Appendix E: Regional and Local Ecological Linkages Report

Regional and Local Ecological Linkages for the Geraldton Local Biodiversity Strategy

A preliminary investigation of Ecological Linkages for the Geraldton Regional Flora and Vegetation Study area.

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INTRODUCTION

The South West Botanical Province has been recognized as a biodiversity hotspot primarily because of the highly endemic flora (Department of the Environment, Sport and Territories, 1994; Myers *et. al.,* 2000). Large areas of this botanical province have been extensively cleared to form the Western Australian Wheatbelt, with some areas as much as 90% turned over to annual crops and pasture (Hobbs *et. al.,* 1993; Shepherd *et. al.,* 2002; Gibson *et. al.,* 2004). Initially the productive soils in the valleys were cleared but it has also extended to the sandy soils on upland areas. The remaining remnant vegetation present in the wheatbelt consists of variously sized fragments surrounded by agricultural farmland. Median size of nature reserves managed by Department of Environment and Conservation (DEC) within the wheatbelt is 116 ha, whereas other government reserves have a median size of < 4ha (Gibson *et. al.,* 2004).

The Geraldton Local Biodiversity Strategy Study Area (GLBSSA) falls within the IBRA 6.1 (Interim Bioregionalisation of Australia; Commonwealth of Australia, 2010) subregion, Geraldton Sandplains other-wise known as the 'Geraldton Hills IBRA sub-region'. The sub-regional area totals 1,968,332ha and forms part of the northern biogeographic zone of the South West Botanical Province (Government of Western Australia, 2010a; Perth Biodiversity Project, 2010).

A total of 54% of the native vegetation within the Geraldton Hills subregion has been cleared (Government of Western Australia, 2010a; Perth Biodiversity Project, 2010), leaving the remaining vegetation (46%) highly fragmented, degraded and susceptible to dryland salinity. Only 18% of the subregional land is within the conservation reserve system, of this, 66.5% is contained in two parks (Kalbarri National Park in the north-western periphery, and Wandana Nature Reserve in the north-eastern periphery; Government of Western Australia, 2010b). A further 28% (nearly 72,000ha) situated on the northern boundary of the Geraldton Hills subregion, parts of former pastoral leases are now being managed for conservation purposes. This means approximately 98% of the conservation estate is now held in nine reserves 1,500ha or larger (Government of Western Australia, 2010b). The remaining 36 reserves are generally small in size, on agriculturally unproductive land and form just over 1.6% of the conservation estate (Government of Western Australia, 2010b).

The majority of the Geraldton Hills subregion reserves have significant threatening processes affecting their ecological stability. They range from rising water tables, increasing levels of dryland salinity, widespread feral herbivore grazing (rabbits, goats and pigs) and feral predators, plus limited resources for wildfire control (Desmond and Chant, 2001).

A flora and vegetation survey (The Geraldton Region Flora and Vegetation Survey, GRFVS) by the Department of Planning in conjunction with Ecoscape (2010) determined that within the GLBSSA only 15% of the original native vegetation remains in 625 discrete remnants and less than 2% is located in DEC reserves. Across the GLBSSA, 9 Beard vegetation associations were identified, of these, three (BVA371, BVA387 and BVA675) have <10% of their original area remaining within the study area (WAPC, 2010). In addition, BVA35 and BVA371 are considered endangered, with a total of <10% remaining in Western Australia (approximately 9%, and, 5.7% of remaining GLBSSA vegetation respectively; WAPC, 2010).

The GRFVS described the vegetation communities in greater detail and at a finer scale than the Beard Associations, thereby representing vegetation community types at the sub-regional and local scale (Department of Planning and Ecoscape, 2010). Seventeen 'GRFVS plant communities' were identified within the GLBSSA; however their distribution outside the study area is currently unknown.

The GLBSSA has been extensively cleared of native vegetation and, consequently as there is little native vegetation remaining, it can be considered to be all regionally significant at either the Beard Association or GRFVS vegetation community level, because the target for representativeness, 30% of original extent, can be rarely met.

This document addresses the issue of connectivity between remaining areas of native vegetation, within and adjacent to the Geraldton Local Biodiversity Strategy Study Area (GLBSSA), through the identification of Ecological Linkages. This is achieved by discussing the methodology used to determine Ecological Linkages, and using this methodology to map a suite of locally and regionally significant Ecological Linkages, within the Study Area.

THE GERALDTON HILLS SUBREGION

As previously stated, south west Western Australia is a mega diverse region with large numbers of diverse and highly endemic flora. One of the factors driving this diversity is the nature of the landscape. The landscape is subdued and highly weathered, forming large complexes of different soils over relatively short distances. It is these differences in soil structure chemistry and physical properties which has promoted the diversification of large numbers of plant species and communities, with many restricted to particular soil complexes.

The climate of the south west ranges from high rainfall in the far south gradually becoming arid in south-to-north and west-to-east directions (Gibson *et. al*., 2004). The Geraldton Sandplains and Hills subregions form the northern extent of the transition zone between the mesic South West and arid Eremaean Botanical Provinces (Hopper 1979; Gibson *et. al*., 2004).

Because of their position on the coast, the Geraldton Sandplains and Hills subregions experience major climatic changes in relatively short distances between mediterranean and arid (a rapid changeover in south-north and west-east directions), ie from a cooler, wetter Mediterranean (coastal ameliorated) to warmer drier Eremaean further inland, compared to other transitional regions along the boundary between these two Provinces. This rapid environmental changeover is unique to the Geraldton subregions with the result that the plant communities present are also unique to the region.

The fauna of the Geraldton subregions show a similar transition from assemblages occurring in wetter cooler areas in the south to more arid adapted faunas in the north and east. In many cases, this region is at the limits of or close to, their natural range, of either southern or northern distributions. For example many of the aquatic fauna recorded by Quinlan *et. al.* (2009) have northern or north-west distributions and their presence in the Geraldton subregions catchments appear to be their southern limits (examples are: the beetles *Megaporus ruficeps* and *Hydroglyphus leai;* and the hemipterans *Anisops stali* and *A. nasuta*). In contrast, various aquatic invertebrates such as the worm *Ainudrilus nharna* appears to be at its most northerly limit in the lower Hutt River in the north of the Geraldton Hills region (Quinlan

et. al., 2009). Sutcliffe (2003) recorded 15 dragonfly and 11 caddisfly species as being at the northern limit of their distributions in the Geraldton region.

Vertebrate fauna distributions show similar patterns, with a distinctly different fauna in northern and north-eastern regions of the South West Botanical Province into the transitional zone, compared to that present in southern areas (Burbidge *et. al.,* 2004). Many vertebrates with otherwise southern distributions are present along the coast into the Geraldton subregions due to the cooler wetter coastal ameliorated climate.

