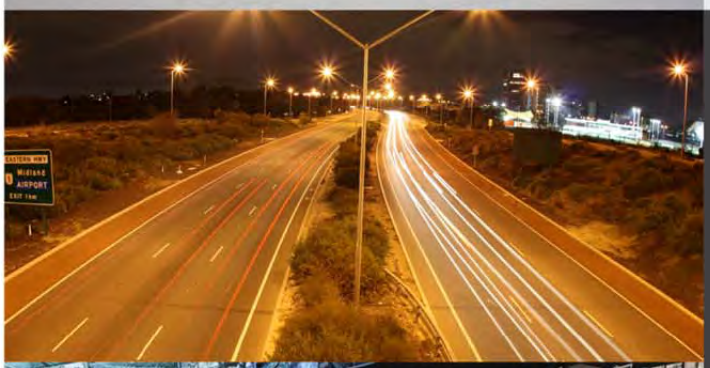
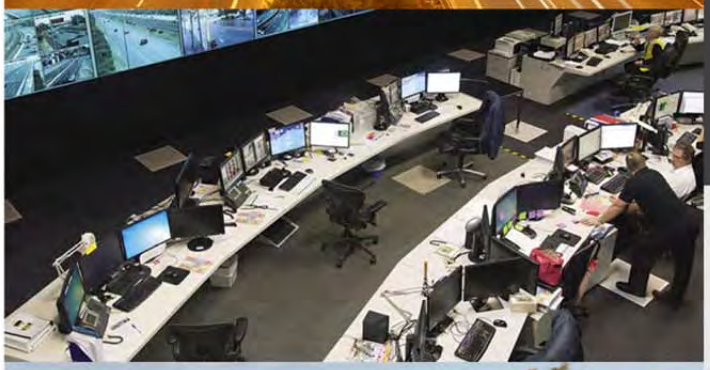
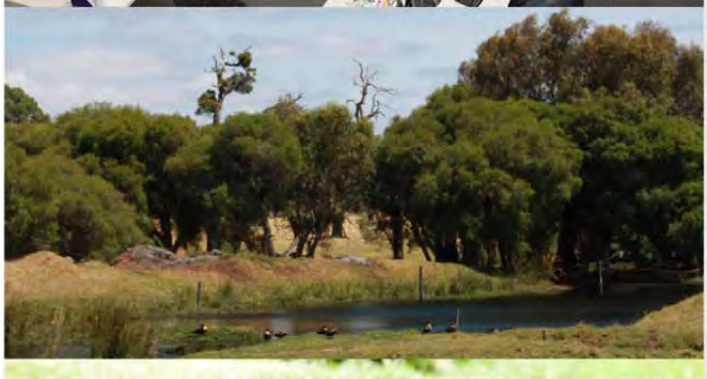
NorthLinkWA

Perth-Darwin National Highway







Wetland Assessment

Perth–Darwin National Highway

DOC NO / NLWA-03-EN-RP-0026

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DATE / 29 May 2015

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Australian Government

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NorthLinkWA

EXECUTIVE SUMMARY

Main Roads Western Australia is proposing to construct the NorthLink WA Project (hereafter referred to as 'the project'). The project will result in 37 km of new dual carriage highway between Tonkin Highway and Reid Highway interchange in the south and Great Northern Highway and Brand Highway interchange in the north (the project area).

This report describes the potential impacts associated with the wetlands (and their buffers) located within or adjacent to the project area that may potentially be impacted upon as a result of the construction and development of the project.

The wetland assessment involved a desktop review; a flora and vegetation survey and wetland site investigation; review of wetland values; and the assessment of the values of the wetlands within the project area and the potential impacts associated with the project.

The assessment of wetlands located within the study area identified:

- A total of 31 wetlands located partially or wholly within the project area. This included:
  - Nine conservation category wetlands (CCW);
  - Six resource enhancement wetlands (REW); and
  - 16 multiple use wetlands (MUW).
- An additional nine conservation category and resource enhancement wetlands occur in close proximity to the project area;
- The wetlands include representatives of four consanguineous wetland suites:
  - The Bennett Brook suite;
  - The Ellen Brook suite;
  - The Jandakot suite; and
  - The Muchea suite.
- One Environmental Protection Policy lake partially occurs within the project area, while an additional seven EPP lakes occur in close proximity to the project area;
- Fifty-five (55) vegetation associations and mapping units (i.e. cleared paddocks) have been mapped across the wetlands recorded within the study area;
- The condition of the vegetation within the wetlands ranged from pristine to completely degraded, while some areas were not given a condition rating and were considered to be cleared due to a lack of native vegetation;
- One State listed Threatened Ecological Community (TEC) (SCP02) was recorded from a REW (Unique Feature Identifier (UFI) 15757);
- One Commonwealth listed TEC (Claypans of the Swan Coastal Plain) was recorded from one location within the MUW UFI 15732 and REW 9174;
- One State and Commonwealth listed TEC (Mound Springs SCP) is known to occur in association with REW UFI 13402.

- One Priority Ecological Community (PEC) (SCP21c) was recorded from three CCWs (UFI 8792, UFI 8802, UFI 15260) and one MUW (UFI 8447);
- The vegetation within the geomorphic wetlands and along Ellen Brook are considered to be groundwater dependent ecosystems;
- One Threatened (*Grevillea curviloba* subsp. *incurva*) and five Priority listed (*Ornduffia submersa, Cyathochaeta teretifolia, Poranthera moorokatta, Millotia tenuifolia* var. *laevis* and *Meeboldina decipiens* subsp. *decipiens* ms) taxa were recorded from wetlands mapped within the study area; and
- Two Weeds of National Significances (**Eichhornia crassipes* and**Rubus laudatus*) and three declared pests (**Eichhornia crassipes*, **Moraea flaccida, *Rubus laudatus* and **Zantedeschia aethiopica*) were recorded in varying densities throughout several wetlands. Higher densities occurred in the wetlands north of Maralla Road in Bullsbrook.

The project area is approximately 765 hectares (ha) in size, with geomorphic wetlands mapped as occurring over 352.35 ha or 46% of the project area. The project will involve the clearing of:

- 14.80 ha of conservation category wetlands;
- 14.30 ha of resource enhancement wetlands; and
- 323.25 ha of multiple use wetlands.

This includes seven conservation category wetlands, four resource enhancement wetlands and 14 multiple use wetlands within the project area.

Based on the results of the wetland assessment and review of the potential and predicted impacts associated with the project, the following recommendations have been made:

- Where possible, the clearing of CCWs and the EPP lake should be avoided. Where the disturbance is unavoidable, the disturbance and clearing of the CCWs and the EPP lake should be kept to as low as reasonably practicable.
- Soil compaction and disturbance outside the project area should be avoided, especially in association with significant wetlands (i.e. CCWs and EPP lakes).
- The hydrological flow across the wetlands should be maintained with the use of appropriate design measures, including culverts and bridges where necessary.
- The drainage management strategy prepared for the project should include strategies for the clearing of wetland vegetation within the project area and the indirect impacts to wetlands located adjacent to the project area.
- Sediment basins and pollutant traps should be incorporated into the design of the project to ensure the quality of surface and underground water does not exceed normal parameters.
- During the construction phase of the project, the groundwater levels and quality should be monitored during abstraction to ensure the project is not causing a significant, irreversible reduction in groundwater levels and quality.
- The GDEs should be monitored post- and pre-construction to determine if the project is impacting on the sensitive wetland receptors, including the Mound Springs SCP TEC, the Claypan on the SCP TEC, the Lexia wetlands and vegetation in good or better condition within CCWs located adjacent to the project area.

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Document *Control*

Revision	Date	Description	Prepared	Reviewed	Approved
Rev A	12/02/2015	Draft to BG&E and Main Roads Western Australia (Coffey – v1)	C. van den Bergh	D. True	D. True
Rev B	30/03/2015	Second draft to BG&E and Main Roads Western Australia (Coffey – v2)	C. van den Bergh L. Dadour	D. True	D. True
Rev 0	29/05/2015	Final to BG&E and Main Roads Western Australia (Coffey – v3)	C. van den Bergh L. Dadour	D. True	D. True

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ABBREVIATIONS

Term	Definition
BAM Act	*Biosecurity and Agriculture Management Act 2007*
BOM	Bureau of Meteorology
CALM	Conservation and Land Management
CCW	Conservation Category Wetland
CEMP	construction environmental management plan
Coffey	Coffey Environments Australia Pty Ltd
DEC	Department of Environment and Conservation
DER	Department of Environment Regulation
DOP	Department of Planning
DOTE	Department of the Environment
DOW	Department of Water
DPAW	Department of Parks and Wildlife
EIA	environmental impact assessment
EP Act	*Environmental Protection Act 1986*
EPA	Environmental Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EPP	Environmental Protection Policy
EPP Lakes	Lakes covered by the Environmental Protection (Swan Coastal Plain Lakes) Policy 1992 (WA).
ESD	Environmental Scoping Document
EWR	Ecological water requirement
FCT	floristic community type
GDE	Groundwater Dependent Ecosystems
ha	hectare
Hwy	Highway
IBRA	Interim Biogeographic Regionalisation for Australia
IUCN	International Union for Conservation of Nature
km	kilometres
m	metres
m^2	metres squared

Term	Definition
mm	millimetres
MNES	Matters of National Environmental Significance
MRS	Metropolitan Region Scheme
MRWA	Main Roads Western Australia
MUW	Multiple Use Wetland
NVIS	National Vegetation Information System
OEPA	Office of the Environmental Protection Authority
PDNH	Perth–Darwin National Highway
PEC	Priority Ecological Community
PER	Public Environmental Review
REW	Resource Enhancement Wetland
RIWI Act	*Rights in Water and Irrigation Act 1914*
SCP	Swan Coastal Plain
TEC	Threatened Ecological Community
UFI	unique feature identifier
WA	Western Australia
WONS	Weeds of National Significance
WSTH	Western Swamp Tortoise Habitat

1 INTRODUCTION

1.1 Background

Main Roads Western Australia (MRWA) is proposing to construct the NorthLink WA Project. This project will result in 37 km of new dual carriage highway between Tonkin Highway and Reid Highway interchange in the south and Great Northern Highway and Brand Highway interchange in the north. The project also includes the grade separation of three intersections on Tonkin Highway between Reid Highway and Guildford Road.

NorthLink WA is the culmination of several decades of planning for the southern terminus of the Perth–Darwin National Highway (PDNH), a key road transport route linking Perth with northern Western Australia (WA) and the Northern Territory.

The NorthLink WA Project Team (hereafter referred to as 'the project team') has been commissioned by MRWA to complete the design and construction of the Swan Valley Bypass section of the PDNH and to obtain the necessary environmental approvals.

The project was referred to the WA Environmental Protection Authority (EPA) on 25 October 2013 to determine the level of assessment that will be required for the project. The EPA determined that the level of assessment would be the Public Environmental Review (PER) level of assessment (6 January 2014), the highest level under the WA *Environmental Protection Act 1986* (EP Act).

In accordance with the PER level of assessment and at the discretion of the EPA, the EPA determined that the Environmental Scoping Document (ESD) (EPA, 2014) would be prepared and issued by the EPA. The ESD identifies the preliminary key environmental factors that the PER would have regard for and would need to identify the direct, indirect, cumulative and residual impacts as a result of the project. The ESD identified that a preliminary key environmental factor would be the potential impacts on the hydrological processes and inland waters environmental quality and native flora and vegetation.

The EPA's objective for the hydrological processes is to '*to maintain the hydrological regimes of groundwater and surface water so that existing and potential uses, including ecosystem maintenance, are protected*' and '*to maintain the quality of groundwater and surface water, sediment and biota so that the environmental values, both ecological and social, are protected*' (EPA, 2014). The potential impacts identified by the EPA on the hydrological processes include (EPA, 2014):

- Crossing and impounding of waterways.
- Dewatering during construction.
- Filling and clearing within Conservation and Resource Enhancement Wetlands and Environmental Protection Policy Lakes.
- Water pollution through road run-off and disturbance of potential acid sulfate soils; and changes to hydrological processes such as compaction.

The EPA's objective for native flora and vegetation, including wetlands, is to '*maintain representation, diversity, viability and ecological function at the species, population and community level*'. The potential impacts identified by the EPA on the native flora and vegetation include (EPA, 2014):

- Loss of flora and vegetation through clearing for road construction.
- Loss of fauna habitat (vegetation loss) short and long term.

- Impacts to wetlands and their buffers.
- Impacts to riparian vegetation and ground water dependent ecosystems.
- Spread of weeds and *Phytophthora* Dieback.
- Fragmentation.

This report addresses the potential impacts associated with the wetlands (and their buffers) located within or adjacent to the project area that may potentially be impacted as a result of the construction and development of the project. The wetland assessment was conducted in conjunction with a Level 2 flora and vegetation survey (Coffey, 2015a) to identify and assess the potential impacts of the project on wetlands and associated vegetation. The remaining potential impacts detailed above are outside the scope of this report and are dealt with by other surveys and reports commissioned by the project team.

1.2 Location

The project area is located within the City of Swan and the Shire of Chittering and extends from the Reid Highway and Tonkin Highway interchange in the City of Swan north for 37 km to the Great Northern Highway and Brand Highway interchange in the Shire of Chittering (Figure 1 and 2). The project area passes through the suburbs of Malaga, Bennett Springs, Ballajura, Cullacabardee, Whiteman, Ellenbrook, Bullsbrook and Muchea.

The project area is approximately 765 hectares (ha) in size and is a mixture of remnant native vegetation, cleared paddocks, rehabilitated land, pine plantations, a mine site and linear infrastructure (i.e. roads, railway, transmission corridor and gas pipeline).

1.3 Report Terms

The following terms have been used within this document:

- Perth–Darwin National Highway (PDNH) – refers to the construction of 37 km of new highway between the Tonkin Highway and Reid Highway interchange in the south and the Great Northern Highway and Brand Highway interchange in the north.
- The Project Area – refers to the proposal footprint and development envelope. The Study Area – refers to the area surveyed within this report. It incorporates the Project area and adjacent lands (Figure 2).
- The Project Team – refers to the NorthLink WA Project Team consisting of seven companies that have been commissioned to design the project.

1.4 Objective

The objectives of this wetland assessment is to review existing wetland field assessment (360 Environmental, 2014a) and address any gaps within the previous studies for the PDNH project area.

1.5 Scope

The scope conducted to meet the objectives consisted of:

- Classification and mapping of wetland flora and vegetation assemblages.

- Mapping of the boundaries of the wetlands, riparian communities and groundwater dependent ecosystems based on the vegetation assemblages.

This assessment does not allow for the review and submission to modify wetland management types, categories or boundaries for the *Geomorphic Wetlands Swan Coastal Plain dataset* managed by the Department of Parks and Wildlife (DPAW).

2 ENVIRONMENTAL POLICY AND LEGISLATION

The assessment of the potential impacts to the wetlands within the study area was undertaken in accordance with the requirements of the following key environmental legislation and regulations:

- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Cwlth).
- *Environmental Protection Act 1986* (WA) (EP Act).
- *Rights in Water and Irrigation Act 1914* (WA) (RIWI).
- Environmental Protection (Swan Coastal Plain Lakes) Policy 1992 (WA) (EPP Lakes).
- Environmental Protection (Gnangara Mound Crown Land) Policy 1992 (WA).
- Environmental Protection (Western Swamp Tortoise Habitat) Policy 2011 (WA).

2.1 Commonwealth Legislation

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the key Commonwealth environmental legislation that protects and manages matters of national and international environmental significance. The administering agency for this act is the Commonwealth Department of the Environment (DOTE).

The eight Matters of National Environmental Significance (MNES) addressed under the Act are:

- World heritage sites.
- National heritage places.
- Wetlands of international importance (i.e. Ramsar listed wetlands).
- Nationally threatened species and ecological communities.
- Migratory species (protected under international agreements).
- Commonwealth marine areas.
- The Great Barrier Reef marine park.
- Nuclear actions.

The key MNES considered relevant to this wetland assessment are nationally threatened species and ecological communities and wetlands of international importance.

2.2 State Legislation

2.2.1 Environment Protection Act 1986

The *Environmental Protection Act 1986* (EP Act) is the primary legislation that governs environmental impact assessment (EIA) and protection in Western Australia. The aim of the Act is:

> *"to provide for an Environmental Protection Authority, for the prevention, control and abatement of pollution and environmental harm, for the conservation, preservation, protection, enhancement and management of the environment and for matters incidental to or connected with foregoing".*

In Section 4A of this Act there are five principles, which are necessary for the objectives of the Act to be realised. Three of these principles are applicable to wetlands:

- The precautionary principle.
- The principle of intergenerational equity.
- The principle of the conservation of biological diversity and ecological integrity.

Authorities under this Act include the Department of Environment Regulation (DER), DPAW (formerly the Department of Environment and Conservation (DEC)) and the Environmental Protection Authority (EPA), including the Office of the Environmental Protection Authority (OEPA).

Part IV of the EP Act relates to the assessment of environmental impacts, and Part V of the EP Act deals with licensing and control of pollution from prescribed premises and permits for land clearing.

2.2.2 Rights in Water and Irrigation Act 1914

The Department of Water (DOW) is responsible for managing the State's water resources. By issuing licences and permits under the *Rights in Water and Irrigation Act 1914* (RIWI), the Department protects the water resources and promotes the sustainable and efficient use of water. The aim of the act is:

> *"to make provisions for the regulation, management, use and protection of water resources, and for related purposes".*

RIWI licensing is active in all proclaimed areas and for all artesian groundwater wells. New licences are only issued where the allocation limit has not been reached. This ensures the protection of the interests of existing users and the environment.

In proclaimed areas under the RIWI it is illegal to take water from a watercourse or groundwater aquifer without a licence. A licence does not guarantee that water is always available to be taken.

During drought periods restrictions are applied so that the available water is shared and damage to the environment, the resource and users is minimised. Conditions are placed to define how and when water may be taken and to specify obligations the licence holder must meet when using the water.

Water can be taken from watercourses in unproclaimed areas without a licence so long as the flow is not "sensibly" diminished, affecting the rights of downstream users. Water can be taken in unproclaimed groundwater areas without a licence so long as the draw is not from an artesian aquifer.

The study area is located within several Groundwater Proclamation Areas (Perth, Mirrabooka, Gnangara, Swan and Gingin) and partially located within a Surface Water Proclamation Area (Swan River System).

2.2.3 Environmental Protection (Swan Coastal Plain Lakes) Policy 1992

The purpose of the Environmental Protection (Swan Coastal Plain Lakes) Policy 1992 (EPP Lakes) is to protect the environmental values of lakes on the Swan Coastal Plain. The lakes protected under the EPP Lakes have in most cases been selected for inclusion in this policy on the basis that they consisted of areas of standing water of 1,000 m^2 or more as of 1 December 1991.

The EPP Lakes made the filling, draining, excavating, polluting and clearing of these lakes an offence unless authorised by the EPA. For the purposes of this report, the EPP Lakes ensures the protection of the lakes by prohibiting the carrying out of activities which cause the destruction and degradation of the lakes and requiring persons who cause the destruction or degradation of lakes to undertake, in certain cases, the rehabilitation or re-establishment of those lakes. The destruction and degradation of the lakes includes the impact to the plant assemblages, soils and hydrology of the lakes.

2.2.4 Environmental Protection (Gnangara Mound Crown Land) Policy 1992

The purpose of the Environmental Protection (Gnangara Mound Crown Land) Policy 1992 (EPP Gnangara) is to protect the level and quality of groundwater on or under the policy area (an area consisting of Crown land and covering a large portion of Gnangara Mound) and native vegetation and wetlands in the policy area.

The filling in of wetlands and the clearing, destruction or removal of native vegetation on or from the policy area is considered to contravene with the purpose of this EPP. The study area is partially located within Crown land on the Gnangara Mound.

2.2.5 Environmental Protection (Western Swamp Tortoise Habitat) Policy 2011

The purpose of the Environmental Protection (Western Swamp Tortoise Habitat) Policy 2011 (EPP WSTH) is to protect habitat suitable for the long-term survival of wild populations of the Western Swamp Tortoise.

This policy is related to the potential clearing and modifications of native vegetation that is consistent with wetland communities and the hydrological regimes that influence flows into Twin Swamp Nature Reserve (A Class Reserve No. 27621). Wetland vegetation and the hydrological regimes that may influence Twin Swamps Nature Reserve are located within and adjacent to the study area.

2.3 Environmental Guidance and Policy

The EPA has produced a number of policy statements, guidelines and technical guides, which provide guidelines and advice regarding the EPA's position on the flora and vegetation of Western Australia. Position statements, guidelines and technical guides relevant to flora and vegetation include:

- Guidance for the Assessment of Environmental Factors No. 6 Rehabilitation of Terrestrial Ecosystems (EPA, 2006a).
- Guidance for the Assessment of Environmental Factors No. 10 Level of Assessment for Proposal Affecting Natural Areas within the System 6 Region and Swan Coastal Plain Portion of the System 1 Region (EPA, 2006b).
- Guidance for the Assessment of Environmental Factors No. 51: Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia (EPA, 2004a).
- Position Statement No. 2 Environmental Protection of Native Vegetation in Western Australia (EPA, 2000).
- Position Statement No. 3 Terrestrial Biological Surveys as an Element of Biodiversity Protection (EPA, 2002).
- Position Statement No. 4 Environmental Protection of Wetlands (EPA, 2004b)
- Position Statement No. 7 Principles of Environmental Protection (EPA, 2004c).
- Department of Parks and Wildlife *Geomorphic Wetlands Swan Coastal Plain Dataset* (last updated January 2015).

