriata, Opercularia vaginata, Patersonia occidentalis* subsp. *occidentalis, Pericalymma ellipticum* var. *floridum*, *Petrophile juncifolia, Petrophile seminuda*, *Philotheca spicata, Scaevola lanceolata, Schoenus odontocarpus*, *Schoenus pedicellatus, Schoenus rigens, Schoenus subfascicularis, Schoenus unispiculatus, *Sparaxis bulbillifera, Stackhousia monogyna* sens. lat., *Stylidium repens, Tetraria octandra*, *Thelymitra crinita, Thysanotus manglesianus, Thysanotus multiflorus, Tribonanthes australis, Trichocline* sp. Treeton (B.J. Keighery & N. Gibson 564), *Tricoryne* aff. e*latior, *Trifolium campestre, Tripterococcus brunonis, Velleia* aff. *trinervis* G.J. Keighery 10429, *Verticordia densiflora* var. *densiflora, Verticordia acerosa* var. *preissii, Viminaria juncea*, *Xanthorrhoea brunonis.*

Vegetation Unit SL2: *Melaleuca seriata - Hypocalymma angustifolium - Kunzea micrantha* mid-dense heath over sparse, species-rich sedges, rushes and herbs.

This vegetation inhabited a palusplain of deep muddy sand over sandy mud in Precinct 2. It was a very species-rich heath (64 taxa per 100 m^2) that was in very good condition. There were invasive weeds nearby (**Gomphocarpus fruticosus* and **Hyparrhenia hirta*) but the dense heath of Vegetation Unit SL2 had not been burnt for many years and included only a few individuals of minor weedy grasses and herbs.

Associates of this vegetation included: *Acacia lasiocarpa* var. *lasiocarpa* sens. strict., *Acacia stenoptera, Acanthocarpus canaliculatus, Actinostrobus pyramidalis, Angianthus preissianus , Aphelia cyperoides, Baeckea* sp. Perth Region (R.J. Cranfield 444), *Banksia dallanneyi* var*. dallanneyi, Borya scirpoidea*,**Briza maxima*, **Briza minor, Centrolepis aristata, *Cicendia filiformis*, *Comesperma* cf. *polygaloides, Chordifex sinuosus* ,**Cyperus tenellus*, **Disa bracteata, Diuris laxiflora, Drosera gigantea* subsp. *gigantea, Drosera glanduligera, Drosera menziesii* subsp. *menziesii*, *Drosera macrantha* subsp. *macrantha*, *Goodenia micrantha, Haemodorum laxum, Haemodorum paniculatum, Hakea candolleana, *Hesperantha falcata, Hydrocotyle alata*, *Hypocalymma angustifolium* Mud Habitat Variant (C.Tauss 1850), *Jacksonia angulata Kunzea micrantha* subsp. *micrantha, Laxmannia ramosa* var. *ramosa, Lepidosperma rostratum, Lepidosperma scabrum* Eastern Terete Form (B.J. Keighery & N. Gibson 232), *Leucopogon strictus, Meeboldina cana*, *Melaleuca seriata, *Monopsis debilis, Neurachne alopecuroidea*, *Patersonia occidentalis* subsp. *occidentalis, Petrophile seminuda*, *Phyllangium paradoxum*, *Philydrella drummondii*, *Podolepis gracilis, Pimelea imbricata* var. *major, Scaevola lanceolata, Schoenolaena juncea, Schoenus odontocarpus*, *Schoenus pennisetis, Schoenus plumosus, Schoenus rigens, Schoenus subflavus* subsp. *subflavus, Schoenus unispiculatus, Stylidium dichotomum, Stylidium calcaratum*, *Stylidium roseoalatum*, *Thelymitra antennifera*, *Thysanotus manglesianus, Tribonanthes australis, Tribonanthes australis* x *brachypetala, Trichocline* sp. Treeton (B.J. Keighery & N. Gibson 564), *Trithuria bibracteata, Utricularia multifida, Verticordia acerosa* var. *preissii*, *Verticordia densiflora* var. *densiflora, Verticordia huegelii* var. *huegelii* and *Viminaria juncea*.

Vegetation Unit SL3: *Acacia lasiocarpa* var. *lasiocarpa - Actinostrobus pyramidalis* mid-dense heath and open, species-rich rushes, sedges and herbs.

This vegetation inhabited a palusplain of shallow muddy sand over sandy mud, coarse muddy sand and calcareous mud in Precinct 3B. The most species-rich area of this vegetation was in very good condition and was dominated by shrubs that re-seeded after a recent fire (*Actinostrobus pyramidalis, Viminaria juncea, and Acacia lasiocarpa* var. *lasiocarpa*), native herbs and grasses. The vegetation structure had been modified but was regenerating well into a dense scrub/heath. It was relatively weed free and resilient against the invasion of weeds that inhabited the more disturbed fringes of this block. There is good potential for the restoration of this entire block to good condition vegetation. Part of the vegetation adjacent to the species-rich area above had been cleared recently (and piles of brush from the clearing were still evident in some places) but was regenerating naturally after the fire. Some of this disturbed area was *Eucalyptus rudis* (Flooded Gum) low open forest with an understorey of *Melaleuca osullivanii* that was re-growing after the fire. **Ehrharta calycina* was the dominant weed (30-50% cover) in the totally degraded area. The only other aggressive weed of the block,**Sparaxis bulbifera,* was sparse (<1% cover) and confined to the degraded area. The weeds could be easily eliminated from the site at present.

Associates of this vegetation included: *Acacia saligna* var. *saligna, Acacia stenoptera, Acanthocarpus canaliculatus, Anigozanthos manglesii* x *bicolor, Anigozanthos viridis* subsp. *viridis, Aphelia cyperoides*, **Arctotheca calendula, Austrodanthonia acerosa*, *Austrostipa compressa*, **Avena barbata*, **Avena fatua, Baeckea* sp. Perth Region (R.J. Cranfield 444), *Banksia dallanneyi* var. *dallanneyi , Banksia telmatiaea, Baumea juncea, Borya scirpoidea, *Briza maxima*, **Briza minor, Caladenia pectinata*, *Caladenia serotina*, *Calandrinia corrigioloides, Calandrinia* sp. Kenwick (G.J. Keighery 10905), *Calothamnus hirsutus*, *Cassytha glabella, Centrolepis aristata, Chaetanthus aristatus, Conostylis festucacea* subsp. *festucacea, *Cotula turbinata, Crassula colorata* var. *acuminata, *Crassula decumbens* var. *decumbens, Cyathochaeta avenacea, Dampiera linearis, Desmocladus fasciculatus, Drosera bulbosa* subsp. *bulbosa, Drosera glanduligera, Drosera heterophylla, Drosera macrantha* subsp. *macrantha, Drosera menziesii* subsp. *menziesii*, *Drosera pallida, *Ehrharta calycina*, *Elythranthera brunonis, *Eragrostis curvula, Eucalyptus rudis, Gahnia trifida, Gompholobium aristatum, Goodenia micrantha, Goodenia pulchella* subsp. Coastal Plain B (M. Hislop 634) p.n., *Grevillea thelemanniana, Haemodorum laxum, Haemodorum paniculatum, *Heliophila pusilla, Hypocalymma angustifolium* Mud Habitat Variant (C.Tauss 1850), *Hypolaena exsulca, *Isolepis marginata, Isotropis cuneifolia* subsp. *cuneifolia, Jacksonia angulata*, *Jacksonia furcellata, Kunzea micrantha* subsp. *micrantha, Laxmannia ramosa* var. *ramosa, *Lolium multiflorum, *Lotus subbiflorus, *Lupinus consentinii, Lyginia imberbis, Melaleuca lateriflora* subsp. *acutifolia, Melaleuca viminea* subsp. *viminea*, **Monopsis debilis, *Moraea flaccida, Neurachne alopecuroidea, Philydrella drummondii, Pimelea imbricata* var. *major, Pogonolepis stricta,*Romulea rosea* var. *australis, *Romulea rosea* var. *communis, Scaevola lanceolata, Schoenus asperocarpus*, *Schoenus rigens*, *Tetraria octandra*, *Tremulina tremula*, *Schoenolaena juncea, Schoenus efoliatus, Schoenus odontocarpus*, *Schoenus pennisetis*, *Schoenus plumosus Schoenus subfascicularis, Schoenus unispiculatus, *Sonchus oleraceus, *Sparaxis bulbillifera, Stylidium roseoalatum, Thysanotus arenarius, Thysanotus manglesianus, Thysanotus multiflorus, Tribonanthes australis, Tribonanthes brachypetala, Tribonanthes longipetala, Tricoryne* aff. e*latior, *Trifolium arvense* var. *arvense, Trithuria bibracteata, Verticordia densiflora* var. *densiflora, Viminaria juncea*, **Vulpia bromoides* and *Xanthorrhoea brunonis.*

Vegetation Unit SL4: *Melaleuca lateriflora – Hypocalymma angustifolium* mid-dense heath over species-rich herbs.

This vegetation was very species-rich and inhabited palusplains of muddy sand over a shallow hardpan Precinct 2. It was generally in good to very good condition except for patchy areas of understorey invaded by pasture grasses and herbs that were interspersed with very species-rich areas of native herbs.

Associates of this vegetation included: *Acacia lasiocarpa* var. *lasiocarpa* sens. strict*., Acanthocarpus canaliculatus, Actinostrobus pyramidalis, Baeckea* sp. Perth Region (R.J. Cranfield 444), *Baumea juncea, Brachyscome pusilla, *Briza minor*, **Briza maxima, Bulbine semibarbata, Burchardia multiflora, Caesia micrantha* sens. lat*., Caladenia pectinata, Calandrinia* sp. Kenwick (G.J. Keighery 10905), *Calothamnus hirsutus*, *Cassytha glabellla*, *Chaetanthus aristatus* , *Centrolepis aristata*, *Centrolepis polygyna*, *Chorizandra enodis*, **Cicendia filifolia, Comesperma* aff. *polygaloides, *Crassula glomerata, Dichopogon preissii*, *Diuris laxiflora, Drosera glanduligera, Drosera heterophylla, Drosera macrantha* subsp. *macrantha, Drosera menziesii* subsp. *menziesii, Drosera rosulata, Gnephosis drummondii*, *Goodenia micrantha, Grevillea thelemanniana*, **Heliophila pusilla*, **Hypochaeris glabra*, **Isolepis marginata, Stoma scapigera, Juncus pauciflorus*, **Juncus capitatus, Lepidosperma rostratum, Lepidosperma* sp. Kenwick (C.Tauss 2598), *Leptoceras menziesii, Leucopogon strictus, Levenhookia pusilla, Lomandra micrantha* subsp. *micrantha, *Lotus subbiflorus, Melaleuca brevifolia, *Moraea flaccida, *Myoporum insulare, Neurachne alopecuroidea*, *Opercularia vaginata, *Parentucellia viscosa*, *Philydrella drummondii, Philydrella pygmaea* subsp. *pygmaea, Podolepis capillaris, Podolepis gracilis* sens. lat., *Pogonolepis strictus, Quinetia urvillei, *Romulea rosea* var. *communis , Samolus junceus*, *Schoenus pennisetis, Schoenus plumosus, Schoenus subflavus* subsp. *subflavus Sporobolus virginicus, Stylidium divaricatum, Stylidium guttatum, Stylidium roseoalatum*, *Thelymitra antennifera*, *Thysanotus manglesianus, Thysanotus tenellus Tribonanthes australis*, **Ursinia anthemoides, Utricularia multifida, Verticordia acerosa* var. *preissii, Verticordia huegelii* var. *huegelii, Verticordia plumosa* var. *brachyphylla* and *Wurmbea dioica* subsp. *alba.*

Vegetation Unit SL5: *Pericalymma ellipticum* mid-dense heath over open, species-rich rushes, sedges and herbs.

Small areas of this vegetation inhabited seasonally waterlogged slopes of humic sand to peaty sand (between seasonally waterlogged or inundated clay flats and low dunes) in Precincts 1 and 2. This vegetation graded upslope into either *Melaleuca preissiana* low woodland and degraded *Banksia menziesii* low woodland or *Corymbia calophylla* low forest.

Associates of this vegetation included: *Banksia littoralis*, *Burchardia bairdiae, Calandrinia* sp. Kenwick (G.J. Keighery 10905), *Drosera nitidula*, *Eutaxia virgata*, *Grevillea pinnatifida* subsp. *pinnatifida, Hydrocotyle diantha*, *Hypocalymma angustifolium* Mud Habitat Variant (C.Tauss 1850), *Juncus caespiticius,*Lotus subbiflorus*, . *Lepidosperma longitudinale, Meeboldina roycei*, *Melaleuca preissiana, Microtis atrata*, *Schoenus asperocarpus, Schoenus discifer*, **Parentucellia viscosa, Patersonia occidentalis* var. *angustifolia, Pimelea imbricata* var. *major, Schoenus rigens, Tremulina tremula, Tribonanthes australis, Verticordia densiflora* subsp. *densiflora, Verticordia lindleyi* subsp. *lindleyi, Viminaria juncea.*

Vegetation Unit SL6: *Hypocalymma angustifolium* and other low, open to mid-dense shrubs over alien understorey. This was a degraded vegetation unit that was probably originally similar to other units such as SL2 or SL3. A number of areas of this vegetation unit in Precinct 2 were interspersed amongst vegetation that was in better condition.

Vegetation Unit SL7: *Tecticornia indica* subsp. *bidens - Tecticornia lepidosperma* low open shrubs over other succulents and naturalised alien grasses and herbs understorey. This was a very degraded vegetation unit that was probably originally similar to ST4. Areas of this vegetation in Precinct 2 were interspersed amongst vegetation that was in better condition.

Vegetation Unit RS1: *Meeboldina cana - Chaetanthus aristatus* mid-dense, species-rich rushes, sedges and open herbs and patchy *Viminaria juncea* tall open shrubs.

This vegetation inhabited muddy floodplains in Precinct 2. It was generally in very good to good condition. There were also some areas where grazing and trampling of soils appeared to have allowed weed invasion and the regrowth was less species-rich.

There were also much smaller, much more degraded stands of this vegetation in Precinct 1.

Associates of this vegetation included: *Acacia lasiocarpa* var. *lasiocarpa* sens. strict., *Acanthocarpus canaliculatus*, *Baeckea* sp. Perth Region (R.J. Cranfield 444), *Angianthus preissianus*, *Baumea arthrophylla, Brachyscome pusilla, Burchardia multiflora*, *Calandrinia* sp. Kenwick (G.J. Keighery 10905), *Centrolepis aristata, *Cicendia filifolia, Drosera gigantea* subsp. *gigantea, Drosera glanduligera*, *Drosera menziesii* subsp. *menziesii* , *Drosera rosulata*, *Drosera tubaestylis*, **Eragrostis curvula,*Ehrharta calycina, Eutaxia virgata, Gahnia trifida, Goodenia micrantha, Goodenia pulchella* sp. Coastal Plain (M. Hislop 634) p.n., *Hakea varia, Hypocalymma angustifolium* Mud Habitat Variant (C.Tauss 1850), *Isolepis cernua* var. *setiformis, Juncus caespiticius, *Juncus capitatus, Lepidosperma rostratum, *Lotus subbiflorus, Meeboldina roycei, Melaleuca lateritia, *Parentucellia viscosa, Pogonolepis stricta*, *Philydrella pygmaea* subsp. *pygmaea, Pimelea imbricata* var. *major*, *Podolepis gracilis* swamp form, **Romulea rosea* var. *australis, Senecio pinnatifolius* var. *latilobus, Scaevola lanceolata, Schoenolaena juncea*, *Schoenus asperocarpus, Schoenus discifer, Schoenus odontocarpus, Schoenus pennisetis*, *Schoenus plumosus*, *Schoenus rigens*, *Sowerbaea laxiflora, Stylidium calcaratum, Stylidium dichotomum*, *Stylidium divaricatum, Tecticornia lepidosperma, Thysanotus arenarius, Tribonanthes australis, Tribonanthes longipetala, Triglochin muelleri, Utricularia multifida, Utricularia inaequalis, Utricularia violacea, Velleia* aff. *trinervis* (G.J. Keighery 10429), *Verticordia acerosa* var. *preissii, Verticordia plumosa* var. *brachyphylla.*

Table 5.4: Classification (by structure and dominant species) of Vegetation recorded in the MKSEA field survey

Map Unit & Total Ha	Vegetation Description	Study Sites (species richness)	Vegetation Condition
Low Woodlands to Low Forests			
T1 3.05	*Corymbia calophylla* low woodland to low open forest over *Xanthorrhoea preissii* and/or *Kingia australis*, low shrubs and *Cyathochaeta avenacea - Mesomelaena tetragona* rushes and sedges.	Sites 17 (31 spp.), 28 (27 spp.)	Good Very good-good