The vertebrate fauna previously recorded in the Geraldton subregions is rich, with approximately 26 mammals, 113 reptiles and 17 frog species (WA Museum records). However, Desmond and Heriot (2002) only recorded 10 native mammal species, 39 reptile species and 6 frog species occurring within the Chapman River Wildlife corridor situated within the greater Geraldton urban area. *Sminthopsis dolichura* and *Tarsipes rostratus* appear to be close to the edge of their range (both southern orientated species) in the Geraldton subregions. Of the nine bat species known from the area, one species appear to be at its northern limits (*Vespadelus finlaysoni);* three at their southern limits (*Mormopterus planiceps*, *Chalinolobus morio, Vespadelus regulus);* four with wide spread distributions (*Nyctophilus geoffroyi, Chalinolobus gouldii, Scotorepens balstorii, Tadarida australis)*; and *Pteropus scapulatus* is an occasional tropical vagrant. The Geraldton Region is an overlap zone for these species.

Terrestrial invertebrate distributions are less clear; however it is likely that there is considerable regionalization among non-aerial dispersing invertebrates (such as mygalomorph spiders, scorpions, various beetle groups, and other invertebrates). Because of their close associations with plants, many insect groups will most likely show similar transitional patterns of distribution as the plant communities.

In summary, the Geraldton subregions are a unique transitional zone between southern plant and fauna communities and the semi and arid plant and faunal communities from northern and central Western Australia. Current climate and weather patterns in combination with diverse and complex soil distributions have allowed unique assemblages of plants and animals to develop in this region. These communities have the potential to extend or retract their distributions in response to the effects of aridification and climate change. In addition there is potential for further mixing and alteration of community structure under these processes.

ECOLOGICAL LINKAGES

Maintenance of the biodiversity of a fragmented landscape is dependant on the distribution of its remaining natural areas. Ecological function can potentially be maintained through a series of linkages or connected patches of remnant vegetation of suitable size. This connectivity is important in assisting with facilitating movement of animals, seeds and pollen and providing resilience to disturbances such as fires and climate change.

Landscape configuration or connectivity becomes increasingly important at low levels of suitable habitat, with different species disappearing at differing levels of habitat loss. Decreasing amounts of habitat combined with increasing levels of habitat fragmentation,

increased amounts of edging and loss of habitat connectivity results in increasing rates of individuals leaving the habitat in search of suitable localities (McAlpine *et. al.,* 2006).

The Environmental Protection Authority (EPA) defines 'ecological linkage' as a network of native vegetation that maintains some ecological functions of natural areas and counters the effects of habitat fragmentation (EPA, 2008).

In the Perth and a portion of the South West region, regional and local ecological linkages have been identified following a methodology outlined in The Local Government Biodiversity Planning Guidelines for the Perth Metropolitan Region (Del Marco *et. al.,* 2004). Del Marco *et. al.* (2004) defines an Ecological Linkage as a series of non-contiguous natural areas that connect larger natural areas by forming stepping stones through the altered landscape that allows the movement over time of organisms between these larger areas and across the landscape.

Ecological Linkages are designed to be used as a tool to recognise the ecological value of close proximity when planning and managing biodiversity at the landscape scale. Therefore the ecological viability of the whole of a natural area which touches or is in close proximity to a linkage will probably be greater than that of a comparable natural area isolated from other natural areas.

Viability of both the Ecological Linkage overall and individual remnant vegetation patches are directly influenced by the size, shape, perimeter to area ratio, condition, and connectivity. Simply put, a larger, more compact remnant vegetation patch in good or better condition is more viable in the long term than a patch that is similar in area but is long and narrow or has an uneven shape, or several small patches equaling the same total area. However, a viable size is dependent on an ecological community being considered as there are examples of small, less than 4 ha patches of remnants that provide a viable refuge to specific communities. The role of scattered trees in many landscapes is also acknowledged, including their contribution to improved connectivity (Manning *et. al.,* 2006).

Well designed Ecological Linkages increase available foraging areas, mosaic of habitats and successional stages. In addition they provide sources of dispersal and recolonisation of vacant habitats, promote gene flow between populations and provide refugia from disturbances and predators. In contrast, poorly designed Ecological Linkages and remnant vegetation patches poorly connected, can be barriers to dispersal and immigration will be limited, promoting inbreeding and loss of genetic variability. In addition there is the potential for ecological sinks to develop (exposure to predators, disease, anthropomorphic), and increased levels of invasion by weeds, feral animals and increased abiotic factors (such as wildfires, erosion, salinity levels).

The distribution of natural areas across the landscape becomes critically important for maintaining biodiversity once a habitat type is reduced to less than 30% of its original extent. Declining resources and ecological function cause a reduction in the number of species persisting in remnant vegetation patches.

The current extent and condition of native vegetation in the GLBSSA has resulted in a landscape which is so highly fragmented that a critical loss of native species has already occurred. It is also probable that climate change, particularly increasing aridity expected in the South West, will exacerbate these impacts (CSIRO, 2007; EPA, 2007; Dunlop and Brown 2008). Therefore, appropriate management, retention and restoration of well planned and

managed Ecological Linkages will be important to the survival of remaining species, even in large, consolidated and regionally significant natural areas.

Identification of Ecological Linkages

Local Natural Areas (LNAs) are natural areas that exist outside of Bush Forever Sites (Swan Coastal Plain; Government of Western Australia, 2000b), the DEC Managed Estate and Regional Parks (previously referred to as Local Biodiversity Areas; Del Marco *et. al.,* 2004). Together with protected areas, these vegetation remnants can maintain connectivity across the landscape.

Ecological Linkages within the GLBSSA have been identified using the following criteria:

- Where continuous corridors of native vegetation are not present, linkages are made of natural areas forming stepping stones between larger intact areas, with priority given to formally protected areas. Any natural areas identified as stepping stones should be retained in their entirety, rather than just a portion of these areas within a conceptual linkage.
- The targeted maximum distance between natural areas is between 100-500m.
- As approximately 39% of the remnant patches are <1 ha in size setting a minimum size threshold for Local Natural Areas would be detrimental to the construction of the Ecological Linkages. In addition there is evidence to support the importance of paddock trees and small remnants (<1 ha in size) in maintaining connectivity through the landscape.
- As many as possible identified natural areas of good or better condition within each vegetation community.
- Each Ecological Linkage is targeted to have the widest range of habitats .
- Each Natural Area to have as many links as possible, thereby maximizing connectivity through the landscape.
- Linkage width, structural complexity and connectivity to be maximized where possible.

High priority areas for inclusion in the linkage are:

- Protected areas.
- Natural Areas identified as having populations of Declared Rare Flora, Threatened Communities, Priority Flora or Threatened Fauna.
- Riparian vegetation along waterways, creeks and channels (including intermittent waterways), including adequate non-riparian vegetation buffers.
- Granite outcrops, associated seepages and surrounding vegetation.
- Coastal vegetation, dunes and floodplains, including bordering vegetation.
- Natural Areas forming a network of linkages across north-south and east-west gradients of variation in ecological communities within the GLBSSA (thereby taking into account changes in soil, geology, landform and climate variables).
- Local Natural Areas forming direct links with Regionally Significant Local Natural Areas.
- Natural Areas within 500m of regionally valuable areas as identified through the local biodiversity planning process for the GLBSSA.