3 BACKGROUND INFORMATION

3.1 Existing and Historical Land Use

The study area is located across several existing land uses, including farmland, conservation reserves, transport corridors, rural infrastructure, industrial areas, Gnangara Pine Plantation, active mining tenement and private land.

The study area is located within the Metropolitan Region Scheme (MRS) (DOP, 2014) and the Shire of Chittering Town Planning Scheme No. 6 (TPS6) (DOP, 2012). The current project alignment is zoned:

- MRS zoning – Rural, Primary Regional Roads, Parks and Recreation and State Forest.
- TPS6 zoning – Highway, Agricultural Resource, Parks and Recreation and Railway.

3.2 Climate

Perth has a Mediterranean climate with warm to hot summers and cool to mild, wet winters. The nearest operating Bureau of Meteorology (BOM) weather stations with relevant long term and recent climatic data to the study area are Pearce RAAF Airbase (Station No. 009053) in Bullsbrook (representative of the northern section of the study area), Gingin Aero (Station No. 009178) in Gingin (both representative of the northern section); the Perth Metro station (Station No. 009225) located in Mt Lawley and the Perth Airport (Station No. 009021) (both representative of the southern section) (Figure 3). Overall, the northern end of the project area receives approximately 50 mm per annum less rain than the southern end, and maximum summer temperatures are approximately 2^{o}C cooler at the southern end, as detailed from each of the BOM weather stations below.

Pearce RAAF Airbase (Station No. 009053)

The Pearce RAAF Airbase is located 2.8 km northeast of the study area and receives an average 680 mm of rain per annum with the majority of the rain (528 mm or 78%) falling between the months of May and September.

The average summer temperatures range from a maximum of 30°C to 33.5°C to a minimum of 14.5°C to 17.5°C during December and February. The average winter temperatures range from a maximum of 18.8°C to a minimum of 8.1°C during June and August (BOM, 2014a). The climatic conditions for Pearce RAAF Airbase are presented in Figure 3.

Gingin Aero (Station No. 009178)

The Gingin Aero is located approximately 15 km to the northwest of the Brand Hwy and Great Northern Hwy interchange. The Gingin Aero receives an average 655 mm of rain per annum, with the majority of the rain (515 mm or 78%) falling between the months of May and September. Average temperatures range from a minimum of 6.1^{o}C in winter to a maximum of 33.2^{o}C in summer (BOM, 2014b, Figure 3).

Perth Metro (Station No. 009225)

The Perth Metro weather station is located in Mt Lawley, approximately 8 km to the southwest of the Tonkin Hwy and Reid Hwy interchange and an average receives 732 mm of rain per annum. The majority of this rain (578 mm or 79%) is received during the late autumn to early spring months of May to September. Average temperatures range from a minimum of 7.6^{o}C in winter to a maximum of 31.6^{o}C in summer (BOM, 2014c, Figure 3).

Perth Airport (Station No. 009021)

The Perth Airport is located approximately 10 km southeast of the Tonkin Hwy and Reid Hwy interchange and receives on average 772 mm of rain per annum, with the majority of the rain (607 mm or 79%) falling between the months of May and September. Average temperatures range from a minimum of 8.0°C in winter to a maximum of 31.9°C in summer (BOM, 2014d, Figure 3).

3.3 Topography and Surface Hydrology

The study area is located within the Bassendean Dunes and the Pinjarra Plain fluvial landforms, which are typically flat with low topographical relief due to the age of the landforms and the weathering period.

The study area is within the Bassendean dune system, this is generally flat low relief with broad swales or moderately flat sand sheets between the dunes. The highest dune of up to 80 metres (m) occurs in the north of the Swan Region, in the area east of Lake Pinjarra, Gnangara, immediately west of the study area (Swan Catchment Council, 2004).

The study area occurs within the sub-catchment boundaries of Bennett Brook catchment (in the south) and Ellen Brook catchment (north) of the Swan Coastal Basin and the Swan Avon (Lower Swan) Catchment. The project intercepts two other minor catchments referred to as Henley Brook and St Leonards Creek catchments.

Ellen Brook is a natural ephemeral waterway, situated in the north of the project area and is a major tributary of the Swan River, flowing south and joining the Swan River near Belhus. The annual flow of Ellen Brook is variable and ranged from 2.1 to 48.6 gigalitres per year (GL/y) between 1997 and 2006 (SRT, 2009). The Ellen Brook surface water catchment is 715 km^2 and one of the highest contributors of elevated nutrients, nitrogen and phosphorus, to the Swan-Canning estuarine system (WRC, 2002). The flat plains of the catchment are prone to inundation in the winter either through rising of the water table or waterlogging on surfaces with low permeability. Stream bank erosion and sedimentation are also major issues where fringing vegetation is absent or damaged through unrestricted stock access (WRC, 2002).

Bennett Brook was once a natural creek system; however, its tributaries to the west have been modified to deeply incised drains to allow for development. The brook, with its headwaters in Whiteman Park, is a slow flowing stream 17 km long with recorded annual flows ranging from 2.5 to 10.1 GL/y between 1997 and 2006. The brook is fed primarily from groundwater seepage from the Gnangara mound, flows south and discharges into the Swan River at Success Hill in Bassendean. The Bennett Brook surface water catchment is 217 km^2, half of which is covered by the Gnangara pine plantation and Whiteman Park (SRT, 2011). Increased groundwater abstraction in the northern part of the catchment has lowered groundwater levels reducing the flow into Bennett Brook; however, development of the southern part of the catchment has resulted in elevated flow due to the construction of drainage networks and increased runoff from hard surfaces (SRT, 2011).

Henley Brook is a smaller ephemeral waterway that feeds the Swan River. The Henley Brook catchment is 12.6 km^2 and discharges on average approximately 681 ML of water per year to the Swan River.

St Leonards Creek is a seasonal tributary to the Swan River, typically flowing between April and September, depending on rainfall and an associated rise in the local groundwater table. The catchment of St Leonards Creek is semi-rural and approximately 11.6 km^2. Contributions to the Swan River from this catchment have been reduced by damming and the creation of water retention features along the creek (e.g. sumps).

The study area is located within the Swan River System Rights in Water and Irrigation (RIWI) surface water area. No RIWI rivers are located within the study area (DOW, 2014).

3.4 Ramsar Convention on Wetlands

The signing of the Convention on Wetlands took place in 1971 at the small Iranian town of Ramsar. Since then, the Convention on Wetlands has been known as the Ramsar Convention. The Ramsar Convention's broad aims are to halt the worldwide loss of wetlands and to conserve, through wise use and management, those that remain.

Australia was one of the first countries to sign the Ramsar Convention, and in 1974 designated the world's first Wetland of International Importance: Cobourg Peninsula in the Northern Territory. Australia currently has 65 Wetlands of International Importance listed under the Ramsar Convention, covering approximately 8.1 million hectares.

No Ramsar listed wetlands occur within the study area. The nearest known Ramsar listed wetland is located south of Perth, approximately 31 km south of the study area, at Forrestdale and Thomsons Lake. The project will not directly or indirectly impact any Ramsar listed wetlands.

3.5 Directory of Important Wetlands in Australia

The Directory of Important Wetlands in Australia was first published in 1993 and was compiled by a cooperative project between the Commonwealth, State and Territory jurisdictions and conservation agencies.

The criteria for determining nationally important wetlands in Australia, and hence their eligibility for inclusion in the Directory, are those agreed to by the former Australian and New Zealand Environment and Conservation Council (ANZECC) Wetlands Network in 1994. A wetland may be considered nationally important if it meets one of the following criteria:

1. It is a good example of a wetland type occurring within a biogeographic region in Australia.
2. It is a wetland which plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex.
3. It is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail.
4. The wetland supports 1% or more of the national populations of any native plant or animal taxa.
5. The wetland supports native plant or animal taxa or communities which are considered endangered or vulnerable at the national level.
6. The wetland is of outstanding historical or cultural significance.

According to the Directory, no nationally important wetlands occur within the study area. The nearest known nationally important wetland (Ellen Brook Swamps System, which includes Ellen Brook Swamp and Twin Swamps) is located approximately 2.5 km to the east of the study area, near Warbrook Road.

3.6 Geomorphic Wetlands

DPAW's *Geomorphic Wetlands Swan Coastal Plain* dataset displays the location, boundary, geomorphic classification (wetland type) and management category of wetlands on the Swan Coastal Plain (SCP). The information contained within this dataset was originally digitised from the Wetlands of the Swan Coastal Plain Volume 2B Wetland mapping, Classification and Evaluation: Wetland Atlas, which was captured at a scale of 1:25,000 (Hill et al., 1996).

Wetlands of the SCP have been classified using a geomorphic wetland classification system based on the characteristics of landform and water permanence (hydroperiod). Table 1 details the geomorphic classification of wetlands by Semeniuk and Semeniuk (1995), which DPAW (2013) has adopted.

Table 1 Geomorphic wetland classification types

Hydroperiod	Landform				
	Basin	Channel	Flat	Slope	Highland
Permanent inundation	Lake	River	–	–	–
Seasonal inundation	Sumpland	Creek	Floodplain	–	–
Intermittent inundation	Playa	Wadi	Barlkarra	–	–
Seasonal waterlogging	Dampland	Trough	Palusplain	Paluslope	Palusmont

DPAW has assigned wetland management categories based on their ecological, hydrological and geomorphological significance, and took into account the degree of disturbance that had occurred. The three Wetland Management Categories on the SCP can be summarised as follows:

1. Conservation Category Wetlands (CCW) – wetlands that support a high level of ecological attributes and functions (generally having intact vegetation and natural hydrological processes), or that have a reasonable level of functionality and are representative of wetland types that are rare or poorly protected.
2. Resource Enhancement Wetlands (REW) – wetlands that have been modified (degraded) but still support substantial ecological attributes (wetland dependant vegetation covering more than 10%) and functions (hydrological properties that support wetland dependent vegetation and associated fauna), and have some potential to be restored to the Conservation management category. Typically, such wetlands still support some elements of the original native vegetation, and hydrological function.
3. Multiple Use Wetlands (MUW) – wetlands that are assessed as possessing few remaining ecological attributes and functions. While such wetlands can still play an important role in regional or landscape ecosystem management, including water management, they are considered to have low intrinsic ecological value. Typically, they have very little or no native vegetation remaining (less than 10%).

According to DPAW's Geomorphic Wetlands Swan Coastal Plain Dataset, approximately 23 wetlands occur within the study area (Figure 4), while a 20 (ten CCWs, five REWs and five MUWs) wetlands occur in close proximity to the study area (Figure 4, Appendix A).

3.7 EPP Lakes

According to mapping, eight EPP Lakes partially occur or wholly occur within the study area (Table 2; Figure 4).

Table 2 EPP Lakes located within and in close proximity to the PDNH boundary

EPP lake no.	Location (inside/outside)	UFI	Wetland type	Management category
436	Outside	8793	Sumpland	Conservation
439	Inside (partially)	8664	Sumpland	Conservation
440	Outside	8812	Dampland	Conservation
441	Inside (partially)	8800	Sumpland	Conservation
451	Outside	15732	Palusplain	Multiple Use
450	Inside (partially)	8785	Floodplain	Multiple Use
449	Outside	8784	Floodplain	Multiple Use
405	Outside	15732	Palusplain	Multiple Use

3.8 Groundwater Dependent Ecosystems

Groundwater Dependent Ecosystems (GDEs) are defined as ecosystems that require access to groundwater to meet all or some of their water requirements so as to maintain communities of plants and animals, ecological processes they support, and ecosystem services they provided (adapted from Richardson et al., 2011).

According the National GDE atlas managed by the Bureau of Meteorology (BOM), the geomorphic wetlands and drainage systems (i.e. Ellen Brook) located within the study area are all classified as GDEs (BOM, 2015).

The National Water Commission (NWC) has recommended the adoption of three classes of GDEs based on the typology developed by Eamus et al. (2006) and Eamus (2009) (adapted from Richardson et al., 2011); aquifer and cave ecosystems (Type 1); ecosystems dependent on the surface expression of groundwater (Type 2); and ecosystems dependent on subsurface presence of groundwater (Type 3).

The majority of the GDEs within the study area are considered to be representative of Type 2 and Type 3 GDEs. No Type 1 GDEs occur within the study area. The GDE types for each wetland are provided in Appendix A.

3.9 Groundwater Hydrology

The project is situated in the northern part of the Perth Basin, comprising deeper Jurassic and Cretaceous age sediments overlying late Tertiary and Quaternary age sediments. The main aquifers present include the superficial, Mirrabooka, Leederville, and Yarragadee aquifers (Golder, 2014).

Bassendean Sand and Gnangara Sand are the dominant water transmitting units in the superficial aquifer. The Guildford Formation may act as an aquitard, which could result in the formation of springs and perched groundwater in some areas (Golder, 2014).

The anticipated hydrogeological conditions within the project area can be broadly characterised into three hydrogeological domains (Golder, 2014) discussed below:

- Hydrogeological Domain 1 (southern part of the alignment) - Bassendean Sand deposits are generally thicker and groundwater is generally 3 m to 10 m below ground surface. Surface water and wetlands are still present in this section and are considered to be associated with the intersection of the groundwater level with the ground surface in interdunal depressions or swales. However, some of these wetlands may also be perched groundwater in distinct areas or pockets of low permeability material either at, or below ground surface.
- Hydrogeological Domain 2 - Springs and wetlands are most common along the interface between the Guildford Formation and the Bassendean Sand. Groundwater levels have historically been generally within 1 m to 5 m of ground surface in this domain. Springs and wetlands form here as the groundwater intersects the ground surface as a result of the difference in permeability of the Bassendean Sand and Guildford Formation.
- Hydrogeological Domain 3 (northern section of the alignment) - The Guildford Formation is the dominant geological unit. During heavy rainfall water may become temporarily perched on this formation or in sandy lenses or pockets due to low permeability materials impeding rainfall infiltration. Groundwater levels are expected to be largely within 5 m of ground surface in this domain.

The Gnangara Groundwater Mound is the most significant source of groundwater for the Perth region. This groundwater mound is associated with groundwater recharge that occurs over the relatively elevated sand dune deposits between Ellen Brook and the coast. The groundwater mound is located to the northwest of the project and is one of the main hydrogeological features affecting groundwater levels within the project area (Golder, 2014).

Groundwater levels within the project area experience a seasonal high following the wet season (around September/October) and are at a seasonal low around April/May. The extent of seasonal variation depends on the hydraulic conductivity of the geological unit, but generally a seasonal fluctuation of about 2 m to 3 m is expected in areas of clay (i.e. Guildford Formation), and about 1 m to 1.5 m in Bassendean Sands (Golder, 2014).

Across the majority of the project area groundwater flow is from the Gnangara Mound in an easterly to southerly direction with groundwater discharging into Ellen Brook to the east or the Swan River to the south. However in the northern section within Geological Domain 3 groundwater generally flows from the Perth Hills and Darling Scarp in a southwest direction with discharge into Ellen Brook (Golder, 2014).

3.10 Landforms, Geology and Soils

The SCP is bounded to the east by the Darling and Gingin Faults, resulting in landforms rising to over 200 m above sea level. The SCP consists of a series of distinct landforms that roughly run parallel to the coast (McArthur and Bettenay, 1974). The landforms, from east to west, comprise the Ridge Hill Shelf, Pinjarra Plain, Bassendean Dunes, Spearwood Dunes and Quindalup Dunes. The study area is located within the Bassendean Dunes and the Pinjarra Plains landforms.

To the west of the colluvial slopes of the Ridge Hill Shelf lies the Pinjarra Plain, a piedmont and valley-flat alluvial plain consisting predominantly of clayey alluvium transported by rivers and streams from the Darling and Dandaragan Plateaux. The plain is about 5 km wide (McPherson and Jones, 2005).

To the west of the Pinjarra Plain, the Bassendean Dune system, the oldest dune system on the SCP, forms a gently undulating Aeolian sand plain about 20 km wide, with the dunes to the north of Perth generally having greater topographic relief than those to the south. The dunes probably accumulated as shoreline deposits and coastal dunes during interglacial periods of high sea level and originally consisted of lime (calcareous) sand with quartz sand and minor fine-grained, black, heavy-mineral concentrations. The

Bassendean Dunes contain little silt or clay, and very low levels of plant nutrients, which are associated with organic matter (Bolland, 1998).

Overall, the study area is characterised by low relief, sandy geology and sandy, infertile soils. Churchward and McArthur (1978) have mapped the study area as:

- Bassendean: sand plains with low dunes and occasional swamps; iron or humus podzols; areas of complex steep dunes.
- Southern River: Sandplain with low dunes and may intervening swamps; iron and humus podzols, peats, and clays.
- Yanga: poorly drained plain with grey sandy benches and intervening swamps; also areas of bog iron ore, marl or solonetzic soils.
- Coonambidgee: gently sloping fringe to the Dandaragan Plateau; deep grey sands.

3.11 Bioregional Context

The Interim Biogeographic Regionalisation for Australia (IBRA) divides Australia into 89 bioregions based on major biological and geographical or geological attributes (Thackway & Cresswell, 1995). The bioregions have been further divided into 419 subregions which are more localised and homogenous geomorphological units in each bioregion. The study area is located within the Perth subregion (SWA02) of the SCP bioregion. The subregional area is 1,333,901 ha in size (Mitchell *et al*., 2002).

The SCP is a low-lying coastal plain, mainly covered with woodlands. It is dominated by Banksia (*Banksia* spp.) or Tuart (*Eucalyptus gomphocephala*) on sandy soils, *Casuarina obesa* on outwash plains, and paperbark (*Melaleuca* spp.) in swampy areas. In the east, the plain rises to duricrusted Mesozoic sediments dominated by Jarrah (*E. marginata*) woodland (Mitchell *et al*., 2002).

The Perth subregion is composed of colluvial and Aeolian sands, alluvial river flats and coastal limestone. Heath and/or Tuart (*E. gomphocephala*) woodlands on limestone, Banksia (*Banksia* spp.) and Jarrah (*E. marginata*)-Banksia (*Banksia* spp.) woodlands on Quaternary marine dunes of various ages, and Marri (*Corymbia calophylla*) on colluvial and alluvial soils. The subregion includes a complex series of seasonal wetlands.

3.12 Regional Vegetation

3.12.1 Beard's Vegetation Mapping

The study area is located within the Drummond Botanical Subdistrict of the SCP Subregion (Beard, 1990). The Drummond Botanical Subdistrict comprises *Banksia* spp. low woodland on leached sands with *Melaleuca* spp. swamps where ill-drained, woodland of Tuart (*E. gomphocephala*), Jarrah (*E. marginata*) and Marri (*C. calophylla*) on less leached sands (Beard, 1990).

John Beard (and others) undertook a systematic survey of native vegetation in Western Australia in the 1970s to describe the vegetation systems present at either a 1:250,000 or 1:1,000,000 scale. The Perth region was mapped by Beard (1979) at a 1:250,000 scale. The vegetation systems have since been reinterpreted and updated by Shepherd *et al*. (2002) to reflect the National Vegetation Information System (NVIS) standards (ESCAVI, 2003). The update also accounts for extensive clearing since Beard's (1979) mapping. Some of Beard's vegetation associations have been separated to remove mosaic vegetation associations; however, some mosaics still occur.

The vegetation associations (Beard, 1979); Shepherd *et al*., 2002), of the study area are:

- 4 – Medium woodland; Marri (Corymbia calophylla) and Wandoo (Eucalyptus wandoo).
- 949 – Low woodland; Banksia spp.
- 1001 – Medium very sparse woodland; Jarrah (Eucalyptus marginata), with low woodland; Banksia (Banksia spp.) & Casuarina (Casuarina obesa).
- 1018 – Mosaic: Medium forest; Jarrah (Eucalyptus marginata)-Marri (Corymbia calophylla)/Low woodland; Banksia (Banksia spp.)/Low forest; Teatree (Melaleuca spp.)/Low woodland; Casuarina obesa.

The extent of the vegetation system associations within the study area is provided in Table 3.

Table 3 Vegetation system association extent in the study area

Code	System	System association code	Extent (ha)
4	Pinjarra	4.3	972.0
949	Bassendean	949.2	580.4
1001	Bassendean	1001.1	807.5
1018	Bassendean	1018.0	602.4
	Pinjarra	1018.1	111.1

3.12.2 Vegetation Complexes

Heddle *et al.* (1980) have described and mapped vegetation complexes of the Darling System at a board floristic scale of 1:250,000, based on data collected from the literature, ground surveys, road traverses and aerial photographs and is related to the landforms, soils and climatic conditions.

Seven vegetation complexes occur across the study area (Figure 5). The seven vegetation complexes are described below, and a breakdown of the extent within the study area is provided in Table 4.