Map Unit & Total Ha	Vegetation Description	Study Sites (species richness)	Vegetation Condition
T2 0.32	*Corymbia calophylla* low open forest over open *Xanthorrhoea preissii* and open *Anarthria laevis- Cytogonidium leptocarpoides* rushes and sedges.	Site 30 (26 spp.)	Good
T3 6.20	*Corymbia calophylla* low woodland to low open forest over alien understorey.	n/a	Degraded
T4 6.90	*Melaleuca rhaphiophylla – Eucalyptus rudis- Actinostrobus pyramidalis* low open forest to low open woodland.	Adj. Sites 1, 2, 5	Degraded, canopy often intact
T5 1.40	*Melaleuca rhaphiophylla – M preissiana* - low open forest over *Cyathochaeta teretifolia* closed sedges.	Site 15 (26 spp.)	Very good
T6 0.68	*Melaleuca preissiana* low open forest over *Lepidosperma longitudinale- Schoenus rigens* open sedges and open herbs.	Site 14-15 Site 13	Good Good
T7 0.86	*Melaleuca preissiana* low open forest over *Dielsia stenostachya* mid-dense rushes and open herbs.	Site 27 (16 spp.)	Good
T8 3.90	*Melaleuca rhaphiophylla- M. preissiana* - low closed forest to low woodland over degraded understorey.	n/a	Degraded understorey
T9 0.18	*Casuarina obesa -Eucalyptus rudis low open woodland.*	Site 3	Degraded
T10 1.90	*Allocasuarina fraseriana- Eucalyptus todtiana- Banksia menziesii low woodland over species-rich low shrubs.*	Site 22 (62 spp.) Site 23 Site 24	Very good Degraded Very good
T11 1.70	*Allocasuarina fraseriana-Banksia spp. degraded low open woodland over aliens.*	Site 25 Site 29	Degraded Degraded
T12 0.19	*Eucalyptus marginata- Allocasuarina fraseriana low woodland over *Leptospermum laevigatum tall shrubland over *Ehrharta calycina- Mesomelaena pseudostygia open grasses and sedges.*	n/a	Good to Degraded
T13	*Eucalyptus gomphocephala scattered trees over alien understorey.*	n/a	Completely Degraded
Mallee			
M1 0.52	*Eucalyptus decipiens* subsp. *decipiens* mallee.	Site 26 (21 spp.)	Degraded
Tall Shrublands			
ST1 3.00	*Actinostrobus pyramidalis* tall open shrubs over *Melaleuca seriata, Jacksonia sternbergiana, Melaleuca viminea* and other shrubs.	Site 1	Degraded
ST2 0.24	*Viminaria juncea* open scrub over *Lepidosperma longitudinale* mid-dense sedges and herbs.	Site 16	Good
ST3 1.20	*Melaleuca rhaphiophylla - Melaleuca viminea - Melaleuca lateritia* open scrub over sparse rushes and sedges and mainly naturalised alien, grasses.	Site 21	Good to Degraded Degraded Degraded
ST4 3.20	*Melaleuca viminea – M. lateriflora – M. brevifolia* open scrub over *Hypocalymma angustifolium - Acacia lasiocarpa* over species-rich herbs.	Site 9 & 10 (51 spp.) Site 20 (19 spp.)	Good to Very good Good
ST5 0.79	*Hakea trifurcata - Xanthorrhoea preissii* open scrub over patchy *Hypocalymma angustifolium- Xanthorrhoea preissii* closed heath over mid-dense *Mesomelaena tetragona- Cyathochaeta avenacea* sedges.	Site 12 (48 spp.)	Good
ST6 2.10	*Acacia saligna- Actinostrobus pyramidalis -Melaleuca viminea* closed scrub over sparse rushes and sedges.	Site 5	Good
Low Shrublands			
SL1 0.53	*Hypocalymma angustifolium –Banksia telmatiaea* mid-dense heath over *Cyathochaeta avenacea- Mesomelaena tetragona* open sedges.	Site 19 (48 spp.)	
SL2 0.65	*Melaleuca seriata - Hypocalymma angustifolium -Kunzea micrantha* mid-dense heath over sparse, species-rich sedges, rushes and herbs.	Site 8 (64 spp.)	Very good

Map Unit & Total Ha	Vegetation Description	Study Sites (species richness)	Vegetation Condition
SL3 0.44	*Acacia lasiocarpa - Actinostrobus pyramidalis* mid-dense heath and open, species-rich rushes, sedges and herbs.	Site 4 (67 spp.)	Very good
SL4 0.42	*Melaleuca lateriflora – M. brevifolia - Hypocalymma angustifolium* mid-dense heath over species-rich herbs.	Site 11 (56 spp.)	Very good
SL5 0.32	*Pericalymma ellipticum* mid-dense heath over open, species-rich rushes, sedges and herbs.	Site 7 (20 spp.)	Good
SL6 1.50	*Hypocalymma angustifolium* and other low, open to mid-dense shrubs over alien understorey.	n/a	Degraded
SL7 0.28	*Tecticornia indica* subsp. *bidens* low open shrubs and other halophytes over alien understorey.	n/a	Degraded
Rushes and Sedgelands			
R-S1 3.1	*Meeboldina cana – Chaetanthus aristatus* mid-dense, species-rich rushes, sedges and open herbs and *Viminaria juncea* tall open shrubs.	Site 6 (35 spp.) Site 13 Site 14 (35 spp.) Site 18 Adj. to Site 28	Very good Good Good Now cleared Good

5.2.2 Vegetation of the MKSEA in comparison to vegetation within the local conservation estate

Many of the vegetation units that were recorded in the current MKSEA survey (T1, T4, T8, T11, ST2, ST3, ST4, ST5, ST6, SL2, SL3, SL4, SL5 and RS1) were similar to those recorded by other workers in BFS 387 (Table 5.4).

A number of vegetation units recorded in the current MKSEA survey (T3, T9, T12, ST1, SL6, and SL7) were relatively degraded units and there were insufficient data to fully evaluate them with regard to previously recorded vegetation in the district. This vegetation was valuable as it included genetic resources, provided habitat for native fauna and could potentially be replanted and form valuable links between areas of high conservation value and wetland buffer zones. The resilience of native vegetation on the eastern side of the Swan Coastal Plain and its potential for regeneration subsequent to appropriate weed control have been shown to be high (Brown *et al*., 2008); therefore, some of the weedy "degraded" vegetation of the MKSEA could, potentially, be restored with appropriate management.

There were, however, seven unusual vegetation types (T2, T5, T6, T7, T10, M1 and SL1) recorded in the current survey of the MKSEA that have not been recorded previously in BFS 387 or in BFS 53. Four of these unusual vegetation units (T5, T6, M1 and SL1) were in sites where calcareous materialwas recorded in this survey in the sediments underlying the sites. The unusual vegetation types recorded in the MKSEA are listed below.

1. **Vegetation Unit T2:** *Corymbia calophylla* low open forest over open *Xanthorrhoea preissii* and open *Anarthria laevis - Cytogonidium leptocarpoides* rushes and sedges. This unit was similar to FCT 3a that has been recorded in BFS 387. It was a Marri low forest located on seasonally waterlogged soils and included many of the floristic indicator species typical of FCT 3a (such as *Kingia australis, Pericalymma ellipticum* and *Philotheca spicata)*. However, the understorey of this vegetation was dominated two native rushes *Anarthria laevis - Cytogonidium leptocarpoides* that are very uncommon on the Swan Coastal Plain. It is most likely to be one the vegetation types that have been almost totally cleared on the ESCP but were part of the group of vegetation types that is represented in Gibson *et al.,* (1994) as FCT 3a.

2. **Vegetation Unit T5:** *Melaleuca rhaphiophylla - M. preissiana* - low open forest over *Cyathochaeta teretifolia* closed sedges. This vegetation was an unusual unit that was only recorded from one area in the MKSEA in association with calcareous sediments. This type of vegetation is not present in BFS 387 or BFS 53 and has not been recorded elsewhere within Bush Forever Sites on the Pinjarra Plain (Government of Western Australian, 2000). It appears to be most similar in floristics and habitat to vegetation recorded in the Bassendean Dunes at the Egerton Mound Spring in Ellenbrook (Government

of Western Australian, 2000) which includes rare invertebrates and is a wetland listed on the Register of the National Estate under the EPBC Act.

3. **Vegetation Unit T6:** *Melaleuca preissiana* low open forest over *Lepidosperma longitudinale - Schoenus rigens* open sedges and open herbs. This vegetation was an unusual unit that was only recorded from one area in the MKSEA, in associationwith calcareous sediment. It is not known in BFS 387 or BFS 53. It is immediately adjacent to Unit T5 and, similarly to it, it is probably of very high conservation significance.

4. **Vegetation Unit T7:** *Melaleuca preissiana* low open forest over *Dielsia stenostachya* mid-dense rushes and open herbs. *Dielsia stenostachya* is a species that is endemic to the SCP in the Perth Metropolitan Region but has not been recorded in BFS 387 or BFS 53. This vegetation was an unusual unit that was only recorded from one area in the MKSEA; it is not known in BFS 387 or BFS 53. This vegetation unit is most similar to Unit T6; it is probably of high conservation significance. The habitat of this vegetation needs to be more fully investigated as the factors maintaining the wetland are not at all clear from the limited investigation that was possible in the current survey.

5. **Vegetation Unit T10:** *Allocasuarina fraseriana- Eucalyptus todtiana- Banksia menziesii* low woodland over species-rich low shrubs. This vegetation included rare or uncommon species such as *Conospermum undulatum*, *Cyathochaeta equitans* and *Dasypogon obliquifolius*; it was extremely rich in species, and it occurred on deep Bassendean Sands over the Guildford Formation. This combination of habitat and vegetation is not present in BFS 387 or BFS 53.

6. **Vegetation Unit M1:** *Eucalyptus decipiens* subsp. *decipiens* mid-dense mallee over **Olea europaea* tall open shrubs, patchy open sedges and mid-dense naturalised alien grasses. This unit occurred on a low mound of Muchea Limestone. *Eucalyptus decipiens* was not found elsewhere in BFS 387 or BFS 53.

7. **Vegetation Unit SL1:** *Hypocalymma angustifolium – Banksia telmatiaea* mid-dense heath over *Cyathochaeta avenacea - Mesomelaena tetragona* open sedges. This vegetation inhabited a palusplain with calcareous mud in a shallow aquifer that is referrable to Muchea Limestone. It was an unusual, species-rich heath that included some floristic elements characteristic of the muddy soil of the understorey of FCT 3a Vegetation Unit T1 (such as *Hakea ceratophylla*), but also *Conospermum undulatum* (which is usually characteristic of deep sand habitats). There are no known occurrences of this type of vegetation in BFS 387 or BFS 53.

8. **Vegetation Unit T13:** *Eucalyptus gomphocephala* scattered trees over alien understorey in some parts of the MKSEA appeared to be natural occurrences of this species associated with sub-surface calcareous material. These trees should be further investigated as rare occurrences of *Eucalyptus gomphocephala* on Muchea Limestone and thus possibly of high conservation significance.

5.2.3 Results of the multivariate analysis of the MKSEA vegetation and assignation of FCTs

The multivariate analysis performed on the MKSEA data against the SCP dataset of Gibson *et al.* (1994) ('the SCP dataset') by Griffin (Appendix C), and assessed against ecological data collected in the current survey suggest some relationships between the MKSEA and FCTs of the SCP (Table 5.5). The relationships described between the MKSEA and FCTs of the SCP (below) should be viewed with caution when attempting to determine the conservation significance of vegetation in the MKSEA. There is little doubt that the vegetation of the sites in the SCP dataset that are the basis of the currently defined Threatened Ecological Communities represent rare, significant and threatened vegetation types. However, as noted in Section 3.4 (Survey Limitations), given the less-than-adequate sample of the SCP vegetation types contained within the SCP dataset, a lack of congruence between the floristic data of survey sites on the eastern SCP, such as the MKSEA, with the SCP dataset of Gibson *et al.* (1994) cannot be interpreted as diminishing the conservation value of the vegetation in the survey area.

The multivariate analysis (Appendix C) conducted on the floristic data collected in the *quadrats* of the MKSEA in combination with the SCP dataset of Gibson *et al.* (1994) ('the SCP dataset'), provided some objective evidence of the occurrence of the three threatened FCTs 3a, 8 and 20a in the MKSEA (Table 5.5, Column 3). The classification dendrogram of the *quadrat only data* ('DEN quads') from the MKSEA provided more unequivocal results than the Nearest Neighbour analysis ('NNB') (Table 5.5, Column 4). The relationships between the *relevés* (that were surveyed in the more degraded areas of the MKSEA) and the SCP dataset in the 'DEN all' classification (Appendix C, Table 2) were less clear. The habitat data collected in the current survey provided additional resources for dealing with some of the shortfalls in the purely floristic approach to vegetation classification that is often used to determine the conservation value of vegetation on the SCP.

The *relevés* (that were surveyed in the more weedy areas of the MKSEA) tended to group preferentially with quadrats of the MKSEA in the 'DEN all' classification rather than with SCP dataset sites (Appendix C, Table 2). This is a common occurrence that has been observed in such analyses that is consistent with the general ecological relationship of distance decay. The similarity indices that were used in the analysis were influenced by both presence and absence of species. Therefore, both a deficit in native species numbers and a surplus of weeds in the MKSEA relevés contributed to decreasing the similarity between MKSEA relevés and SCP dataset sites. The addition of relevé data to quadrat data in the MKSEA (the 'DEN all') analysis resulted in a disruption of the pattern observed between the quadrat data and the SCP data in the 'DEN quads' analysis and did not provide additional insights. Thus, the discussion below is confined mainly to the 'DEN quads' (Table 5.5, Column 3) and 'NNB' (Table 5.5, Column 4) results rather than the 'DEN all' results.

Quadrats 4, 6, 8, 10, 11, 12, 15, 16, 17, 19, 20, 22 and 28 of the MKSEA were sampled in the most species-rich and undisturbed vegetation of the survey area, and Relevés 14, 24 and 26 were analysed with them, as quadrats. All of these quadrats (except 15, 16 and 27, the only three sites with affinities to FCT 11) clustered in the classification of the quadrat data 'DEN quads' with three FCTs of the SCP that are Threatened Ecological Communities (3a, 8 and 20a) (Table 5.5, Column 3). The nearest neighbours for the quadrats of the MKSEA in the NNB analysis were (as expected) other quadrats and relevés from the MKSEA, followed by sites of the SCP dataset from FCTs 3a, 8, 20a and other FCTs. Any ambiguities that were added to the relatively simple 'DEN quads' pattern by the NNB results provided further insights about the MKSEA quadrat sites.

The multivariate analysis of the MKSEA sites against the SCP dataset produced ambiguous results with regard to all MKSEA sites where Muchea Limestone was identified in the stratigraphic or hydrological survey. This is significant as Gibson *et al.* (1994) ('the SCP survey') did not identify any vegetation inhabiting Muchea Limestone as a FCT. Firstly, the SCP survey was limited to publicly owned land and there was no extant native vegetation on limestone outcrops within these lands on the eastern side of the SCP. Secondly, the SCP survey did not investigate habitat in sufficient detail to detect the potential presence of calcareous sediments unless it was a surface outcrop. Thirdly, the SCP survey did not generally include a very representative sample of seasonal wetland sites. Fourthly, the SCP survey used only floristic data to determine clusters of sites. The Muchea Limestone TEC as currently defined (Keighery and Keighery, 1995; English and Blyth, 2001) is not a Floristic Community Type. It is a heterogeneous suite of native vegetation types that inhabit a specific but rare habitat on the eastern SCP.

Consideration of the multivariate analysis summary (Table 5.5, Column 5) with the ecological evidence from the MKSEA survey leads to the inference that six groups (A, B, C, D, E and F) of sites that correspond to FCT 3a, FCT 20a, FCTs 7/8/10a, ML, Degraded Sites and Unassigned Sites occur in the MKSEA. The 32 MKSEA floristic sites and their groups and conservation values are listed in Columns 6a and 6b of Table 5.5, and the groups of FCTs and the sites assigned to them are discussed below.

Group A. FCT 3a

Results

Sites 12, 17, 19, 26 and 28 of the MKSEA clustered with FCT 3a sites of the SCP dataset (Marri-*Kingia* TEC) in 'DEN quads' (Appendix C). The nearest neighbours of most of these sites in 'NNB' (Appendix C) were other sites within this group in the MKSEA or FCT 3a sites in the SCP dataset (such as MUD-4, brick6, brick3, brick5, MUD-5, BRIX-2, brick7, brick8 and waro 06). The nearest neighbours of Site 28 were FTC 3a sites but also included the *Melaleuca preissiana* dampland FCT 4 sites (MODO-1 and FL-1 of the Southern River Vegetation Complex) and card12 (FCT 3b) . The apparent similarity of Site 28 with FCT 4 was probably due to the lack of discrimination in the SCP dataset between the Southern River (sand habitat) form of *Hypocalymma angustifolium* and the Pinjarra Plain form of this taxon that occurred in Site 28 and also the encroachment of *Dasypogon bromeliifolius* into Site 28 (<1% cover) from the sandy area immediately upslope of Site 28.

The exception to the clear clustering of these MKSEA sites with FCT 3a was MKSEA Site 26, for which the nearest neighbour (after MKSEA Sites 17 and 28) was cool 09 (FCT 19), from Lake Cooloongup (a calcareous mud habitat in the Quindalup Dunes), and yarl01 (FCT 3c) from Yarloop. MKSEA Site 26 was dominated by the obligate calcicole species *Eucalyptus decipiens* and was located on a calcareous outcrop.

Site 19 of the MKSEA was located very close to Site 26. The classification and the nearest neighbour analysis unequivocally supported Site 19 as FCT 3a. However, Site 19 was underlain by calcareous mud and had a number of floristic elements that have not been recorded in FCT 3a before, such as *Boronia crenulata* (regionally significant) and *Conospermum undulatum* (Declared Rare Flora). This site lends evidence to the notion that within the Marri-*Kingia* vegetation (that is thought to have been a very common vegetation type on the eastern SCP in the past but has now been critically reduced through the clearing of vegetation) there was, originally, a subtype of vegetation that only occurred on the rare calcareous sediments on the Eastern SCP. This sub-type of vegetation was probably more rare than the generic Marri-*Kingia* unit before clearing of the SCP, and its present extent is obviously extremely limited. Site 19 is the only documented occurrence of this subtype of vegetation in the literature and is thus of high scientific importance. It was thus assigned to the Muchea Limestone TEC (See Group D below). This case illustrates how the current method of defining TECs on the SCP on the basis of floristic data *alone* using Gibson *et al.* (1994) as the floristic benchmark, can be inadequate in accurately assessing the conservation value of the more rare forms of vegetation that are still present on the SCP.