Identification of Regional Linkages

The identification of potential Ecological Linkages is the initial step in the process of identifying conservation assets that can act as stepping stones through the landscape, which as a whole form Regional Ecological Linkages. Once identified, the Ecological Linkages provide a focal point for the restoration of ecological communities and landscape rehabilitation around remaining remnants (Keighery *et. al.,* 2006).

The purpose of identifying ecological linkages is to ensure connectivity is maintained through the landscape. So a patch of vegetation on a linkage is of higher value then a patch that is outside, however, in a highly fragmented landscape and depending on the vegetation community represented within that patch the isolated patch still can be of high value. Therefore, a linkage is just one in the series of criteria being used to prioritize natural areas.

The GLBSSA and wider Geraldton Hills area is a highly fragmented landscape, with many very small native vegetation patches resulting from agricultural land clearing processes. These remaining patches are often on agriculturally unproductive or inaccessible land. In this landscape therefore, the presence of isolated paddock trees and small vegetation fragments become important stepping stones through the landscape to connect the larger remnant patches.

Often the only remaining representatives of highly cleared vegetation communities, paddock trees are important for maintaining biodiversity in the landscape (Central West Catchment Authority; Manning *et. al.*, 2006; Department of Primary Industries, 2009) Paddock trees and tree patches have been shown to have significant influence on the agricultural land around them, by providing shelter from extremities of temperature and wind to stock, pastures and crops (Central West Catchment Authority; Carruthers and Hodder, 2005; Gibbons and Boak, 2002; DEC, 2005; Manning *et. al.,* 2006; Oliver *et. al.,* 2006 and references there in). Their presence also affects erosion patterns, water table height and potentially influences levels of dryland salinity.

Importantly for maintaining biodiversity in the landscape, paddock trees provide food and habitat resources for wildlife (nectar, seeds, fruits, and other fauna; holes and hollows for nesting sites, and perches; Central West Catchment Authority; Carruthers and Hodder, 2005; Gibbons and Boak, 2002; DEC, 2005; Manning *et. al.*, 2006). In addition soil invertebrates have been found to be more diverse under paddock trees than in surrounding grazed paddocks (Oliver *et. al.,* 2006). This has implications for maintaining biodiversity, conservation of soil invertebrates and providing habitat for invertebrate predators of pasture pest species as well as maintaining soil nutrient cycling. At the landscape scale paddock trees provide increased tree cover, and increased connectivity for fauna through the landscape (with scattered trees reducing the negative edge effects associated with remnant vegetation patch-agricultural area interface). In addition they are important sources for in situ genetic variability for natural regeneration.

As a significant component of vegetation cover, paddock trees and small isolated remnant vegetation patches need to be accounted for in landscape planning (Carruthers and Hodder, 2005). They can represent large proportions of remnant vegetation in some plant communities, especially in highly agriculturally productive areas, such as the Geraldton Hills, and therefore are important for maintaining biodiversity in the landscape. The adequate protection of some vegetation communities therefore relies on the protection and management

of these remnants. Failure to arrest paddock tree decline will further contribute to the loss of some vegetation communities.

Likewise, trees in urban landscapes can be seen as the remaining representatives of vegetation communities isolated in a foreign matrix. They provide similar roles to that of the paddock tree, providing food, habitat and connectivity through the urban landscape for native wildlife and well as shade and associated benefits to humans. Urban trees also act as stepping stones in conjunction to a lesser degree with native gardens to link remnant native vegetation patches in parks and reserves.

Potentially significant Local Natural Areas and biodiversity conservation assets for the GLBSSA are identified and mapped (Figure 1).

Several steps were undertaken to identify potential Ecological Linkages:

- Locate regionally significant protected areas and regionally significant unprotected areas. Currently, 6 of the 9 Beard Association communities at the Study area level have <30% of their original extent remaining and therefore qualify as regionally significant. At the State level, 4 of the 9 Beard Association communities are at <30% of their original extent, therefore these Associations are regionally significant.
- Undertake an analysis of vegetation connectivity and coverage as a function of distance between edges of remnant patches and a function of a size and perimeter ration of remnant patches and groupings of remnant patches.
  (Figure 2).

- Determine if all ecological communities are being represented – following an array of landscape features within individual linkages.
- Distinguish between regionally significant and locally significant e.g. the coastal north-south linkage is of regional significance and also any east-west between the coast and protected regionally significant area to the east are regionally significant links.

Coastal North/South ecological linkages: these broadly link areas of the same major landform elements. They contribute to the overall size of habitat accessible to habitat specialist fauna, promoting: seasonal movement, regular genetic exchanges between populations, re-establishment of populations through immigration into vacant habitat after significant events such as fire. A similar north/south ecological linkage of stepping stones is present along the eastern margin of the study area, along the foothills of the Moresby Range. This linkage extends outside of the study area and links several inland Reserves. The East/West ecological linkages join differing landform units and ecological units. They contribute to the persistence of fauna that require seasonal resources available in and between closely associated differing ecosystems. They also often consist of extensive contiguous but narrow waterways, creeks and channels including intermittent waterways

Identification and Overview of GLBSSA Regional and Local Ecological Linkages

Identification of the Regional and Local Linkages are only possible if the study area is examined in conjunction with the surrounding area. In the following Figures 3-5, red indicates a Regional Linkage, and, blue indicates a Local Linkage.

The Regional Linkages form three separate groups: coastal (north-south); riverine catchments (primarily east-west); and 'eastern landscape'. All three have elements which exist outside of the study area and link it to the wider Geraldton Hills IBRA sub-region.

Regional Linkages: Coastal:

The coastal vegetation forms a continuous remnant of dune vegetation along the shore, extending from north of the GLBSSA around to the port, it then continues, forming the southern extent of the Coastal Regional Linkage as an unbroken remnant to the Greenough River mouth, and further south to Dongara. A secondary link, sometimes present as stepping stones or interconnected remnants, is present as areas of coastal *Acacia* linking the Foredune vegetation communities with riverine communities as well as large ecologically important remnants containing Declared Rare Flora, Threatened Communities, Priority Flora or Threatened Fauna.

Regional Linkages: Riverine Catchments:

The catchments of the Oakajee River, Buller River, Dolby's Gully, Chapman River, Rudd's Gully and Greenough River (from north to south) are identified as forming regional east-west linkages. These six semi permanent rivers drain the western side of the Moresby Ranges in addition to the wider Geraldton Hills area outside of the study area, flowing in an east to west direction.

Regional Linkages: Eastern Landscape:

The Moresby Range is a major influencing component of the landscape and must be considered an integral part of the Regional Linkages despite being outside of the GLBSSA. The Range extends from beyond the northern boundary of the study area along its eastern border, directly affecting the presence of the rivers dissecting the GLBSSA. In addition, the presence of the Moresby Range directly affects the course of the Chapman River. East of the Range this river drains the Victoria Plain in a north to south direction before turning north-west at Moonyoonooka. The Range and the river systems, while intermittent, east of the GLBSSA must be taken into consideration as the Regional Linkages as they directly affect many physical aspects of the GLBSSA.