- Bassendean Complex – Central and South: ranges from woodland of Jarrah (*Eucalyptus marginata*)-Sheoak (*Allocasuarina fraseriana*)-Banksia (*Banksia* spp.) on the sand dunes, to a low woodland of *Melaleuca* spp., and sedgelands on the low-lying depressions and swamps.
- Bassendean Complex – North Transition: consists of low open forest and low woodland of Banksia (*Banksia* spp.)-Prickly Bark (*Eucalyptus todtiana*) and is structurally similar to several other vegetation complexes, but differs in the floristic composition of the understorey.
- Bassendean Complex – North: consists of a range of vegetation from low open forest and low woodland of Banksia (*Banksia* spp.)-Prickly Bark (*Eucalyptus todtiana*) to low woodland of *Melaleuca* spp., and sedgelands which occupy moister sites.
- Coonambidgee Complex: consists of vegetation ranging from a low open forest and low woodland of Prickly Bark (*Eucalyptus todtiana*)-Banksia (*Banksia attenuata-B. menziesii-B. ilicifolia*) with local admixtures of *B. prionotes*, to open woodland of Marri (*Corymbia calophylla*)-Banksia (*Banksia* spp.).
- Reagan Complex: supports vegetation ranging from low open woodland of *B. attenuata-B. Menziesii-Eucalyptus todtiana* to closed heath, depending on the depth of the soil.
- Southern River Complex: consists of open woodland of Marri (*Corymbia calophylla*)-Jarrah (*Eucalyptus marginata*)-Banksia (*Banksia* spp.) on the elevated areas and fringing woodland of *Eucalyptus rudis-Melaleuca rhaphiophylla* along the streams.

- Yanga Complex: a low open forest of Swamp Sheoak (*Casuarina obesa*) occurs on the low-lying flats, with patches of *Actinostrobus pyramidalis* and *Melaleuca* spp. (including *Melaleuca lateritia* and *M. hamulosa*).

Table 4 Vegetation complex extent within the study area

Vegetation complex	Extent within the study area	
	ha[1]	%
Bassendean Complex-Central and South	315.0	27.6
Bassendean Complex-North Transition	31.2	2.7
Bassendean Complex-North	292.9	25.7
Coonambidgee Complex	24.1	2.1
Reagan Complex	13.2	1.2
Southern River Complex	288.2	25.3
Yanga Complex	175.1	15.4

1: Only includes intact native vegetation within the study area (1,139.62 ha)

3.13 Bush Forever Strategy

The Bush Forever Strategy is a ten year strategic plan which formally commenced in 2000 to protect approximately 51,200 ha of regionally significant bushland within approximately 290 Bush Forever Sites, representing, where achievable, a target of at least 10% of each of the original 26 vegetation complexes of the Swan Coastal Plain portion of the Perth Metropolitan Region (Government of Western Australia, 2000).

There are 14 Bush Forever Sites located within or adjacent (within 1 km) to the study area (Figure 4), listed below:

- Bush Forever Site No. 2: North East Ellen Brook Bushland, Bullsbrook.
- Bush Forever Site No. 6: Cooper Road Water Reserve and Adjacent Bushland, Bullsbrook.
- Bush Forever Site No. 13: Sawpit Road Bushland, Bullsbrook.
- Bush Forever Site No. 97: Kirby Road Bushland, Bullsbrook.
- Bush Forever Site No. 100: Neaves Road Creek, Bullsbrook.
- Bush Forever Site No. 192: Wetherell Road Bushland, Lexia/Ellenbrook.
- Bush Forever Site No. 195: Wetherell Road Bushland, Lexia/Ellenbrook.
- Bush Forever Site No. 198: Beechboro Road Bushland, Cullacabardee/Ballajura.
- Bush Forever Site No. 300: Maralla Road Bushland, Ellenbrook/Upper Swan.
- Bush Forever Site No. 304: Whiteman Park, Whiteman/West Swan.
- Bush Forever Site No. 307: Lightning Swamp and Adjacent Bushland, Noranda.
- Bush Forever Site No. 385: Reid Highway Bushland, Mirrabooka/Malaga.
- Bush Forever Site No. 399: Melaleuca Park and Adjacent Bushland, Bullsbrook/Lexia. Bush Forever Site No. 480: Victoria Road Bushland, Malaga/Beechboro.

4 METHODS

4.1 Desktop Assessment

A desktop assessment was undertaken prior to the field component of the assessment. The desktop assessment involved a review of existing environmental or biological data available for the wetlands within the study area and wetlands located adjacent to the study area. The desktop assessment involved the review of State and Federal wetland datasets, regional and local contextual data for the wetlands in the northern SCP and existing wetland and biological surveys undertaken on the SCP. The results of the desktop assessment are detailed in Chapter 5.

4.2 Field Survey

The field component of the wetland assessment was undertaken in conjunction with the Level 2 flora and vegetation survey of the study area. The field studies were led by Senior Botanists, Clinton van den Bergh and Bethea Loudon and were assisted by Botanists Lucy Dadour and Alison Saligari. The field component of the assessment was completed over 10 days in September 2014 (Table 5). The survey botanists held appropriate flora collecting licences, including declared rare flora.

Table 5 Survey timing and scientific licences

Team member	Role	Survey period	Licence to take flora for scientific or other prescribed purposes	Permit to take declared rare flora
Clinton van den Bergh	Senior Botanist	15–19 & 22–26 September 2014	SL010743	73-1314
Bethea Loudon	Senior Botanist	15–19 & 22–26 September 2014	SL010956	108-1314
Lucy Dadour	Botanist	15–19 & 22–26 September 2014	SL011069	
Alison Saligari	Botanist	15–19 & 22–26 September 2014	SL010959	107-1314

The study area is partially located within conservation estates (Unnamed Reserve 46875, Unnamed Reserve 46919, Unnamed Reserve 46920 and State Forest 65) vested in the Conservation Commission and managed by DPAW. In accordance with the *Conservation and Land Management Regulations 2002*, a Regulation 4 Authority was applied for, and granted by DPAW. The sampling of flora and vegetation within the conservation estate was undertaken in accordance with Regulation 4 Authority number CEO04590.

A Level 2 flora and vegetation survey, consistent with the EPA's Guidance for the Assessment of Environmental Factors No. 51; Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia (EPA, 2004a), was undertaken within the study area (Coffey, 2015a).

A total of 120 flora sampling sites, consisting of 93 quadrats 100 m^2 in size (10 m x 10 m) and 27 relevés (unmarked quadrats) were established and sampled within the study area (Figure 6). The survey consisted of the re-sampling of 29 quadrats established and originally sampled in 2013 (360 Environmental, 2014b). The remaining 64 quadrats were established and sampled in September 2014 (Coffey, 2015a).

Approximately 56 sample sites (including quadrats and relevés) were located in wetlands within the study area. Sampling sites were randomly located within structural communities. Where possible, two sampling sites were established and sampled within each structural community.

The information recorded at each of the quadrats and the relevés within the wetlands included:

- Location: GDA94 coordinates (equivalent of WGS84) were taken from each of the four corners of the quadrats and from a central point for the relevés. The coordinates were taken using a handheld Garmin Global Positioning System (GPS) to an accuracy of ±5 m.
- Vegetation description: the vegetation structure was described to broad floristic formation and vegetation association, where possible.
- Disturbance details: the condition of the vegetation was assessed according to the condition rating scale developed by Keighery (1994). Additional information on feral pests, introduced weeds, dieback and anthropogenic disturbances were also recorded.
- Taxa: an inventory of the taxa located within the quadrat and within the 20 m radius of the relevés central point, was taken.
- Foliage cover and height: the percentage cover and height was visually estimated for the taxa located at each sampling point. Estimate were made to the nearest percentage and tenth of a metre (i.e. 0.1 m), where possible.
- Habitat: the aspect and slope within and surrounding the sampling point was recorded. Additional information of wetlands, or other prominent geological features was also recorded.
- Soil: colour and soil texture within the sampling points was recorded.
- Rock and litter cover: estimates were made on the rock type, size and cover within each sampling point. The litter cover was also noted for each sampling point.

The broad floristic formations and vegetation associations were described based on the floristic data recorded from the quadrats, relevés and from visual observations while traversing the study area. The broad floristic formations and vegetation associations were described utilising the standardised terminology for vegetation structural classes detailed in the Australian Vegetation Attribute Manual (ESCAVI, 2003) (Appendix B). The vegetation structural terminology of the National Vegetation Information System (NVIS) was adapted from Specht (1970), Specht et al. (1974), and Walker and Hopkins (1990) (ESCAVI, 2003).

The condition of the vegetation identified within the study area was described based on the condition rating scale developed by Keighery (1994) and published in the Bush Forever Strategy (Government of Western Australia, 2000) (Appendix C).

4.3 Multivariate Statistical Analysis

The floristic data collected from the flora and vegetation survey (Coffey, 2015a) was used to conduct the statistical multivariate analysis using the PATN analysis package (Belbin, 1987). Several modules of the PATN analysis package were used for the statistical analysis, including:

- ASO (calculation of similarity matrix).
- FUSE (classification based on the results of ASO).
- DEND (representation of classification, in a dendrogram).
- NNB (Determination of sites most similar to each site, called nearest neighbour analysis).

The analysis was undertaken on 94 sites (including the 56 sites established and sampled within geomorphic wetlands) assessed during this survey and an additional ten sites originally sampled in 2013 (360 Environmental, 2014b). Only permanent quadrats with sufficient data of high quality were used in the analysis.

The floristic data were compared against the 509 sites sampled by Gibson *et al*. (1994) to determine regionally significant vegetation associations. An additional analysis was undertaken which included a comparison of the floristic data collected from this survey (site comparison) and the floristic data collected from surveys nearby, in order to identify additional locally significant vegetation associations (Trudgen, 1998), Trudgen & Associates, 1999) and Weston *et al* , 1993).

4.4 Wetland Assessment

The wetland assessment involved three steps: 1) desktop assessment; 2) site visit including a flora and vegetation survey; and 3) wetland review and reporting. The methods and approach for the flora and vegetation component of the assessment is detailed in Section 4.2.

The desktop assessment involved a review of documents, databases and mapping platforms to identify the location of any wetlands within the study area. The documents, databases and mapping platforms reviewed prior to the field component of the assessment included:

- DPAWs *Geomorphic Wetlands Swan Coastal Plain dataset*.
- Directory of Important Wetlands in Australia.
- Internationally recognised Ramsar listed wetlands.
- Lakes listed within the Environmental Protection (Swan Coastal Plain Lakes) Policy 1992 as significant lakes.
- Groundwater dependent ecosystems mapped by the Bureau of Meteorology *Groundwater Dependent Ecosystem Atlas*.
- WA Atlas Shared Land Information Platform, Landgate.
- General, Stratigraphy, Wetland Hydrology and Wetland Vegetation for the Swan Valley Bypass, NorthLink WA (360 Environmental 2014a).
- The Bush Forever Strategy (Government of Western Australia, 2000).

In addition the list of documents and databases above, the surveys and assessments previously commissioned to identify and assess the impacts to wetlands include:

- A Level 2 flora and vegetation survey (Coffey, 2015a), which identifies and assesses the potential impacts to intact native vegetation, including wetland vegetation.
- Position Paper on the road embankment assessment (groundwater) (NorthLink, 2014a) to identify and assess if groundwater levels will rise and pond at the surface on the upstream side of the project and decrease on the downstream side of the project.
- Position Paper on Twin Swamps hydrology (NorthLink, 2014b) to identify and assess the potential impact the project may have on Twin Swamps Nature Reserve.
- Position Paper on Ellen Brook Nature Reserve (NorthLink, 2015) to identify and assess the potential impact the project may have on Ellen Brook Nature Reserve.

- A hydrogeological review of the TEC Mound Springs SCP (GHD, 2008), which identified and assessed the potential impacts of the project area on the hydrogeological processes of the TEC Mound Springs.

At the completion of the desktop assessment and the collection and collation of floristic and site data from the Level 2 flora and vegetation survey, the wetlands were reviewed to determine the potential impacts associated with the project. The project area and the known location of wetlands was interrogated to determine the extent of the potential impact.

4.5 Assessment Limitations

The field survey was undertaken in September 2014. The rainfall recorded at the four nearest weather stations were between 5% and 25% below average (year to date and the winter months of June, July and August). Although not ideal conditions, the number of flowering ephemerals, annuals and orchids were high. For example, over 35 spring flowering orchids were recorded during the September 2014 survey. As is typical for vascular flora surveys, fungi and non-vascular flora (e.g. bryophytes, mosses, etc.) were not collected or recorded.

The study area traverses numerous land holdings and ownerships ensuring some difficulty in gaining access to all of the wetlands located across the study area. The key wetlands, namely CCWs, REWs and EPP lakes were accessed. However, several land holdings that are not directly impacted by the project were not accessed and as a result, the wetland values, functions and attributes have been determined based on the baseline stratigraphy and wetland hydrology report prepared for the alignment (360 Environmental, 2014a).

An assessment of wetland categorisation (i.e. determination of conservation or resource enhancement category) and boundary definition (including buffer requirement) was outside the scope of this study. This study was undertaken to identify the attributes, values and functions of the wetland within and adjacent to the study area and the potential impacts on these attributes, values and functions as a result of the development of the project.

A statement of the botanical survey limitations for the flora and vegetation assessment of the study area is provided in Table 6.

Table 6 Survey limitations

Limitation	Constraint (yes or no)	Comment
Competency/experience of the survey team conducting the survey and the identifications	No	The survey team has a combined 25+ years' experience conducting surveys, including wetland assessments, in Western Australia, with particular experience on the Geomorphic Wetlands of the Swan Coastal Plain.
Level of survey	No	A Level 2 flora and vegetation survey was completed, which sampled 120 sites located throughout the study area, including the majority of the 40 wetlands located within the study area.
Sources of information	No	The wetlands on the Swan Coastal Plain have been extensively surveyed in the past, including an assessment of the wetlands within and adjacent to the study area in 2013 (November and December) and 2014 (January).
Scope	No	The entire scope was met.

Limitation	Constraint (yes or no)	Comment
Proportion of Task achieved and further work that may be required	No	The entire task was achieved. No further work is considered necessary.
Completeness	No	The wetlands were adequately traversed and sampled.
Mapping reliability	No	The mapping reliability is considered to be high due to the intensity of the flora sampling sites within the wetlands and the previous surveys undertaken within the study area.
Timing/weather/season/cycle	No	The survey was undertaken in September 2014. Although Perth recorded below average winter rainfall, the lack of rainfall is not considered to be sufficient to constitute a constraint. Surface water and/or soil moisture was evident in all the sampled wetlands within and adjacent to the study area. The vegetation was considered to be flowering (although slightly earlier than usual) and generally in good phenology health.
Disturbances which affected the results of the survey	Yes	The wetlands recorded within the study area were highly disturbed from historical and current practices (i.e. land clearing and stock grazing) while uncontrolled access and the dumping of rubbish is having an impact on the wetlands with the spread of weeds. A small fire has burnt a portion of a wetland at the Reid Highway and Tonkin Highway interchange. The fire occurred within the last 10 months and as a result, the vegetation structure has been altered. The vegetation was noted as recovering well from the fire. Portions of the study area have been impacted by *Phytophthora* Dieback and as a result, the overstorey and understorey of some of the plant communities were disturbed sufficiently that the plant community identification may have been compromised.
Intensity of the survey	No	The intensity of the survey was sufficient.
Resources	No	Adequate resources were assigned to the field survey and the reporting components of the assessment.
Remoteness and/or access problems	Yes	Access was available to the majority of the study area. However, certain land holdings that are privately owned and do not occur directly within the project were not accessed in September due access arrangements. The constraint is considered to be minor because the land holdings do not occur within the project. The indirect impacts on the wetlands located within the private land holdings may not be sufficiently identified as a result of the lack of survey in September 2014.
Availability of contextual information	No	The Swan Coastal Plain has been extensively surveyed in the past, with numerous documents with contextual information available.

5 RESULTS

5.1 Review of Existing Wetland Assessment

An existing stratigraphy, wetland hydrology and wetland vegetation assessment (360 Environmental, 2014a) was prepared for the project. The objectives of the assessment was to establish a preliminary baseline for the wetlands within and near the project area and to identify the potential effects that may alter these wetlands as a result of the construction of the project (360 Environmental, 2014a). It must be noted that the project area has changed since the existing assessment and this report.

The assessment identified 38 basin and flat wetlands as being either located in the direct path of the project area or in close proximity. Only CCWs or REWs were chosen for further assessment. Of the 38 wetlands, 37 were mapped for plant assemblages, 13 were selected for installing water monitoring bores and obtaining sediment profiles (360 Environmental, 2014a).

Of the 38 wetlands included with the existing assessment, eight have intact native vegetation, natural wetland stratigraphic fills, one or more natural recharge mechanisms (i.e. direct rainfall, perching, lateral groundwater flows, seasonal vertical water table rise) and are of conservation significance (UFIs 8416, 15260, 8439, 8541, 8664, 8792, 8812 and 8926).

Five wetlands (UFIs 15028, 15033, 13867, 8800 and 8798) have very good intact wetland vegetation, and in some cases, uncommon plant composition. Four wetlands (UFIs 8911, 8910, 8909 and 8773) have hydrological mechanisms which potentially were considered to be impacted by the construction of the project. The remaining 17 wetlands (360 Environmental 2014a) were considered unlikely to be impacted, or are not ecologically significant.

5.2 Current Wetland Assessment

The information presented below has been distilled from the results of the Level 2 spring flora and vegetation survey of the study area by the project team (Coffey, 2015a).

5.2.1 Condition of Wetland Condition

The condition of the wetlands ranged from excellent to completely degraded based on the vegetation extent and the condition rating scale developed by Keighery (1994). In general, the wetlands that had a well-developed vegetation structure were considered to be in good or better condition, while the wetlands that were open paddocks or highly modified environments were generally degraded or worse in condition.

The condition of each wetland located within the study area is detailed in Table 7 below and mapped on Figure 7.

Table 7 Wetland condition ratings (based on vegetation condition)

Unique feature identifier (UFI)	Wetland type	Management category	Vegetation condition (Keighery, 1994)
8416	Palusplain	Conservation	Good
8429	Sumpland	Conservation	Good
8773	Palusplain	Conservation	Good to Completely Degraded

Unique feature identifier (UFI)	Wetland type	Management category	Vegetation condition (Keighery, 1994)
8792	Dampland	Conservation	Very Good
8800	Sumpland	Conservation	Excellent
8802	Dampland	Conservation	Pristine to Very Good
8909	Palusplain	Conservation	Good to Completely Degraded
8910	Palusplain	Conservation	Good to Degraded
8911	Palusplain	Conservation	Good to Degraded
8914	Palusplain	Conservation	Completely Degraded
15028	Sumpland	Conservation	Pristine to Good
15033	Sumpland	Conservation	Excellent to Very Good
15260	Palusplain	Conservation	Excellent to Very Good
8541	Dampland	Resource Enhancement	Very Good to Completely Degraded
8554	Sumpland	Resource Enhancement	Excellent to Very Good
8779	Sumpland	Resource Enhancement	Completely Degraded
8783	Sumpland	Resource Enhancement	Degraded
15752	Palusplain	Resource Enhancement	Completely Degraded
15757	Sumpland	Resource Enhancement	Very Good to Completely Degraded
8254	Dampland	Multiple Use	Excellent to Completely Degraded
8262	Dampland	Multiple Use	Good
8411	Dampland	Multiple Use	Degraded
8438	Dampland	Multiple Use	Degraded
8447	Dampland	Multiple Use	Excellent to Completely Degraded
8449	Dampland	Multiple Use	Good
8450	Dampland	Multiple Use	Good to Degraded
8464	Sumpland	Multiple Use	Pristine to Completely Degraded
8785	Floodplain	Multiple Use	Degraded to Completely Degraded
8936	Sumpland	Multiple Use	Good to Completely Degraded
13096	Sumpland	Multiple Use	Completely Degraded
15029	Palusplain	Multiple Use	Very Good to Completely Degraded
15030	Sumpland	Multiple Use	Excellent to Good
15175	Palusplain	Multiple Use	Degraded to Completely Degraded
15200	Sumpland	Multiple Use	Excellent to Completely Degraded
15732	Palusplain	Multiple Use	Excellent to Completely Degraded

The vegetation north of Maralla Road and located in association with the large palusplain (Ellen Brook floodplain) was considered to be highly variable. Small pockets of good vegetation were interspersed amongst large cleared paddocks. The wetland vegetation that was in good or better condition were isolated and consisted of resilient patches of vegetation where external pressures (i.e. grazing, anthropogenic disturbances) were low due to fencing and connectivity to larger patches of vegetation.

The wetlands located south of Maralla Road were generally in better condition, especially the CCWs and some of the REWs. The MUWs were located in the historically disturbed areas (paddocks within Whiteman Park), including housing, infrastructure corridors and areas previously cleared of vegetation.

5.2.2 Wetland Vegetation

A Level 2 flora and vegetation survey was undertaken in the study area, with 120 sites (including quadrats and relevés) sampled. Statistical multivariate analysis was performed on the floristic data collected from the sample sites to determine the vegetation associations present within the study area (Coffey, 2015a).

The statistical analysis identified 31 wetland vegetation associations and five transitional (wetland/dryland) vegetation associations. In addition, several 'dryland' communities were mapped as occurring in association with the margins of the wetlands. In total, there are 55 vegetation associations and mapping units located within wetlands across the study area (Table 8).

Table 8 lists the vegetation associations recorded from each wetland (based on UFI numbers) recorded within the study area, while the vegetation associations for each wetland is mapped on Figure 8.