Assignation of FCTS (Table 5.5, Column 6a)

Sites 12, 17 and 28 were thus assigned to FCT 3a on the basis of the floristic analysis.

Site 26 was assigned to the Muchea Limestone TEC on habitat and floristic characteristics; it was clearly a very unusual occurrence on the eastern SCP and part of the Muchea Limestone TEC.

Site 19 remained somewhat unresolved as FCT 3a/ML but clearly of the highest conservation significance.

Site 30 (surveyed after the multivariate analysis was carried out) was also inferred as FCT 3a. Although it contained rush species that were uncommon anywhere on the SCP, it otherwise included many of the floristic elements characteristic of FCT 3a.

Group B. FCT 20a

Results

Sites 22 and 24 of the MKSEA clustered with FCT 20a sites (such as KOON-1, KOON-2, and M53) of the SCP dataset (Species-rich *Banksia* woodland TEC) in 'DEN quads' (Appendix C). The nearest neighbours of these sites in the 'NNB' (Appendix C) were MKSEA Rrelevés 23, 25 and 29, and SCP dataset sites from FCTs 20a, 23a and 20c. MKSEA Sites 22, 23 and 24 were in close proximity to each other and all included *Cyathochaeta equitans* (syn. *Cyathochaeta clandestina* in the SCP survey of Gibson *et al*., 1994) a species that is strongly indicative of FCT 20a on the SCP (B.J. Keighery ,pers. comm.). Sites 22 and 24 were also extremely species-rich, although complete data of the species-richness of Site 24 were not available due to site access problems.

Site 23 was adjacent to Site 22 and was somewhat degraded whilst still retaining sufficient floristic elements (including *Cyathochaeta equitans*) that enabled its recognition as FCT 20a.

Assignation of FCTs (Table 5.5, Column 6a)

Sites 22, 23 and 24 were assigned to FCT 20a on the basis of the floristic analysis.

Sites 25 and 29 were degraded and there was insufficient evidence to assign them to FCT 20a. It appears, from the floristic analysis, that they are more likely to be related to FCT 23a.

Group C. FCTs 7/8/10a

Results

In the classification analysis (DEN quads), Sites 4, 6, 8, 10, 11, 14, 18 and 20 of the MKSEA clustered exclusively with FCT 8 (Species Rich Shrublands in Claypans) sites of the SCP dataset (such as BRIX-1, BRIX-3, ELLEN1-5, MEELON1&2). The nearest neighbours of these sites were generally either other quadrats within the MKSEA, relevés in the MKSEA (1, 3, 5, 9, 13, 18, 21) or FCT 10a sites in the SCP dataset (such as KOOLJ-7, FISH-3, KOOL-6, BULL-8, Yule-5). FCT 7 sites of the SCP dataset including GINGIN-1, YULE-5, BULL-8, were also, more rarely, near neighbours of these sites.

Table 5.5: Floristic Community Types (FCTs) determined in MKSEA study sites

KEY TO FCTs and regional landforms associated with these
FCT 3a (TEC 16): *Eucalyptus* **(***Corymbia***)** *calophylla – Kingia australis* [Marri-*Kingia*] woodlands on heavy soils (Pinjarra Plain)
FCT 6: Weed dominated wetlands on heavy soils (Pinjarra Plain)
FCT 7 (TEC 32): Herb rich saline shrublands in claypans (Pinjarra Plain)
FCT 8 (TEC 33): Herb rich shrublands in claypans (Pinjarra Plain)
FCT 10a (TEC 35): Shrublands on dry clay flats (Pinjarra Plain)
FCT 11: Wet forests and woodlands (Bassendean and Pinjarra Plain)
FCT 12: *Melaleuca teretifolia/Astartea* aff. *fascicularis* shrublands (Bassendean)
FCT 13: Deeper wetlands on heavy soils (Pinjarra Plain and Bassendean)
FCT 17: *Melaleuca rhaphiophylla-Gahnia trifida* seasonal wetlands (Quindalup/Spearwood).
FCT 20a (TEC 1): *Banksia* woodlands over species-rich dense shrublands (Spearwood and Bassendean)
FCT 23a: Central *Banksia attenuata – B. menziesii* woodlands (Bassendean)
FCT S2: Northern *Pericalymma ellipticum* dense low shrublands
not FCT (TEC 11) ML: Shrublands and woodlands on Muchea Limestone (Pinjarra Plain and Bassendean)

1. Sites Q=quadrat R=relevé	2. Vegetation Condition	3. Dendrogram ('DEN quads' from App. C, p. 10, Table 2)	4. Nearest Neighbour Analysis ('NNB' from Appendix C, p. 10, Table 2)	5. Summary from Appendix C	6a. FCT(s) suggested by total evidence	6b. Conservation Value
1R	degraded		?6/8	?6/8	?6/8	
2R	degraded				?	
3R	degraded		13/8	13/8	13/8	
4Q	very good	?8	?3a/10a	?3a/10a	ML	
5R	good		?17	?17	ML	
6Q	very good	?8	10a/?8	10a/?8	7/8	
7R	good			inferred	S2/?10a	
8Q	very good	?8	8/?10a	8/?10a	?8/10a	
9R	good		?8	?8	?8/10a/ML	
10Q	very good	?8	8	8	?8/10a/ML	
11Q	very good	?8	8/7	8/7	?8/10a	
12Q	very good	3a	3a	3a	3a	
13R	good		6	6	?8/10a	
14R	good	?6	?8	?7/8	7/8	
15Q	very good	11	?11/12	?11/12	ML	
16Q	very good	9/11/12	?9/12	?9/12	ML	
17Q	good	3a	3a	3a	3a	
18R	degraded		?8	?8	?8/10a	
19Q	very good	3a	3a	3a	ML/3a	
20Q	good	?8	?12/7	?12/7/8	ML	
21R	good		?17/6	?17/6	ML	
22Q	very good	20a	23a/20	20a/23a	20a	
23R	degraded		6?28	6?28	20a	
24R	very good	20a	20a/?23	20a/?23	20a	

1. Sites Q=quadrat R=relevé	2. Vegetation Condition	3. Dendrogram ('DEN quads' from App. C, p. 10, Table 2)	4. Nearest Neighbour Analysis ('NNB' from Appendix C, p. 10, Table 2)	5. Summary from Appendix C	6a. FCT(s) suggested by total evidence	6b. Conservation Value
25R	degraded		24/23a	24/23a	23a	
26R	good	3a	?3c	?3c	ML	
27Q	good	11/14	??11/6/9	??11/6/9	?	
28Q	very good	3a	?3a/4	?3a/4	3a	
29R	degraded		23b/24	23b/24	23a	
30R	good			inferred	3a	
31R	degraded			inferred	S2/?10a	
32R	good-degraded			inferred	?8/10a	

Note 1: Sites 14R, 24R and 26R went through the multivariate analysis as quadrats, although they are relevés.

Note 2: The colours in Column 6a indicate Groups: A B C D E F

Note 3: The colours in Column 6b indicate, respectively, an EPBC-listed TEC, a WA DEC-listed TEC, or a Degraded FCT &/or FCT 23a (these are the colours used in an FCT map to show the conservation status of the FCTs)

Site 4 was unusual in Group C as its nearest neighbours in the SCP sites were Sites 8, 13 and 10 in the MKSEA and MUD-5 (FCT 3a), Site 11 of the MKSEA, YULE-4 (10a) of the SCP dataset, Sites 1 and 12 of the MKSEA, TWIN-2 (FCT 6) and ELLEN-5 (FCT 8) of the SCP dataset. Site 4 was located in palusplain and the vegetation and was very species-rich and in good to very good condition. It included several calcicole species (*Gahnia trifida, Thysanotus arenarius* and *Tricoryne elatior*) and was underlain by a shallow Muchea Limestone aquifer (Appendix C). The ambiguity associated with Site 4 with regard to the FCTs of the SCP was probably due to the presence of the Muchea Limestone. Other sites in the MKSEA that showed high similarity with Site 4 in the NNB were Sites 8, 10, 11, 12, 13 that also included a numbers of calcicole species (*Gahnia trifida, Melaleuca brevifolia, Samolus junceus, Wilsonia backhousei*) although shallow hardpans at these sites prevented a thorough investigation of the stratigraphy and hydrology.

Sites 5, 6, 14 and 21 of the MKSEA were the sites in Group B that were most similar to the habitat described for FCT 7 in Gibson *et al.* (1994) as they were the sites that had the most persistent standing water in winter and spring. They also included aquatic species and/or emergent macrophytes that are a hallmark of FCT 7 (e.g. *Amphibromus nervosus*, *Baumea arthrophylla*, **Cotula coronopifolia*, **Crassula natans, Lepyrodia glauca, Triglochin linearis*, *Utricularia* spp., *Villarsia capitata*) in or adjacent to the sites surveyed. However, the habitat of these areas in the MKSEA was best described as floodplains (seasonally inundated flats) rather than the sumplands or claypans that are typical of FCT 7.

Site 5 in the nearest neighbour analysis was atypical as it had high similarity to sites at Paganoni Swamp (FCTs 17 and 13 from Spearwood Dunes with Tamala Limestone) in the SCP dataset; Sites 21, 4 of the MKSEA (that both showed evidence of Muchea Limestone); Site 1, another site adjacent to Yule Brook in the MKSEA; and cool-11 (FCT 11, Quindalup Dunes and calcareous mud). The stratigraphy and hydrology of Site 5 was not investigated in detail; however, there were calcicole species in and adjacent to Site 5 (*Casuarina obesa, Gahnia trifida, Melaleuca brevifolia, Samolus junceus, Tricoryne elatior, Wilsonia backhousei)* and small pieces of limestone evident in firebreaks in this area.

Site 21 in the NNB was most similar to Sites 5, 20 and 10 in the MKSEA and PAGA-5 (FCT 17) in Paganoni Swamp (Spearwood Dunes with Tamala Limestone) in the SCP dataset, Site 4 (Muchea Limestone), MTB-5 (FCT 17) and cool-11 (FCT 17 from Spearwood Dunes with Tamala Limestone)) of the SCP. Site 21 was inhabited by the rare calcicole species *Eremophila glabra* subsp. *chlorella* and other calcicoles (*Melaleuca brevifolia* and *Gahnia trifida*) and was adjacent to Site 20 where calcareous material was noted in the shallow sediments.

Sites 8 and 11 of the MKSEA were palusplain areas where a shallow hardpan limited the investigation of sediments and hydrology. Neither of these areas had standing water in winter and spring or aquatic species; the habitats were more akin to those of FCT 10a than FCT 8.

Sites 9, 10 and 20 of the MKSEA were all palusplain areas where a shallow hardpan limited the investigation of sediments and hydrology. None of these areas had standing water in winter and spring or aquatic species; the habitats were more akin to those of FCT 10a than FCT 8. These sites included a number of calcicole species (*Gahnia trifida, Melaleuca brevifolia, Samolus junceus, and Wilsonia backhousei)* that suggested

that they may be underlain by Muchea Limestone. However, Site 20 showed evidence of calcareous material in the shallow sediments.

Sites 7 and 31 were narrow zones dominated by *Pericalymma ellipticum* that were not included in the multivariate analysis because they were thought to be transitional zones between other vegetation units. *Pericalymma ellipticum* dominated shrubs are not uncommon in BFS 387 (Table 4.4) where they occur either as an understorey in FCT 3a or as narrow zones on gentle slopes (as they do in Sites 7 and 31 in the MKSEA) that are flanked on the upland side by low lying *Banksia* woodland (FCT 21c) and downslope by species-rich rush/sedge/herblands of FCTs 7 and 8. MKSEA Sites 7 and 31 were most similar to FCT 10a, as inferred from species lists in Table 12 (Gibson *et al*., 1994).

Assignation of FCTs (Table 5.5, Column 6a)

Sites 4 and 5 were assigned to the Muchea Limestone TEC as this best reflected the total data available for this area.

Sites 6 and 14 were assigned to FCTs 7/8 as apart from their species-richness and the results of the floristic analysis which tended to indicate FCT 8, they were inundated for a lengthy period each spring and they included aquatic species.

Sites 20 and 21 were assigned to the Muchea Limestone TEC as this best reflected the total data available for this area.

Site 18 was cleared shortly after the survey; the floristics indicated FCT 8 or 10a.

Sites 8 and 11 were species-rich with numerous shrubs as well as geophytes, did not include aquatic species and were not inundated (except for short periods after rain). The floristic analysis indicated an affinity with FCT 8 and the ecological data with FCT 10a. These sites were tentatively assigned to FCTs 8/10a.

Sites 9, 10 and 18 were species-rich with annuals and geophytes, did not include aquatic species and were not inundated (except for short periods after rain). The floristic analysis indicated an affinity with FCT 8, the ecological data with FCT 10a and floristic indicator species (except for Site 18) with ML. Sites 9 and 10 were tentatively assigned to FCTs 8/10a/ML pending further hydrogeological investigation.

Sites 7 and 31 were tentatively assigned to FCT 10a, as inferred from species lists in Table 12 (Gibson *et al*., 1994).

From the above, the vegetation of Sites 4, 5 and 20 should be regarded as part of the complex of vegetation types associated with the Muchea Limestone Threatened Ecological Community (EPBC Category Endangered). The other blocks that included sites provisionally assigned to FCTs 7, 8 or 10a require further hydrogeological investigations to determine the Muchea Limestone issue. Pending these investigations, all of the remnant vegetation of Sites 6, 8, 9, 10 and 11 Rd should be protected as representatives of the complex of FCTs (7, 8, 10a) that are part of the mosaic of very species-rich seasonal wetland vegetation of the Guilford Vegetation Complex.

Group D. ML

Results

The MKSEA quadrat sites 15, 16 presented a very ambiguous pattern in relation to the SCP dataset and the vegetation of these sites was also unlike any other vegetation previously recorded in BFS 387 or BFS 53. The investigations in the current survey showed that an active spring (associated with Muchea Limestone) contributed to the maintenance of the wetland and vegetation at Sites 15, 16 and probably to some extent to Site 14. Unlike the other wetlands of the MKSEA that were investigated in this survey and other wetlands of BFS 387 (VCSRG, 2001) the water table of the wetlands at Sites 14 and 15 was constantly high, the area remained waterlogged throughout the year and there was a layer of peat at the ground surface. The understorey of Site 15 was dominated by the sedge *Cyathochaeta teretifolia.* This sedge is rare In the Perth Metropolitan Region this sedge is known from Whiteman Park, Lake Gnangara, Ellenbrook, Bullsbrook, Pinjar, Wanneroo and Muchea but is rare on the Pinjarra Plain and south of the Swan River. It is usually associated with artesian springs or other hydrological settings that are uncommon on the SCP (for an example of such unusual settings see the listing for the Egerton Mound Spring on pages 226-227 in Government of Western Australian, 2000). This species is no longer extant in many locations on SCP where

it was recorded previously (including Bassendean and Midland). There are a number of other regionally significant species in Sites 15 and 16, including *Thysanotus arenarius* (a calcicole species that is an indicator of ML on the Pinjarra Plain), *Burchardia bairdiae, Gastrolobium ebracteolatum, Prasophyllum drummondii, Sphaerolobium vimineum* and *Utricularia inaequalis.*

Assignation of FCTs (Table 5.5, Column 6a)

The vegetation of Sites 15 and 16 should be regarded as part of the complex of vegetation types associated with the Muchea Limestone TEC.

From the data collected in the current survey and the (sometimes ambiguous) trends expressed by the results of the multivariate analysis of these sites against the SCP dataset, Sites 4, 5, 19, 20, 21 and 26 were assigned to the Muchea Limestone TEC (see Groups A and C above).

Sites 8, 9, 10, 11 and 18 were tentatively assigned to FCTs 8/10a pending further hydrogeological investigation of the contribution of Muchea Limestone aquifers to the maintenance of vegetation in these areas (see Group C above).

Group E. Degraded Sites

Results

Sites 1, 3, 25, 29 and 32 were relatively degraded sites. Sites 1 and 3 were wetland sites on Guildford Formation sediments and Sites 25 and 29 were upland sites on Bassendean Sands.

Assignation of FCTs (Table 5.5, Column 6a)

These sites were not reliably assigned to FCTs by the floristic analysis and there was insufficient other evidence to further inform the analysis results. Sites 1 and 3 were probably most similar to Sites 4 and 5 before disturbance.

Sites 25 and 29 were probably not part of FCT 20a but the more common FCT 23a that has been recorded previously in BFS 387 (Government of Western Australian, 2000).

Group F. Unassigned Sites

Results

MKSEA Site 2 was too weedy for assigning it to any FCT, and Site 27 presented a very ambiguous pattern in relation to the SCP dataset. The vegetation of this site was also unlike any other vegetation previously recorded in BFS 387 or BFS 53.

Site 27 was not able to be investigated in as much detail as the other sites due to access problems. There was no evidence of calcareous material at the site (although one calcicole species *Thysanotus arenarius* was recorded) and the water table was relatively low. Unlike Sites 15 and 16 there was no evidence of a well-developed peat layer in this wetland. However, the vegetation recorded at this site had species that were undeniably obligate and facultative wetland species. The unusual wetland vegetation at this site appeared somewhat at odds with the physical conditions at the site.

Assignation of FCTs (Table 5.5, Column 6a)

It was not possible to assign Site 27 to any FCT or TEC. This area requires further hydrogeological investigation to determine the habitat. However, as intact remnant vegetation of the eastern SCP this area has, at least, high regional significance.