At the time of writing, the GLBSSA already has areas with significant developmental plans in place. It is therefore prudent to describe the regional and local linkages in terms of the three main sections facing development, namely the Oakajee Port and Industrial and Buller regions in the north; the Glenfield-Chapman River urban development (encompassing Glenfield, Waggrakine and Chapman River) in the centre; and the Cape Burney and Greenough River in the south.

Northern Section: Oakajee Port and Industrial and Buller regions (Figure 3):

This northern section corresponds to the Oakajee industrial area and the 'Buller Locality', these areas are currently gazetted for major development projects, and the southern boundary is the Shire boundary (City of Geraldton-Greenough with Shire of Chapman Valley).

Two major intermittent rivers, the Oakajee and Buller Rivers, and their tributaries, drain this northern section. The upper reaches of both river catchments have 'Land monitor Salinity Threats' and therefore the vegetation communities are threatened by salinity.

Nine GRFVS plant communities have been identified within this northern section of the study area. The plant communities PC4 Swale (Fin), PC11 Limestone ridge (Mc/Espp), PC16 Woodland (Aa/At/Hp) and PC17 Woodland (El) are almost exclusively restricted to this region (Department of Planning and Ecoscape, 2010). Significant numbers of DRF and Priority Flora are found in the region, primarily around the headwaters of the catchments.

The Regional linkages in this northern section are represented by the north-south coastal dune pathway along the coast, a stepping stone connection pathway of coastal remnant vegetation and the Moresby Range to the east of the GLBSSA, in addition to the main tributaries of the Buller and Oakajee Rivers forming the east-west regional linkages (Figure 3; indicated in red). These Regional Linkages connect the Bella Vista and Howatharra Natures Reserves (situated outside the GLBSSA) with the Oakajee and Wokatherra Nature Reserves and with the remaining coastal vegetation. Secondary tributaries of the Oakajee and Buller Rivers in conjunction with local remnants as stepping stones, form an important network of Local Linkages (Figure 3; indicated in blue) connecting the regional linkages, intermittently flowing river headwaters and Nature Reserves with the Moresby Range.

To protect these vegetation communities from further degradation by salinity, a combination of revegetation and regeneration of the cleared land to the north of the Oakajee River in addition to the land around the headwaters is required.

Using the plant community data from the GRFVS as a guide, a program to re-establish vegetation along the drainage lines of these rivers and to reconnect the various close but still isolated remnant patches could be commenced. By using local provenance seed from the local remnants plus seedlings grown from local provenance seed, these communities can be re-established in their former range, and where two communities abut one another specialist expertise can be sought for determining how to integrate the communities. Due to the large area involved this process will require considerable investment in time as reseeding and seedling planting may be necessary. In addition it is important that revegetated areas are mapped and recorded accurately for future monitoring and treatments as required.

If this revegetation is undertaken the benefits will include the potential to limit the current and future salinity risk, the re-establishment of a large area of native vegetation and the significant contribution to the conservation of the regional biodiversity.

As the Oakajee region has been allocated for port, rail and industrial development the potential for large-scale destruction of the coastal vegetation and dune degradation is very high in addition to the loss of several DRF and Priority Flora. However, if a suitable minimal development envelope can be established with limited incursions along the Oakajee River and coastal vegetation in conjunction with a suitably placed access for the port (a potential placement could be where the current blowouts and bare dunes are) in combination with

revegetation programs for the surrounding areas (ie to the north of the River and the headwaters) the regional and local linkages can be maintained.

Central Section: Glenfield- Chapman River urban development (encompassing Glenfield, Waggrakine and Chapman River; Figure 4):

This central section encompasses the urban developments of Glenfield, Glenfield Beach, Waggrakine and the Chapman River area and its southern boundary is the Geraldton-Mount Magnet Road.

Water courses draining this section are Dolby's Gully and the Chapman River. Eight GRFVS plant communities have been identified within the central section of the study area. The plant communities PC1 Estuarine (Co/Te/Sa), PC2 Riparian (Ec/Co/Mr), PC3 Foredune (Ati/Spl), PC8 Coastal (cAr), PC10 Near Coastal (ncAr), PC14 Chapman River Reserve (Ar/Mspp) and PC15 Thicket (Mspp/mx) are restricted in this region (Department of Planning and Ecoscape, 2010).

Several DRF and Priority Flora plus populations of native fauna are found in the region, and the Chapman River Wildlife Corridor forms an important Regional Linkage between the coastal environs and the southern extent of the Moresby Range to the east of the GLBSSA. The upper reaches of the Chapman River catchment has a 'Land monitor Salinity Threat' and therefore the vegetation communities are threatened by salinity.

This central section is dominated by several Regional Linkages (Figure 4; indicated in red). North-south Regional Linkages are represented by the Moresby Range just to the east of the GLBSSA, plus the Foredune pathway along the coast, and a small north-south extension along the Chapman Road connecting the Foredune vegetation communities with Dolby's Gully. East-west Regional Linkages are represented by Dolby's Gully and the Chapman River and associated Wildlife Corridor which connect the coastal vegetation communities with Cutubury Nature Reserve and ultimately via the Chapman River's upper course, remnant vegetation on the Victoria Plateau east of the GLBSSA. Between these two drainage lines, three smaller east-west pathways connect the north-south pathways on the coast to that of the Moresby Range. Local Linkages (Figure 4; indicated in blue) form two north-south pathways, along the Beattie Road, and as stepping stones between the Chapman River Reserve and remnant bushland areas associated with the Geraldton Golf Course and Geraldton Cemetery. In addition, eight local linkages connecting local remnants and creek drainage lines interconnect with the east-west directional Regional Linkages.

The upper reaches of the Chapman River catchment are significant in forming part of the major tributary system east of the Moresby Range. However much of this area has a significant salinity threat and therefore there is strong potential for the lower reaches of the Chapman to also become saline.

Revegetation of the upper reaches of the Chapman River in the Chapman River Valley is currently unfeasible. However, widening of the wildlife corridor by revegetation and regeneration using seeds sourced from the Chapman River Regional Park would be possible, especially along the northern bank. Widening of the wildlife corridor could extend to the Cutubury Nature Reserve (situated on the Chapman River but outside of the GLBSSA) and beyond, in conjunction with revegetating certain points along the river course (within the

'oxbow', eastern section of river). The GRFVS plant community data along with specialist expertise could be used as a guide for the revegetation process.

If revegetation and widening of the Wildlife Corridor are undertaken the benefits will include the potential to limit the current and future salinity risk, the re-establishment of a large area of native vegetation and the significant contribution to the conservation of the regional biodiversity.

Southern Section: Cape Burney and Greenough River (Figure 5):

This southern section encompasses the urban developments south of the Geraldton-Mount Magnet Road, including Cape Burney and the Greenough River area.