Table 8 Wetland and transitional wetland vegetation associations recorded from the study area

Unit code	Vegetation association description	Photograph
As	*Astartea scoparia*, *Kunzea glabrescens* tall shrubland to tall open shrubland over **Holcus lanatus, *Bromus diandrus* and **Vulpia bromoides* low grassland over **Romulea rosea, *Hypochaeris glabra* and **Lotus subbiflorus* open to isolated low herbs.	
AsMlEv	*Astartea scoparia, Melaleuca lateritia, Eutaxia virgata* closed mid shrubland over *Lepidosperma striatum* and *Lepidosperma longitudinale* sparse tall sedgeland with occasional *Meeboldina* spp. and *Hypolaena exsulca* sparse tall rushland.	

Unit code	Vegetation association description	Photograph
Ba	*Banksia attenuata* sparse low woodland and *Eucalyptus todtiana* isolated low mallee trees over *Melaleuca seriata, Eremaea pauciflora* var. *pauciflora* and *Xanthorrhoea preissii* sparse low shrubland over *Phlebocarya ciliata* open low herbland.	
BaBm[1]	*Banksia attenuata* and *Banksia menziesii* low woodland to sparse low woodland over *Eremaea pauciflora* var. *pauciflora, Hibbertia hypericoides, Hibbertia subvaginata* sparse low shrubland over *Patersonia occidentalis* subsp. *occidentalis* sparse low herbland.	
BaBm[2]	*Banksia attenuata* and *Banksia menziesii* low woodland to sparse low woodland over *Calytrix fraseri* (Ellenbrook Form), *Verticordia nitens* and *Beaufortia elegans* sparse mid shrubland over *Alexgeorgea nitens* and *Desmocladus flexuosus* sparse low rushland.	

Unit code	Vegetation association description	Photograph
BaBm[3]	*Banksia attenuata, Banksia menziesii* low woodland over *Eremaea pauciflora* var. *pauciflora, Scholtzia* aff. *involucrata, Hibbertia hypericoides* open to sparse low shrubland over *Patersonia occidentalis* subsp. *occidentalis* sparse mid herbland.	
Bl	*Banksia littoralis* sparse low woodland over *Hypocalymma angustifolium* and *Pericalymma crassipes* closed mid shrubland over *Meeboldina scariosa* sparse tall rushland.	
BlMp	*Banksia littoralis* and *Melaleuca preissiana* sparse low woodland over *Astartea scoparia*, *Pericalymma crassipes* and *Kunzea glabrescens* closed mid shrubland to mid shrubland over *Schoenus caespititius* open tall sedgeland.	

Unit code	Vegetation association description	Photograph
Cc/Mp	*Corymbia calophylla* and/or *Melaleuca preissiana* mid woodland over *Banksia littoralis* sparse low woodland over *Xanthorrhoea preissii* and *Taxandria linearifolia* open to sparse tall shrubland.	
Cc[1]	*Corymbia calophylla* isolated clumps of mid trees with occasional *Eucalyptus marginata* subsp. *thalassica* mid trees over *Xanthorrhoea preissii* sparse mid shrubland over **Ehrharta calycina* and **Briza maxima* sparse low grassland.	
Cc[2]	*Corymbia calophylla* isolated mid trees over *Melaleuca preissiana* isolated low trees over *Xanthorrhoea preissii* sparse mid shrubland.	

Unit code	Vegetation association description	Photograph
Cc[4]	*Corymbia calophylla* mid woodland over *Melaleuca preissiana* low woodland to sparse low woodland over *Dielsia stenostachya* closed mid rushland.	
Cc[5]	*Corymbia calophylla* mid woodland over *Xanthorrhoea preissii* and *Jacksonia furcellata* sparse tall shrubland over *Dasypogon bromeliifolius*, *Patersonia occidentalis* subsp. *occidentalis*, **Ursinia anthemoides* low herbland.	
Cc[6]	*Corymbia calophylla* sparse mid woodland over *Banksia menziesii, Banksia attenuata* and *Nuytsia floribunda* sparse low woodland over *Xanthorrhoea preissii* sparse tall shrubland.	

Unit code	Vegetation association description	Photograph
CcEm[2]	*Corymbia calophylla* and *Eucalyptus marginata* subsp. *thalassica* mid woodland to sparse mid woodland over *Xanthorrhoea preissii*, *Calytrix fraseri* (Ellenbrook Form), *Verticordia nitens* sparse mid shrubland over *Hibbertia hypericoides, Eremaea pauciflora* var. *pauciflora, Scholtzia* aff. *involucrata* open to sparse low shrubland.	
CcEr[1]	*Corymbia calophylla* and *Eucalyptus rudis* subsp. *rudis* isolated mid trees over *Astartea scoparia* and *Taxandria linearifolia* tall shrubland over **Cenchrus clandestinus* and **Holcus lanatus* closed low grassland.	
CcEr[2]	*Corymbia calophylla* and *Eucalyptus rudis* subsp. *rudis* isolated clumps of low trees over *Jacksonia furcellata* sparse tall shrubland over **Ehrharta calycina, *Bromus diandrus* and **Ehrharta longiflora* closed mid grassland.	

Unit code	Vegetation association description	Photograph
CcEr[3]	Open paddocks with remnant *Corymbia calophylla* and *Eucalyptus rudis* subsp. *rudis* over pasture species (introduced) dominated by **Cenchrus clandestinus.*	
CcMp	*Corymbia calophylla* and *Melaleuca preissiana* sparse mid woodland over *Banksia attenuata* and *Banksia ilicifolia* sparse low woodland over *Kunzea glabrescens* open tall shrubland.	
CcMpMr	*Corymbia calophylla* isolated clumps of mid trees over *Melaleuca preissiana* and *Melaleuca rhaphiophylla* isolated clumps of low trees over grassland dominated by introduced grasses.	
Co	*Casuarina obesa* isolated low trees over *Melaleuca concreta* open tall shrubland over *Lepidosperma longitudinale, Juncus pallidus* and *Schoenus caespititius* open mid sedgeland.	

Unit code	Vegetation association description	Photograph
Em[1]	*Eucalyptus marginata* subsp. *thalassica* isolated mid trees over *Melaleuca preissiana* and occasional *Banksia attenuata* and *Banksia ilicifolia* low woodland over *Xanthorrhoea preissii*, *Hypocalymma angustifolium* and *Astroloma xerophyllum* open to sparse mid shrubland.	
Em[2]	*Eucalyptus marginata* subsp. *thalassica* sparse mid woodland over *Banksia menziesii* low woodland over *Xanthorrhoea preissii* sparse tall shrubland.	
Ep	*Banksia* spp. sparse low woodland over *Eremaea pauciflora* subsp. *pauciflora Melaleuca striata, Beaufortia elegans* low shrubland over *Patersonia occidentalis* and *Dasypogon bromeliifolius* sparse herbland.	

Unit code	Vegetation association description	Photograph
Er[1]	*Eucalyptus rudis* subsp. *rudis* and occasional *Corymbia calophylla* sparse mid woodland over *Astartea scoparia*, *Kunzea glabrescens* and *Aotus gracillima* open tall shrubland over *Desmocladus flexuosus* and *Dielsia stenostachya* isolated low rushes.	
Er[2]	*Eucalyptus rudis* subsp. *rudis* isolated mid trees over *Astartea scoparia, Melaleuca teretifolia* and *Melaleuca lateritia* closed tall shrubland to open tall shrubland over *Lepidosperma longitudinale* and *Schoenus caespititius* sparse mid sedgeland.	
Er[3]	*Eucalyptus rudis* subsp. *rudis* isolated mid trees over *Melaleuca preissiana, Banksia littoralis* and occasional *Melaleuca rhaphiophylla* sparse low woodland over *Astartea scoparia, Melaleuca teretifolia,* and *Hypocalymma angustifolium* closed tall shrubland to tall shrubland.	

Unit code	Vegetation association description	Photograph
Er[4]	*Eucalyptus rudis* subsp. *rudis* open mid forest over *Hardenbergia comptoniana* open tall shrubland over *Pteridium esculentum* subsp. *esculentum* tall herbland.	
Er[5]	*Eucalyptus rudis* subsp. *rudis* sparse mid woodland over *Melaleuca preissiana* and *Melaleuca rhaphiophylla* low woodland over **Zantedeschia aethiopica* and **Rorippa nasturtium-aquaticum* open mid herbland.	
Er[6]	*Eucalyptus rudis* subsp. rudis sparse mid woodland over *Melaleuca rhaphiophylla* sparse low woodland over **Lolium rigidum, *Ehrharta longiflora* and **Cenchrus clandestinus* low grassland.	

Unit code	Vegetation association description	Photograph
Er^{7}	*Eucalyptus rudis* subsp. *rudis* sparse mid woodland over **Zantedeschia aethiopica* tall herbland over low grassland (dominated by introduced species).	
Er^{8}	*Eucalyptus rudis* subsp. *rudis*, *Corymbia calophylla* sparse mid woodland over *Melaleuca preissiana* and *Melaleuca rhaphiophylla* isolated clumps of low trees over **Holcus lanatus* and **Cenchrus clandestinus* closed mid grassland.	
ErCo	*Eucalyptus rudis* subsp. *rudis, Casuarina obesa* and *Melaleuca* sp. open low forest over **Ehrharta longiflora, *Ehrharta calycina* and **Lolium rigidum* low grassland over **Lotus subbiflorus* and **Moraea flaccida* sparse low herbland.	

Unit code	Vegetation association description	Photograph
ErMp	*Eucalyptus rudis* subsp. *rudis* and *Melaleuca preissiana* sparse mid woodland over **Acacia longifolia* subsp. *longifolia* closed tall shrubland over *Astartea scoparia* sparse mid shrubland.	
ErMrMc	*Eucalyptus rudis* subsp. *rudis, Melaleuca rhaphiophylla* and *Melaleuca concreta* open low forest over **Moraea flaccida* sparse mid herbland over **Lolium rigidum, *Ehrharta longiflora* and **Cynodon dactylon* mid grassland.	
Et[2]	*Eucalyptus todtiana* isolated mid mallee trees over *Banksia attenuata, Banksia menziesii* and *Nuytsia floribunda* sparse low woodland over *Verticordia nitens, Beaufortia elegans*, *Jacksonia floribunda*.	

Unit code	Vegetation association description	Photograph
Et[3]	*Eucalyptus todtiana* sparse mid mallee trees over *Banksia attenuata, Banksia menziesii* and *Banksia ilicifolia* sparse low woodland over *Adenanthos cygnorum* subsp. *cygnorum* and *Jacksonia furcellata* sparse tall shrubland.	
Mp[1]	*Melaleuca preissiana* closed low forest over *Histiopteris incisa* and *Pteridium esculentum* subsp. *esculentum* sparse tall herbland over *Cyathochaeta teretifolia* open mid sedgeland.	
Mp[2]	*Melaleuca preissiana* isolated mid trees over *Banksia attenuata, Banksia menziesii* and occasional *Banksia ilicifolia* sparse low woodland over *Xanthorrhoea preissii, Adenanthos cygnorum* subsp. *cygnorum* and *Hypocalymma angustifolium* mid shrubland.	

Unit code	Vegetation association description	Photograph
Mp[3]	*Melaleuca preissiana* low woodland over *Astartea scoparia, Taxandria linearifolia* and *Aotus gracillima* open tall shrubland over *Cyathochaeta avenacea* and *Juncus pallidus* open tall sedgeland.	
Mp[4]	*Melaleuca preissiana* mid woodland over *Banksia littoralis* sparse low woodland over *Lepidosperma striatum* and *Lepidosperma longitudinale* closed tall sedgeland.	
Mp[6]	*Melaleuca preissiana* sparse low woodland over *Pericalymma crassipes, Hypocalymma angustifolium* and *Xanthorrhoea preissii* open tall shrubland over *Lepidosperma striatum* and *Lepidosperma longitudinale* tall sedgeland.	

Unit code	Vegetation association description	Photograph
Mp[7]	*Melaleuca preissiana* sparse to open low woodland over **Zantedeschia aethiopica* sparse tall herbland over **Cenchrus clandestinus* and **Holcus lanatus* sparse mid grassland.	
Mp[8]	*Melaleuca preissiana* sparse to open low woodland over *Xanthorrhoea preissii* sparse mid shrubland over *Lepidosperma longitudinale* sparse mid sedgeland.	
Mp[9]	*Melaleuca preissiana* sparse to open low woodland over *Xanthorrhoea preissii* tall shrubland over *Astartea scoparia* and *Taxandria linearifolia* sparse mid shrubland.	

Unit code	Vegetation association description	Photograph
Mp[10]	*Melaleuca preissiana* open low woodland to forest over *Juncus kraussii* subsp. *australiensis* sparse mid sedgeland over **Cynodon dactylon* open low grassland.	
MpAl	*Melaleuca preissiana* and **Acacia longifolia* subsp. *longifolia* sparse low woodland over *Xanthorrhoea preissii* sparse mid shrubland over **Bromus diandrus, *Ehrharta calycina* and **Avena barbata* tall grassland.	
MpBl	*Melaleuca preissiana* and *Banksia littoralis* open low woodland to forest over *Melaleuca lateritia* and *Melaleuca teretifolia* sparse mid shrubland over *Schoenus caespititius* sparse mid sedgeland.	

Unit code	Vegetation association description	Photograph
MpMr	*Melaleuca preissiana* and *Melaleuca rhaphiophylla* low (open) woodland over **Zantedeschia aethiopica* and **Typha orientalis* open mid herbland.	
PeAsMtMl	*Pericalymma ellipticum* var. *floridum, Astartea scoparia, Melaleuca teretifolia* tall shrubland.	
Xp[1]	*Xanthorrhoea preissii* tall open shrubland over **Ehrharta calycina* sparse mid grassland.	
Xp[2]	*Xanthorrhoea preissii* sparse mid shrubland to open tall shrubland.	

Unit code	Vegetation association description	Photograph
R	*Corymbia calophylla, Eucalyptus camaldulensis* and *Eucalyptus todtiana* low woodland over *Calothamnus quadrifidus* and *Banksia nivea* sparse mid shrubland over **Bromus diandrus* and **Ehrharta calycina* sparse mid grassland over **Ursinia anthemoides* and **Hypochaeris glabra* sparse low herbland (Revegetation site).	
Rehab	Rehabilitation sites associated with Rocla mine site and other sites of rehabilitation, including road sides.	
Cl	Cleared areas, consisting of paddocks, infrastructure corridors (i.e. Roads and Highways), building envelopes (i.e. residential housing, industry etc.) and the former Ellenbrook settlement (within Rocla mine tenement).	

Source Coffey (2015a).

5.2.3 Significant Wetland Vegetation

5.2.3.1 Threatened and Priority Ecological Communities

According to a statistical analysis of the floristic data collected from the sample sites within the wetlands undertaken (Coffey, 2015a) and review of the floristic data collected from the sample sites and the vegetation associations, three Threatened Ecological Communities (TECs) and one Priority Ecological Community (PEC) occur within eight wetlands in the study area (Figure 8).

The list of wetlands representing conservation significant vegetation (TECs and the PEC) is provided in Table 9.

Table 9 Threatened and priority ecological communities recorded within wetlands

Ecological community	Federal code	State code	Wetland UFI	Management category	Vegetation associations
Claypans of the Swan Coastal Plain	Critically Endangered (TEC)	N/A	• 9174 • 15732	• Resource Enhancement • Multiple Use	• Co & Mp[10]
Mound Springs SCP	Endangered (TEC)	Critically Endangered (TEC)	• 13402	• Resource Enhancement	• Mp[1]
SCP02 (Southern wet shrublands)	N/A	Endangered (TEC)	• 15757	• Resource Enhancement	• Mp[3]
SCP21c (Low lying *Banksia attenuata* woodlands or shrublands)	N/A	Priority 3 (PEC)	• 8447 • 8792 • 8802 • 15260	• Multiple Use • Conservation • Conservation • Conservation	• Ba, CcEm[2], CcMp, Cc/Mp & Ep

The location of the TECs and the PEC are centred on individual sampling sites within the study area and include the 100 m^2 sampling site and adjacent mapped vegetation. Based on aerial interpretation and review of the TEC and PEC descriptions, the extent of each TEC and PEC within the wetlands and the study area is detailed in Table 10.

Table 10 TEC and PEC extent within the study area and the wetlands

Ecological community	Extent within study area (ha)	Extent within wetlands[1] (ha)
Claypans of the Swan Coastal Plain (Commonwealth TEC)	9.8	9.8
Mound Springs SCP	1.5	1.5
SCP02 (Southern wet shrublands) (State TEC)	1.4	1.1
SCP21c (Low lying *Banksia attenuata* woodlands or shrublands) (State PEC)	178.0	18.8

The Federal TEC, Claypans of the Swan Coastal Plain, is located in the northern end of the study area on the eastern side of Great Northern Highway (north of Brand Highway) and is partially located within MUW

15732 and REW 9174. The mapped extent of the TEC is approximately 9.8 ha, of which the entire extent is located within wetlands. The extent of the TEC occurs within vegetation associations Co and Mp[10].

The identification of the Federal TEC (Claypans of the Swan Coastal Plain) was not confirmed by the statistical analysis. The Federal TEC is a combination of four State TECs and one PEC (SCP07, SCP08, SCP09, SCP10a and Claypans on mid dense shrublands of *Melaleuca lateritia* over herbs) that occur on clay pans and clay flats.

The statistical analysis of the floristic data collected from a sample site within UFI 15732 was classified as SCP11 or SCP17, which are not clay-based sites. This is considered to represent a misclassification due to the presence of introduced species, with the site considered to be a representative of a Priority 1 PEC, *Casuarina obesa* association, or the Priority 1 PEC, Claypans on mid dense shrublands of *Melaleuca lateritia* over herbs.

However, due to the presence of clay-based soils, the sampling site is considered to be representative of the Commonwealth TEC. The vegetation that is representative of the Commonwealth TEC is located outside of the project area and will not be directly impacted.

The TEC Mound Springs SCP is known to occur within the study area and adjacent to the project area (Figure 8). The habitat of this community is characterised by the continuous discharge of groundwater in raised areas of peat. The peat and immediate surrounds provide a stable, permanently moist series of microhabitats.

The Mound Springs SCP TEC was not identified from statistical analysis; however, it has been the subject of several surveys to identify and delineate the boundary. A Level 1 flora and vegetation survey was conducted in July 2007 to support the realignment of the project area to the east of the known mound spring, ensuring that there would be no direct impacts to the TEC or the catchment which is located to the west of the spring (GHD 2007).

The Mound Springs SCP TEC was mapped in association with Mp[1] which consists of a low closed forest of *Melaleuca preissiana* over open mid sedgeland of *Cyathochaeta teretifolia*. The vegetation surrounding the spring has not been included in the mapping of the TEC; however, it is highly likely that the vegetation is supported by the constant discharge of groundwater in the raised area of peat in the spring.

The TEC SCP02 was identified from one sampling site near the intersection of Marshall Road and Hepburn Avenue (Figure 8). The statistical analysis of the sampling site could not separate the vegetation between SCP02 and SCP11 (Wet forest and shrublands) based on the statistical analysis. SCP11 is not known to be a TEC or a PEC. The sampling site is more than likely to be consistent with SCP11; however, further sampling and analysis would be required to confirm the identification. Taking a precautionary approach, the site is considered to be the TEC SCP02 until further advice and assessments can be completed.

The vegetation association within the TEC SCP02 consisted of low woodland of *Melaleuca preissiana* over an open tall shrubland of *Aotus gracillima*, *Astartea scoparia* and *Taxandria linearifolia* over an open tall sedgeland. The TEC is located within the project area with the entire extent proposed to be impacted as a result of the project.

The PEC SCP21c was identified from sampling sites located within four wetlands (Figure 8). The four wetlands are considered to be damplands and palusplains which are seasonally waterlogged flats and basins. The PEC occurs within vegetation associations Ba, CcEm[2], CcMp, Cc/Mp and Ep. The PEC is located between Maralla Road in the north to Cullacabardee in the south and covers an extent of approximately 178.0 ha, of which 18.8 ha is located within wetlands.

5.2.3.2 Significant Vegetation Associations

Two vegetation associations (AsMlEv and CcMp) were only recorded from wetlands which are either wholly located within the project area or have a significant extent (greater than 90%) mapped within the project area.

Vegetation association AsMlEv was mapped as occurring within the proposed Tonkin Highway and Reid Highway interchange and is wholly located within the project area, within UFIs 15028, 8464, 15030 and 15033. In addition, the vegetation association, in combination with Mp[8], Cc[2], Mp[6] and BaBm[3] within Bush Forever site 480, is considered to represent a rare or uncommon assemblage on the Swan Coastal Plain (360 Environmental, 2014a).

The vegetation within Bush Forever site 480 includes the spectrum of species from open forest *Eucalyptus marginata* and *Corymbia calophylla* to heaths of *Melaleuca rhaphiophylla* and *Melaleuca lateritia*, which are all considered to be facultative and obligate wetland species (see Section 5.8).

Vegetation association CcMp, mapped in association with UFI 8792, is almost wholly (90%) located within the project area. The vegetation association CcMp represents PEC SCP21c; however, the PEC occurs extensively within the study area (178.0 ha).