Table 5.6: Vegetation of the MKSEA. Summary of Floristic Community Types (FCTs) of the SCP and Conservation Significance

Veg Unit and Location in MKSEA	Vegetation Description	Explanatory Notes
***Eucalyptus (Corymbia) calophylla – Kingia australis* woodlands on heavy soils of the Swan Coastal Plain (FCT 3a). CONSERVATION STATUS: EPBC Endangered**		
T1 Site 17	*Corymbia calophylla* low woodland to low open forest over *Xanthorrhoea preissii* and/or *Kingia australis*, low shrubs and *Cyathochaeta avenacea-Mesomelaena tetragona* rushes and sedges.	Floristic analysis unequivocally assigned this vegetation to FCT 3a. Muchea Limestone is also present throughout this area (see Sites 19 and 26).
T1 Site 28	*Corymbia calophylla* low open forest over *Kingia australis, Xanthorrhoea preissii, Hakea ceratophylla, Pericalymma ellipticum* open shrubs and *Cyathochaeta avenacea-Mesomelaena tetragona* open sedges.	Floristic analysis, Guildford Formation stratigraphy, and high abundance of *Kingia australis* immediately adjacent to sample site all confirm FCT 3a.
T2 Site 30	*Corymbia calophylla* low open forest over open *Xanthorrhoea preissii* and open *Anarthria laevis - Cytogonidium leptocarpoides* rushes and sedges.	Floristic composition indicates this vegetation is part of FCT 3a complex. Uncommon rushes dominating understorey suggest this is an uncommon variant of TEC 3a not surveyed in Gibson *et al.* (1994).
ST5 Site 12	*Hakea trifurcata* open scrub over patchy *Hypocalymma angustifolium- Xanthorrhoea preissii* closed heath over mid- dense *Mesomelaena tetragona- Chordifex sinuosus- Cyathochaeta avenacea* sedges.	Floristic analysis unequivocally assigned this vegetation to FCT 3a. Patchiness observed in this vegetation may be consistent with partial clearing many years ago.
Shrublands and Woodlands on Muchea Limestone of the Swan Coastal Plain. CONSERVATION STATUS: EPBC Endangered		
T5 Site 15	*Melaleuca rhaphiophylla – M. preissiana* low open forest over *Cyathochaeta teretifolia - Lepidosperma longitudinale* closed sedges.	An active spring associated with Muchea Limestone maintains this vegetation; a rare vegetation type that was not sampled in Gibson *et al.* (1994).
T6 Site 14	*Melaleuca preissiana* low open forest over *Lepidosperma longitudinale-Schoenus rigens* open sedges and open herbs.	An active spring associated with Muchea Limestone maintains this vegetation; a rare vegetation type that was not sampled in Gibson *et al.* (1994).
T13	*Eucalyptus gomphocephala* scattered trees over alien understorey.	Associated with Muchea Limestone near Yule Brook; a rare vegetation type that was not sampled in Gibson *et al.* (1994).
M1 Site 26	*Eucalyptus decipiens* subsp. *decipiens* mid-dense mallee.	*Eucalyptus decipiens,* an indicator species on the eastern SCP for Muchea Limestone (Keighery & Keighery, 1995) grows on a low mound of calcareous material confirmed as Muchea Limestone at this site.
SL1 Site 19	*Hypocalymma angustifolium – Pericalymma ellipticum - Banksia telmatiaea* mid-dense heath over *Cyathochaeta avenacea - Mesomelaena tetragona* open sedges.	Floristic analysis assigned this vegetation to FCT3a. Stratigraphic study shows Muchea Limestone at depth and this may account for the structural and floristic variation in the vegetation of this site c.f. that previously described in this TEC
ST3 Site 21	*Melaleuca rhaphiophylla- Melaleuca viminea- Melaleuca lateritia* open scrub over sparse rushes and sedges and naturalised alien grasses.	Ambiguous floristic analysis, a rare calcicole species and presence of limestone traces in sediments indicates this vegetation is probably one of the vegetation types associated with Muchea Limestone.
ST4 Sites 9,10 & 20	*Melaleuca viminea – M. lateriflora – M. brevifolia* open scrub over *Hypocalymma angustifolium- Acacia lasiocarpa* over species-rich herbs.	Ambiguous floristic analysis, a number of calcicole species and the presence of limestone traces in sediments indicate this vegetation is probably one of the vegetation types associated with Muchea Limestone.
SL3 Site 4	*Acacia lasiocarpa - Actinostrobus pyramidalis* mid-dense heath and species-rich open rushes, sedges and herbs.	Analysis indicates possible affinity to three TECs. Stratigraphy and calcicole species present indicates this vegetation is one of the vegetation types associated with Muchea Limestone.
ST6 Site 5	*Acacia saligna - Actinostrobus pyramidalis - Melaleuca viminea* closed scrub.	Surface limestone in places, calcicole species and proximity to Site 4 indicates this vegetation is one of the vegetation types associated with Muchea Limestone.

Veg Unit and Location in MKSEA	Vegetation Description	Explanatory Notes
ST2 Site 16	*Viminaria juncea* open scrub over *Lepidosperma longitudinale* mid-dense sedges and *Burchardia bairdiae – Drosera gigantea open herbs.*	Calcicole species present and proximity to spring with Muchea Limestone indicates this vegetation is one of the vegetation types associated with Muchea Limestone.
***Banksia attenuata* woodlands over species-rich dense shrublands (FCT 20a). CONSERVATION STATUS: Endangered B) ii [W.A.]**		
T10 Sites 22, 23 & 24	*Allocasuarina fraseriana - Eucalyptus todtiana - Banksia menziesii* low woodland over species-rich low shrubs.	High species-richness, floristic analysis and indicator species *Cyathochaeta equitans* all consistent with this FCT.
Herb rich saline shrublands in claypans/Herb rich shrublands in claypans (FCTs 7 or 8). CONSERVATION STATUS: Vulnerable B) [W.A]		
R-S1 Sites 6 & 14	*Meeboldina cana - Chaetanthus aristatus* mid-dense, species-rich rushes, sedges and open herbs and *Viminaria juncea* tall open shrubs.	High species richness of annuals and geophytes, inundated habitat, aquatic species and floristic analysis all consistent with these FCTs.
Shrublands on Dry Clay Flats (FCT10a). CONSERVATION STATUS: Endangered B) ii [W.A]		
SL2 Site 8	*Melaleuca seriata-Hypocalymma angustifolium-Kunzea micrantha* mid-dense heath over sparse, species-rich sedges, rushes and herbs.	Very high species richness including many shrubs, waterlogged habitat, shallow hardpan layer, no aquatic species and floristic analysis indicate this FCT.
SL4 Site 11	*Melaleuca lateriflora –M. brevifolia- Hypocalymma angustifolium* mid-dense heath over species-rich herbs.	Very high species richness including many shrubs, waterlogged habitat, shallow hardpan layer, no aquatic species and floristic analysis indicate this FCT.
Site 7	*Pericalymma ellipticum* mid-dense heath over open, species-rich rushes, sedges and herbs.	Inferred from comparison with floristic composition of this FCT in Table 12 of Gibson et al. (1994).
Miscellaneous Vegetation of Regional Conservation Significance (or not allocated to FCTs)		
T7 Site 27	*Melaleuca preissiana* low open forest over *Dielsia stenostachya* mid-dense rushes and open herbs.	Requires further study of habitat.
T4 Adjacent to Yule Brook	*Melaleuca rhaphiophylla – Eucalyptus rudis- Actinostrobus pyramidalis* low open forest to low open woodland.	Conservation significance as riparian vegetation.
T9 Site 3	*Casuarina obesa -Eucalyptus rudis* low open woodland.	Conservation significance as riparian vegetation.
ST1 Site 1	*Actinostrobus pyramidalis* tall open shrubs over *Melaleuca seriata, Jacksonia sternbergiana, Melaleuca viminea* and other shrubs.	Conservation significance as riparian vegetation.
T8 Small remnants throughout MKSEA	*Melaleuca preissiana – M. rhaphiophylla*-low closed forest to low woodland over degraded understorey.	Conservation significance as vvegetation of CCW/REW wetlands.
T11 Sites 25 & 29	*Allocasuarina fraseriana-Banksia spp. degraded* low open woodland.	FCT 23a on floristic analysis.

6. Wetlands Field Survey

The current wetlands survey built on the foundation provided by the mapping of Hill *et al.* (1996). It enabled the recognition of additional wetlands, geomorphic wetland types and wetland values that were not previously known in the area. It also provided a fine scale management category assessment for all of the wetlands that are mapped as CCW and or REW in DEC (2008a). To complete the wetland assessment required by DEC (2007) for recommendations to amend or modify the SCP Wetlands Dataset, further study is indicated to delineate wetland boundaries more accurately and characterise factors (such as Muchea Limestone aquifers) that maintain wetlands, particularly along the interfaces of the Pinjarra Plain with the Bassendean Dunes. As there are complex stratigraphic/hydrological features and threatened ecosystems in the area, this study should be carried out by specialist wetland scientists with ecological expertise. It should also be at a fine scale that is appropriate to the processes that affect native vegetation and part of an overall plan for determining and restoring the environmental water requirements of the vegetation of the greater area of the alluvial fan and increasing the quality and quantity of the groundwater in the Yule Brook and Bickley Brook catchments.

The MKSEA is part of an alluvial fan complex that forms an almost continuous wetland ecosystem that extends over most of Kenwick and Maddington and has been mapped as about 70 wetlands (palusplains, sumplands or damplands) that are identified under Unique Function Identifiers (UFIs) in the SCP Wetlands Dataset (DEC, 2008a; Table 6.1). Other wetland types (palusplains and floodplains) that are rarer on the SCP have also been described at a finer scale in the vicinity of the MKSEA (VCSRG, 2001). The system for numbering individual wetlands using UFIs in DEC (2008a); Figures 9, 10; Table 6.1) is somewhat artificial in the MKSEA (and other areas of the Pinjarra Plain) as the boundaries of wetlands are not clearly evident in low relief, predominantly wetland landscapes that are underlain by complex stratigraphy. UFI boundaries in such areas are largely artefacts of the various land uses and cadastral boundaries, whereas the natural wetland boundaries are, usually, the interfaces between the wetland landscape of the Pinjarra Plain and any upland areas of low dunes of Bassendean Sands.

From the broadscale mapping of surface sediments and landforms in Kenwick and Maddington (Jordan, 1986; Figure 6) and the climate of the SCP, it could be predicted that the only parts of the MKSEA area that are not waterlogged or inundated in winter would be relatively small areas of dunes. In the project area, such uplands all occur in the broadscale soil type S8 (Figures 6, 11) where deep Bassendean Sands overlie the muddy sediments of the Guildford Formation. Under the Mediterranean climate that is experienced by Gosnells (with a mean rainfall of approximately 838 mm per annum) most of the flat or gently undulating lands of shallow Bassendean Sands over the Guildford Formation (S10), the clayey sands (Sc) and the sandy clays (Cs) of the MKSEA could be expected to be poorly drained. Given appropriate topography, these areas on the eastern SCP readily form palusplains (seasonally waterlogged flats), sumplands (seasonally inundated basins) or damplands (seasonally waterlogged basins), due to the perching of rainwater by shallow aquitards. To database the plethora of wetlands on the SCP, DEC (2008b) has allotted a Unique Function Identifier (UFI) to each wetland. This number usually applies to the full natural extent of the wetland irrespective of cadastral boundaries. An exception to this rule (that applies in the MKSEA) concerns the more extensive wetlands in the dataset (those with an area greater than 70 ha) that are not lakes or sumplands and have been degraded over part of their extent. These are divided into several sections (according to wetland condition) and have a separate UFI for each section. In the MKSEA, although the wetlands in DEC (2008b) are mapped under a total of about 70 UFI numbers, this large number of wetlands is mainly a consequence of the patchy land use history of this area (and subsequent wetland degradation) and not the natural wetland boundaries. In this ecosystem, the individual wetland areas that are mapped under separate UFIs are generally interconnected by such factors as groundwater flow, subsurface water flows along impermeable layers and channelled surface water flows (Perth Groundwater Atlas, 2004; VCSRG, 2001).

The natural wetland boundaries of the MKSEA (including the main boundaries between the wetland landscape of the Pinjarra Plain and the small upland area of the Bassendean Dunes) particularly in the areas that have been cleared of native vegetation, are not sharply marked and are difficult to delineate without detailed hydrogeological studies. This was illustrated in BFS 387, where the wetlands were investigated by VCSRG (2001) using the same principles that they had developed in Hill *et al.* (1996), but at a finer scale.

The stratigraphic sequences (that underlie the superficial sediments that were mapped simply by Jordan in 1986 as S10, Cs and Sc) were found to be complex and varied. Also many factors (groundwater, artesian flow, subsurface seepage etc) apart from rainfall were found to contribute to the recharge and discharge of wetlands in this area (VCSRG, 2001). Thus in some areas of the dunes, (e.g. in the University of Western Australia Allison Baird Flora Reserve), the seasonal waterlogging was found to extend over part of the slopes of dunes and to form paluslopes (seasonally waterlogged slopes). Floodplains (seasonally inundated flats) were also found to be present adjacent to the dunes. The paluslopes and floodplains described in BFS 387 in VCSRG (2001) have not, as yet, been incorporated into the SCP Wetland Dataset. Paluslope wetlands are uncommon in south west Western Australia. Paluslopes have not been characterised in any other areas of the SCP. Floodplains with intact native vegetation are also very uncommon on the SCP as most of these wetlands have been cleared for agriculture or highly modified by drainage works. Both paluslopes and floodplains are represented by areas of intact native vegetation in BFS 387; these wetlands are of high conservation significance.

The primary task of the current survey was to characterise the conservation values in the MKSEA. As intact native vegetation is usually a good proxy for high conservation values on the eastern SCP, the current survey focussed primarily on all of the areas of remnant native vegetation in the MKSEA that could be classed as 'native bushland' according to Government of Western Australia (2000). Each area of native bushland was examined in the reconnaissance survey and most were later sampled in the site-based flora and vegetation study. Many of the sampled sites were also investigated with regard to stratigraphy and hydrology to verify wetland status in the manner recommended by DEC (2007). This approach captured all of the high conservation value wetlands in the MKSEA that are currently assessed as CCW and or REW (DEC, 2008). It also enabled the recognition of some additional wetlands, some wetland types and wetland processes in the MKSEA that are of high conservation value and that were not previously known from Government of Western Australia (2000) or the SCP Wetlands Dataset (DEC, 2008).

The current survey was not intended as a fine scale mapping of the wetland boundaries and a definitive assessment of the management categories of wetlands (in order to submit a case for changes to the SCP Wetlands Dataset DEC or to develop a plan to manage the important wetlands of the area for conservation) but as an overview that reliably identified areas of the highest conservation significance/ecological sensitivity and priorities for further investigation. Similarly, the water monitoring currently commissioned by the City of Gosnells (where the sampling of water levels has been confined to a small number of piezometers spread over a large area) will not be sufficiently intensive to adequately characterise the wetlands of the area to the standard required prior to rezoning and development proposals according to DEC (2007). Due to the complicated stratigraphy, hydrology and biology of the area, further fine-scale wetland studies at a scale and intensity similar to VCSRG (2001) should be carried out to map the main wetland boundaries more accurately and to investigate and analyse the processes that maintain the wetlands. This additional wetland mapping and assessment should be carried out at a scale that will take into account the effect of the drainage measures that are installed on individual landholding blocks in the MKSEA. Implicit in such a study would be an examination of the stratigraphy and hydrology at a scale appropriate to habitat variables that determine native vegetation. It would be most appropriate to carry out such further wetlands work as part of the development of an integrated management plan for remediating the hydrological cycle in the area and the sustainable management of the water resources of Yule Brook, BFS 387, BFS 53 and areas of high conservation significance in the MKSEA.

The wetlands identified and delineated in the current survey, the geomorphic classification and the management category determined for each wetland are presented below in Sections 6.1, 6.2 and 6.3 respectively.

Table 6.1: Summary of wetlands as mapped in DEC SCP Wetlands Dataset 2008b (See Figures 9 and 10)

The MKSEA Precincts below are as per Figure 3 (City of Gosnells Concept Plan, July 2008).