The Greenough River, which runs through valleys on the Yilgarn Plateau east of the GLBSSA, descends to the coastal plain at the Waterloo Ranges (to the south of the GLBSSA). A few kilometres from the sea it is obstructed by dunes, and turns to the north-west, running along a dune swale parallel with the coast for about 35 km before finally discharging into the Indian Ocean at Cape Burney (Brearley, 2005). A major northern tributary of the Greenough River and close to the coast, Rudd's Gully initially drains the hills in a south-west direction before turning north-west and ultimately draining into the lower reaches of the Greenough River.

Eight GRFVS Plant communities have been identified within this southern section of the study area. Plant communities PC1 Estuarine (Co/Te/Sa), PC2 Riparian (Ec/Co/Mr), PC11 Limestone Ridge (Mc/Espp) and PC12 Limestone Ridge (rMc) are restricted in this region (WAPC, 2010).

The north-south Regional Linkages of the southern section of the GLBSSA are the foredune pathway along the coast and a short connection from the foredune vegetation around the eastern edge of a dune blowout by a large remnant bushland area to the Greenough River, which runs in north-west before draining into the ocean (Figure 4; indicated in red). Rudd's Gully forms an east-west Regional Linkage with the areas to the southern Hills east of the study area. The Local Linkages are a series of remnants forming several stepping stone routes, including utilising remnant roadside vegetation, connecting remnant vegetation stabilizing the dunes between the Greenough River and Rudd's Gully; and between these rivers and the Chapman River Wildlife Corridor and remnant vegetation associated with the Geraldton Cemetery (Figure 4; indicated in blue). Three Local Linkages occur on the extreme eastern edge of the GLBSSA; the first connects the Chapman River where it drains onto the plain at Moonyoonooka, isolated remnant vegetation and Rudd's Gully; the other two follow drainage channels into Rudd's Gully further south (Figure 4; indicated in blue).

Large mobile dunes on either side of the Greenough River mouth have been formed by strong winds and continue to grow and move northwards. Projections for their continual movement indicate that by 2045 the southern dune will have reached the Greenough mouth and the river become increasingly prone to flooding or be forced to change its course (Brearley, 2005). Stabilisation of parts of the dune systems in the area now with revegetation and regeneration is important for social, economic and conservation reasons. This will also have the additional benefit of strengthening the linkages that connect the Greenough River with Dongara and further south.

REFERENCES

Brearley, Anne (2005). *Ernest Hodgkin's Swanland: Estuaries and coastal lagoons of Southwestern Australia*. University of Western Australia Press. pp. 278–279. ISBN 1-920694-38-2.

Burbidge, A.H., Rolfe, J.K., McKenzie, N.L. and Roberts, J.D. (2004). Biogeographic patterns in small ground-dwelling vertebrates of the Western Australian wheatbelt. *Records of the Western Australian Museum* Supplement No. **67**:109-137

Carruthers, S. and Hodder, M. (2005). *A Landscape Approach to Determine the Ecological Value of Paddock Trees*. Land and Water Australia Project Reference DEP11, Final Report. Prepared for Land and Water Australia and the South Australian Native Vegetation Council. Land and Water Australia, Canberra.

Del Marco, A., Taylor, R., Clarke, K., Savage, K., Cullity, J. and Miles, C. (2004). *Local Government Biodiversity Planning Guidelines for the Perth Metropolitan Region.* Perth Biodiversity Project, Western Australian Local Government Association. West Perth, Western Australia

Desmond, A. and Chant, A. (2001). Geraldton Sandplains 2 (GS2 - Geraldton Hills subregion). *In* May, J.E. and McKenzie, N.L. (eds), *A biodiversity audit of Western Australia's biogeographical subregions in 2002*. Department of Conservation and Land Management. Pp265-292.

Desmond, A.J. and Heriot, S.M. (2002). Fauna monitoring of the Chapman River Wildlife Corridor, Geraldton

Government of Western Australia. (2010a) *CAR Analysis Report 2009*. Accessed October 2010. WA Department of Environment and Conservation, Perth, https://www2.landgate.wa.gov.au/slip/portal/services/files/carreserveanalysis2009.xls

Government of Western Australia. (2010b) *DEC Managed Terrestrial Lands by IBRA Sub Regions July 2010 (unpublished internal report)*. WA Department of Environment and Conservation, Perth.

Department of the Environment, Sport and Territories (1994). *Australia's Biodiversity: an overview of selected significant components*. Biodiversity Unit, Department of the Environment, Sport and Territories. Pp35

Department of the Environment, Water, Heritage and the Arts (2010). Australia's Bioregions. http://www.environment.gov.au/parks/nrs/science/bioregion-framework/ibra/index.html

Department of Planning and Ecoscape (2010). Geraldton Regional Flora and Vegetation Survey. Western Australian Planning Commission. March 2010.

Hopper, S.D. (1979). Biogeographical aspects of speciation in the southwest Australian flora. *Annual Review of Systematics and Ecology* **10**:399-422

Gibson, N., Keighery, G.J., Lyons, M.N. and Webb, A. (2004). Terrestrial flora and vegetation of the Western Australian wheatbelt. *Records of the Western Australian Museum* Supplement No. **67**: 139-189

Government of Western Australia. (2000). Bush Forever. Vol. 2: directory of bush forever sites. Department of Environmental Protection, Perth.

Hobbs, R.J., Saunders, D.A., Lobry de Bruyn, L.A. and Main, A.R. (1993). Changes in biota. *In* R.J. Hobbs and D.A. Saunders (eds), *Reintergrating fragmented landscapes: towards sustainable production and nature conservation*: 65-106. Springer-Verlag, New York.

Keighery, B.J., Dell, J., Keighery, G.J., Madden, S., Longman, V.M., Green, B., Webb, A., McKenzie, B., Hyder, B., Ryan, R., Clarke, K.A., Harris, E., Whisson, G., Olejnik, C. and Richardson, A. (2006). The vegetation, flora, fauna and natural areas of the Peel Harvey Eastern Estuary Area Catchment (Swan Coastal Plain). A report for the Department of Environment and Conservation as a contribution to the Peel Harvey Eastern Estuary Area Catchment Environmental Assessment Project and Swan Bioplan Project. Department of Environment and Conservation.

Manning, A.D, Fischer, J. Lindenmayer, D.B (2006) Scattered trees are keystone structures – Implications for conservation. *Biological Conservation* **132**: 311-321

McAlpine, C.A., Bowen, M.E., Callaghan, J.G., Lunney, D., Rhodes, J.R., Mitchell, D.L., Pullar, D.V. and Poszingham, H.P. (2006). Testing alternative models for the conservation of koalas in fragmented rural-urban landscapes. *Austral Ecology* **31**:529-544.

Myers, N., Mittermeler, R.A., Mittermeler, C.G., da Fonseca, G.A.B. and Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature* **403**: 853-858

Oliver, I., Pearce, S., Greenslade, P.J.M. and Britton, D. (2006). Contribution of paddock trees to the conservation of terrestrial invertebrate biodiversity within grazed native pastures. *Austral Ecology* **31**:1-12.

Quinlan, K., Pinder, A. and Cale, D. (2009). Assessment of the Aquatic Fauna Conservation Assets of Wetlands in the Hutt River/Hutt Lagoon Catchments. Report to Department of Environment and Conservation, Mid-West Regional Office.