The extent of vegetation association mapped within the wetlands that will be impacted by the project is detailed in Table 11.

Table 11 Vegetation association extent to be impacted within geomorphic wetlands

Unit code	Wetlands (UFI)	Area (ha)[1]		% disturbance	Presence of relevant TEC/PEC
		Study area	Project area		
As	15732	3.4	1.9	55.9	-
AsMlEvCl	8464, 13096, 15028, 15030, 15033	5.2	5.2	100.0	-
Ba	8447, 8464	2.3	2.3	100.0	SCP21c
BaBm[1]	8661, 8792, 8793, 8812	0.1	0.0	0.0	SCP23b; SCP21c
BaBm[2]	8254, 8404, 8439, 8442, 8661, 8664, 8792, 8793, 8802, 15175, 15260, 15757	4.5	1.1	24.4	SCP20a; SCP23b; SCP21c
BaBm[3]	8447, 8464, 13096, 15028, 15029, 15030, 15033, 15757	4.1	4.1	100.0	SCP24; SCP23b; SCP21c
Bl	8661, 8793	2.5	0.0	0.0	-
BlMp	8661, 8664, 8793	7.0	0.0	0.0	-
Cc/Mp	8792, 8802, 8943	11.3	0.1	0.9	SCP21c
Cc[1]	8254, 8411, 8416, 8438, 8439, 8442, 8444, 8454, 15029, 15175, 15732	50.6	6.0	11.9	-
Cc[2]	15033, 15200, 15732	7.4	1.6	21.6	-
Cc[4]	13402, 15732	12.2	1.5	12.3	-
Cc[5]	8254, 15732	15.9	6.8	42.8	-
Cc[6]	8404, 8439, 8442, 8444	3.0	0.0	0.0	-
CcEm[2]	8254, 8404, 8442, 8444, 15260	18.4	4.6	25.0	SCP23b; SCP21c

Unit code	Wetlands (UFI)	Area (ha)[1]		% disturbance	Presence of relevant TEC/PEC
		Study area	Project area		
CcEr[1]	8784, 8785, 15732	8.1	1.1	13.6	-
CcEr[2]	8262, 8449, 8464, 15200	1.0	0.8	80.0	-
CcEr[3]	8773, 8784, 8785, 8914, 8915, 8916, 8919, 8926, 9173, 9174, 13387, 15732	526.4	75.7	14.4	-
CcMp	8792, 8802	0.8	0.7	87.5	SCP21c
CcMpMr	15732, 15757	11.1	1.2	10.8	-
Co	9174, 15732	5.2	0.2	3.8	-
Em[1]	8254	2.5	0.0	0.0	SCP24; SCP21c
Em[2]	15732	2.5	0.0	0.0	-
Ep	15260	4.2	0.0	0.0	SCP21c
Er[1]	13402, 15732	8.2	1.7	20.7	-
Er[2]	8541	4.5	0.0	0.0	-
Er[3]	8664, 8793, 8812	8.8	0.0	0.0	-
Er[4]	8554	1.9	0.0	0.0	-
Er[5]	8773, 15732	0.9	0.0	0.0	-
Er[6]	15732	50.7	5.7	11.2	-
Er[7]	8927, 15732	4.4	0.0	0.0	-
Er[8]	15732	5.7	0.6	10.5	-
ErCo	15732	4.7	2.0	42.6	-
ErMp	8450, 15200, 15757	9.1	6.3	69.2	-
ErMrMc	15732	2.3	0.0	0.0	-
Et[2]	8802, 8943	0.2	0.0	0.0	SCP23b; SCP21c
Et[3]	8800, 8936	2.8	0.0	0.0	-
Mp[1]	13402, 15732	1.5	0.0	0.0	-
Mp[10]	9174, 15732	4.6	0.0	0.0	-
Mp[2]	8661	0.1	0.0	0.0	SCP22
Mp[3]	13402, 15732, 15752, 15757	4.4	1.1	25.0	SCP02
Mp[4]	8416, 8429, 8800, 8936, 15029, 15259, 15732	8.6	0.3	3.5	-
Mp[6]	15030, 15033, 15200	2.5	1.3	52.0	-
Mp[7]	8773, 8783, 8909, 15732	3.1	0.1	3.2	-
Mp[8]	15029, 15030, 15033, 15200	5.4	4.6	85.2	-
Mp[9]	8802	0.8	0.0	0.0	-
MpAl	15757	4.3	2.4	55.8	-

Unit code	Wetlands (UFI)	Area (ha)[1]		% disturbance	Presence of relevant TEC/PEC
		Study area	Project area		
MpBl	8661, 8793, 8812	5.1	0.0	0.0	-
MpMr	8773, 8909, 8910, 8911, 15732	6.8	1.4	20.6	-
PeAsMtMl	8664	8.0	0.0	0.0	-
Xp[1]	15732	5.4	0.3	5.6	-
Xp[2]	8416, 8429, 15029	14.2	10.1	71.1	-
R	8773, 8784, 8909, 15732	26.6	3.1	11.7	-
Rehab	15732	0.6	0.3	50.0	-
Cl	8254, 8262, 8416, 8439, 8442, 8444, 8447, 8449, 8450, 8464, 8541, 8554, 8664, 8770, 8773, 8776, 8779, 8782, 8911, 8935, 8936, 13096, 13387, 13392, 13402, 15028, 15029, 15030, 15033, 15175, 15200, 15732, 15752, 15757	730.9	196	26.8	-
Total	-	**1,646.8**	**352.2**	**21.4**	-

1. The extent of the vegetation associations within mapped wetlands has been provided. For the total extent within the study area and the project area, refer to Coffey (2015a)

5.2.4 Significant Vascular Taxa

The results of the flora and vegetation assessment (Coffey, 2015a) identified one threatened (*Grevillea curviloba* subsp. *incurva*) and five priority listed taxa (*Ornduffia submersa, Cyathochaeta teretifolia, Poranthera moorokatta, Millotia tenuifolia* var. *laevis* and *Meeboldina decipiens* subsp. *decipiens* ms) occurring within geomorphic wetlands within the study area (Figure 9).

Table 12 lists the conservation significant taxa that were recorded within wetlands sampled within the study area.

Table 12 Conservation significant taxa recorded within wetlands

Conservation significant taxa	Conservation code	Wetland UFI	Management category	Number of records
Grevillea curviloba subsp. *incurva*	T	15732	Multiple Use	2
Millotia tenuifolia var. *laevis*	P2	8943	Conservation	1
		15260	Conservation	1
Poranthera moorokatta	P2	8661	Conservation	1
		8793	Conservation	1
		8943	Conservation	1
Cyathochaeta teretifolia	P3	13402	Resource Enhancement	1
		15033	Conservation	1
Meeboldina decipiens subsp. *decipiens* ms	P3	15028	Conservation	1
		15033	Conservation	1
Ornduffia submersa	P4	15732	Multiple Use	1

Grevillea curviloba subsp. *incurva, Cyathochaeta teretifolia, Meeboldina decipiens* subsp. *decipiens* ms and *Ornduffia submersa* are known to occur in winter-wet depressions, swamps and creeks and their presence in the study area, although significant, is to be expected with known records in close proximity to those recorded by Coffey (Coffey, 2015a).

The identification of *Millotia tenuifolia* var. *laevis* within wetlands on the Swan Coastal Plain, is significant. Previous specimens have only been recorded on granite or laterite soils (DPAW, 2014). In contrast to the typical soil preferences, the plants in the study area occur on deep Bassendean Sands. Importantly, the Priority taxon has never been recorded from the Swan Coastal Plain bioregion and represents a range extension of over 50 km from the Jarrah Forest bioregion, and is therefore considered locally and regionally significant.

Of the conservation significant taxa recorded within the mapped wetlands, only *Millotia tenuifolia* var. *laevis* (P2) from UFI 15260 and *Meeboldina decipiens* subsp. *decipiens* ms (P3) from UFI 15028 and UFI 15033 are located within the project area. This will result in the loss of individuals within the local area.

The project will result in the loss of approximately three individuals of *Millotia tenuifolia* var. *laevis*, including the individual within CCW 15260; however, an additional four individuals recorded from the study area will be retained (Coffey, 2015a).

The project will result in the removal of 11 individuals of *Meeboldina decipiens* subsp. *decipiens* ms recorded within the project area. *Meeboldina decipiens* subsp. *decipiens* ms was recorded from the proposed Tonkin Highway and Reid Highway interchange. The population represents the most northerly record and is locally and regionally significant.

According to DPAW (2014), approximately 22 individuals of *Meeboldina decipiens* subsp. *decipiens* are known, including the 11 recorded from the project area. As a consequence, 50% of the known individuals may potentially be impacted during the clearing and construction for the project.

The remaining conservation significant taxa recorded from the mapped wetlands are located outside of the project area and are not proposed to be impacted.

5.2.5 Introduced Taxa

According to the results of the flora and vegetation assessment (Coffey, 2015a) two Weeds of National Significance (WONS), **Rubus laudatus* (blackberry) and **Eichhornia crassipes* (water hyacinth), were recorded from three wetlands in the study area.

Four taxa (**Moraea flaccida, *Zantedeschia aethiopica* and the two WONS) are declared pests listed under Section 22 of the *Biosecurity and Agricultural Management Act 2007* (BAM Act) were recorded from numerous wetlands located throughout the study area. Landowners and land managers at all levels are responsible for managing WONS and Declared Pests.

The wetlands where WONS and declared pests have been recorded are detailed in Table 13.

Table 13 Wetlands with WONS and declared pests

Wetland UFI	Management category	WONS/declared pest
8773	Conservation	**Moraea flaccida, *Zantedeschia aethiopica*
8792	Conservation	**Zantedeschia aethiopica*
8793	Conservation	**Moraea flaccida*
8916	Resource Enhancement	**Rubus laudatus, *Zantedeschia aethiopica*
13402	Resource Enhancement	**Rubus laudatus, *Zantedeschia aethiopica*
8784	Multiple Use	**Moraea flaccida, *Zantedeschia aethiopica*
15732	Multiple Use	**Eichhornia crassipes *Moraea flaccida, *Rubus laudatus, *Zantedeschia aethiopica*

Weed invasion was relatively high across the majority of the study area, in particular where clearing and urban development is high and in association with disturbed waterways and wetlands (Ellen Brook, the palusplain zone north of Warbrook Road). Weeds such as Kikuyu grass (**Cenchrus clandestinus*) occurred throughout the open paddocks and disturbed waterways and wetlands north of Maralla Road. Arum Lily (**Zantedeschia aethiopica*) and One-leaf Cape Tulip (**Moraea flaccida*) were prevalent within the wetlands, with higher densities in palusplain zone and the disturbed wetlands south of Maralla Road.

The project will need to implement effective weed hygiene measures to prevent the spread of these species and the introduction of new species to the area. This is particularly important for wetlands that are located adjacent to the project area.

5.2.6 Groundwater Dependent Ecosystems

The vegetation associations recorded from the geomorphic wetlands are considered to be GDEs due to the presence of groundwater or surface water dependent flora that accesses the groundwater permanently or episodically, via groundwater interaction within the root zone. As a result, GDEs occur across approximately 361.5 ha of the study area.

A list of species recorded from this assessment that are considered to be either groundwater dependent or maintained by surface runoff are listed in Table 14 (adapted from 360 Environmental, 2014a and Syrinx, 2011). *Banksia ilicifolia* displays the greatest susceptibility and lowest net recovery to groundwater abstraction (Groom et al., 2000), while plants with shallow roots (i.e. sumpland sedges) are dependent on moisture in the vadose zone. Stratigraphic changes which affect the vadose zone will impact on the health and survival of these species (e.g. *Hypocalymma angustifolium*) (360 Environmental, 2014a).

The impacts to GDEs are discussed further in Chapter 6 and Chapter 8.

Table 14 Groundwater dependent taxa

Taxa	Hydrological classification
Astartea scoparia	Subsurface – perched
Banksia ilicifolia	Groundwater dependent (obligate)
Banksia littoralis	Groundwater dependent
Baumea articulata	Groundwater or surface water (obligate)
Baumea juncea	Groundwater or surface water (obligate)
Corymbia calophylla	Groundwater dependent (facultative)
Eucalyptus rudis	Groundwater dependent (obligate)
Eucalyptus todtiana	Groundwater dependent (facultative)
Hypocalymma angustifolium	Vadose (saturated) zone
Meeboldina scariosa	Groundwater or surface water (obligate)
Melaleuca lateritia	Groundwater dependent (obligate)
Melaleuca preissiana	Groundwater dependent (obligate)
Melaleuca rhaphiophylla	Groundwater dependent (obligate)
Melaleuca teretifolia	Groundwater dependent (obligate)
Scholtzia involucrata	Vadose (saturated) zone
Stirlingia latifolia	Vadose (saturated) zone
Taxandria linearifolia	Groundwater dependent

Source: 360 Environmental (2014a) and Syrinx (2011).

6 GROUNDWATER DEPENDENT ECOSYSTEMS

The groundwater dependent ecosystems, as mapped by the BOM, coincide with the geomorphic wetlands of the Swan Coastal Plain and Ellen Brook (Figure 10). The vegetation associations recorded from the wetlands and along the banks of Ellen Brook are consistent with GDE and the majority of the dominant taxa recorded from each vegetation association are considered to be groundwater dependent taxa (i.e. *Melaleuca preissiana* and *Eucalyptus rudis* subsp. *rudis*) (Figure 10).

The literature was reviewed to determine the potential impacts associated with the construction of the project on the GDEs recorded within and adjacent to the study area.

The potential impacts to GDEs within the study area include:

- A reduction in wetland vegetation condition due to a falling groundwater table and the movement from a wetland habitat to a dryland habitat (terrestrialisation).
- The direct loss of GDEs through the clearing and in-filling of wetlands supporting GDEs.
- Changes to GDEs as a result of changes to the hydrological regimes, including surface and underground water movement and the impoundment of wetlands and waterways.

Section 8 provides further detail on the potential impacts of the project on GDEs and the mitigation measures to minimise the impacts.

The Lexia Wetlands (Lexia 86, Lexia 96 and Lexia 186), located adjacent to the project area near the suburb of Ellenbrook, have been the subject of hydrological and wetland studies to determine the extent of impact groundwater abstraction is having on a diverse and unique set of wetlands as summarised in DOW (2011). The results from these studies has been used a case study for the potential impacts to the wetlands located within the project area (Figure 11). The Lexia Wetlands are a series of sumplands and damplands which are consistent with the majority of the wetland types located within and adjacent to the project area. The Lexia Wetlands coincide with several wetland UFIs as mapped by the *Geomorphic Wetlands Swan Coastal Plain dataset* (Table 15).

Table 15 Wetland UFIs represented by the Lexia Wetlands

Lexia wetland	Wetland UFIs	Wetland type	Wetland management
Lexia 86	8793 (partially outside of study boundary)	Conservation	Sumpland
	8661 (partially outside of study boundary)	Conservation	Dampland
	8657 (outside of study boundary)	Conservation	Sumpland
	8656 (outside of study boundary)	Conservation	Sumpland
	8803 (outside of study boundary)	Conservation	Sumpland
Lexia 94	8664 (partially outside of study boundary)	Conservation	Sumpland
Lexia 186	8660 (outside of study boundary)	Conservation	Sumpland
	8659 (outside of study boundary)	Conservation	Sumpland
	8811 (outside of study boundary)	Conservation	Sumpland
	8665 (outside of study boundary)	Conservation	Sumpland
	8662 (outside of study boundary)	Conservation	Sumpland

The Lexia Wetlands are CCWs and a Ministerial criteria site (EP Act). In 1988, water level criteria were established at the wetlands to protect its good water quality, rich aquatic fauna and wading waterbird habitat. However, due to a combination of land use, abstraction and climate, water levels at the wetlands have declined. This, combined with fire, physical disturbances and invasion of exotic species has caused declines in ecological condition. The most notable ecological impacts have been terrestrialisation[1] and reduced occurrence of surface water. The wetlands are also at risk of acidification due to declining water levels and the drying of the wetland basins. Wetland vegetation monitoring has been carried out at Lexia Wetlands since 1996 with a monitoring transect located at each wetland (Cullinane et al. 2009).

Froend et al. (2004a) identified a set of groundwater depth ranges and duration of inundation/waterlogging requirements for a subset of common groundwater dependent taxa recorded from wetlands on the Gnangara and Jandakot mounds (Table 16). The species listed in Table 16 are present within the study area, excluding *Astartea fascicularis*, which is now considered to be *Astartea scoparia* on the SCP.

Table 16 Groundwater requirement for groundwater dependent taxa

Species	5–year mean water depth range (m)	5–year absolute water depth ranges (m)	5–year mean duration of inundation/ waterlogging*	5–year absolute duration of inundation/ waterlogging*
Melaleuca preissiana	-0.54 to -2.62	1.03 to -5.04	0.6	4.4
Banksia littoralis	-0.39 to -1.92	0.43 to -3.09	0.3	2.8
Astartea fascicularis	-0.35 to -2.26	1.03 to -4.60	0.66	2.6
Pericalymma ellipticum	-0.61 to -2.22	0.00 to -3.53	0.2	0.6
Hypocalymma angustifolium	-0.16 to -3.53	-0.16 to -3.53	0.1	0.6
Baumea articulata	0.28 to -1.22	0.81 to -2.59	3.26	12
Melaleuca rhaphiophylla	0.006 to -2.14	1.03 to -4.49	2.15	9.4
Eucalyptus rudis	-0.7 to -3.26	1.03 to -6.44	1.55	12

*Months per year.
Source: Froend (2004a) and DOW (2011).

In 2004, the ecological values for Lexia Wetlands were re-assessed and new ecological water requirements (EWRs) were proposed (adapted from DOW, 2011, originally from Froend et al. 2004b and 2004a). These EWRs have not been adopted as Ministerial criteria, but are used by the Department of Water to assess the possible impact of changes to groundwater levels on ecological values.

The new EWR for vegetation condition for the Lexia Wetlands are presented in Table 17. Ecological monitoring at the Lexia Wetlands since 2004 has indicated that ecological condition has declined further (DOW, 2011).

[1] Terrestrialisation: a shifting to a drier climate vegetation complex (i.e. moving from a phreatophytic to xerophytic vegetation community) (DOE, 2005)

Table 17 Revised vegetation Ecological Water Requirements

Wetland	Description	Vegetation minimum level[1] (mbgl)
Lexia 86	Supports diverse fringing and wetland vegetation. Supports significant macro invertebrate and vertebrate communities.	-2.91
Lexia 94	Supports diverse fringing and wetland vegetation. Fringing vegetation supports a range of habitat types.	-3.72
Lexia 186	Fringing vegetation supports a range of habitat types.	-2.29

1: Adapted from DOW (2011) and converted to mbgl based on DOE (2004).
mbgl: metres below ground level.

The monitoring of groundwater changes in association with the Lexia wetlands (CCWs 8793, 8661, 8657, 8656, 8803, 8664, 8660, 8659, 8811 and 8665) may provide information with regards to vegetation structure and condition change as a result of a falling or rising groundwater table. The construction phase of the project may require groundwater abstraction which may influence the Lexia wetlands (and other sensitive wetland receptors in close proximity to the project, for example the mound springs and other CCWs). Existing piezometers installed within the study area (360 Environmental, 2014a) should be monitored to identify groundwater changes, while additional piezometers should be installed across the study area in close proximity to sensitive receptors (i.e. the Mound Springs SCP TEC, Claypan of the SCP TEC, CCWs 15260 and 8800 and Ellen Brook).

In addition to the monitoring of groundwater levels, the structure and condition of GDEs should occur during the construction phase of the project to identify if the significant GDEs (i.e. Mound Springs SCP TEC, claypan TEC, and intact native vegetation in good or better condition within CCWs) are being impacted as a result of the project. This could continue during operation to identify if the management measures regarding hydrological regimes are impacting positively or negatively on the GDEs.

7 WETLAND BUFFERS

The buffer adjoining a wetland helps to maintain the ecological processes and functions associated with the wetland, and aims to protect the wetland from potential adverse impacts. A buffer can also help to protect the community from potential nuisance insects. To maintain wetland values, it is important to determine, protect and manage an adequate buffer.

DPAW recommends a minimum 50 m buffer distance for CCWs that are to be protected (DPAW, 2015). The 50 m buffer distance is considered to be generic and can be amended based on the values of the wetlands to be protected. The extent of the buffer around a particular wetland should be based on an assessment which takes into account:

- The wetlands values.
- The activities, land uses or development near the wetland, existing and proposed.
- The threats posed by the adjacent activities, land uses or development.

The values of each CCW and REW located within the study area are detailed in Section 5. The activities and land uses proposed for the project include:

- Clearing of native vegetation within and adjacent to mapped wetlands.
- Alteration of hydrological regimes during the construction phase of the project.
- Operation of a major highway with the aid of banks, culverts, seepage ponds and basins.

The assessment of buffer distance has only been applied to wetlands that are classified as CCWs and REWs and are not proposed to be cleared, based on the project area. The potential direct and indirect impacts on the wetlands within the study area as a result of the project include:

- Filling and clearing within CCW and REW and EPP Lakes.
- Changes to the hydrological regimes, including surface and underground water movement and the impoundment of wetlands and waterways.
- Water pollution through road run-off and disturbance of potential acid sulfate soils; and changes to hydrological processes such as compaction.
- Dewatering during construction.
- Spread of weeds and *Phytophthora* Dieback.
- Fragmentation.
- Loss of fauna habitat (vegetation loss), including avian fauna habitat for breeding and feeding.