MKSEA Precincts and Study Sites	Wetland UFI	Geomorphic Classification	Management Category
3A	7632	Dampland	MUW
3A	7633	Sumpland	MUW
3B	7634	Palusplain	REW
3A/3B **MKSEA Study Site 4**	7635	Palusplain	REW
3A/3B **MKSEA Study Site 5**	7635	Palusplain	REW
3B	7635	Palusplain	REW
3B	7636	Palusplain	REW
3B	7774	Palusplain	CCW
3B	7776	Palusplain	MUW
3B	7779	Palusplain	MUW
3B **MKSEA Study Sites 20 & 21**	7780	Palusplain	CCW
3B	7781	Palusplain	CCW
3B	7784	Palusplain	CCW
3B	7787	Palusplain	CCW
3B **MKSEA Study Site 32**	7787	Palusplain	CCW
3B **MKSEA Study Site 1**	13362	Palusplain	MUW
3B **MKSEA Study Site 2**	13362	Palusplain	MUW
3B **MKSEA Study Site 3**	13362	Sumpland	MUW
3A/3B	13362	Palusplain	MUW
3B	13362	Palusplain	MUW
2	7645	?Palusplain	?MUW
2	7647	?Sumpland	?REW
2	7774	Palusplain	CCW
2	7782	Palusplain	CCW
2	7783	Palusplain	MUW
2 **MKSEA Study Site 8**	7785	Palusplain	CCW
2	7786	Palusplain	CCW
2	7788	Palusplain	CCW
2	7789	Palusplain	CCW
2	7797	Palusplain	CCW
2	7798	Palusplain	MUW
2	7799	Palusplain	MUW
2 **MKSEA Study Site 7**	7800	Palusplain	MUW
2	7805	Palusplain	MUW
2	8030	Palusplain	MUW
2	8031	Sumpland	CCW
2	8032	Sumpland	CCW
2 **MKSEA Study Site 12**	8033	Palusplain	CCW
2 **MKSEA Study Site 13**	8034	Sumpland	REW
2	8035	Sumpland	CCW
2	8036	Sumpland	REW

MKSEA Precincts and Study Sites	Wetland UFI	Geomorphic Classification	Management Category
2	8038	Sumpland	REW
2	8045	Palusplain	REW
2 **MKSEA Study Site 19**	8046	Palusplain	CCW
2	8047	Dampland	MUW
2	13128, 7637, 7787	Palusplain	CCW
2	13368	Palusplain	CCW
2	13542	Palusplain	MUW
2	13541	Palusplain	MUW
2 **MKSEA Study Site 27**	Not on DEC maps	nil	nil
2	13826	Palusplain	REW
2 **MKSEA Study Sites 14, 15, 16**	13827	Palusplain	CCW
2	14115	Palusplain	MUW
2	14116	Palusplain	REW
2	14117	Palusplain	MUW
2	14118	Palusplain	REW
2	14119	Palusplain	MUW
2	14120	Palusplain	REW
2	14122	Palusplain	REW
2 **MKSEA Study Site 6**	14122	Palusplain	REW
2	14122	Palusplain	REW
2 **MKSEA Study Sites 9 & 10**	14122	Palusplain	REW
2 **MKSEA Study Site 11**	14122	Palusplain	REW
2 **MKSEA Study Sites 17 & 26**	14122	Palusplain	REW
2	14122	Palusplain	REW
1	7961	Sumpland	MUW
1	8048	Palusplain	MUW
1	8049	Palusplain	MUW
1 **MKSEA Study Site 28**	8050	Sumpland	REW
1 **MKSEA Study Site 18**	8051	Sumpland	MUW
1	8052	Palusplain	MUW
1	8053	Sumpland	MUW
1 **MKSEA Study Site 18**	8054	Sumpland	MUW
1	8055	Dampland	MUW
1	12114	Palusplain	CCW
1	12115	Palusplain	MUW
1	12116	Palusplain	CCW
1 **MKSEA Study Sites 30, 31**	13368	Palusplain	MUW
1	13369	Palusplain	MUW
1 **MKSEA Study Site 18**	13369	Palusplain	MUW
1	13369	Palusplain	MUW
1	13999	Palusplain	MUW

6.1 Identification and delineation of wetlands in the MKSEA

The identification and delineation of wetlands relies on the characterisation of the hydrology, hydric soils and vegetation (Hill *et al*., 1996; Tiner,1999) and a general guide for this is provided in DEC (2007). In accordance with these principles, investigations were conducted to distinguish between putative wetland and upland zones in the MKSEA. A limited field survey of the hydrology and shallow stratigraphy of the vegetated wetlands of the MKSEA that are mapped in DEC (2008a) was undertaken in addition to the detailed flora and vegetation study reported above. Obligate and facultative wetland flora plants at each study site in the survey area and elsewhere were noted during the flora and vegetation survey (Appendix D).

In the current survey, the uplands of the MKSEA were found to be either naturally elevated landforms or more low-lying areas where the land surface had been elevated above the high watertable of the surrounding terrain by the importation of sand (or other fill materials). The natural upland areas of the MKSEA were all deep Bassendean Sands. The boundaries between the natural uplands of the area and the wetlands (that were all underlain by muddy sediments of the Guildford Formation or shallow sand over muddy sediments) were subtle in some areas and difficult to map. The locations of these boundaries are provisionally indicated (Figure 11). However, they will require detailed topographic survey and further study of hydrology and stratigraphy to map at a finer scale prior to a final determination of development and buffer zones. There were two main locations of boundaries of this type in the MKSEA.

- In Precinct 2 of MKSEA there was an irregular boundary between the Pinjarra Plain wetlands and the Bassendean Dune uplands that extended obliquely from Tonkin Highway (just south of Brentwood Rd) to Victoria Rd. This was a sensitive boundary in terms of the very high natural conservation values that are located in several areas along this boundary and the wetland processes that still operate along the areas where native vegetation has been cleared.
- In Precinct 1 the boundary above continued along the contact between the Pinjarra Plain wetlands and the Bassendean Dunes and divided this precinct into an upland zone in the north east and a wetland zone in the south-west.

The artificially raised areas throughout the MKSEA were mapped, very approximately, from aerial photographs, as non-wetlands. This mapping was also not a definitive assessment and there was not sufficient access to many properties to verify the location of many areas of fill. This mapping does, however, provide an indication of the scale and pattern of the (largely unregulated) filling of the local wetlands.

There was ample evidence of hydric soils, high water tables and surface and groundwater dependant vegetation indicative of wetland conditions in most of the sample sites representative of the MKSEA in the current survey (Table 6.2). The native vegetation of most of the MKSEA had predominantly obligate wetland species in the areas of shallow sand over Guildford Formation and in areas of clayey sands and sandy clays. Most of the areas mapped as wetlands in the SCP Wetland Dataset (DEC, 2008a) were confirmed as wetlands in the current survey (Figure 11). There was also an additional wetland area identified in the current survey that had not been mapped previously as wetland area in DEC (2008a).

The boundaries between the extensive palusplains and the Bassendean Dune uplands that were mapped in the current survey (Figure 11) differ somewhat from the boundary mapped in the SCP Wetland Dataset (Figures 9 and 10). There was also an additional wetland area identified in the current survey that had not been mapped previously as wetland area in DEC (2008a). To provide the evidence necessary to support a modification of the wetland boundary in the SCP Wetland Dataset (i.e. to more accurately delineate the wetlands in this area prior to any planning decisions), a fine scale hydrogeological study to describe the stratigraphy and the hydrology of the wetlands along the interface of the wetlands and the Bassendean Dunes is recommended. It is likely that Muchea Limestone aquifers in the MKSEA are closely connected to wetlands in BFS 387. The occurrences of Muchea Limestone in the MKSEA (and the catchment areas of the aquifers associated with these occurrences) require further investigation and detailed mapping to understand how these wetlands are maintained and how they interact with the Greater Brixton Street Wetlands. Subsequently, measures can be taken to protect catchment areas, conserve and restore wetlands in the MKSEA and link them via vegetated corridors to bushlands reserved in the Greater Brixton Street Wetlands.

6.2 Geomorphic classification of wetlands in the MKSEA area

The wetlands of the MKSEA were classified in this survey according to the geomorphic system of Semeniuk (1987), in which the hydroperiod and geomorphic features of wetlands were the sole determinants of wetland class (regardless of wetland biota or the factors that maintain the wetland conditions). Most of the existing geomorphic classifications and mapping of the wetlands of the MKSEA in DEC (2008a) were confirmed in the current field survey. From the additional fine-scale data that were collected in the current survey (Appendix D) there were, however, some wetlands (Table 6.2) that may require changes to the current geomorphic classification. If any changes were to be made to the geomorphic classification of wetlands in the MKSEA relative to DEC (2008a), these changes would not affect the wetland management categories of these wetlands. The wetlands involved will require detailed survey of the topography and an appropriately-designed ground and surface water monitoring program in order to compile the data necessary for proposing changes to the SCP Wetlands Dataset. Given the expert resources of wetland specialists to design such a detailed study, a range of pragmatic objectives that could contribute to the remediation of the hydrological regime and better management of the biodiversity of the area, apart from a scientifically accurate classification of the wetlands, could be met by such a study. Some of these objectives could include a characterisation of the processes that have been important in the development of the wetland (and thus a determination of the baseline hydrological regime of these wetlands, prior to the widespread alteration of the catchment) an assessment of the effects of the local drainage scheme on these wetlands and a determination of the environmental water requirements of the biota of the wetlands. In the interim, the recommendations of the current survey may be useful as a preliminary guide to inform the more sustainable management of these wetlands and the biodiversity that many of them support.

The conclusions reached about the geomorphic classification of wetlands in the MKSEA are listed below.

a. Palusplains that are mapped in DEC (2008b) where no change in geomorphic classification is recommended from the current survey

   Most of the study sites surveyed in the MKSEA (Sites 1, 2, 4, 7, 8, 9, 10, 11, 12, 13, 17, 18, 19, 20, 26, 28, 30, 31 and 32) were located on gently sloping to gently undulating plains that were underlain by shallow aquitards and were waterlogged in the early spring of 2007 and 2008 (Table 6.2). These areas were all mapped as palusplains in DEC (2008b) and were confirmed as palusplains in the current field survey.

   Sites 1, 2 and 4 are located adjacent to Yule Brook and were floodplains before the brook was excavated in response to the greater volume of surface flow that was initiated by clearing in the catchment area and the need to increase the conveyance of this storm water (and water drained from superficial aquifers by drains) via Yule Brook towards the Canning River. These floodplain areas should be restored.

b. Palusplains that are mapped in DEC (2008b) where a change of classification to floodplain may be considered

   A few of the study sites surveyed in the MKSEA (Sites 3, 5, 6, 14, 16 and 21) were located on gently undulating plains (that occasionally included a few very small basins or channels). All of these areas were shallowly inundated in early spring of 2007 and 2008. These areas were all mapped as palusplains in DEC (2008b) but were considered to be floodplains on the data obtained in the current field survey.

   Sites 3, 5 and 21 are located adjacent to Yule Brook and were probably inundated for longer and, at times, experienced higher standing water levels that at present. The vegetation of these floodplain areas should be regenerated as part of a comprehensive plan to restore Yule Brook as a living stream. Sites 6, 14 and 16 are located at the base of sand dunes and the wetlands there are probably partly maintained by seepage from the base of these dunes. These wetlands are currently drained by excavated channels that export water downslope to Yule Brook via Lot 106 Wanaping Rd or via Brentwood Rd and a drain in the University of Western Australia Allison Baird Flora Reserve.

   These wetlands require protection by the reservation of an appropriate buffer zone upslope from them in the dunes that should be revegetated and kept free of all development and infrastructure. The stormwater from any developments upslope from these wetlands should be infiltrated at source to maintain seepage

onto the floodplains below. The drains downslope from these floodplains should be redesigned to allow the infiltration into the groundwater and nutrient stripping by vegetation in extensive but shallow, vegetated swales that mimic the original floodplains of the area.

c. Palusplain mapped in DEC (2008b) where a change of classification to paluslope may be considered

Site 15 of the MKSEA study was located on a gentle slope that was mapped as a palusplain in DEC (2008b), but it was considered to be a paluslope on the data obtained in the current field survey. This is the most well developed peat paluslope that has been identified locally and requires further study and careful management to conserve its significant natural values.

d. Upland mapped in DEC (2008b) where a change of classification to dampland may be considered

Site 27 of the MKSEA study was located in a shallow basin and was seasonally waterlogged. This area was not mapped as part of a wetland in DEC (2008b) but was considered to be a dampland on the data obtained in the current field survey. The hydrological factors maintaining this wetland are not clear and need to be investigated in detail in order to manage the surrounding areas in a manner that is compatible with the conservation of this wetland.

e. Sumpland mapped in DEC (2008b) where a change of classification to palusplain may be considered

UFI 8050 is mapped in DEC (2008b) as a sumpland. The area where this wetland is located is the lowest lying area in Precinct 1 and there is obviously a high watertable in this area (probably due to seepage from the base of the adjoining dunes of Bassendean Sands onto the Pinjarra Plain surface in the vicinity of UFI 8050. There are small sumplands in this area.However, these sumplands appear to have been excavated by landowners for use as ornamental ponds, and the fringing vegetation is degraded to completely degraded. The sumplands are interconnected by excavated channels to two drains (one of which conveys water north via BFS 387 to Yule Brook, and the other west to Bickley Brook).

The current investigation showed that the vegetated area of UFI 8050 is a palusplain (seasonally waterlogged flat). It comprised *Corymbia calophylla* low forest over *Kingia australis* and mid-dense low shrubs in which about half of the species were obligate wetland plants.

As with other areas of the MKSEA where there is a boundary between the Bassendean Sands and the Pinjarra Plain, this area requires hydrogeological study to accurately map the wetland to define an appropriate buffer zone above the wetland and to develop a plan to restore the hydrological regime in this area.

f. Creeks that were not indicated in DEC (2008b)

There was a small watercourse mapped in the current survey that extended from the UFI 7632 dampland to Yule Brook via UFI 7635. Part of the upper reaches of this creek were modified into an excavated drain. However, the creek retained its natural form over much of its course.

There was also a drain that extended from the UFI 7633 sumpland to Yule Brook via Coldwell Rd. This drain was aligned along the route of a pre-existing creek in the area.

A drain north-west of wetland UFI 7800 was also probably aligned along the route of a pre-existing creek in the area.

g. Uplands where no changes to the DEC (2008b) classification were recommended in the current survey

MKSEA Sites 22, 23, 24, 25 and 29 were located in dunes of deep, well-drained Bassendean Sands. These areas were not mapped as wetlands in DEC (2008b), which was confirmed in the current field survey.

Table 6.2: MKSEA Study sites and their wetland identification

Site No.	1. Hydroperiod and Water Table (WT) Relative to Ground Surface 2. Landform	Stratigraphy	Facultative & Obligate Wetland Taxa 1. F (as % total site flora) 2. O (as % total site flora)	Wetland Criteria of Site 1. Hydric soils 2. Hydrology 3. Wetland taxa (O+F % of Total site flora)	UFI and Wetland Type 1. Classification in SCP Wetlands Dataset 2. Classification in Current Survey
Site 1	1. Surface waterlogged in spring. 2. Flat.	Shallow muddy quartz sand – sandy mud perches rainwater. (Deeper sediments not investigated)	1. 59% 2. 34%	1. Hydric soils: shallow aquitard. 2. Hydrology: waterlogged surface in winter, previously flooded by Yule Brook in winter. 3. Vegetation dominated by wetland taxa (93% of taxa are O or F wetland taxa).	1. UFI 13362 Palusplain 2. Palusplain
Site 2	1. Surface waterlogged in spring except where artificial fill has been dumped. 2. Flat.	Shallow muddy quartz sand – sandy mud perches rainwater. (Deeper sediments not investigated)	Mostly naturalised and planted aliens except riparian vegetation which is like Site 1	1. Hydric soils: shallow aquitard. 2. Hydrology: waterlogged surface in winter where sand fill has not been dumped, previously flooded by Yule Brook in winter. 3. Vegetation dominated by wetland taxa at edge of Yule Brook.	1. UFI 13362 Palusplain 2. Palusplain
Site 3	1. Inundated to about 30 cm in spring. 2. Small basin within a flat.	Shallow sandy mud perches rainwater. (Deeper sediments not investigated)	1. 21% 2. 53%	1. Hydric soils: shallow aquitard. 2. Hydrology: inundation. Whole area previously flooded by Yule Brook in winter. 3. Vegetation dominated by wetland taxa (74% of taxa are O or F wetland taxa).	1. UFI 13362 Palusplain 2. Palusplain/ sumpland
Site 4	1. Waterlogged at surface in spring. Deeper aquifer at about -145 cm. 2. Flat.	Muddy quartz sand over sandy mud (perches rainwater) over coarse, gravelly-muddy sand, over calcareous mud.	1. 43% 2. 36%	1. Hydric soils: shallow aquitard, calcareous mud at depth. 2. Complex hydrology: waterlogged surface, also shallow confined aquifer. Previously flooded by Yule Brook in winter. 3. Vegetation dominated by wetland taxa (79% of taxa O or F)	1. UFI 7635 Palusplain 2. Palusplain
Site 5	1. Standing water up to about 0.5 m in places, flooded by Yule Brook and a tributary of Yule Brook that drains part of Precinct 3. 2. Mosaic of flats, shallow channels and basins.	Shallow sandy clay. (Deeper sediments not investigated)	1. 47% 2. 41%	1. Hydric soils: shallow aquitard. 2. Complex hydrology: inundated and waterlogged areas in spring, maintained by several sources 3. Vegetation dominated by wetland taxa (88 % of taxa O or F)	1. UFI 7635 Palusplain 2. Floodplain
Site 6	1. Shallow standing water in spring approx +5cm max., deeper near Bickley Rd (except where sand fill has been dumped near road). Shallow sandy clay perches rainwater. Wetland partly maintained by seepage from adjacent dune and possibly other factors. 2. Flat.	Shallow sandy clay over hardpan at -80cm.	1. 16% 2. 81%	1. Hydric soils: shallow aquitard. 2. Complex hydrology: surface inundated in spring due to perching, seepage and possibly other factors 3. Vegetation dominated by wetland taxa (97% of taxa O or F)	1. UFI 14122 Palusplain 2. Floodplain