Shepherd, D.P., Beeston, G.R. and Hopkins, A.J.M. (2002). Native vegetation in Western Australia: extent, type and status. Resource Management Technical report 249. Department of Agriculture, Perth.

Sutcliffe, K. (2003). *The conservation status of aquatic insects in south-western Australia.* PhD, Murdoch University, Perth, Western Australia.

List of Figures

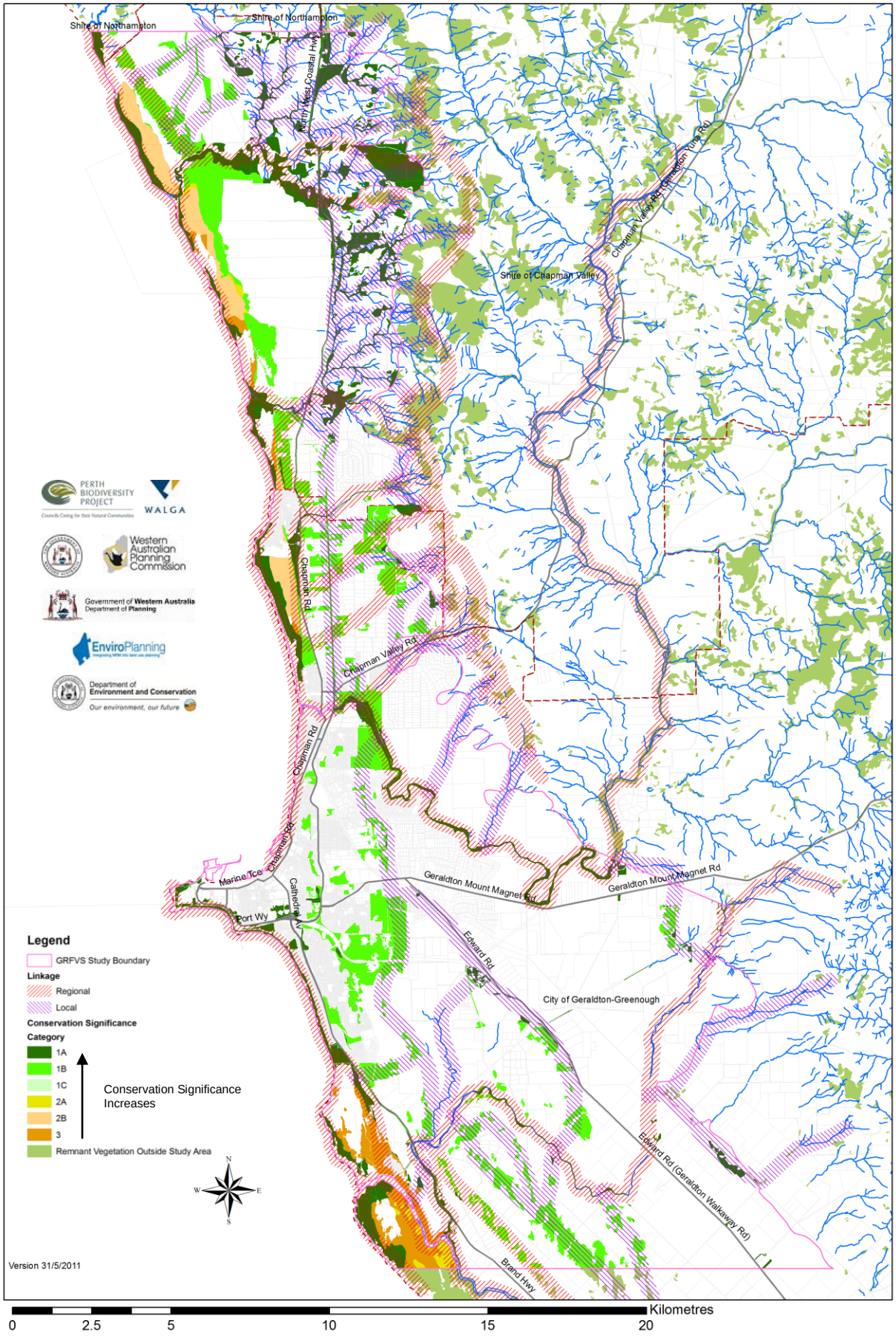
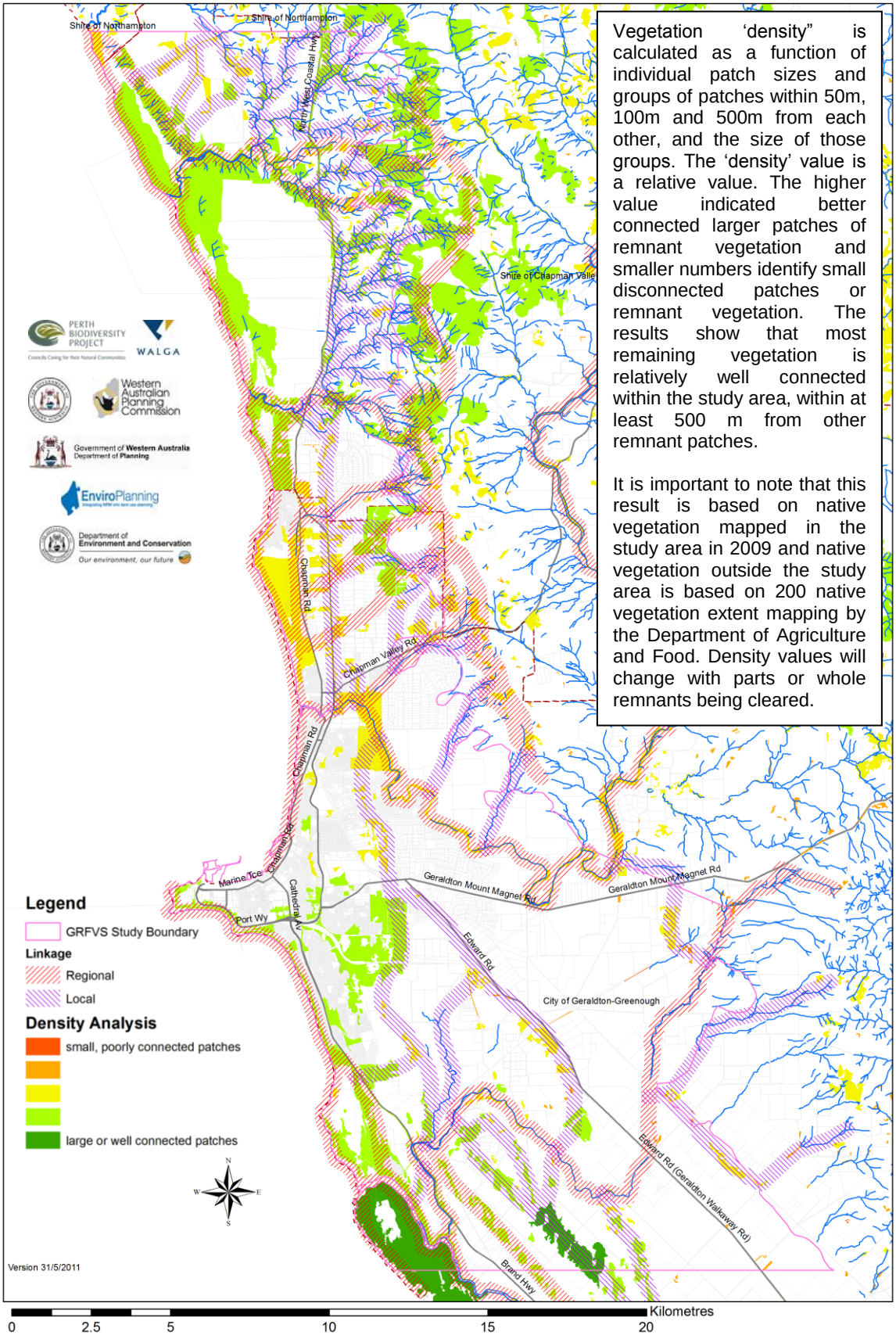