The buffer distances have been determined based on the values of the wetlands and the potential direct and indirect impacts on the wetlands within the study area. The recommended separation distances for CCWs and REWs from the draft *Guideline for the Determination of Wetland Buffer Requirements* (WAPC, 2005) has been applied (Table 18). The buffer distances are a guide and may be amended dependent on final designs and construction requirements.

Table 18 Recommended Buffer Distances for CCWs and REWs

Key threatening process	Wetland category	Recommended separation and/or management
Alteration to the water regime	CCWs	Regulation of groundwater abstraction as catchment management measure.
	REWs	Regulation of groundwater abstraction as catchment management measure.
Habitat modification	CCWs	• 100 m for weed infestation. • Up to 100 m for bird habitat dependent on extent of use. • 6 to 50 m for firebreak. • Fence for controlling exotic fauna access. • ≥ 100 m to minimise edge effects.
	REWs	• 50 m weed infestation. • 50 m avifauna habitat. • 6 m firebreak.
Inappropriate recreational uses	CCWs	• ≥ 50 m to improve aesthetics. • ≥ 50 m for barrier. • Fence, paths for controlling access.
	REWs	• 10 m to 50 m for improving aesthetics. • 10 m to 50 m for barrier. • Fence, paths for controlling access.
Diminished water quality	CCWs	• Drainage inflows eliminated or managed. • Where a proposal may affect wetland water quality, particularly through un-channelised flow, detailed site specific work should be undertaken to determine the specific separation measures required, including management measures.
	REWs	• Drainage inflows eliminated or managed. • Where a proposal may affect wetland water quality, particularity through un-channelised flow, detailed site-specific work should be undertaken to determine the specific separation measures required, including management measures.

Source: WAPC (2005).

Based on the potential impacts and the values of the CCWs and REWs within the study area, the buffer distance considered necessary during the clearing of native vegetation, construction of the project and the operation of the highway is:

- 100 m for CCWs.
- 50 m for REWs.
- No buffer is required for MUWs.

Where the minimum buffer distance is not feasible for the CCWs and REWs, construction and design mitigation measures, including retaining walls, basins, seepage ponds and culverts, are recommended to ensure the hydrological regime of the wetlands are not adversely impacted. Revegetation of seepage ponds and basins should occur, utilising local provenance wetland species to provide fauna habitat.

8 IMPACT ASSESSMENT

8.1 Background

The impact of the project with regards to the study area and the presence and location of the wetlands within the project area, is detailed below. The extent of the wetlands located within the project area is shown in Figure 11. The assessment considers the potential and predicted impacts on the sensitive wetland receptors, with particular emphasis on CCWs and EPP lakes.

The assessment has taken into account the EPAs views on the environmental protection of wetlands detailed in Position Statement No. 4 (EPA, 2004b) and the information provided in DPAWs methodology for evaluating wetlands on the Swan Coastal Plain (DPAW, 2013).

8.2 Potential and Predicted Impacts

The clearing of native vegetation, construction and operation of the project will directly impact on wetlands and wetland values, function and attributes located within the project. The project will also directly impact on wetlands and wetland values, function and attributes.

These potential and predicted impacts include:

- The permanent loss of wetland vegetation in good or better condition, according to the condition rating scale developed by Keighery (1994).
- Filling and clearing within Conservation and Resource Enhancement Wetlands and Environmental Protection Policy Lakes.
- Changes to the hydrological regimes, including surface and underground water movement and the impoundment of wetlands and waterways.
- Water pollution through road run-off and disturbance of potential acid sulfate soils; and changes to hydrological processes such as compaction.
- Dewatering during construction.
- Impacts to wetlands and their buffers.
- Impacts to riparian vegetation and ground water dependent ecosystems.
- Spread of weeds and *Phytophthora* Dieback.
- Fragmentation.
- Loss of fauna habitat (vegetation loss), including avian fauna habitat for breeding and feeding.

One of the controls in the mitigation and management of hydrological impacts associated with the project is the implementation of the project specific drainage strategy (BG&E, 2015) during the design and construction of the project.

The objective of the drainage strategy is to maintain drainage across the site to as close as practicable to the pre-development condition. The drainage strategy has been designed in accordance with the principles of water resource management developed by the DOW, as detailed in the Stormwater Management Manual for Western Australia (2004) and the Decision Process for Stormwater Management in Western Australia (2009).

The general drainage strategy is to minimise pit and pipe drainage systems and maximise disconnection of the drainage system where possible (i.e. preference to avoid sealed systems and instead allow water to infiltrate via open surface drainage systems). Where pit and pipe drainage systems are required and the pipe inverts (i.e. the base of the interior level of a pipe) are above maximum groundwater level, these will feature soak well type pit bases to encourage infiltration of storm events as close to the source as possible.

8.3 Impact Assessment

8.3.1 Geomorphic Wetlands

According to the geomorphic wetland mapping, approximately 46% of the project area has been mapped as occurring in association with a wetland (Table 19). This includes approximately 1.9% mapped as CCWs.

As detailed in Table 19, of the 352.3 ha mapped as wetland, 91.7% is multiple use wetlands. The majority (264.6 ha) of this is the Ellen Brook floodplain MUW (UFI 15732). The project will impact 14 MUWs listed in Table 20.

Table 19 Category extent within project area

Wetland category	Extent within project area	
	ha	%
Conservation	14.8	4.2
Resource Enhancement	14.3	4.1
Multiple Use	323.3	91.7
Total	**352.4**	**100.0**

The individual wetlands located within the project area, and the percentage extent proposed to be impacted is provided in Table 20. Based on the project area, 24 individual wetlands will be wholly or partially impacted, this includes six CCWs, four REWs and 14 MUWs.

Table 20 Wetland extent to be impacted

Wetland	Category	Extent of wetland (ha)	Extent within the project area	
			ha	%
8416	CCW	2.4	0.1	5.4
8773	CCW	3.2	0.0	0.0
8792	CCW	0.9	0.9	96.7
8800	CCW	0.9	0.0	0.0
8802	CCW	7.7	0.0	0.0
8909	CCW	0.4	0.0	0.0
8910	CCW	0.2	0.0	0.0
8911	CCW	0.6	0.0	0.0
15028	CCW	4.4	0.5	12.1
15033	CCW	9.9	7.4	74.8

Wetland	Category	Extent of wetland (ha)	Extent within the project area	
15260	CCW	68.4	5.5	8.0
8541	REW	6.6	0.0	0.0
8554	REW	4.2	0.0	0.0
8779	REW	20.3	0.4	1.8
13387	REW	27.3	0.3	1.0
15752	REW	239.6	0.9	0.4
15757	REW	34.0	12.8	37.6
8254	MUW	11.6	2.1	17.9
8262	MUW	2.3	0.0	0.0
8411	MUW	2.6	0.4	15.8
8438	MUW	3.8	0.0	0.0
8447	MUW	15.9	9.7	60.9
8449	MUW	5.0	0.2	4.2
8450	MUW	96.5	3.2	3.3
8464	MUW	14.2	6.3	44.6
8785	MUW	2.2	0.6	25.5
8936	MUW	14.7	2.2	15.2
13096	MUW	0.3	0.3	83.3
15029	MUW	51.3	18.5	36.0
15030	MUW	6.8	3.7	54.4
15175	MUW	74.1	4.6	6.2
15200	MUW	28.0	1.6	5.6
15732	MUW	13,744.4	234.0	1.7
Total	N/A	14,504.7	315.9	2.2

The vegetation associations mapped as occurring within the wetlands that will be impacted by the project are detailed in Table 11. A more detailed discussion on the potential impacts to the vegetation associations within the project area is provided in Coffey (2015a). The majority (77%) of the mapped wetlands do not support intact native vegetation.

Multiple Use Wetlands

MUWs are assessed as possessing few remaining ecological attributes and functions. While such wetlands can still play an important role in regional or landscape ecosystem management, including water management, they are considered to have low intrinsic ecological value. Typically, they have very little or no native vegetation remaining (less than 10%). As a result there is no legislative requirement to protect or retain them and impacts to these MUWs are not discussed any further.

Any significant environmental features (i.e. threatened flora, ecological communities, threatened fauna) of the MUWs, are discussed in the relevant studies undertaken to identify the flora, vegetation and fauna within the project area (Coffey, 2015a, b).

The impact on REW and CCW is discussed in Sections 8.3.1.1 and 8.3.1.2, respectively.

8.3.1.1 Resource Enhancement Wetlands

The project will impact 14.3 ha of four REWs (UFIs 8779, 13387, 15752 and 15757). This equates to 4.1% of mapped wetlands within the project area and approximately a direct loss of 12.5% of the entire mapped extent of REWs identified within and adjacent to the project area. The impacts include the clearing of native vegetation, and soil and hydrological disturbances related to site earthworks and construction of the project. These four REWs are only partially located within the project area. Approximately 37.6% of REW 15757 will be directly impacted as a result of the project. The remaining REWs will have less than 2% of their mapped extent impacted by the project.

Resource Enhancement Wetland 13387 (Halden Road, Bullsbrook)

The project will upgrade (i.e. widening) an existing local road (Halden Road, Bullsbrook) that traverses REW 13387. The road already exists in its current position and the project will only involve minor alterations to the current alignment. A site visit was undertaken in January 2015 (Coffey, 2015c) to map the vegetation associations and conditions. The REW crossed over Halden Road with the vegetation consistent with previously described vegetation associations, CcEr[3]. The vegetation was mapped along the verge between the road and private property.

The impacts of the project to the REW will include minor wetland vegetation clearing along the road verge, the compaction of soils and minor alterations to the existing hydrology. However, it is anticipated that these impacts will be minor (0.3 ha of vegetation clearing and ground disturbance within the REW) and standard construction measures, including culverts and clearing minimisation will be employed during the construction of the project. In addition the drainage strategy (BG&E, 2015) will ensure the natural water flows are maintained, where possible.

Resource Enhancement Wetland 15757 (Marshall Road and Hepburn Avenue intersection)

The project will divide REW 15757 into four separate wetlands located at the corners of the proposed interchange. However, south of Marshall Road, there is no native vegetation in good or better condition and recent approved site disturbance for industrial development has further impacted the soil composition and hydrological regime of the REW. It is quite feasible that the REW no longer reflects the values of an REW and is more likely to be appropriately assessed as a MUW (360 Environmental, 2014a).

The condition of the native vegetation north of Marshall Road ranged from completely degraded to very good, with the majority considered to be degraded to completely degraded. A small portion of the wetland is considered to be very good along the northeastern edge on either side of Hepburn Avenue.

In addition, a small portion of remnant native vegetation on the western side of Hepburn Avenue may potentially represent a State listed TEC (SCP02: Southern wet shrublands, Swan Coastal Plain). Based on a statistical analysis of the floristic data collected for the small portion of the vegetation, the data could not separate between floristic units FCT02 (consistent with SCP02) and FCT11 (Wet forests and woodlands).

SCP02 generally occurs south of Perth and is not known to occur in the northern suburbs, therefore, the vegetation might better represent FCT11 which is not considered to be a threatened or priority ecological community. Further floristic sampling would be required to accurately determine the floristic unit and whether the vegetation represents a TEC.

The impact to the wetland hydrology is considered to be minor with portions of the REW already modified from the construction of a light industrial zone and historic clearing. The impact on the TEC associated with

the wetland is considered high. The project will not result in any additional fragmentation as the area of this wetland to the southwest of the interchange has already been cleared and developed. Impacts to the wetland are considered to be minor given the scale of the impact and the current condition of the wetland.

Resource Enhancement Wetlands 15752 (Beechboro Road North, Whiteman) and 8779 (Morley Road, Bullsbrook)

The two remaining REWs that partially occur within the project area, do not support any native vegetation and have been mapped as 'Cleared' (does not support native vegetation) and as a result are more likely to be appropriately assessed as a MUW (360 Environmental, 2014a). Therefore, the impact on wetland vegetation is considered to be negligible. However the project may still impact the wetland via soil compaction and alteration to the hydrological flow and quality. Impacts to both of these wetlands are not considered to be significant given the minor scale of the impact and their existing condition.

REW 15752 is located in association with Beechboro Road North and the project will involve the minor upgrade and integration of Beechboro Road North to the PDNH. Therefore, the impacts relating to soil compaction and alteration to the hydrology is only considered to provide a minor increase to the current impacts through the operation of the road.

REW 8779 is located north of Neaves Road in open paddocks with only occasional scattered paddock trees. There will be no direct loss of wetland vegetation with the remaining impacts related to soil compaction and alteration to the hydrology. The impact will be isolated to the eastern edge of the REW and impacts will be managed via a Construction Environmental Management Plan (CEMP).

8.3.1.2 Conservation Category Wetlands

Seven CCWs will be directly impacted by the project, this includes the partial clearing of native vegetation consistent with the wetlands and their vegetated buffers and the clearing of the entire wetland. The seven CCWs have intact native vegetation in good or better condition and the clearing of vegetation (partial clearing and the clearing of the entire wetland) and in-filling of the wetland may impact on the remaining wetland vegetation and the associated buffers required to ensure the functionality of the wetlands are not degraded. The clearing may also influence the hydrology causing an increase or decrease in the groundwater table via the removal of vegetation. greater surface expression may occur and issues associated with erosion through surface water movement may occur.

The project will clear 14.8 ha of native vegetation consistent with CCWs. The extent of CCWs within the mapped wetlands that will be impacted within the project area is 4.2%. The remaining 95.8% of wetlands within the project area include REWs and MUWs, with MUW 15732 comprising 75% of the wetlands within the project area.

The extent of intact native vegetation proposed to be cleared within the wetlands is detailed in Table 11. The project will potentially have a direct significant impact on wetland vegetation (i.e. clear greater than 90% of the intact native vegetation within the wetland) within CCWs 8792, 8802, 15028 and 15033. The intact native vegetation occurring within the remaining CCWs will not be significantly impacted.

Extent within consanguineous suites

The current extent of CCWs within each consanguineous suite (DPAW, 2013) was reviewed to determine if the clearing of the CCWs will decrease the extent to levels considered to be below significant thresholds.

The CCW 8802 has not been discussed further as the wetland occurs on the edge of the project area and the error associated with the dataset has indicated that less than 0.00001 of a hectare occurs within the project area.

In consideration of the criterion used by DPAW to determine if a wetland meets the criteria for recognition as a CCW (DPAW, 2013), the impacts to CCWs are considered to be of regional significance if:

- They reduce the proportion of CCWs within any impacted consanguineous suite of wetlands to below 10%.
- Impact any CCW within a consanguineous suite of wetlands whose proportion of CCW is already below 10%.

The percentage of CCWs within the consanguineous suites being impacted upon as a result of the project is provided in Table 21.

Table 21 Extent of CCWs within the consanguineous suites

Consanguineous suite	CCW UFI	Total area of CCW (ha)	% CCW in suite	Direct loss of CCWs (ha)	Revised % CCW in suite	Vegetation associations
Bennett Brook	8416, 15260	2490.8	7.7	5.6	7.6	**8416**: Mp[4], Xp[2] **15260**: BaBm[2], CcEm[2], Ep
Ellen Brook	8773, 8909	437.6	3.1	0.4	3.1	**8773**: Er[5], MpMr, Mp[7] **8909**: MpMr, Mp[7]
Jandakot	8792, 15028, 15033	4378.9	21.3	8.8	21.2	**8792**: CcMp, Cc/Mp **15028**: AsMlEvCl, BaBm[3] **15033**: AsMlEvCl, BaBm[3], Cc[2], Mp[6], Mp[8]

The percentage extent of CCWs within the Bennett Brook and Ellen Brook suites are already below the 10% level and any clearing within these two consanguineous suites is considered to be a high impact. UFI 8416 and UFI 15260 are representative of the Bennett Brook suite and UFI 8773 and UFI 8909 are representative of the Ellen Brook suite, with all four UFIs located within the project area. As a result the extent of CCWs within the consanguineous suites will be further reduced.

The clearing of CCWs 8416, 8773, 8909 and 15260 is considered to be a high impact and avoidance measures should be undertaken to ensure the direct loss of CCW is minimised. If the clearing was to occur, the percentage extent of CCWs within the Bennett Brook and Ellen Brook consanguineous suite would be reduce by 0.1%. The clearing extent is not considered to be high; however, avoidance measures should still be implemented to ensure the clearing is kept to a minimum.

The percentage extent of CCWs within the Jandakot suite is 21.3% prior to the clearing associated with the project. The extent of the CCWs within the Jandakot suite will be reduced by 0.1% to an overall percentage extent of 21.2%. As such the impact of clearing CCWs 8792, 15028 and 15033 is not considered to be high from the perspective of regional representation within the Jandakot consanguineous suite.

Extent of CCWs within the project area

CCWs 8773 and 8909 only partially occur within the project area, 0.4 and 0.1 ha respectively. The clearing, draining and filling of the portion of CCWs within the project area will occur. This impact is considered to be minor due to the overall extent of the wetland to be impacted and the degraded condition of the CCWs. The indirect impacts associated with the CCWs, includes alteration to the hydrology and accidental clearing.

The natural surface water flows will be maintained in accordance with the drainage strategy (BG&E, 2015). This will include, but not limited to, the installation of culverts and associated structures in association with the minor flowline that feeds into the CCWs 8773 and 8909 to minimise the impacts on the natural hydrology of the area. Accidental clearing will be managed through the implementation of the CEMP.

CCW 8416 will partially (0.1 ha) be cleared and impacted within the project area. The direct impacts are considered to be minor due to the small extent to be cleared and the degraded condition rating. The current hydrological flow into the CCW is already compromised due to the existing Beechboro Road North and the lack of culverts. The construction of the project will provide sufficient culverts in this area of the project area to restore the natural flows.

The project will involve the severance of a small fragment of CCW 15260 from the remainder of the mapped CCW extent. The CCW is classified as a palusplain, which is a flat seasonally waterlogged area. The construction of the project will involve the clearing of native vegetation and the compaction of soil and filling of the palusplain with fill material. The hydrological regime will be maintained with the construction of culverts and underpasses that will allow surface water to move across the landscape in patterns equal to or similar to current regimes. The design and installation of the culverts will ensure the surface water flows are maintained, including the hydraulic connectivity between areas of wetlands intersected/fragmented by the project (for example, the intersection of CCW 15260).

The clearing of vegetation, draining and filling of CCW 15028 within the project area will result in the complete loss of wetland vegetation within the portion of the CCW mapped within the project area. The mapped extent of the CCW extends outside of the project area in association with a light industrial zone that has recently been cleared and is currently subject to industrial development. The loss of the vegetation within the remaining vegetated portion of the CCW is considered to be a high impact and along with the development of the light industrial zone, the hydrology and wetland soils will be altered with the filling and draining of the sumpland.

The project will result in approximately 75% of the mapped extent for CCW 15033 (located within Bush Forever Site 480: Victoria Road bushland, Malaga) being impacted. A small portion (approximately 2 ha) of the CCW will be retained to the east of the project area. The clearing of 75% of the CCW is considered to be a high impact and the retention of vegetation within the CCW should be considered a priority. The remainder of the CCW that will not be impacted should be managed appropriately to ensure the wetland does not degrade through disturbance to small fragments in highly urbanised areas (for example, edge effects, uncontrolled access, dumping of refuse).

The project will involve impacts to CCW 8792, which is located entirely within the project area. The wetland vegetation within the CCW is considered to be transitional and has elements of dryland and wetland vegetation. The wetland is considered to be a dampland and a falling groundwater table would suggest the transitional environment. The impact on the CCW is considered high and the project should be designed to avoid the CCW, where possible.

8.3.2 EPP Lakes

Eight EPP lakes are located within the study area. The project area will avoid seven of the eight EPP lakes, resulting in the impact of one EPP lake. EPP lake 450, which is mapped in association with the MUW 8785, is partially located within the proposed Cooper Road and Stock Road interchange within the project area. The project will involve the clearing and in-filling of a small portion (0.6 ha) of the EPP lake.

The section of the EPP lake located within the project area is mapped as:

> *Corymbia calophylla* and *Eucalyptus rudis* subsp. *rudis* isolated mid trees over *Astartea scoparia* and *Taxandria linearifolia* tall shrubland over *Juncus pallidus, *Typha orientalis* and **Zantedeschia aethiopica* sparse tall herbland over **Cenchrus clandestinus* and **Holcus lanatus* closed low grassland

The vegetation was considered to be in degraded condition with a high density and prevalence of weeds, including declared plants under the BAM Act.

The impact of the project on the EPP lake is considered to be minor due to a small portion (0.6 ha) of the EPP lake proposed affected, and the condition of the vegetation within the EPP lake is considered to be degraded. The project will also ensure the natural hydrological flows are maintained with the construction of culverts linking the EPP Lake with the minor flow line to the southeast.

The mapped boundaries of EPP lakes 439 and 441 also partially occur within the project area. The boundaries of these lakes appear to be associated with CCW 8664, CCW 8800 and REW 8801 (Geomorphic Wetlands Dataset), although the boundaries for these lakes and wetlands are not completely aligned. Review of spatial data suggests that the variance in these boundaries is likely to be a result of spatial error which has included areas of upland/dryland habitat not part of the EPP lakes. As a result, direct impacts to EPP lakes 439 and 441 are not anticipated.