Site No.	1. Hydroperiod and Water Table (WT) Relative to Ground Surface 2. Landform	Stratigraphy	Facultative & Obligate Wetland Taxa 1. F (as % total site flora) 2. O (as % total site flora)	Wetland Criteria of Site 1. Hydric soils 2. Hydrology 3. Wetland taxa (O+F % of Total site flora)	UFI and Wetland Type 1. Classification in SCP Wetlands Dataset 2. Classification in Current Survey
Site 7	1. Waterlogged in spring. 2. Flat to gentle slope.	Peaty quartz sand over sandy clay (Deeper sediments not investigated)	1. 14% 2. 76%	1. Hydric soils: peaty sand over shallow hardpan. 2. Complex hydrology: surface waterlogged in spring due to perching, seepage and possibly other factors. 3. Vegetation: dominated by wetland taxa (90% of taxa O or F).	1. UFI 7800 Palusplain 2. Palusplain
Site 8	1. Surface waterlogging in spring. 2. Flat.	Muddy quartz sand over muddy sand with gravel, mottles from -60 cm, over sandy mud. Hardpan at-130cm.	1. 37% 2. 47%	1. Hydric soils: shallow aquitard and mottling. 2. Hydrology: waterlogged in spring. 3. Vegetation dominated by wetland taxa (84% of taxa O or F)	1. UFI 7785 Palusplain 2. Palusplain
Site 9	1. Surface waterlogging in spring. 2. Flat.	Muddy-sand over sandy mud at -30 and hardpan at -50cm.	1. 31% 2. 53%	1. Hydric soils: shallow aquitard. 2. Hydrology: waterlogged surface in winter. 3. Vegetation dominated by wetland taxa (84% of taxa O or F)	1. UFI 14122 Palusplain 2. Palusplain
Site 10	1. Surface waterlogging in spring. 2. Flat.	Muddy quartz sand with mottles at -30cm, layers of sandy mud and muddy sand over quartz sand from -180 cm and hardpan at -250cm.	1. 39% 2. 48%	1. Hydric soils: shallow aquitard. Complex stratigraphy. 2. Complex hydrology: waterlogged surface in winter. 3. Vegetation dominated by wetland taxa (87% of taxa O or F)	1. UFI 14122 Palusplain 2. Palusplain
Site 11	1. Surface waterlogging in spring. 2. Flat.	Muddy quartz sand over hardpan at -60cm.	1. 39% 2. 41%	1. Hydric soils: shallow aquitard. 2. Hydrology: waterlogged surface in winter. 3. Vegetation dominated by wetland taxa (80% of taxa O or F).	1. UFI 14122 Palusplain 2. Palusplain
Site 12	1. Surface waterlogging in early spring and WT at about -110 in late spring. 2. Flat.	Shallow peaty, quartz sand over muddy sand, hardpan at about -120cm.	1. 56% 2. 21%	1. Hydric soils: peaty sand, mottling, shallow aquitard. 2. Hydrology: waterlogged surface in winter. 3. Vegetation dominated by wetland taxa (77% of taxa O or F)	1. UFI 8033 Palusplain 2. Palusplain
Site 13	1. A mosaic of surface waterlogged areas and some smaller areas of inundation. Not mapped in detail. 2. Flat.	Shallow sandy mud perches rainwater. (Deeper sediments not investigated)	1. 29% 2. 50%	1. Hydric soils: shallow aquitard. 2. Hydrology: waterlogged/or shallowly inundated in spring. 3. Vegetation dominated by wetland taxa (79% of taxa O or F)	1. UFI 8034 Palusplain 2. Palusplain
Site 14	1. Shallow standing water in spring approx +5cm max., perched rainwater. Wetland partly maintained by rainfall, seepage from dune and flow from spring. Requires further study to manage values sustainably. 2. Flat.	Peaty muddy sand to hardpan at -30cm.	1. 32% 2. 51%	1. Hydric soils: peaty, muddy aquitard. 2. Complex hydrology: surface inundated in spring due to perching of rainfall, seepage from dune and flow from spring. 3. Vegetation dominated by wetland taxa (83% of taxa O or F)	1. UFI 13827 Palusplain 2. Palusplain-floodplain

Site No.	1. Hydroperiod and Water Table (WT) Relative to Ground Surface 2. Landform	Stratigraphy	Facultative & Obligate Wetland Taxa 1. F (as % total site flora) 2. O (as % total site flora)	Wetland Criteria of Site 1. Hydric soils 2. Hydrology 3. Wetland taxa (O+F % of Total site flora)	UFI and Wetland Type 1. Classification in SCP Wetlands Dataset 2. Classification in Current Survey
Site 15	1. Surface waterlogged all year, WT to -25 cm in late spring. Wetland maintained by rainfall, seepage from dune and flow from spring. Requires further study to manage values sustainably. 2. Gentle slope.	30cm of peat over peaty sand over coarse muddy quartz sand at about -80.	1. 29% 2. 54%	1. Hydric soils: deep layer of peat and peaty sand. 2. Complex hydrology: surface waterlogged due to rainfall, seepage from dune and flow from active ML spring. 3. Vegetation dominated by wetland taxa (83% of taxa O or F)	1. UFI 13827 Palusplain 2. Paluslope
Site 16	1. Surface waterlogged in spring. Wetland partly maintained by rainfall, seepage from dune and flow from spring. Requires further study to manage values sustainably. 2. Flat.	Sandy peat over peaty sand and muddy sand, hardpan at -80cm.	1. 22% 2. 67%	1. Hydric soils: sandy peat, peaty sand and shallow aquitard. 2. Hydrology: waterlogged and sometimes shallowly inundated in late winter. 3. Vegetation dominated by wetland taxa (89% of taxa O or F).	1. UFI 13827 Palusplain 2. Floodplain
Site 17	1. Surface waterlogging in spring 2. Flat.	Slightly muddy, quartz sand, muddy, quartz sand, sandy mud, cream carbonate mud at -60cm, hard pan at -105 cm	1. 48% 2. 13%	1. Hydric soils: shallow aquitard, carbonate mud. 2. Hydrology: waterlogging in spring due to perched rainwater. 3. Vegetation dominated by wetland taxa (61% of taxa O or F).	1. UFI 14122 Palusplain 2. Palusplain
Site 18	1. Surface waterlogging in spring 2. Flat.	Muddy, quartz sand, mottled at -70cm, hard pan at -160cm	1. 22% 2. 65%	1. Hydric soils: mottling and shallow aquitard. 2. Hydrology: waterlogged in spring due to perched rainfall 3. Vegetation dominated by wetland taxa (87% of taxa O or F).	1. UFI 13369 Palusplain 2. Palusplain
Site 19	1. Surface waterlogged in spring. WT in late spring at -140 cm. 2. Flat.	Quartz sand over muddy, quartz sand with calcareous nodules, sandy mud, cream carbonate mud from -80cm to -220cm over non –calcareous mud.	1. 40% 2. 31%	1. Hydric soils: shallow aquitard, calcareous mud attributable to Muchea Limestone. 2. Hydrology: waterlogged in spring and deeper (confined) aquifer. 3. Vegetation dominated by wetland taxa (71% of taxa O or F).	1. UFI 8046 Palusplain 2. Palusplain
Site 20	1. Surface waterlogged in spring. 2. Flat.	Muddy sand, grey sandy mud with white (weakly calcareous) nodules from 30-40cm, cream mud (weakly calcareous) hardpan at -40cm.	1. 47% 2. 32%	1. Hydric soils: shallow aquitard, calcareous nodules. 2. Hydrology: waterlogging in spring 3. Vegetation dominated by wetland taxa (79% of taxa O or F).	1. UFI 7780 Palusplain 2. Palusplain
Site 21	1. Surface waterlogged to shallowly inundated in spring. 2. Flat.	Shallow sandy mud over mud. (Deeper sediments not investigated).	1. 45% 2. 44%	1. Hydric soils: shallow aquitard calcareous nodules. 2. Hydrology: inundation in winter. 3. Vegetation dominated by wetland taxa (89% of taxa O or F).	1. UFI 7780 Palusplain 2. Floodplain
Site 22	1. WT in late spring below -300cm. 2. Dune.	Humic quartz sand, over grey, brown, pale yellow, cream and pale orange quartz sand with ferruginous nodules to -300.	1. 26% 2. 0% i.e. Vegetation dominated by upland taxa	1. None. 2. None. 3. 26%	Not wetland

Site No.	1. Hydroperiod and Water Table (WT) Relative to Ground Surface 2. Landform	Stratigraphy	Facultative & Obligate Wetland Taxa 1. F (as % total site flora) 2. O (as % total site flora)	Wetland Criteria of Site 1. Hydric soils 2. Hydrology 3. Wetland taxa (O+F % of Total site flora)	UFI and Wetland Type 1. Classification in SCP Wetlands Dataset 2. Classification in Current Survey
Site 23	1. No waterlogging or inundation observed. 2. Dune.	Quartz sand (Deeper sediments not investigated).	1. 25% 2. 0% i.e. Vegetation dominated by upland taxa	1. None. 2. None. 3. 25%	Not wetland
Site 24	1. No waterlogging or inundation observed. 2. Dune.	Quartz sand (Deeper sediments not investigated).	1. 21% 2. 0% i.e. Vegetation dominated by upland taxa	1. None. 2. None. 3. <21%	Not wetland
Site 25	1. No waterlogging or inundation observed. 2. Dune.	Quartz sand (Deeper sediments not investigated).	1. 18% 2. 0% i.e. Vegetation dominated by upland taxa	1. None. 2. None. 3. 18%	Not wetland
Site 26	1. Surface waterlogged in spring. 2. Low mound.	Shallow muddy sand over Muchea Limestone and also outcropping limestone in places.	1. 25% 2. 5%	1. Hydric soils: shallow aquitard 2. Hydrology: waterlogging in spring 3. Vegetation dominated by wetland taxa (30% of taxa O or F).	1. UFI 14122 Palusplain 2. Palusplain
Site 27	1. Surface waterlogged in spring. 2. Shallow basin.	Peaty sand over hardpan at -60.	1. 63% 2. 25%	1. Hydric soils: shallow aquitard. 2. Hydrology: waterlogging in spring 3. Vegetation dominated by wetland taxa (88% of taxa O or F).	1. Not wetland 2. Dampland
Site 28	1. Surface waterlogged in spring. 2. Undulating plain.	Peaty, quartz sand over muddy sand, muddy sand with gravel and coarse sand with gravel. Hardpan -250.	1. 48% 2. 15%	1. Hydric soils: shallow aquitard. 2. Hydrology: waterlogging in spring 3. Vegetation dominated by wetland taxa (63% of taxa O or F).	1. UFI 8050 Palusplain 2. Palusplain
Site 29	1. No waterlogging or inundation observed. 2. Dune.	Quartz sand (Deeper sediments not investigated).	1. 19% 2. 0%. i.e. Vegetation dominated by upland taxa	1. None. 2. None. 3. 19%	Not wetland
Site 30	Surface waterlogged in spring.	Muddy sand. (Deeper sediments not investigated).	1. 42% 2. 23%	1. Hydric soils: shallow aquitard. 2. Hydrology: waterlogging in spring 3. Vegetation dominated by wetland taxa (65% of taxa O or F).	1. UFI 13368 Palusplain 2. Palusplain
Site 31	Surface waterlogged in spring.	Muddy sand. (Deeper sediments not investigated).	1. 57% 2. 14%	1. Hydric soils: shallow aquitard 2. Hydrology: waterlogging in spring 3. Vegetation dominated by wetland taxa (71% of taxa O or F).	1. UFI 13368 Palusplain 2. Palusplain
Site 32	Surface waterlogged in spring.	Muddy sand. (Deeper sediments not investigated).	1. 43% 2. 36%	1. Hydric soils: shallow aquitard 2. Hydrology: waterlogging in spring 3. Vegetation dominated by wetland taxa (79% of taxa O or F).	1. UFI 7787 Palusplain 2. Palusplain

6.3 Evaluation of wetland management categories in the MKSEA

Each wetland in the MKSEA was assessed (after Hill *et al.,* 1996 and DEC, 2007) as being one of three management categories: Conservation Category Wetland (CCW), Resource Enhancement Wetland (REW) or Multiple Use Wetland (MUW). The wetlands of the area differed in the degree of anthropogenic modification they had been subjected to and their position along the topographical gradient of the alluvial system associated with Yule Brook between the Darling Range and the Canning River. A number of changes to the management categories of the wetlands as mapped in the SCP Wetlands Dataset (DEC 2008a) and shown in Figure 10 are proposed. DEC (2008a) management categories for the wetlands and proposed changes to them are listed in Table 6.3, along with their DEC (2008b) geomorphic classifications, which wetlands MKSEA study sites are in and which wetlands are in BFS 387 or 53.

The Yule Brook alluvial fan system, unlike most of the other alluvial fans on the SCP, is mainly zoned rural and is thus relatively undeveloped and retains native vegetation over some of its extent. Most of the wetlands associated with this system are therefore rare or scarce on the SCP and thus (regardless of their vegetation condition) were carefully considered against CCW criteria for rarity, representativeness and the scientific importance of this alluvial fan and its wetlands on the SCP.

The wetlands of the MKSEA and BFS 387 are interconnected by groundwater and surface flow. Some of the major conservation and management issues in the MKSEA include the restoration of wetland functions and habitats in order to sustain the exceptional biodiversity values in the MKSEA, in BFS 387 and BFS 53. Other important issues are the relationship of the MKSEA, Yule Brook and Bickley Brook to issues of water quality and quantity management in the context of the Swan River Trust Water Quality Improvement Plan (GHD, 2008). In this context, all remnant native vegetation in wetlands in the MKSEA, even if it lacks understorey in good condition, is important as it assists in the local infiltration of rainfall into the groundwater which is one of the main management objectives for the area. Degraded vegetation and road verge remnants of vegetation in the area also often include significant stands of taxa such as *Actinostrobus pyramidalis, Banksia telmatiaea* and *Corymbia calophylla* that are of regional flora conservation importance (see Section 4.0) or provide regionally scarce fauna habitat. The wetlands of Precinct 2 are located upslope (i.e. in the groundwater catchment area) of the high biodiversity CCW of BFS 387 and thus the enhancement of the wetland resources (w.r.t. quality and quantity of water) in Precinct 2 is a major objective in the long term sustainability of these CCWs. Many of the more degraded wetlands of the MKSEA were therefore carefully considered with regard to REW criteria for enhancement of wetland functions and attributes to achieve some of the water management objectives above.

All of these factors, combined with the comprehensive range of criteria used to evaluate the wetlands, resulted in a number of wetlands that initially appeared relatively degraded (in, for example, the condition of the wetland vegetation) achieving a higher score in terms of wetland management category than currently mapped in the SCP Wetland Dataset (Table 6.3, Columns 3, 4).

The evaluation of wetlands in the MKSEA resulted in the mapping of a patchwork pattern of management categories and small areas of uplands (Figure 11). This pattern was particularly complex in Precinct 2 as this area had the most complex mix of land uses; retained a number of patchy native vegetation remnants and road verges with native vegetation in very good to degraded condition; was relatively densely populated; included hydrological attributes that were conducive to the excavation of many small dams; and encompassed a long and particularly complex boundary between the natural upland and wetland zones.

Most of the wetlands of the MKSEA that were assigned the management category of CCW in the current survey were largely unmodified with regard to topography, hydrology and/or vegetation. These wetlands included palusplains, paluslopes, floodplains and sumplands of the Pinjarra Plain. All of these wetland types (if they are unmodified and include native vegetation) are scarce or even rare on the SCP.

Eight wetland areas in the MKSEA (UFIs 7635, 8038, 8050 and five areas of the extensive palusplain 14122) that are currently mapped as REWs are recommended for CCW status in this study (Table 6.3; Figure 11). Wetland UFIs 7800 and 8046 (that are currently MUW) are also recommended for CCW status in this study.

Some wetlands in the MKSEA were more modified than the CCW above with regard to wetland vegetation and other wetland attributes and processes. These wetlands were palusplains, sumplands, damplands and creeks of the Pinjarra Plain and thus scarce wetland types. Some of these wetlands retain open to scattered native vegetation canopy species and/or were important to the maintenance of wetland values and processes (e.g. biodiversity, groundwater quality and quantity) of adjoining CCW and of the Swan Canning River system. The modification that these wetlands have been subject was considered as capable of being remediated by re-vegetation and by the application of best practice water sensitive design and catchment management principles in the overall plan for the area.

In accord with the above, part of UFI 7645, UFI 7783 and part of UFI 8047 (that are currently MUWs in DEC, 2008a) were assigned the management category of REW in the current survey (Table 6.3; Figure 11).

Parts of UFI 13362 adjacent to Yule Brook (that are currently MUW) were also recommended for REW status in this study, as part of the proposed amelioration of the hydrological regime in BFS 387 and the MKSEA, the restoration of the former Yule Brook floodplain and to enable catchment management objectives with regard to the Swan-Canning River Water Quality Improvement Plan as listed by GHD (2008).

One of the areas in UFI 13362 where existing wetland values can be enhanced to meet the objectives above is the least altered area of UFI 13362 with regard to soil, landforms and hydrology. Floodplains of this type (that have not had not been built upon and have their geomorphic integrity and hydrology remaining more or less unaltered are scarce wetland types of the Pinjarra Plain (more than 94% of wetlands of the Pinjarra Plain have been developed or degraded, Hill *et al.,*1994). The paddocks of this large area are currently sparsely stocked and there are few buildings. There is a small creek that traverses UFI 13362 before entering the thickly vegetated, natural area of UFI 7635 (which is recommended as a CCW in the current survey) and flowing into Yule Brook. This creek retains its natural course for much of its length as it traverses the paddocks and the area around its confluence with Yule Brook (at UFI 7635). This area is the least disturbed area of floodplain vegetation adjacent to Yule Brook. The Yule Brook floodplain and creek in Lot 2008 can be enhanced by the regulation of land uses to avoid further modification, control of weeds, revegetation to increase infiltration of rainfall and surface water into groundwater and appropriate re-design of the MUW at the head of the tributary (UFI 7632) to improve water quality. The tributary can then function to recharge the floodplain as well as to provide drainage to developed land to the east.