Figure 1: Portion of the City of Geraldton-Greenough and Shire of Chapman Valley region with regional and local ecological linkages over remnant vegetation classified by conservation significance.



Vegetation 'density" is calculated as a function of individual patch sizes and groups of patches within 50m, 100m and 500m from each other, and the size of those groups. The 'density' value is a relative value. The higher value indicated better connected larger patches of remnant vegetation and smaller numbers identify small disconnected patches or remnant vegetation. The results show that most remaining vegetation is relatively well connected within the study area, within at least 500 m from other remnant patches.

It is important to note that this result is based on native vegetation mapped in the study area in 2009 and native vegetation outside the study area is based on 200 native vegetation extent mapping by the Department of Agriculture and Food. Density values will change with parts or whole remnants being cleared.

Figure 1: Portion of the City of Geraldton-Greenough and Shire of Chapman Valley region with regional and local ecological linkages over remnant vegetation.

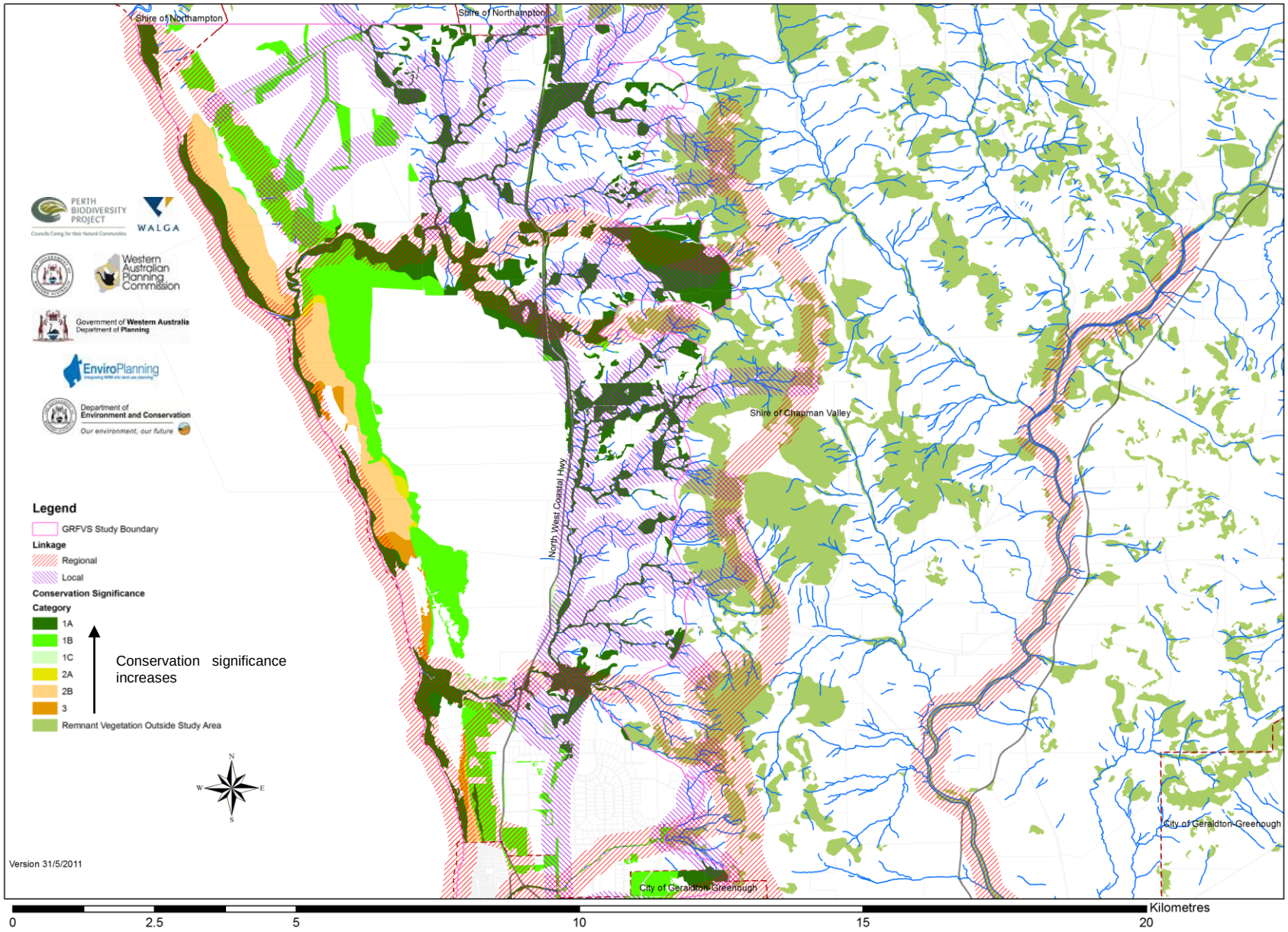


Figure 3: *Northern Section: Oakajee Port and Industrial and Buller regions* with regional and local ecological linkages illustrated

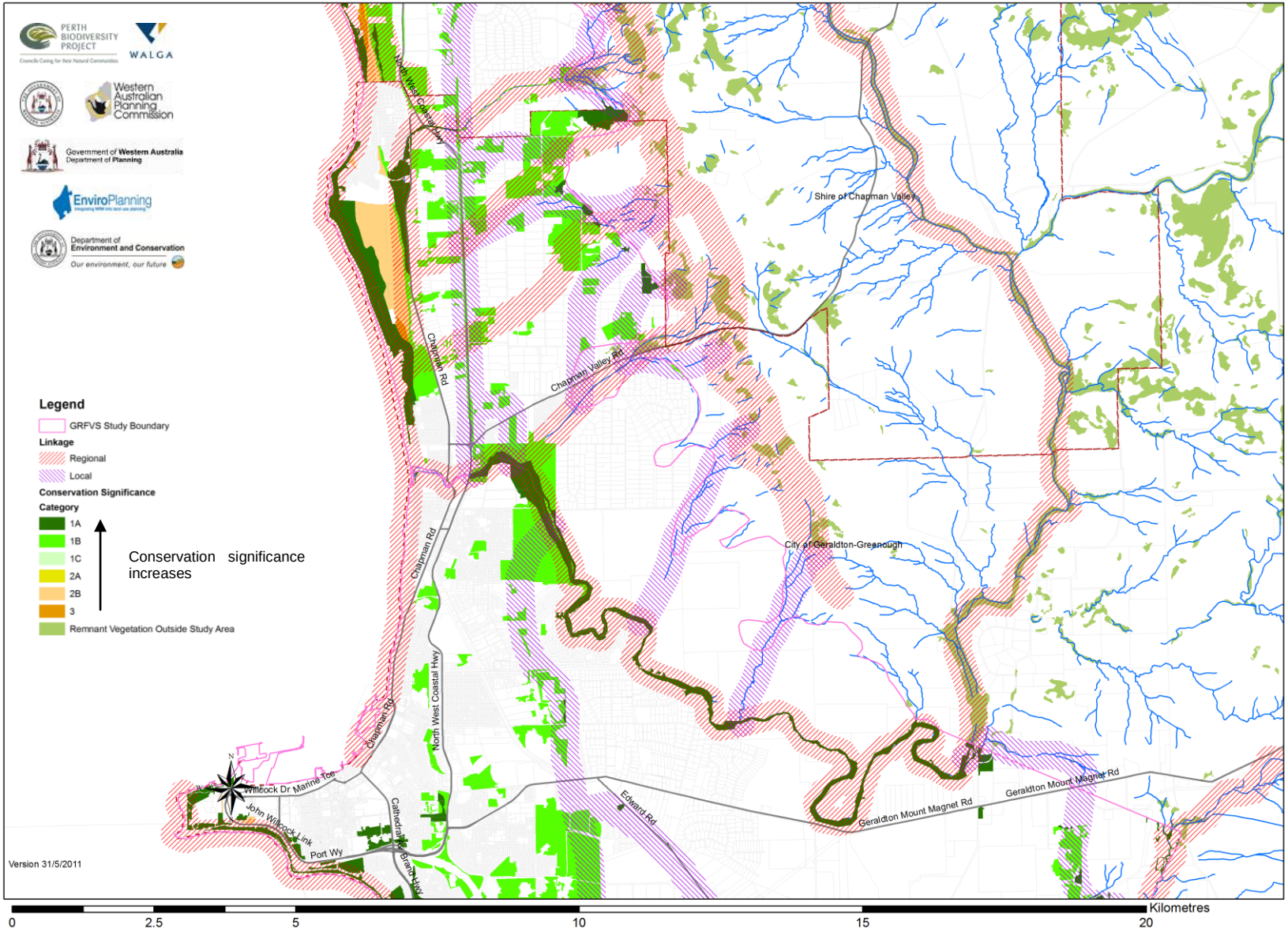


Figure 4: ***Central Section: Glenfield- Chapman River urban development (encompassing Glenfield, Waggrakine and Chapman River)*** **with regional and local ecological linkages illustrated.**

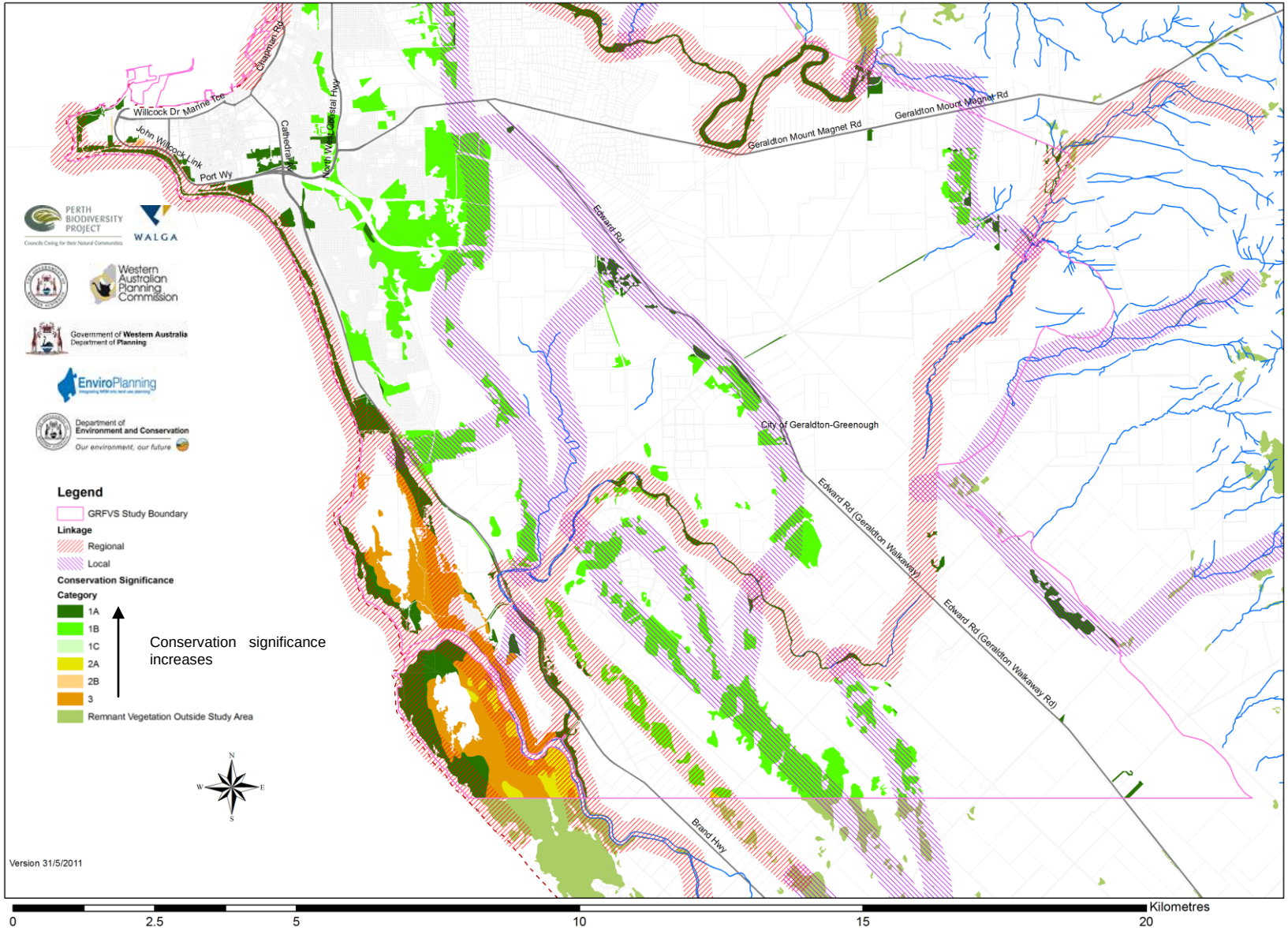


Figure 5: ***Southern Section: Cape Burney and Greenough River*** **with regional and local ecological linkages illustrated.**