8.3.3 Significant Vegetation Occurring Within Wetlands

Three TECs (one State and two State and Federal) occur in mapped wetlands in the study area. The Mound Springs SCP (State and Federal TEC) occurs in association with REW 13402 and is located on the upslope of the project area. The project area has previously been altered to ensure that there are no direct or indirect impacts from the project on the TEC (GHD, 2008). The REW and the TEC are considered to be significant and the design of the project will ensure that there are no direct and indirect impacts to the TEC.

The TEC Claypans of the Swan Coastal Plain has been mapped in association with REW 9174 and MUW 15732. MUW 15732 is an extensive palusplain type wetland and extends from Maralla Road in Bullsbrook to just south of Gingin. The TEC is located near Muchea on the eastern side of the Great Northern Highway. The soil is clay based, while the vegetation recorded from sample sites within the TEC is consistent with a State Priority 1 ecological community (Claypans with dense shrublands of *Melaleuca lateritia* over herbs) which is consistent with the Federal TEC (Claypans of the Swan Coastal Plain). The project will not impact on the TEC.

The State TEC SCP02 has tentatively been recorded as occurring within REW 15757, which is located near the intersection of Marshall Road and Hepburn Avenue. The TEC has only tentatively been recorded within the project area and requires further assessment to determine if the TEC is present. The vegetation in association with the TEC may represent a different floristic community that is not considered to be significant (Section 5.5.1). The project will clear the majority (84%) of the TEC and may potentially indirectly impact on the remaining portion of the TEC via alterations to the hydrology.

The PEC SCP21c has been mapped as occurring within CCWs 8792, 8802 and 15260 and MUW 8447. The PEC occurs across 18.8 ha of wetlands within the project area. The clearing of the PEC within the project area is considered to be minor and represents approximately 11% of the mapped PEC within the study area.

8.3.4 Wetland Buffers

The clearing associated with the project will impact on the current buffer distances for CCWs and REWs occurring within the project area and immediately adjacent to the project area. A vegetated buffer utilising existing remnant native vegetation is the ideal for the buffers for each of the CCWs and REWs. Where vegetation is degraded or a vegetated buffer is not possible, buffers involving rehabilitated areas or seepage basins (and similar road basins) can be useful in providing a barrier between environmentally significant wetland vegetation and potential pollutants and impacts associated with the project.

8.3.5 Groundwater Dependent Ecosystems

The geomorphic wetlands and vegetation along the bank of the Ellen Brook are considered to be GDEs. The project may potentially impact approximately 352 ha of vegetation consistent with GDEs. A high proportion (91.7%) of the GDEs located within the project area where mapped as MUWs, while 81.8% of the MUWs

was represented by one large MUW (UFI 15732) referred to as the Ellen Brook floodplain. The majority of this MUW was considered to be completely degraded with only scattered paddock trees or highly altered drainage lines dominated by significant weeds present throughout the project area.

If the MUWs are removed from the calculations, including the riparian vegetation alongside Ellen Brook, approximately 30 ha of GDEs occur within the project area. The 30 ha of GDE within the project area coincides with the CCWs and REWs mapped within the project area. The condition of the GDEs range from pristine to completely degraded with the GDEs located in the Tonkin Highway and Reid Highway interchange, Cullacabardee and Ellenbrook area considered to be in good or better condition, while the GDEs near Hepburn Avenue, Stock Road and Neaves Road were considered be in poorer condition.

The impact on the remainder of the GDEs (the CCWs and REWs) located within and adjacent to the project area is considered to be low, with the majority of the impacts isolated to small areas of GDEs mapped within the CCWs (14.8 ha) and the REWs (14.3 ha).

There may be indirect impacts to GDEs located adjacent to the project area, including:

- Compaction of soil.
- Altered surface and groundwater hydrology.
- Spread of weeds and *Phytophthora* Dieback.

The potential indirect impacts will be managed through the development and implementation of a CEMP prior to the clearing of native vegetation.

8.4 Mitigation Measures

The clearing, in-filling and disturbance of regionally significant CCWs and the EPP lake and associated plant assemblages will occur under the current conditions and plans for the project. This will include the clearing and in-filling of the whole or partial extent of CCWs UFI 8416, 8773, 8792, 15028, 15033 and 15260. The project will also impact on a portion (0.6 ha) of EPP Lake 450. Natural hydrological regimes may be altered as a result of the project, including an increase in surface ponding, shadowing on the downstream side of culverts and the potential for an increase and/or decrease in groundwater levels.

To minimise the impacts, the following mitigation measures should be considered:

- Where possible, the clearing of CCWs and the EPP lake should be avoided. Where the disturbance is unavoidable, the disturbance and clearing of the CCWs and the EPP lake should be kept to as low as reasonably practicable.
- Soil compaction and disturbance outside the project area should be avoided, especially in association with significant wetlands (i.e. CCWs and EPP lakes).
- The hydrological flow across the wetlands should be maintained with the use of appropriate design measures, including culverts and bridges where necessary.
- The drainage management strategy prepared for the project should include strategies for the clearing of wetland vegetation within the project area and the indirect impacts to wetlands located adjacent to the project area.
- Sediment basins and pollutant traps should be incorporated into the design of the project to ensure the quality of surface and underground water does not exceed normal parameters.

- During the construction phase of the project, the groundwater levels and quality should be monitored during abstraction to ensure the project is not causing a significant, irreversible reduction in groundwater levels and quality.
- The GDEs should be monitored post- and pre-construction to determine if the project is impacting on the sensitive wetland receptors, including the Mound Springs SCP TEC, the Claypan on the SCP TEC, the Lexia wetlands and vegetation in good or better condition within CCWs located adjacent to the project area.

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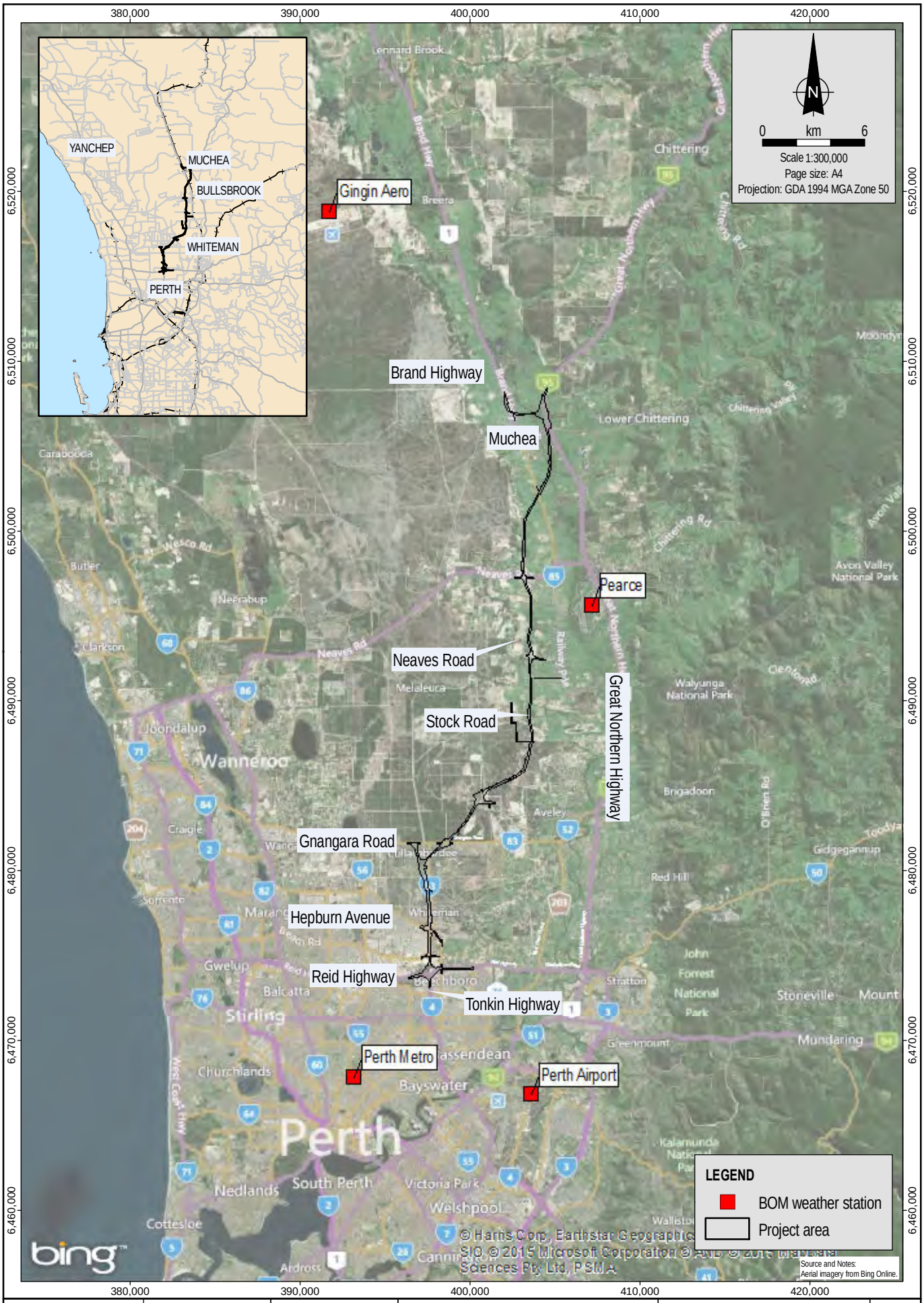
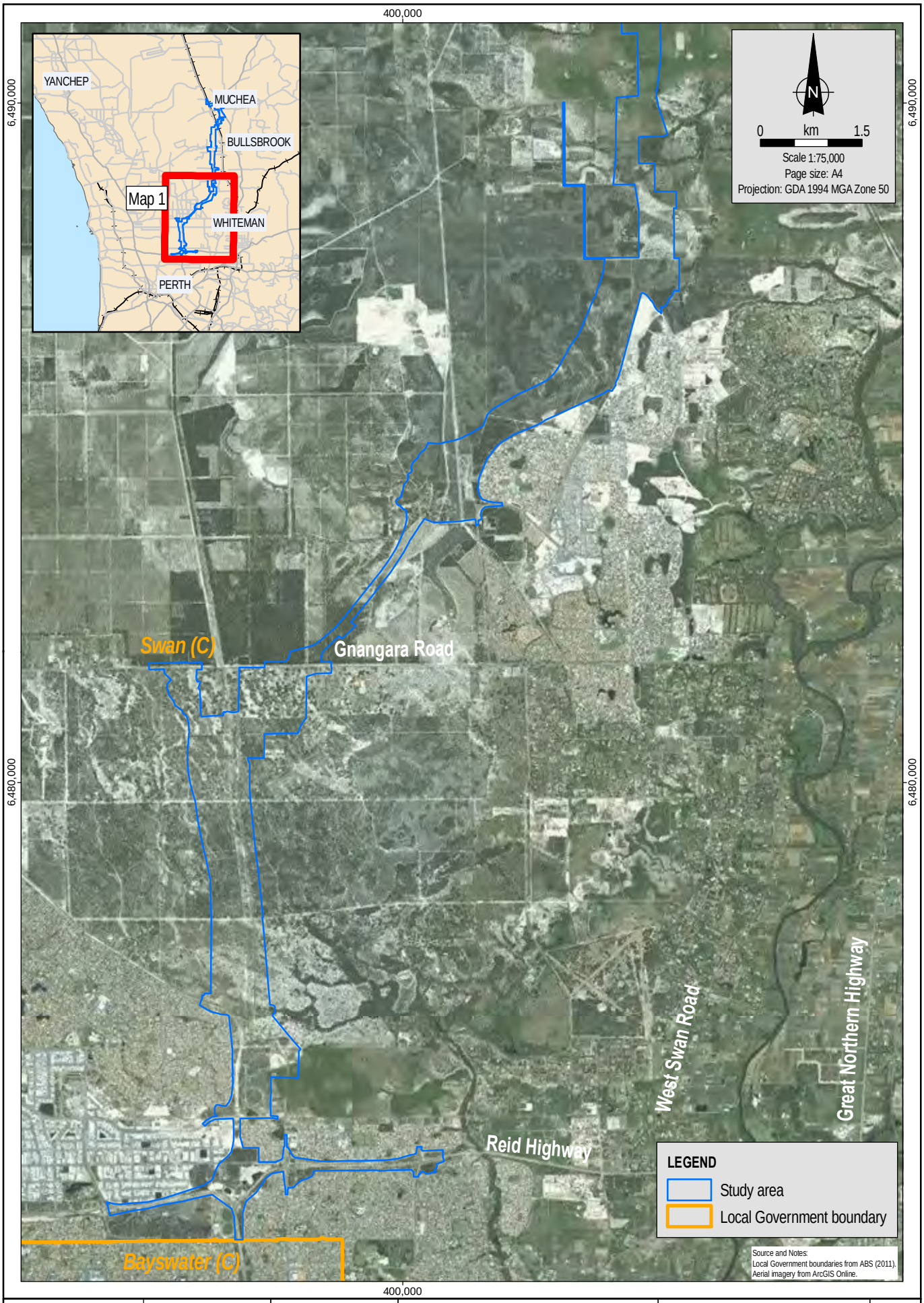
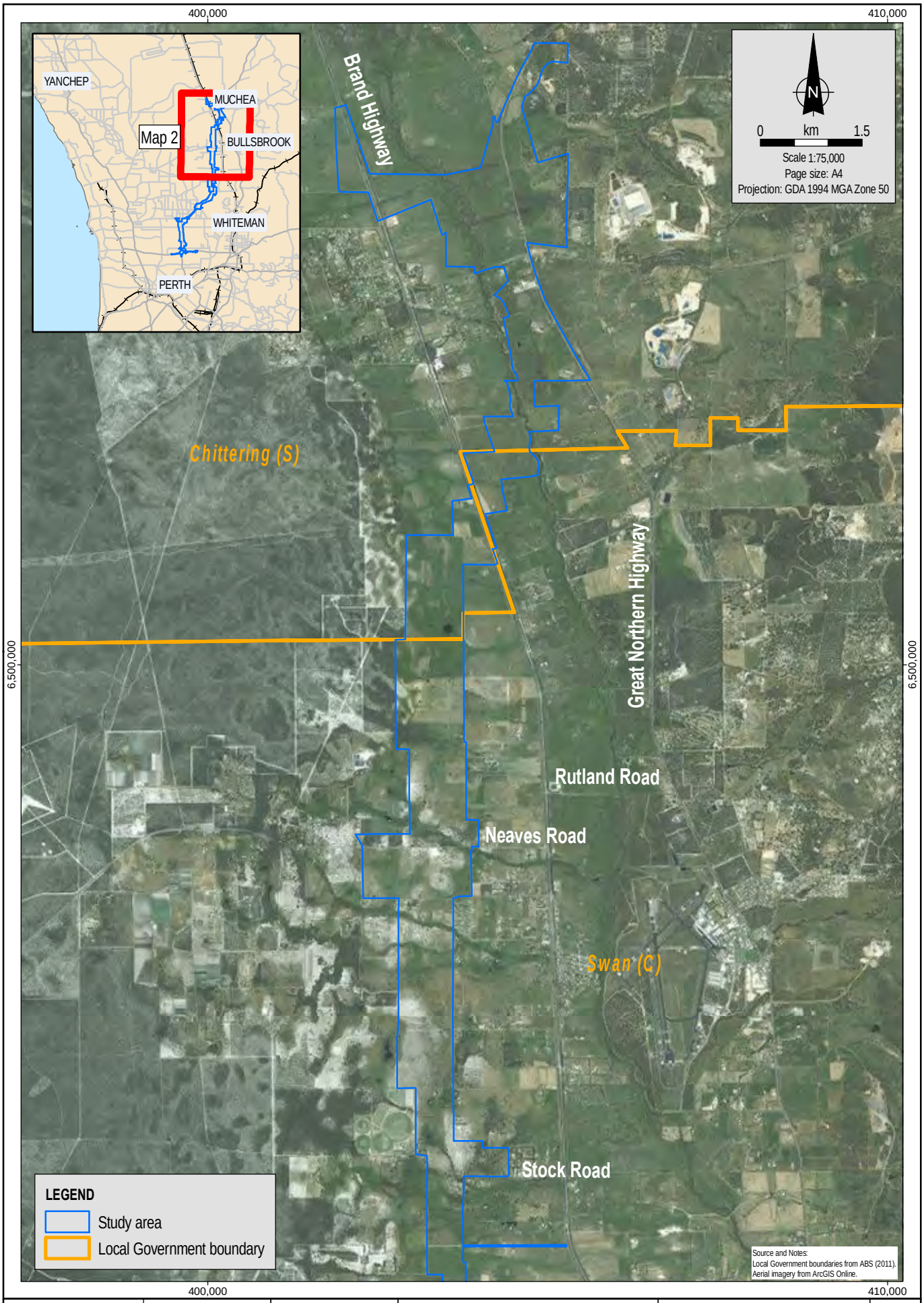
FIGURES



NorthLinkWA	coffey	Date: 27.03.2015 MXD: 4483AA_30_GIS008_1 File Name: 4483AA_30_F001_GIS	Main Roads WA Wetland Assessment Perth–Darwin National Highway	Regional area	Figure No: 1

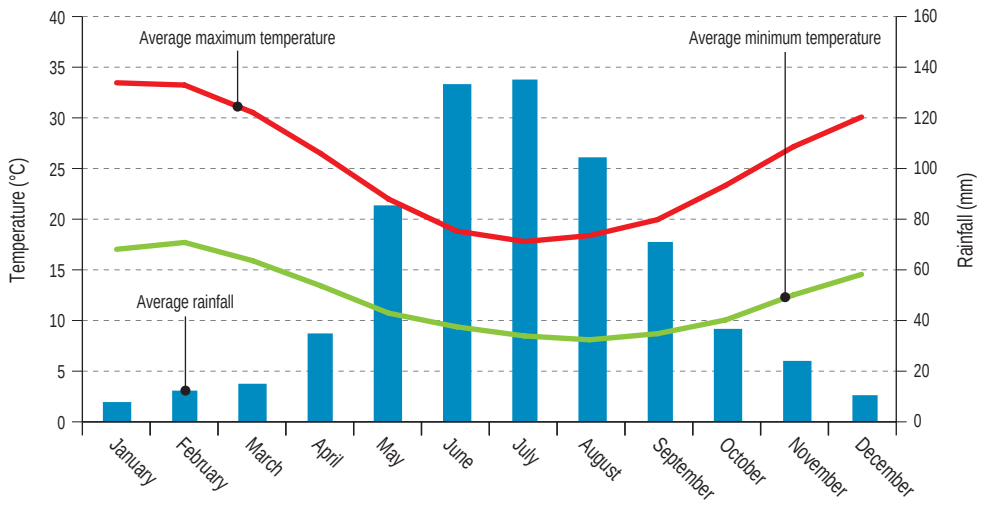


NorthLinkWA	coffey	Date: 27.03.2015 MXD: 4483AA_30_GIS009_1 File Name: 4483AA_30_F002A_GIS	Main Roads WA Wetland Assessment Perth–Darwin National Highway	Study area Map 1 of 2	Figure No: 2A

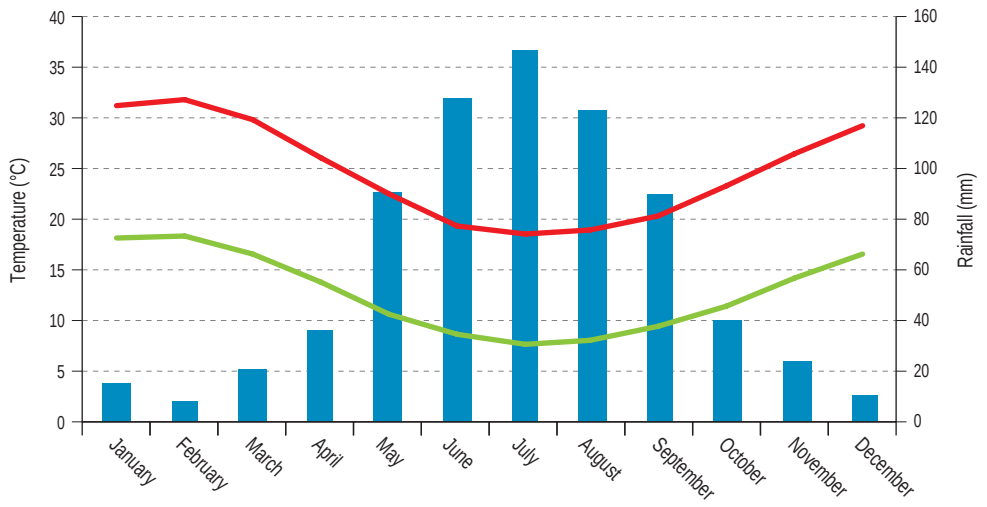


NorthLinkWA	coffey	Date: 27.03.2015 MXD: 4483AA_30_GIS010_1 File Name: 4483AA_30_F002B_GIS	Main Roads WA Wetland Assessment Perth–Darwin National Highway	Study area Map 2 of 2	Figure No: 2B

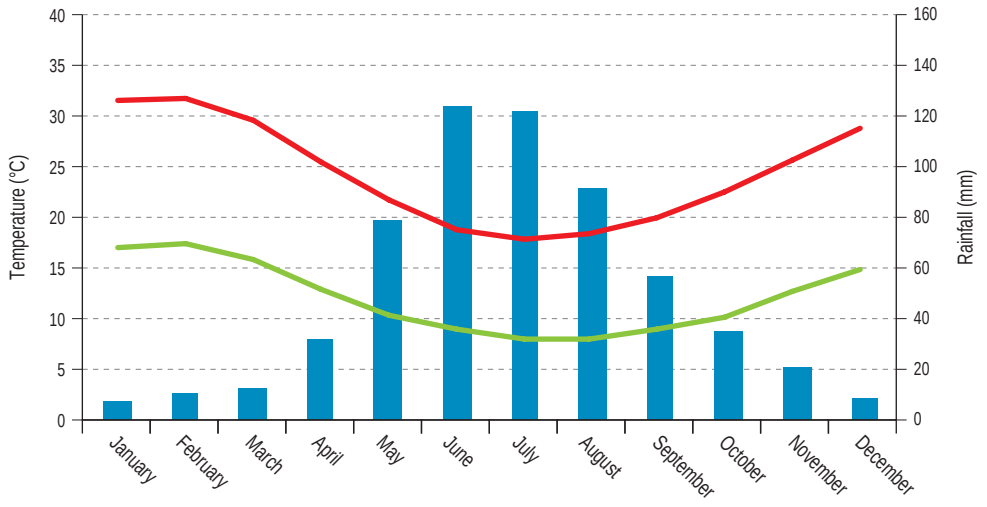
Location: Pearce RAAF (Station No. 009053)
(1940-2014)



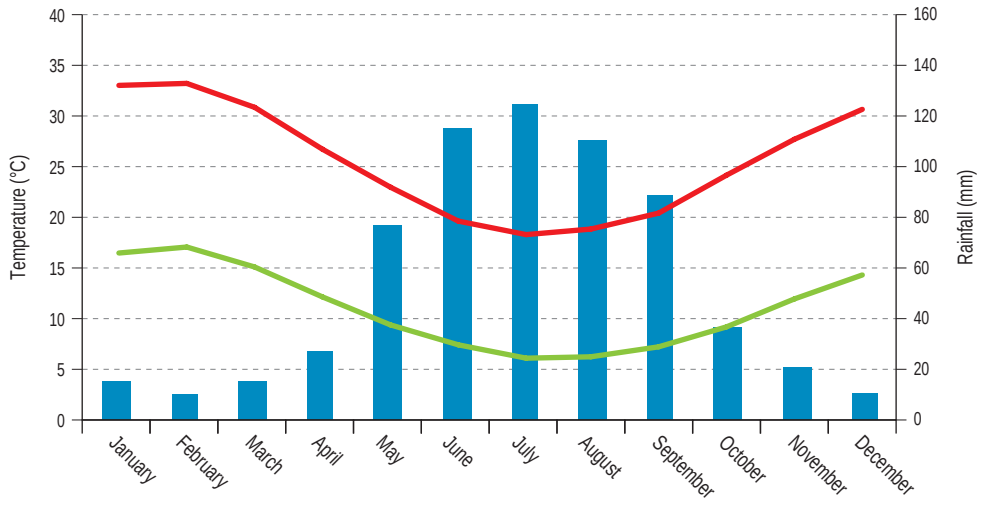
Location: Perth Metro (Station No. 009225)
(1994-2014)



Location: Perth Airport (Station No. 009021)
(1944-2014)



Location: Gingin Aero (Station No. 009178)
(1996-2014)



Source: Bureau of Meteorology

coffey

Date: 02.02.2015

File Name: 4483_P02_F003_GL_5

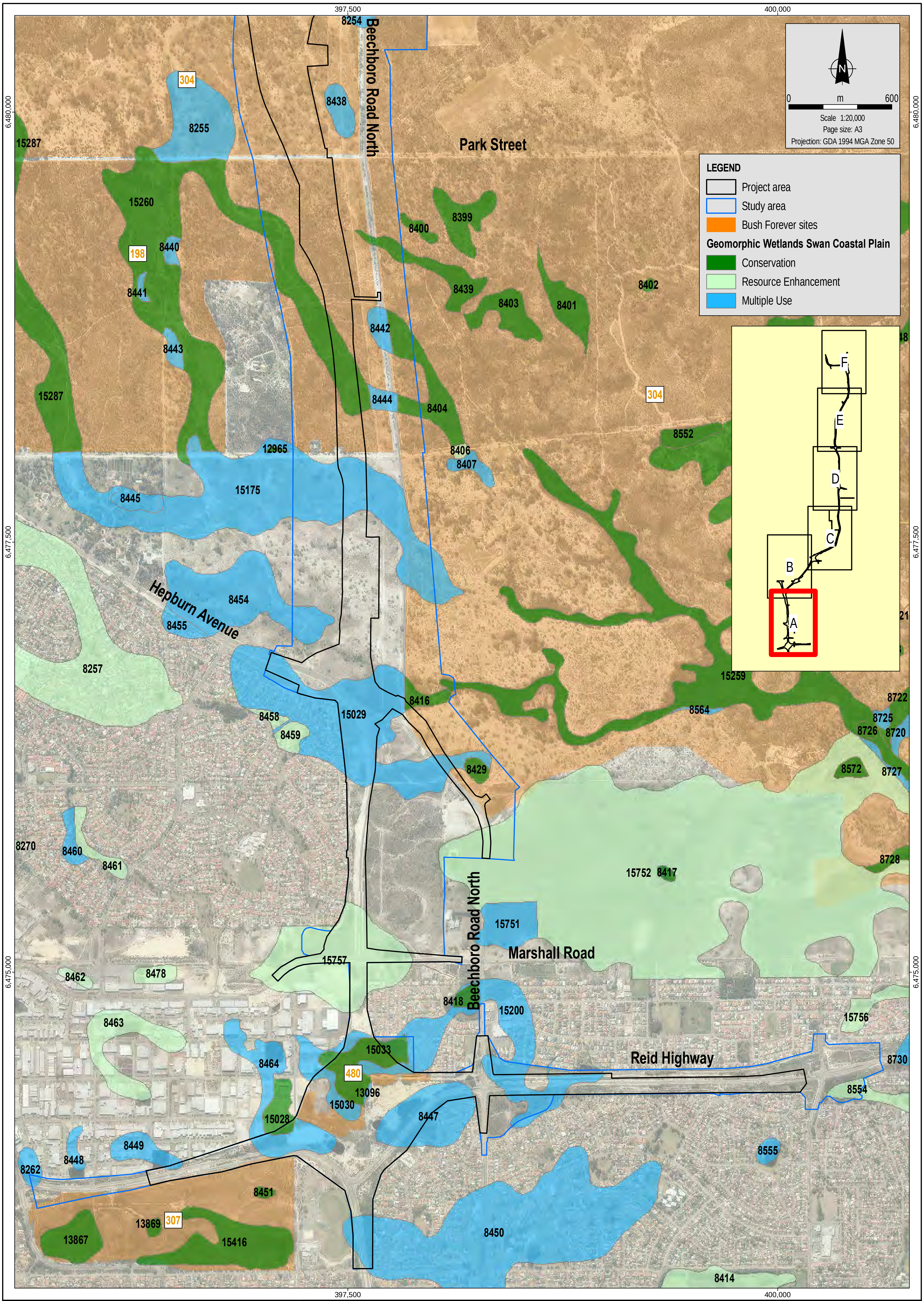
Main Roads WA

Public Environmental Review
Perth Darwin National Highway

NorthLinkWA

Climatic conditions along the project

Figure No: 3



Source & Notes
Geomorphic Wetlands Swan Coastal Plain mapping from DPAW (January 2015)
Bush Forever sites from DoP (January 2015)
Aerial imagery from Landgate (August 2014)

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Date: 27.03.2015
MXT: 4483AA_30_GIS011_2
File Name: 4483AA_30_F004A_GIS

Main Roads WA
Wetland Assessment
Perth–Darwin National Highway

Geomorphic Wetlands Swan Coastal Plain and Bush Forever sites

Figure No: 4A

397,500

400,000

6,485,000

6,482,500

6,480,000

N

0 m 600

Scale 1:20,000
Page size: A3
Projection: GDA 1994 MGA Zone 50

LEGEND

- Project area
- Study area
- Bush Forever sites

Geomorphic Wetlands Swan Coastal Plain

- Conservation
- Resource Enhancement
- Multiple Use

F
E
D
C
B
A

8409
8408
8249
399
8253
8394
8395
8396
8540
8397
8541
195
192
8269
8258
Gnangara Road
8411
13381
8413
8412
8410
304
8254
304
Beechboro Road North
8260
15287
8255
15260
8438
Park Street

Source & Notes
Geomorphic Wetlands Swan Coastal Plain mapping from DPAW (January 2015)
Bush Forever sites from DoP (January 2015)
Aerial imagery from Landgate (August 2014)

NorthLinkWA

coffey

Date: 27.03.2015
MXT: 4483AA_30_GIS011_2
File Name: 4483AA_30_F004B_GIS

Main Roads WA

Wetland Assessment
Perth–Darwin National Highway

Geomorphic Wetlands Swan Coastal Plain and Bush Forever sites

Figure No: 4B

400,000 402,500 405,000

6,490,000 6,487,500 6,485,000

N

0 m 600

Scale 1:20,000
Page size: A3
Projection: GDA 1994 MGA Zone 50

LEGEND

- Project area
- Study area
- Bush Forever sites

Geomorphic Wetlands Swan Coastal Plain

- Conservation
- Resource Enhancement
- Multiple Use

F E D C B A

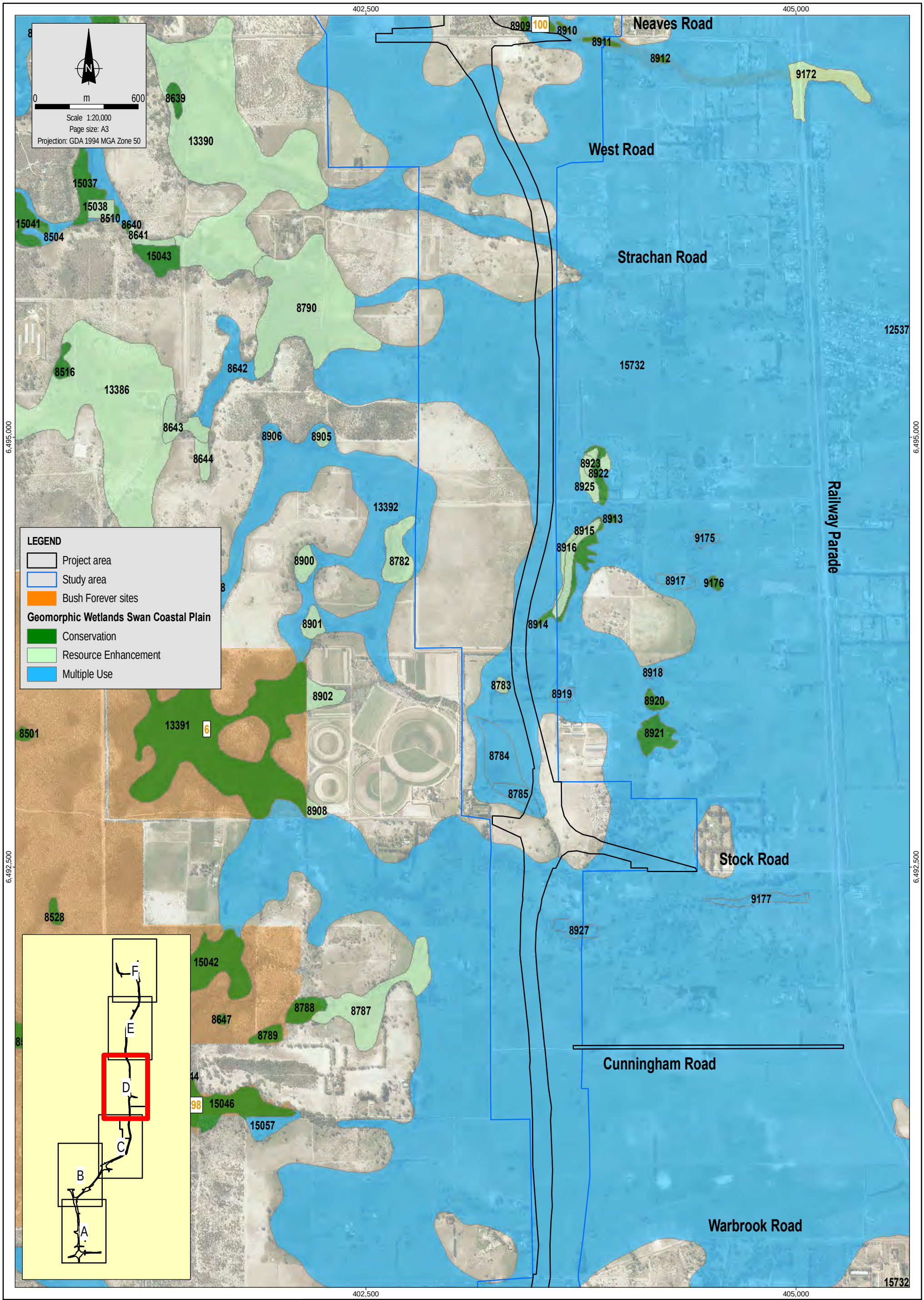
Warbrook Road

Maralla Road

The Broadway

The Promenade

8519 8645 15732 8926 13 13387 8907 8798 8799 8935 8936 9185 8801 8800 8665 8811 8664 8812 15389 8943 15067 8659 8660 300 8938 8802 8662 8803 8656 8939 8792 14074 8657 8661 9179 8793 15090 15065 23 8794 14075 15066 8795 14138 8658 8797 22 15790 15787 8796 8541 8940 15788 300 8809 8941 192 14136 8810



Source & Notes
Geomorphic Wetlands Swan Coastal Plain mapping from DPAW (January 2015)
Bush Forever sites from DoP (January 2015)
Aerial imagery from Landgate (August 2014)

NorthLinkWA

coffey

Date: 27.03.2015
MXT: 4483AA_30_GIS011_2
File Name: 4483AA_30_F004D_GIS

Main Roads WA

Wetland Assessment
Perth–Darwin National Highway

Geomorphic Wetlands Swan Coastal Plain and Bush Forever sites

Figure No: 4D

402,500 405,000

6,502,500

6,500,000

6,497,500

N

0 m 600

Scale 1:20,000
Page size: A3
Projection: GDA 1994 MGA Zone 50

Muchea South Road

Neaves Road

LEGEND

Project area
Study area
Bush Forever sites

Geomorphic Wetlands Swan Coastal Plain

Conservation
Resource Enhancement
Multiple Use

8620 8884 8885 8887 8888 8886 8766 8626 8860 8861 8862 15064 8866 8865 8867 8869 8868 8864 8871 8872 8873 8874 8870 8875 8876 8767 8877 8768 8769 8770 8636 8891 8774 8892 8775 8777 8776 8895 8896 8778 8780 8903 8786 8904 8779 8897 97 13402 8500 8898 8899 8781 8487 8633 15034 8634 8635 8889 8890 100 8773 8909 8910 8911 8912 12945 2 15732 12255 12256 12262 12260 12535 294

A B C D E F

Source & Notes
Geomorphic Wetlands Swan Coastal Plain mapping from DPAW (January 2015)
Bush Forever sites from DoP (January 2015)
Aerial imagery from Landgate (August 2014)

NorthLinkWA

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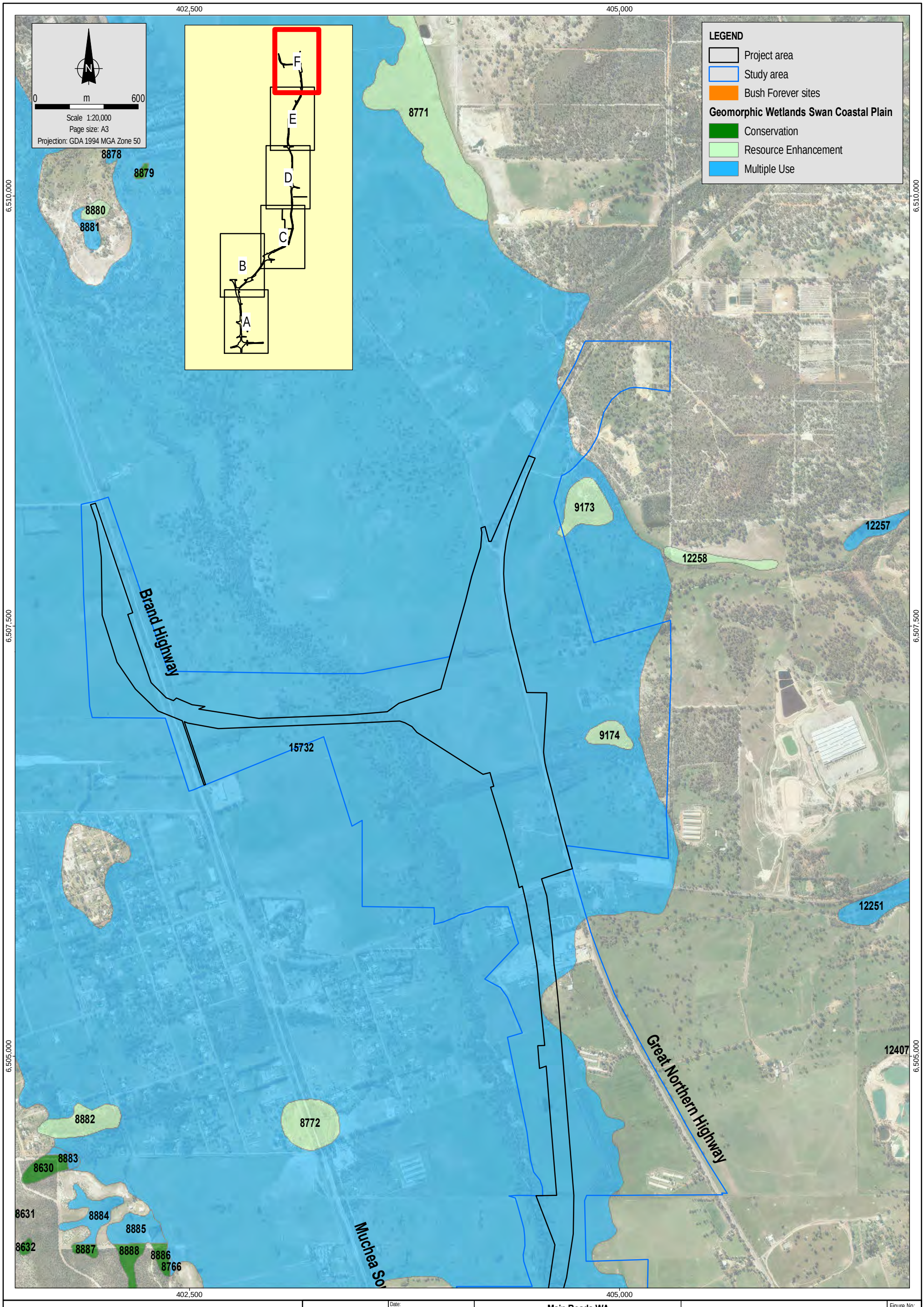
Date: 27.03.2015
MXT: 4483AA_30_GIS011_2
File Name: 4483AA_30_F004E_GIS

Main Roads WA

Wetland Assessment
Perth–Darwin National Highway

Geomorphic Wetlands Swan Coastal Plain and Bush Forever sites

Figure No: 4E



Source & Notes
Geomorphic Wetlands Swan Coastal Plain mapping from DPAW (January 2015)
Bush Forever sites from DoP (January 2015)
Aerial imagery from Landgate (August 2014)

NorthLinkWA

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Date: 27.03.2015
MXT: 4483AA_30_GIS011_2
File Name: 4483AA_30_F004F_GIS

Main Roads WA

Wetland Assessment
Perth–Darwin National Highway

Geomorphic Wetlands Swan Coastal Plain and Bush Forever sites

Figure No: 4F

N

0 km 3

Scale 1:100,000
Page size: A3
Projection: GDA 1994 MGA Zone 50

387,500 390,000 392,500 395,000 397,500 400,000 402,500 405,000 407,500 410,000 412,500

6,507,500 6,505,000 6,502,500 6,500,000 6,497,500 6,495,000 6,492,500 6,490,000 6,487,500 6,485,000 6,482,500 6,480,000 6,477,500 6,475,000

Reid Highway

LEGEND

Project area
Study area

Vegetation complex

- Bassendean Complex-Central And\South
- Bassendean Complex-North
- Bassendean Complex-North-\Transition Vegetation Complex
- Coonambidgee Complex
- Reagan Complex
- Southern River Complex
- Yanga Complex

Source & Notes
Only vegetation complexes intersecting with study area are shown on this figure.
Vegetation complexes from DPAW (December 2014)
Aerial imagery from Landgate (September 2013)

NorthLinkWA

coffey

Date: 27.03.2015
MXT: 4483AA_30_GIS012_2
File Name: 4483AA_30_F005_GIS

Main Roads WA

Wetland Assessment
Perth–Darwin National Highway

Vegetation complexes

Figure No: 5