In general, the remainder of the wetlands in the MKSEA had either been excavated to form dams and drains, or had been severely eroded by the intensive grazing of stock or they had been totally or partially filled. They were usually totally cleared of native vegetation. These wetlands were assigned the management category of MUW. Such wetlands are the only category of wetland that can be modified for use in storm water run-off treatment and, if appropriately designed and engineered, such facilities could contribute to supporting the wetland attributes and functions of nearby CCW and REW wetlands in the MKSEA (as above for REW 13362). These wetlands are often located in areas adjacent to CCW and REW and should be reserved as buffer zones for them (Figures 11, 12). Land uses in wetlands in this category (particularly around BFS 387 and the CCWs and REWs of Precinct 2) should be regulated to exclude any additional activities that may impact negatively on water quality and quantity of the adjacent CCW and REW and of the Swan Canning River system. Revegetation should be a major objective for the MUW of the MKSEA.

The management categories that were assigned to wetlands in the current survey are listed in full (in comparison with the corresponding categories in the Swan Coastal Plain Wetlands Dataset) in Table 6.3 below.

Table 6.3: Review of Wetland Classification and Management Category for wetlands of MKSEA against the existing DEC Wetland Database

The MKSEA Precincts below are as per Figure 3 (City of Gosnells Concept Plan, July 2008). MKSEA Study Site and BFS wetlands are indicated in Column 1.

MKSEA Precinct	Wetland UFI	DEC 2008b DEC 2008a	Proposed in this Survey	Comments
3A	7632	Dampland MUW	Dampland MUW and Palusplain REW	Vegetation degraded and wetland highly modified but retains important wetland function as part of surface water catchment and headwaters of tributary that delivers into Yule Brook floodplain UFI 13362. Wetland requires restoration and replanting to function in collecting stormwater, stripping nutrients and retaining gross debris. Should be part of a comprehensive plan to restore Yule Brook as a living stream.
3A	7633	Sumpland MUW	Sumpland MUW	Vegetation degraded and wetland area highly modified but retains important wetland function as part of surface water catchment and headwaters of tributary that delivers into Yule Brook. Requires wetland restoration, replanting and management as part of a planned process to restore Yule Brook as a living stream.
3B	7634	Palusplain REW	Palusplain REW	This is a mature stand of *Corymbia calophylla* trees that requires linking to the riparian vegetation of Yule Brook by the revegetation of the intervening paddock.
3A/3B **MKSEA Study Site 4** **MKSEA Study Site 5**	7635 13362 adj. to Yule Brk	Palusplain REW Palusplain MUW	Palus- and flood-plains CCW Palusplain and floodplain REW	Current flora survey showed very high conservation values in part of this wetland, so it should be recommended for change to CCW. The rest of the riparian zone of Yule Brook and all areas between Yule Brook and BFS 387 should be managed as REW, i.e. enhanced by replanting and linked to UFI 7636 and BFS 387. Regulate land uses to avoid further modification and negative impact on Yule Brook and adjacent CCW in BFS 387. Revegetate, restore flooding of former floodplain zone and provide fauna habitat.
3B	7636	Palusplain REW	Palusplain REW	Link to UFI 7635 by REW adjacent to Yule Brook Regulate land uses to avoid further modification, revegetate to promote groundwater recharge and provide fauna habitat.
3B	7774 7776	Palusplain CCW Palusplain MUW	Palusplain CCW Palusplain MUW	Current flora survey showed very high conservation values. All of lot should be either CCW, REW for riparian zone of Yule Brook or MUW (managed as a buffer for CCW and REW).
3B	7779	Palusplain MUW	Palusplain MUW	Manage as a buffer for adjoining CCW and REW. Regulate land uses to avoid further modification and negative impact on adjacent CCW in BFS 387, revegetate to promote groundwater recharge and provide fauna habitat.
3B **MKSEA Study Sites 20 & 21**	7780	Palusplain CCW	Palusplain CCW	Current flora survey showed very high conservation values. All of lot should be either CCW, REW for riparian zone of Yule Brook or MUW (managed as a buffer for CCW and REW).
3B **MKSEA Study Site 32**	7787 13362	Palusplain Palusplain MUW	CCW Palusplain/ Sumplands/ creek MUW	Regulate land uses to avoid further modification and negative impact on adjacent CCW in BFS 387, revegetate to promote groundwater recharge and provide fauna habitat. Control aquatic weeds in dams. Remediate current drainage channel to Yule Brook: control weeds and nutrient enrichment.

MKSEA Precinct	Wetland UFI	DEC 2008b DEC 2008a	Proposed in this Survey	Comments
3B **MKSEA Study Sites 1 & 2**	13362	Palusplain MUW	Palusplain REW	Regulate land uses to avoid further modification and negative impact on Yule Brook. Revegetate, restore flooding of former floodplain zone and provide fauna habitat.
3B **MKSEA Study Site 2A**	13362	Palusplain MUW	Palusplain MUW	Regulate land uses to avoid further modification and negative impact on Yule Brook revegetate, restore flooding of former floodplain zone and provide fauna habitat.
3B **MKSEA Study Site 3**	13362	Sumpland MUW	Sumpland MUW	Regulate land uses to avoid further modification and negative impact on Yule Brook revegetate, restore flooding of former floodplain zone and provide fauna habitat.
3A/3B	13362	Palusplain MUW	Floodplain/palusplain/creek REW Palusplain MUW	Restore and revegetate floodplain of Yule Brook and tributary of Yule Brook that runs through this area. Conserve all stands of native trees, revegetate to increase infiltration into groundwater and improve water quality of any excess run-off to Yule Brook reconstructed floodplain.
2	7645 -- 7647	?Palusplain ?MUW -- ?Sumpland ?REW	Palusplain REW -- Sumpland REW	This area is currently very poorly managed with over-stocking, dumping of fill, excavation of wetlands and nutrient enrichment. It is linked to BFS 387 by flow of groundwater and superficial aquifers. Should be managed as part of groundwater control area and buffer zone for BFS 387. Regulate land uses to avoid further modification and negative impact on surrounding less-modified palusplain (REW) and adjoining CCWs, revegetate to promote groundwater recharge and provide fauna habitat.
2 (in BFS 387)	7774	Palusplain CCW	Palusplain CCW	
2 (in BFS 387)	7781	Palusplain REW	Palusplain REW	Regulate land uses to avoid further modification and negative impact on adjacent CCW in BFS 387, revegetate to promote groundwater recharge and provide fauna habitat.
2 (in BFS 387)	7782	Palusplain CCW	Palusplain CCW	
2	7783	Palusplain MUW	Palusplain Parts are MUW REW & CCW	Highly modified lot should remain MUW and form part of the buffer to adjoining wetlands with land-uses on it regulated to avoid negative impact on adjoining CCWs. Lot with degraded native vegetation but otherwise retainng wetland attributes and should be REW to support adjoining CCWs. Lot with good condition vegetation should be changed to CCW.
2 (in BFS 387)	7784	Palusplain CCW	Palusplain CCW	
2 **MKSEA Study Site 8**	7785	Palusplain CCW	Palusplain CCW	Very high conservation values found here in current survey. Extend current CCW over northern half of this block

MKSEA Precinct	Wetland UFI	DEC 2008b DEC 2008a	Proposed in this Survey	Comments
2 (in BFS 387)	7786	Palusplain CCW	Palusplain CCW	
2 (in BFS 387)	7787	Palusplain CCW	Palusplain CCW	
2 (in BFS 387)	7788	Palusplain CCW	Palusplain CCW	
2 (in BFS 387)	7789	Palusplain CCW	Palusplain CCW	
2 (in BFS 387)	7797	Palusplain CCW	Palusplain CCW	
2	7798	Palusplain MUW	Sumpland MUW	Excavated dams/ponds. Part of groundwater control area and buffer zone for BFS 387. Regulate land uses to avoid further modification and negative impact on surrounding less-modified palusplain (REW) and adjoining CCWs, revegetate to promote groundwater recharge and provide fauna habitat.
2	7799	Palusplain MUW	Palusplain MUW	Part of groundwater control area and buffer zone for BFS 387. Regulate land uses to avoid further modification and negative impact on surrounding less-modified palusplain (REW) and adjoining CCWs, revegetate to promote groundwater recharge and provide fauna habitat.
2 **MKSEA Study Sites 6 & 7**	7800 -- 14122	Palusplain REW -- Palusplain REW	Palusplain CCW -- Floodplain/ sumpland CCW	Current flora survey showed very high conservation values over a large part of this block. Recommend this block be changed from REW to CCW over much of this block. The part of the area that is inundated in winter should be changed to sumpland or floodplain. -- Part of groundwater and surface water control area for BFS 387. Investigate hydrology of this area that previously formed the headwaters of a creek that drained to BFS 387. Now this creek has been interrupted and converted to a drain that crosses Brentwood Rd near Bickley Rd and proceeds to BFS 387 in the Wanaping Rd bushland.
2	7805	Palusplain MUW	Sumpland MUW	Part of this block is very degraded by excavations and is flooded in winter. Regulate land uses to avoid further modification and negative impact on adjoining CCW 7800. Revegetate to promote groundwater recharge and provide fauna habitat.
2 (in BFS 387)	8028	Sumpland CCW	Sumpland CCW	
2 (in BFS 387)	8030	Palusplain MUW	Palusplain REW	The vegetation is somewhat degraded but could regenerate well with some weed control. Regulate land uses to avoid further modification and negative impact on adjoining CCW, revegetate to promote groundwater recharge and provide fauna habitat.
2 (in BFS 387)	8031	Sumpland CCW	Sumpland CCW	Part of this area has been modified by importing fill and excavations. Regulate land uses to avoid further modification and negative impact on adjoining CCW, revegetate to promote groundwater recharge and provide fauna habitat.
2 (in BFS 387)	8032	Sumpland CCW	Sumpland CCW	Part of this area has been modified by grazing of horses. This is causing degradation of parts of the adjacent BFS 387 vegetation and requires urgent regulation.

MKSEA Precinct	Wetland UFI	DEC 2008b DEC 2008a	Proposed in this Survey	Comments
2 **MKSEA Study Site 12**	8033	Palusplain CCW	Palusplain CCW	Part of groundwater control area and buffer zone for BFS 387. Current flora survey showed very high conservation values over a large part of this block.
2 **MKSEA Study Site 13**	8034	Sumpland REW	Sumpland REW	Part of groundwater control area and buffer zone for BFS 387. Regulate land uses to avoid further modification and negative impact on surrounding less-modified CCW, revegetate to promote groundwater recharge and provide fauna habitat.
2 (in BFS 387)	8035	Sumpland CCW	Sumpland CCW	
2	8036	Sumpland REW	Sumpland REW	Part of groundwater control area and buffer zone for BFS 387.Regulate land uses to avoid further modification and negative impact on adjacent CCW in BFS 387, revegetate to promote groundwater recharge and provide fauna habitat. Add two small MUW sumplands nearby (dams) to dataset.
2	8038	Sumpland REW	Sumpland REW	Part of groundwater control area and buffer zone for BFS 387. Although most of the vegetation has been cleared in this wetland and the palusplain has been excavated to form a series of dams, this wetland area is of high conservation significance as it maintains adjacent vegetation. Regulate land uses to avoid further modification and negative impact on surrounding less-modified CCW vegetation, revegetate to promote groundwater recharge and provide fauna habitat.
2	8045	Palusplain REW	Palusplain REW	Part of groundwater control area and buffer zone for BFS 387. Regulate land uses to avoid further modification and negative impact on adjacent CCW in BFS 387, revegetate to promote groundwater recharge and provide fauna habitat.
2 **MKSEA Study Site 19**	8046	Palusplain CCW	Palusplain CCW	Current flora survey showed very high conservation values over the north part of this block. Part of groundwater control area and buffer zone for BFS 387.
2	8047	Dampland MUW	Dampland REW	Recommend resource enhancement to support values in CCW 8046 Part of groundwater control area and buffer zone for BFS 387. Regulate land uses to avoid further modification and negative impact on adjacent CCW, revegetate to promote groundwater recharge and provide fauna habitat
2	No number	nil	CCW	Current flora survey showed wetland vegetation in good condition high water table and wetland soils. Significant conservation values in this area. Part of groundwater control area and buffer zone for BFS 387. Investigate hydrology, regulate land uses to avoid further modification and negative impact, revegetate to promote groundwater recharge and provide fauna habitat.
2 (in BFS 387)	13128, 7637,7787	Palusplain CCW	Palusplain CCW	
2 (in BFS 387)	13368	Palusplain CCW	Palusplain CCW	
2	13542	Palusplain MUW	Palusplain MUW	Part of groundwater control area and buffer zone for BFS 387. Regulate land uses to avoid further modification and negative impact on adjacent CCW, revegetate to promote groundwater recharge and provide fauna habitat.

MKSEA Precinct	Wetland UFI	DEC 2008b DEC 2008a	Proposed in this Survey	Comments
2	13541	Palusplain MUW	Palusplain MUW	Part of groundwater control area and buffer zone for BFS 387. Regulate land uses to avoid further modification and negative impact on adjacent CCW, revegetate to promote groundwater recharge and provide fauna habitat.
2	13826	Palusplain REW	Palusplain REW	Part of groundwater control area and buffer zone for BFS 387. Regulate land uses to avoid further modification and negative impact on adjacent CCW, revegetate to promote groundwater recharge and provide fauna habitat.
2 **MKSEA Study Sites 14, 15, 16**	13827	Palusplain CCW	Palusplain, paluslope, floodplain CCW	Current flora survey showed very high conservation values over most of this block. Also part of groundwater control area and buffer zone for BFS 387. Revegetate to promote groundwater recharge and provide fauna habitat.
2	14115	Palusplain MUW	Palusplain MUW	Part of groundwater control area and buffer zone for BFS 387. Regulate land uses to avoid further modification and negative impact on adjacent CCW, revegetate to promote groundwater recharge and provide fauna habitat.
2	14116	Palusplain REW	Palusplain REW	Part of groundwater control area and buffer zone for BFS 387. Regulate land uses to avoid further modification and negative impact on adjacent CCW, revegetate to promote groundwater recharge and provide fauna habitat.
2	14117	Palusplain MUW	Palusplain MUW	Part of groundwater control area and buffer zone for BFS 387. Regulate land uses to avoid further modification and negative impact on adjacent CCW, revegetate to promote groundwater recharge and provide fauna habitat
2	14118	Palusplain REW	Palusplain REW	Part of groundwater control area and buffer zone for BFS 387. Regulate land uses to avoid further modification and negative impact on adjacent CCW, revegetate to promote groundwater recharge and provide fauna habitat.
2	14119	Palusplain MUW	Palusplain MUW	Part of groundwater control area and buffer zone for BFS 387. Regulate land uses to avoid further modification and negative impact on adjacent CCW, revegetate to promote groundwater recharge and provide fauna habitat.
2	14120	Palusplain REW	Palusplain REW	Part of groundwater control area and buffer zone for BFS 387. Regulate land uses to avoid further modification and negative impact on adjacent CCW, revegetate to promote groundwater recharge and provide fauna habitat.
2 **MKSEA Study Sites 9 & 10**	14122	Palusplain REW	Palusplain CCW	Current flora survey showed very high conservation values over most of the northern part of this block. The currently mapped conservation category wetland on this block UFI 7785 should be recommended to be extended to include this part of the palusplain (currently mapped as REW 14122). Part of groundwater control area and buffer zone for BFS 387. Regulate land uses to avoid further modification and negative impact on adjacent CCW in BFS 387, revegetate to promote groundwater recharge and provide fauna habitat.
2 **MKSEA Study Site 11**	14122	Palusplain REW	Palusplain CCW	Current flora survey showed very high conservation values over most of the northern part of this block. Recommend change part of this block to CCW. Part of groundwater control area and buffer zone for BFS 387. Regulate land uses to avoid further modification and negative impact on adjacent CCW in BFS 387, revegetate to promote groundwater recharge and provide fauna habitat.
2 **MKSEA Study Sites 17 & 26**	14122	Palusplain REW	Palusplain CCW	Current flora survey showed very high conservation values over most of this block. Also part of groundwater control area and buffer zone for BFS 387. Revegetate to promote groundwater recharge and provide fauna habitat.
2	14122	Palusplain REW	Palusplain CCW	Current flora survey showed very high conservation values over the eastern edge of this block. Recommend this area should be changed from REW to CCW. Over the remainder of the block, regulate land uses to avoid further modification and negative impact on adjoining CCW, revegetate to promote groundwater recharge and provide fauna habitat.

MKSEA Precinct	Wetland UFI	DEC 2008b DEC 2008a	Proposed in this Survey	Comments
1	7961	Sumpland MUW	Sumpland MUW	Vegetation and other wetland values very modified. Revegetate where possible and manage in context of Bickley Brook catchment to improve water quality.
1	8048	Palusplain MUW	Palusplain MUW	Vegetation and other wetland values very modified. Revegetate where possible and manage in context of buffer zone to 8050 and Bickley Brook catchment to improve water quality.
1	8049	Palusplain MUW	Palusplain MUW	Vegetation and other wetland values very modified. Revegetate where possible and manage in context of buffer zone to 8050 and Bickley Brook catchment to improve water quality.
1 **MKSEA Study Site 28**	8050	Sumpland REW	Palusplain CCW Sumplands MUW Palusplain MUW	Current flora survey showed high flora and vegetation conservation values over part of this area. In other parts degraded vegetation where a number of small dams linked by channels are excavated. They retain important wetland function as the headwaters of a drainage system that delivers into Yule Brook via BFS 387. Regulate land uses in a buffer around CCW to avoid further modification and negative impact. Investigate hydrology to understand the headwater of this previously natural creek and factors maintaining high watertable here. Manage drainage more sustainably, revegetate to promote groundwater recharge and maintain fauna habitat. Promote link between 8050 and adjacent CCW by revegetating a buffer zone that would include 8052 and 8055 and regulating activities in this buffer zone.
1	8051	Sumpland MUW	Dampland MUW	Vegetation and other wetland values very modified. Revegetate where possible and manage in context of Bickley Brook catchment to improve water quality.
1	8052	Sumpland MUW	Palusplain MUW	Vegetation and other wetland values very modified. Revegetate where possible and manage as buffer to CCW on 8050 and to promote link between 8050 and adjacent CCW and in context of Bickley Brook catchment to improve water quality.
1	8053	Sumpland MUW	Sumpland MUW	Vegetation and other wetland values very modified. Revegetate where possible and manage in context of Bickley Brook catchment to improve water quality.
1	8054	Sumpland MUW	Dampland MUW	Vegetation and other wetland values very modified. Revegetate where possible and manage in context of Bickley Brook catchment to improve water quality.
1	8055	Dampland MUW	Dampland MUW	Vegetation and other wetland values very modified. Revegetate where possible and manage as buffer to CCW on 8050 and to promote link between 8050 and adjacent CCW and in context of Bickley Brook catchment to improve water quality.
1 (in BFS 53)	12114	Palusplain CCW	Palusplain CCW	
1	12115	Palusplain MUW	Palusplain MUW	Vegetation and other wetland values very modified. Revegetate where possible and manage as part of buffer zone to BFS 53 and linkage of nearby CCW wetland with BFS 53.
1 (in BFS 53)	12116	Palusplain CCW	Palusplain CCW	
1 (in BFS 53)	12117	Palusplain MUW	Palusplain CCW	

MKSEA Precinct	Wetland UFI	DEC 2008b DEC 2008a	Proposed in this Survey	Comments
1 **MKSEA Study Sites 30, 31**	13368	Palusplain MUW	Palusplain CCW	Current flora survey showed high flora and vegetation conservation values over part of this area. Regulate land uses in a buffer around CCW to avoid further modification and negative impact. Link to 8050 and BFS 53 via a revegetated buffer zone.
1 **MKSEA Study Site 18**	13369	Palusplain MUW	Palusplain MUW	The native vegetation on this block was cleared and the block was graded just after current survey so now the area is completely degraded.
1	13369	Palusplain MUW	Palusplain MUW	Vegetation and other wetland values very modified. Revegetate where possible and manage in context of Bickley Brook catchment to improve water quality and other catchment issues. Do not continue to export storm water from this area to Precinct 2 via current constructed drainage system.

6.4 Buffer zones for wetlands, foreshore reserves for waterways and ecological linkages in the MKSEA

6.4.1 Buffer zones and foreshore reserves

Buffer zones are areas that may not include significant natural values but are required, by regulatory authorities, to be set aside from development (and certain other activities) in order to protect the values of wetlands. All CCW and REW (including channel wetlands such as Yule Brook, that provide ecological linkages between areas of high conservation significance) on the SCP are expected to be protected by the reservation of a buffer zone of, at least, 50 m in width around the entire wetland (Del Marco *et al*., 2004; EPA, 2004a; EPA, 2008). The term 'foreshore reserve' is used interchangeably with 'buffer zone' to designate the area to be reserved for these purposes on both sides of a channel wetland (stream). To map a buffer zone, the wetland boundary must first be accurately delineated according to hydrological, stratigraphic and/or vegetation criteria as summarised in DEC (2007). The wetland boundary can coincide thus with the edge of the wetland-dependant vegetation around a wetland, or the edge of the riparian vegetation that borders a stream, or the edge of a floodplain adjacent to a stream. The actual width of the buffer zone, above the minimum of 50 m required by EPA (2008) should be determined according to the type of development planned adjacent to the wetland or stream (Essential Environmental Services, 2005; EPA, 2008). For example, industrial developments are usually required to be separated from wetlands by a minimum vegetated buffer zone of about 200 m.

The following management principles are encouraged in buffer zones of wetlands and waterways foreshore reserves (EPA, 2008):

- Retention of all remnant native vegetation.
- No fill, fertiliser or chemical application, no drainage in or out other than natural or approved stormwater management, no groundwater or wetland water abstraction, no liquid or solid waste disposal, no excavation permitted in the wetland or the buffer zone.
- Repair of degraded or eroded portions of the buffer.
- Rehabilitation of wetland vegetation and adjacent dryland zones with indigenous species of local provenance.
- Removal of inappropriate infrastructure.
- Installation of fences, paths and gates to control access.
- Replacement of inappropriate drainage facilities.

In the current survey a number of buffer zones were mapped around all areas of high conservation significance, such as the CCW and REW of the MKSEA, BFS 387 and BFS 53, the Yule Brook riparian zone and the Yule Brook floodplains (Figure 12). These buffers are intended to protect conservation values, serve as areas where revegetation can take place to improve ecological functions (such as infiltration of rainfall into groundwater) and to increase the connectivity among the vegetated MKSEA blocks and between vegetated blocks in the MKSEA and nearby Bush Forever sites.

As much of the MKSEA is a continuous palusplain terrain, the lands (that would normally be designated as buffer zones) adjacent to many CCW and REW were usually either wetlands that had been modified sufficiently to be categorised as REW and MUW respectively, or areas of artificially raised land that often included substantial existing developments. Unfortunately, many of the Conservation Category Wetlands in the MKSEA and adjacent areas are often subjected to the dumping of fill, refuse and hazardous materials; over-stocking; groundwater and surface water pollution and nutrient enrichment; excavation; unregulated clearing and burning of native vegetation, and weed proliferation. Many areas of the MKSEA are also dewatered by drainage channels and then risk further degradation due to salinisation and acidification of the land. The proposed wetland buffer zones around the CCWs and REWs in the MKSEA in these cases cannot be treated as areas where rapid revegetation and dismantling of existing infrastructure should take place. The

existing land uses within wetland buffer zones in the MKSEA should be audited to determine the activities that are currently incompatible with the principles that apply to buffer zones (EPA, 2008; see above). Existing land uses incompatible with this should be regulated and slowly phased out. New or additional infrastructure or developments in the buffer zones should not be permitted.

6.4.2 Ecological linkage corridors (greenways)

Connectivity between areas of refugial natural habitat is anticipated to be one of the crucial determinants in biodiversity survival in the future under fluctuating climatic conditions and increasing anthropogenic stress on the biota (DEWHA, 2009). Ecological linkage corridors (also referred to as greenways) are designed to increase connectivity by linking high conservation value wetlands and bush reserves through any other remnant native vegetation, parks and areas with minimal development that are known as 'regional open space'. The MKSEA is located in a strategic ecological area with regard to the opportunity to increase the connectivity of BFS 387 (the most important Bush Forever Site on the SCP) with the large National Parks of the Darling Range and the Canning Regional Park. There were two ecological linkage areas proposed in the vicinity of the MKSEA prior to the current survey (by Government of Western Australia, 2000, and by Del Marco *et al.,* 2004), both of which are considered below with regard to the findings of the current survey.

6.4.2.1 The Yule Brook- BFS 387 Greenway

Yule Brook and BFS 387 are part of a natural ecological linkage corridor between the Darling Range and the Canning River that was recognised by Government of Western Australia (2000). Yule Brook is a natural ecological corridor and this waterway was, over long periods of time, fundamental to the development of the complex natural habitats of the local alluvial fan and the biodiversity it supports. The brook also originally enabled the dispersal of flora propagules from the Darling Range to the SCP. For fauna, it provided pristine quality water, diverse aquatic habitats and a sheltered, densely vegetated migration corridor.

A number of indigenous heritage sites have been recorded in the vicinity of Yule Brook. Interestingly, the natural history of Yule Brook parallels the indigenous cultural heritage of the area with regard to the creative force of waterways. The connections between the cultural and natural values of the area are very important with regard to the heritage values of the area and the potential interpretive and educational activities that could be developed in the area.

The current survey identified additional areas adjacent to Yule Brook in the MKSEA that have nationally-significant values that are not currently represented in BFS 387. These values included the EPBC-listed Muchea Limestone Threatened Ecological Community, a Declared Rare Flora Species (*Eremophila glabra* subsp. *chlorella*), three Priority Flora Species, a suite of regionally significant flora, and vegetation of the very poorly conserved Guildford Vegetation Complex (in good condition). The areas that include these values should be managed as CCWs 7635, 7774 and 7780. The other remnant riparian vegetation of Yule Brook and any undeveloped floodplains adjacent to Yule Brook should be allotted a new UFI and managed as a REW to protect and enhance the existing wetland values and to support the restoration of the former hydrological regime (i.e. seasonal inundation of floodplains) of this stream. A foreshore reserve of at least 50 m in width (or wider in some areas) should be reserved adjacent to the wetlands above on either side of Yule Brook between Welshpool Rd and Roe Highway. Part of the function of the foreshore reserve should be to link BFS 387 to the CCWs and REW adjacent to Yule Brook and support the restoration of the former hydrological regime of this stream.

Most of the other waterways connecting the Darling Range to the SCP in the Perth Metropolitan Region are more degraded than Yule Brook and do not flank significant biodiversity conservation areas of the calibre of BFS 387. The restoration of Yule Brook represents one of the few remaining opportunities on the SCP to maintain and reinforce the natural ecological connectivity between native vegetation and fauna habitats of the Darling Range, the Swan Coastal Plain and the Swan-Canning River system. To restore the role of Yule Brook as an active participant in the sedimentary and hydrological processes of the area and as a high quality ecological and biological linkage area, a number of objectives (including those listed below) should be pursued.

1. The hydrological regime of the MKSEA should be gradually restored and the water pollution and nutrient enrichment sources in the MKSEA should be identified and ameliorated so that the volume and speed of run-off into Yule Brook is gradually reduced and the quality of the water is improved.

2. The excavation of the Yule Brook channel and the ploughing of firebreaks and mowing of vegetation in the riparian zone should be discontinued.

3. The natural regime of seasonal inundation of the floodplains adjacent to Yule Brook should be gradually re-established, where possible. This will require the reservation of floodplain land adjacent to Yule Brook as conservation areas or foreshore reserve, the gradual phasing out of residential areas adjacent to the brook, and potentially some design and engineering of appropriate measures to protect any remaining infrastructure.

4. The vegetation of the Yule Brook riparian area and floodplains should be regenerated and restored. This will require a considerable effort in fencing, the control of weeds and the replanting of native vegetation in some parts. The restoration of the flooding regime over the floodplains may assist in weed control and vegetation restoration as seasonal inundation will not be tolerated by a number of weeds that currently inhabit these areas.

5. The Yule Brook floodplains should be linked to the adjacent high biodiversity wetlands in BFS 387 (particularly in the vicinity of the intersections of Brook Rd and Grove Rd and of Brook Rd and Bickley Rd) by revegetated areas. The roads are poorly designed in this area; they present hazards to traffic and they fragment and alter the Yule Brook floodplains in an ecologically sensitive area. Rather than upgrade these roads to carry a larger volume of traffic and perpetuate the environmental problems, traffic reduction measures (including the closure of parts of these roads and the reclamation of some areas of road area to bushland) may be possible and would support environmental objectives in this area.

6.4.2.2 The BFS 387 – BFS 53 Greenway

The Muchea Limestone aquifers and the native vegetation maintained by springs and other hydrological processes that operate along the interface of the Bassendean Sands and Pinjarra Plain in Precincts 1 and 2 form a natural ecological linkage between BFS 387 and BFS 53. In the current survey, there were many highly significant conservation values (that are not currently represented in BFS 387) identified within this corridor in Precincts 1 and 2 of the MKSEA. These values include two EPBC-listed Threatened Ecological Communities, three EPBC-listed Threatened Flora Species, numerous Priority Flora Species, numerous Conservation Category Wetlands, paluslope wetlands that are rare on the SCP, vegetation assemblages that have not been recorded elsewhere on the SCP and a suite of regionally significant flora. The areas in Precincts 1 and 2 of the MKSEA that were identified above as highly significant were previously flagged by Del Marco *et al.* (2004) as potentially requiring incorporation into an ecological linkage corridor that extended from BFS 387 to BFS 53 and hence to the Darling Range (Figure 4).

The ecological linkage corridor proposed by Del Marco *et al.* (2004) should be supported and should be located to encompass as many of the high conservation values of Precincts 1 and 2 as possible. It is particularly important to link the Muchea Limestone, spring-fed, CCW wetlands along the interface of the Bassendean Sands and Pinjarra Plain in Precincts 1 and 2 to each other and to BFS 387 and BFS 53.

To consolidate and protect the conservation values in this corridor, a number of objectives (including those listed below) should be pursued.

1. The high conservation areas identified in the current survey in Precinct 2 should be added to BFS 387. Alternatively, the reservation of a separate conservation area (that encompasses the contact between the Bassendean Sands and Pinjarra Plain in Precincts 1 and 2) should be considered.

2. Wetland buffers of at least 50-200 m should be reserved around all CCW and REW in Precincts 1 and 2 after a detailed hydrogeological study and delineation of wetland boundaries.

3. The wetlands and associated native vegetation along the interface of the Bassendean Sands and Pinjarra Plain should be linked to each other and to BFS 387 and BFS 53 via revegetated areas.

The regional greenways in the MKSEA discussed above were mapped (Figure 12) over the high conservation significance areas identified in the current survey of the MKSEA. All of the high conservation elements of the MKSEA should, ideally, be linked to BFS 387 via buffer zones proposed in this survey (Figure 12) and ecological linkage areas, and they should be managed as one unit. The revegetation of the currently degraded areas in these linkage corridors in the MKSEA would provide substantial environmental and aesthetic benefits to the area. The conservation of the existing native vegetation along roadsides in the MKSEA (which currently include a number of attractive Priority Species and regionally significant species) and the replanting of roadside reserves and aquatic species in the drainage channels along all of the roads in the MKSEA would provide additional ecological linkage at a finer scale.

The areas of high conservation significance identified in this study, when linked to each other and to BFS 387 and BFS 53 (via areas identified as buffer zones and linkage areas above) could, with appropriate restoration of ecological functions and appropriate management, enable a functional and sustainable conservation reserve interspersed with regional open space and well-regulated, low impact, rural land uses. This combination of land uses may allow an attractive, low density community to develop in the area that would be a valuable asset to the City of Gosnells whilst conserving and protecting the exceptional local biodiversity, geoheritage and indigenous heritage values of the area.

7. Conclusions

The current survey shows that many parts of the MKSEA have values of national, state and regional significance that are of, at least, equivalent importance to the values of the local Bush Forever Sites (BFS 387 and BFS 53) (Table 7.1). Moreover, some of the more significant values (rare flora and vegetation types, TECs and rare wetland types) in the MKSEA are not represented in these Bush Forever Sites. The high conservation significance areas in the MKSEA provide some unique insights into the remarkable story of natural history development in the area that complement and enrich the values found in the Bush Forever Sites.

Connectivity between areas of refugial natural habitat is anticipated to be one of the crucial determinants in biodiversity survival in the future under fluctuating climatic conditions and increasing anthropogenic stress on the biota (DEWHA, 2009). The conservation values of the MKSEA and of both Bush Forever Sites (particularly BFS 387) are currently subject to levels of stress that are unacceptably high, given the national significance of the natural values of these areas. The MKSEA is located in an extremely strategic ecological area with regard to the opportunity to increase, via buffer zones and greenways, the connectivity and thus the long term viability of BFS 387, which is generally considered to be the most biodiverse Bush Forever Site in the Perth Metropolitan Region.

The Greater Brixton Street Wetlands and the Clifford Street Bushland include multiple values that are listed under the Federal Environmental Protection and Biodiversity Conservation Act 1999 and on the Register of the National Estate (DEWHA, 2008a). Prior to the current survey there was evidence that the MKSEA also included nationally significant conservation values (Cardno BSD, 2005; DEC, 2008a, 2008b). The Greater Brixton Street Wetlands, the Clifford Street Bushland and the MKSEA lands are separated from each other by cadastral boundaries, but they are an indivisible unit ecologically because they are all part of the same local-scale hydrogeological system.

The Federal EPBC Act is expected to be triggered by proposals for industrial development in the MKSEA due to the close proximity of the MKSEA to the Greater Brixton Street Wetlands and the Clifford Street Bushland and the ecological interdependence of the MKSEA and these Bush Forever sites (DEH, 2006). The EPBC Act will also be triggered by any proposals for industrial development in the MKSEA that threaten to impact on the nationally significant conservation values contained within the MKSEA (DEH, 2006).

In the planning process for the MKSEA, the environmental regulatory authorities (both State and Federal) are anticipated to require that the high conservation value areas of the MKSEA (including all CCW and REW wetlands) are conserved and that the high conservation values of the MKSEA and both Bush Forever Sites are protected by the additional reservation of buffer zones and ecological linkage areas. There are also practical limitations involved in developing the MKSEA because most of it is wetland underlain by clay sediments and the economic and environmental costs of overcoming these limitations are high. Typically, development in such catchments, even if native vegetation is not cleared and wetlands are not destroyed, results in negative impacts on water quality and quantity both locally and in the Swan-Canning River system.

The current survey concluded (as suggested in the earlier reports to the City of Gosnells by GHD and BSD Cardno in 2005) that, given the regulatory, practical and environmental constraints on the site, the area of the MKSEA that could be developed without substantial environmental loss or harm is much less than envisaged in the City of Gosnells (2008) MKSEA Concept Plan (Figure 3).

On a broader scale, it is evident that all of the alluvial fan system associated with the tributaries of the Canning River in Wattle Grove, Kenwick and Maddington that remains undeveloped is significant when assessed against the Criteria for the Register of the National Estate (DEWHA, 2008f). This alluvial fan should, ideally, be viewed as one unit with regard to planning, conservation and management in order to deliver the best outcomes for the important biodiversity, geoheritage and cultural heritage values of the area. Three planning and management zones (listed below) are evident within the alluvial fan system, and each of these zones should be governed by individual objectives: