10 HYDROLOGICAL PROCESSES AND INLAND WATERS ENVIRONMENTAL QUALITY

10.1 EPA Objectives

The EPA's objectives related to hydrological processes and water quality are (EPA, 2015a):

- To maintain the hydrological regimes of groundwater and surface water so that existing and potential uses, including ecosystem maintenance, are protected.
- To maintain the quality of groundwater and surface water, sediment and biota so that the environmental values, both ecological and social, are protected.

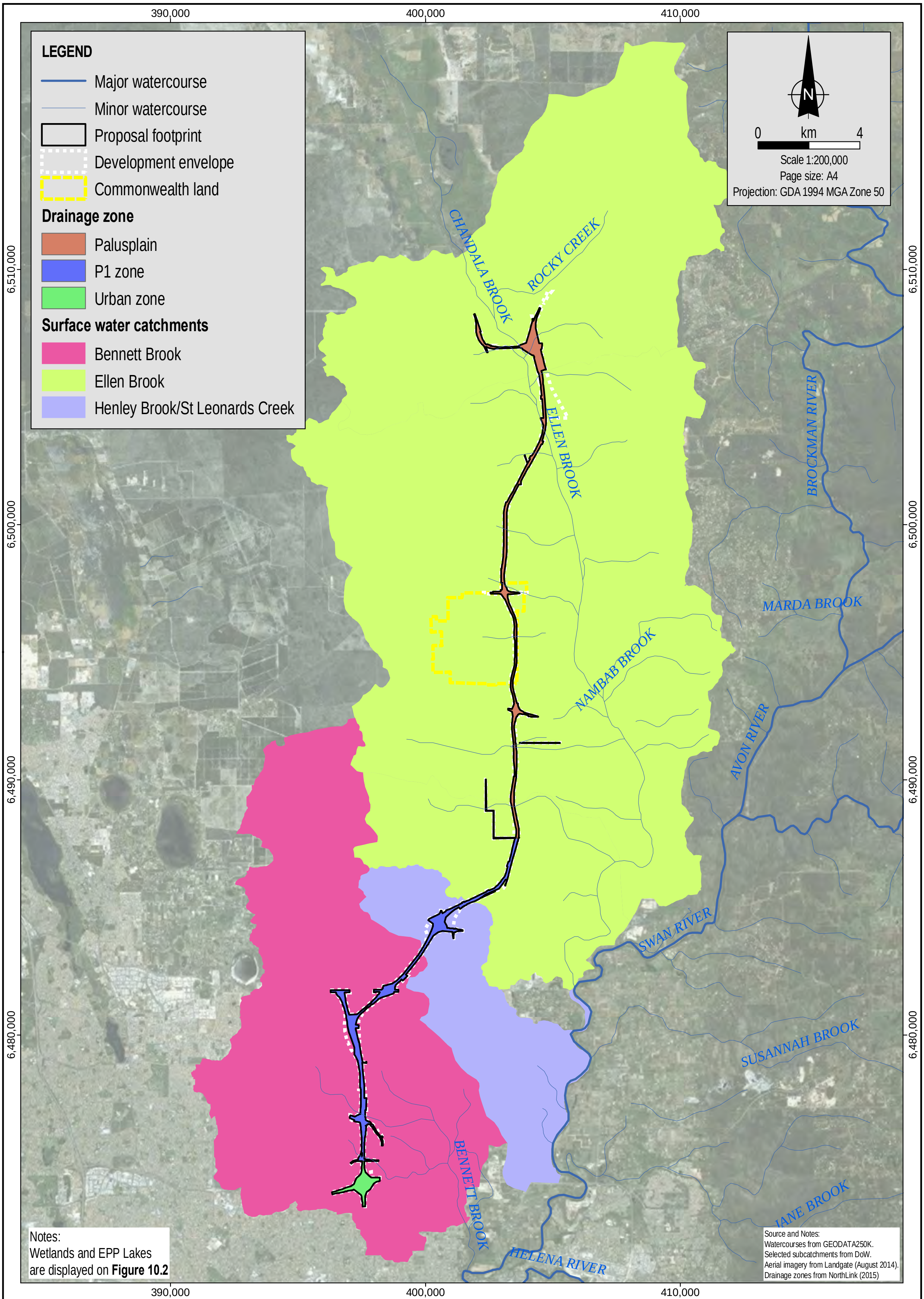
10.2 Existing Environment

10.2.1 Surface Water Features, Catchments and Flow

The major surface water features intercepted by the proposal footprint are Ellen Brook and its catchment and the Bennett Brook catchment (Figure 10.1). The proposal also 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 proposal footprint 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, 2009a). 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 through either rising of the watertable 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). Ellen Brook is a focus catchment of the Swan River Trust through the Swan Canning Clean-up Program, based on its annual elevated contributions of nitrogen and phosphorus to the Swan River (SRT, 2009a).

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, which 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, 2011a). 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, 2011a). Bennett Brook is also a focus catchment of the Swan River Trust through the Swan Canning Clean-up Program, based on its annual elevated contributions of nitrogen and phosphorus to the Swan River (SRT, 2011a).



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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. While phosphorus levels are within required targets, nitrogen levels within this system are high (SRT, 2009b).

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 (i.e. sumps). Water quality monitoring has shown high levels of nitrogen, phosphorous and other non-nutrient pollutants (i.e. chromium, copper and zinc) (SRT, 2011b).

The drainage strategy developed for this proposal (BG&E, 2015) (Appendix H) has characterised three different drainage zones along the proposal footprint, as detailed in Table 10.1 and depicted on Figure 10.1.

Table 10.1 Drainage zones within the proposal area

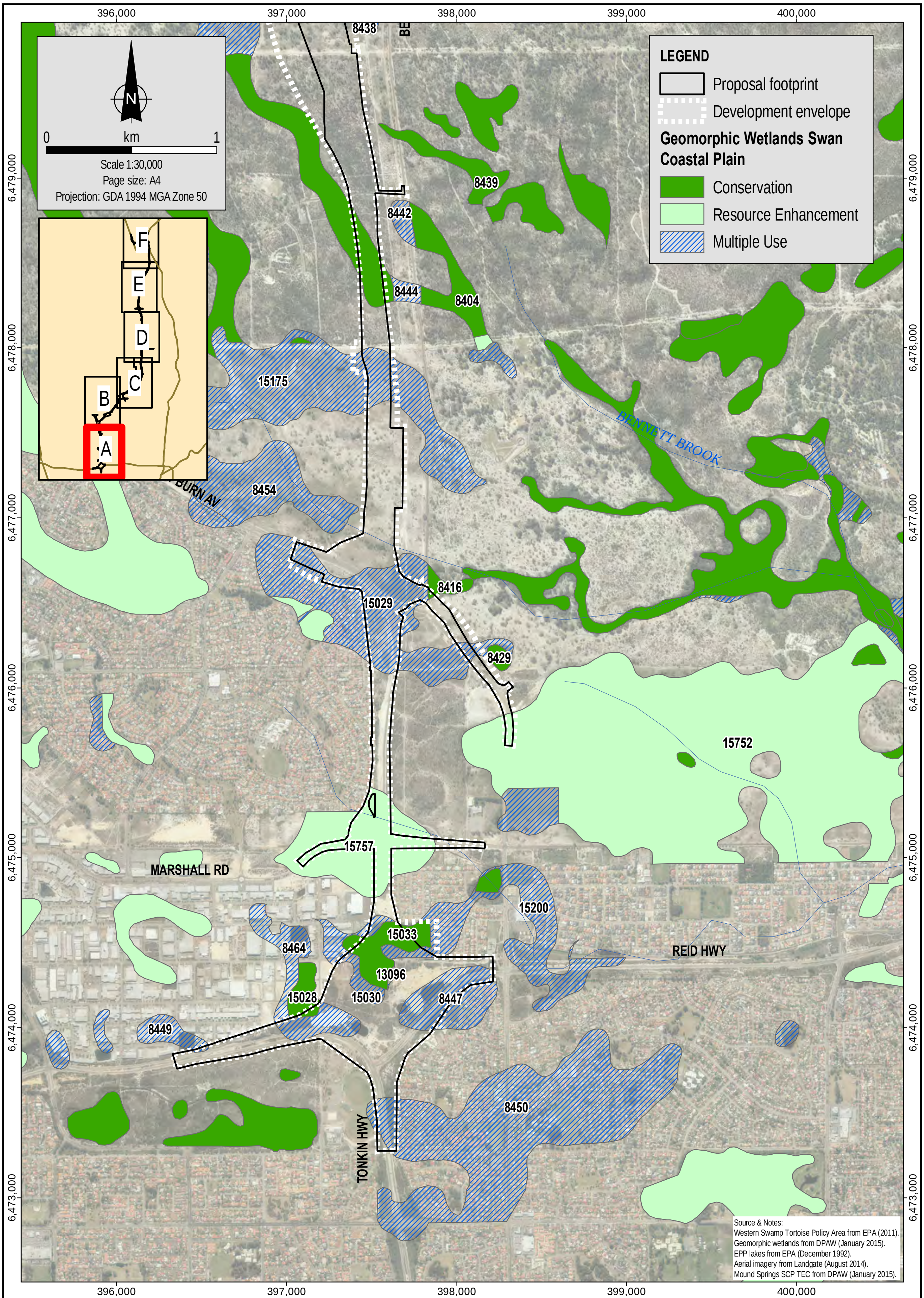
Drainage zone	Drainage characteristics
Urban zone	This zone lies within a predominantly urbanised landscape with extensive formal drainage systems. Soils are typically Bassendean Sand with isolated areas of peaty clay swamp deposits and the groundwater level is generally within 1 to 10 m of the surface.
P1 zone	This zone is largely low density land use and is characterised by an interdunal landscape, with limited watercourses present. Soils are typically Bassendean Sand with isolated areas of peaty clay swamp deposits, the groundwater level is generally within 1 to 10 m of the surface, and surface water and wetlands are present within interdunal swales. This zone is largely located within the Priority 1 protection area of the Gnangara UWPCA.
Palusplain	This zone has largely been cleared for agriculture and is characterised by a gently sloping plain subject to seasonal inundation and waterlogging associated with a shallow watertable. It contains numerous small ephemeral streams, wetlands and the major waterway of Ellen Brook. Soils in the vicinity of Ellen Brook and further east comprise a variable thickness of Bassendean Sand overlying and interfingering with both sandy and clayey soils of the Guildford Formation. Isolated peaty clay swamp deposits are also present and discrete clayey lenses or a more extensive clayey layer has been encountered at 2 m depth near Ellen Brook.

10.2.2 Environmental Protection Policy Lakes

The Environmental Protection (Swan Coastal Plain Lakes) Policy 1992 (1992 Lakes EPP) protects the environmental values of lakes on the Swan Coastal Plain (SCP). The 1992 Lakes EPP made the filling, draining, excavating, polluting and clearing of these lakes an offence unless authorised by the EPA. 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 (WAPC and WRC, 2001b).

The 1992 Lakes EPP ensures the protection of the lakes by prohibiting the carrying out of activities, unless authorised under the EP Act, 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.

Three Environmental Protection Policy (EPP) lakes partially occur within the proposal footprint, while another two EPP lakes occur in close proximity (i.e. within 100 m), as detailed in Table 10.2 and illustrated on Figure 10.2 (Coffey, 2015d; Appendix I).



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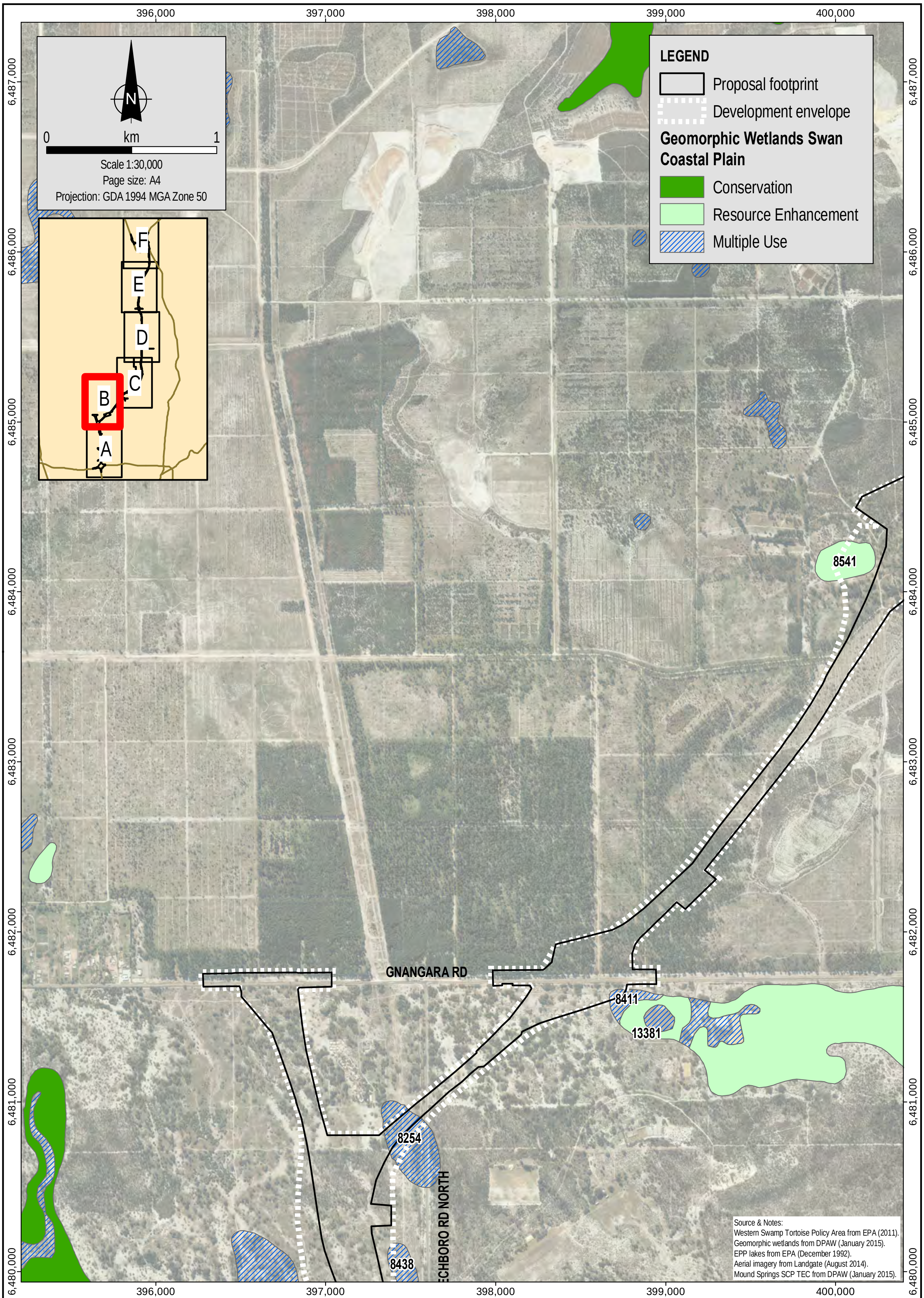
Geomorphic wetlands and EPP lakes
Map 1 of 6

Figure No: 10.2A



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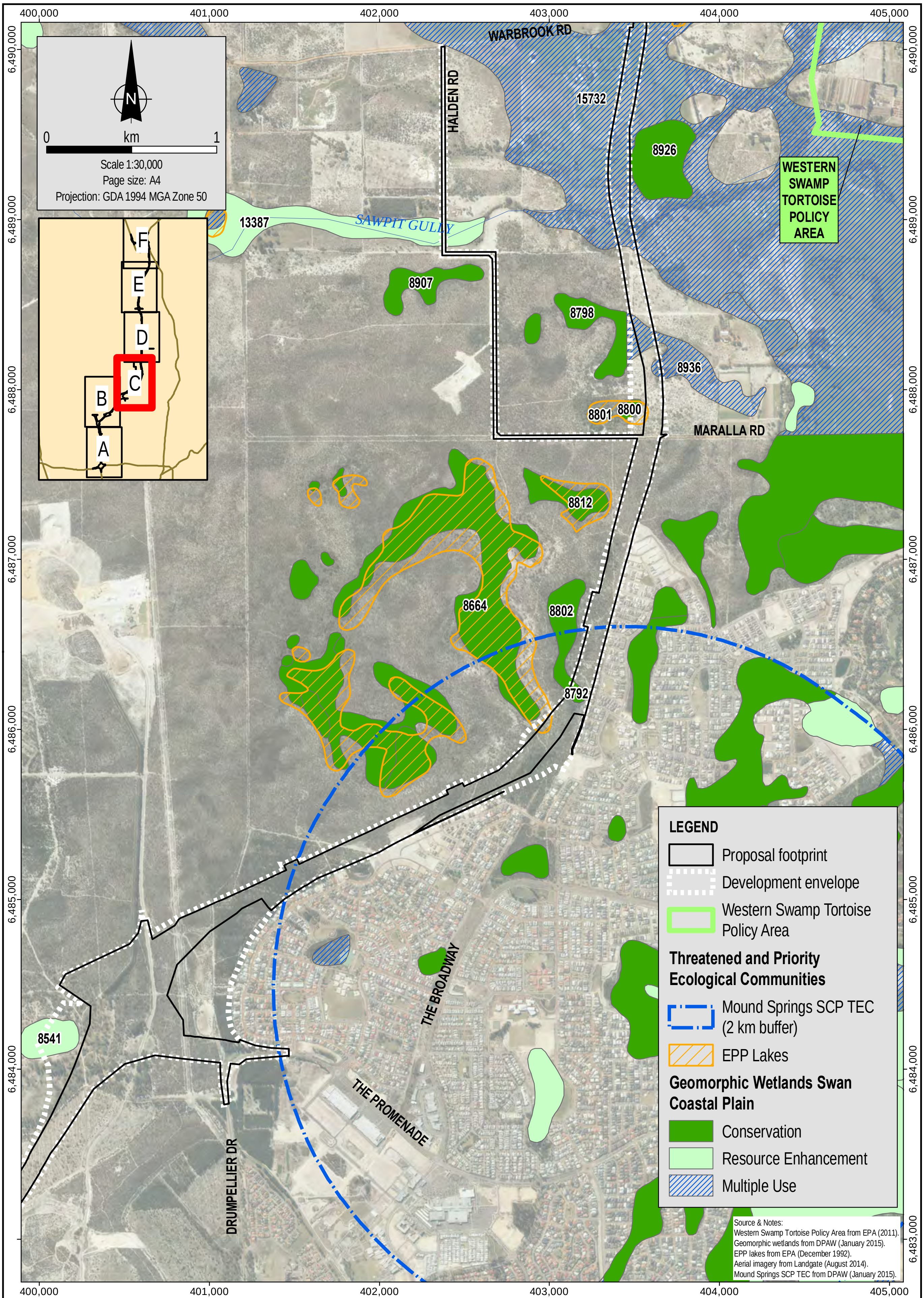

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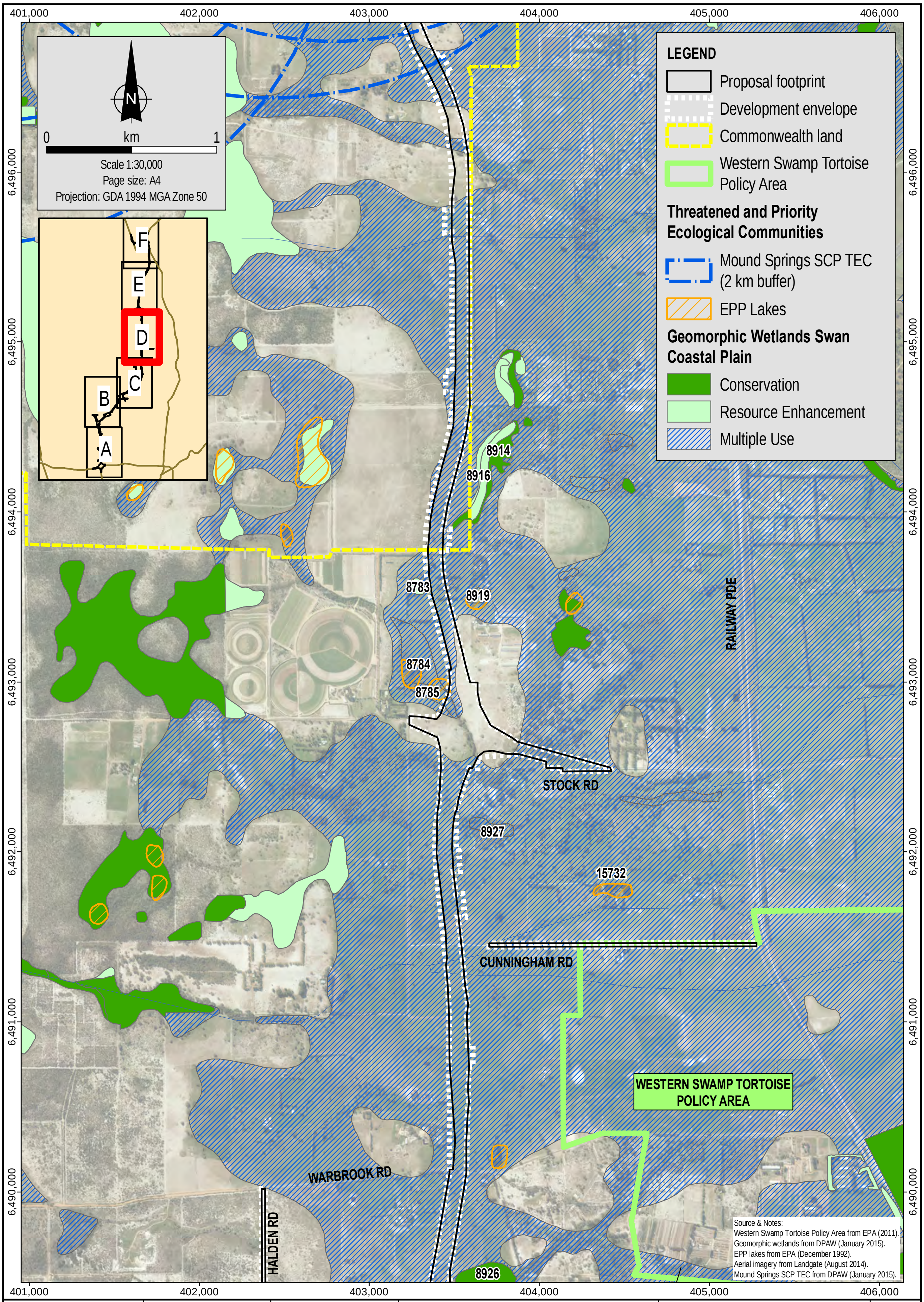

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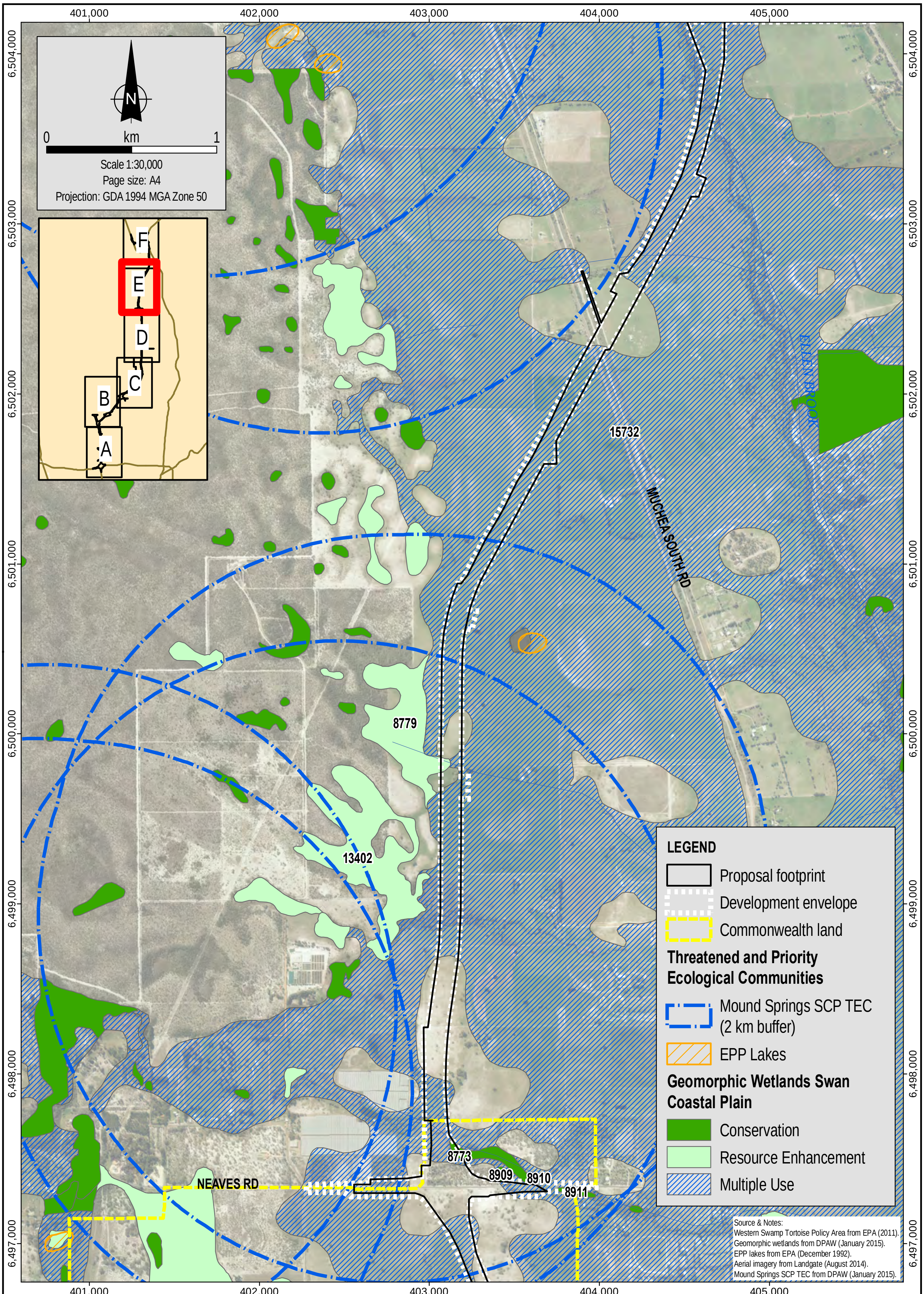

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Geomorphic wetlands and EPP lakes Map 5 of 6

Figure No: **10.2E**

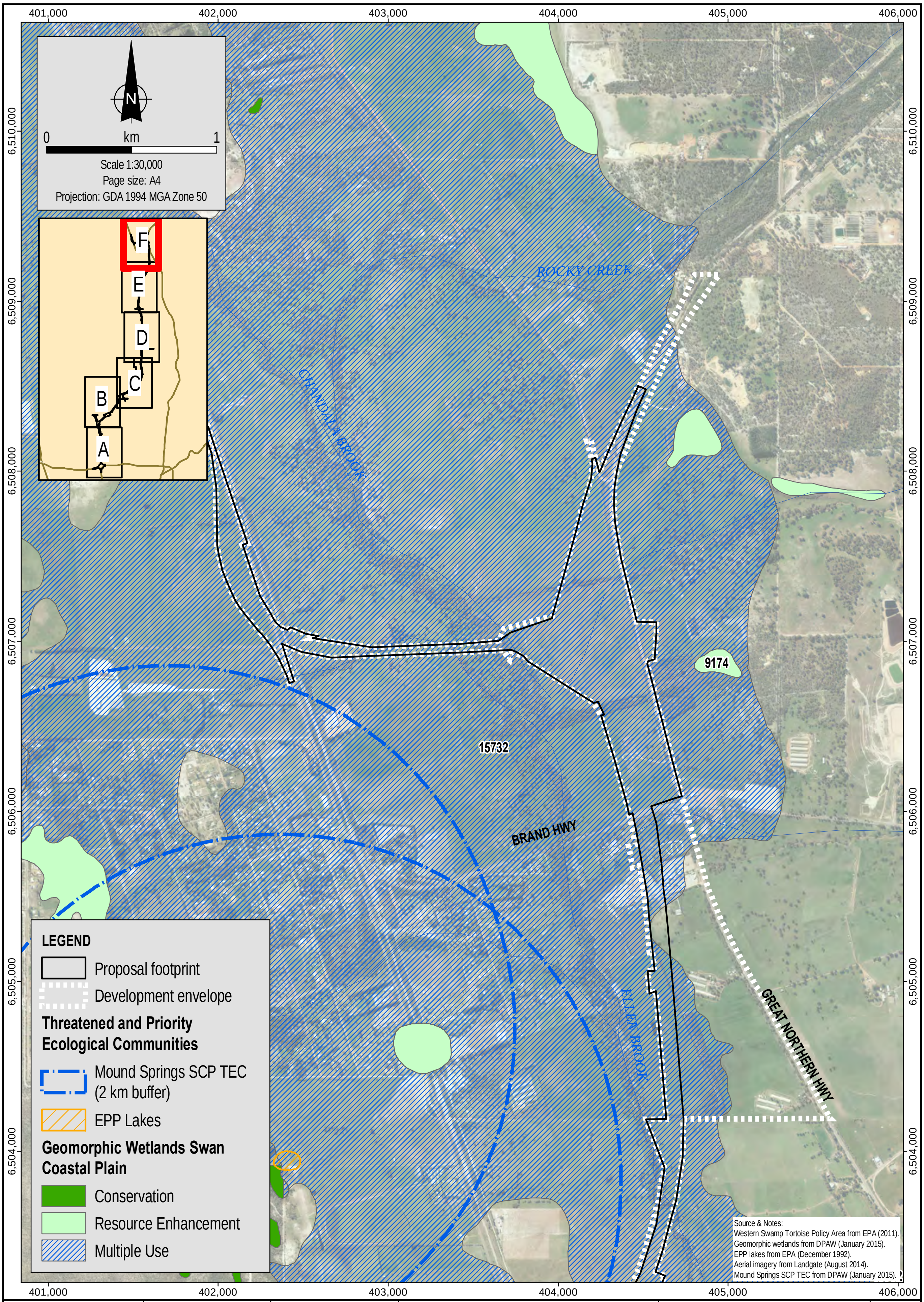

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Table 10.2 EPP Lakes located within and in close proximity to the proposal footprint

EPP Lake No.	Location in relation to the proposal footprint	Related wetland UFI[1]	Wetland type	Management category
439	Partially within	8664	Sumpland	Conservation
440	Within 50 m	8812	Dampland	Conservation
441	Partially within	8800	Sumpland	Conservation
450	Partially within	8785	Floodplain	Multiple Use
453	Within 100 m	8919	Sumpland	Multiple Use

Source: Coffey (2015d).

1. Unique feature identifier.

10.2.3 Wetlands

No nationally important wetlands occur within the proposal footprint. 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 proposal footprint, near Warbrook Road (see Figure 10.2). Furthermore, there are no Wetlands of International Importance within 10 km of the proposal footprint (DOTE, 2014f).

Twenty-five geomorphic wetlands on the SCP (hereafter referred to as wetlands) occur within the proposal footprint and another 26 wetlands occur in close proximity (i.e. within 100 m) to the proposal footprint (Coffey, 2015d; Appendix I). These wetlands are shown in Table 10.3 and on Figure 10.2, along with one nearby wetland associated with the Claypans of the SCP TEC (discussed in Chapter 8).

Table 10.3 Geomorphic wetlands located within and in close proximity to the proposal footprint

Wetland (UFI[1])	Management category[2]	Wetland type	Suite	Location in relation to the proposal footprint
8404	CCW	Palusplain	Bennett Brook	Within 53 m
8416	CCW	Palusplain	Bennett Brook	Partially within
8429	CCW	Sumpland	Bennett Brook	Within 40 m
8439	CCW	Palusplain	Bennett Brook	Within 72 m
15260	CCW	Palusplain	Bennett Brook	Partially within
8773	CCW	Palusplain	Ellen Brook	Partially within
8909	CCW	Palusplain	Ellen Brook	Partially within
8914	CCW	Palusplain	Ellen Brook	Within 47 m
8664	CCW	Sumpland	Jandakot	Within 50 m
8792	CCW	Dampland	Jandakot	Completely within
8802	CCW	Dampland	Jandakot	Directly adjacent
8812	CCW	Dampland	Jandakot	Within 66 m
8907	CCW	Dampland	Jandakot	Within 50 m
8910	CCW	Palusplain	Jandakot	Within 31 m
8911	CCW	Palusplain	Jandakot	Within 62 m

Wetland (UFI[1])	Management category[2]	Wetland type	Suite	Location in relation to the proposal footprint
15028	CCW	Sumpland	Jandakot	Partially within
15033	CCW	Sumpland	Jandakot	Partially within
8798	CCW	Sumpland	Muchea	Within 20 m
8800	CCW	Sumpland	Muchea	Within 28 m
8926	CCW	Sumpland	Muchea	Directly adjacent
13381	REW	Dampland	Bennett Brook	Within 69 m
15752	REW	Palusplain	Bennett Brook	Partially within
8783	REW	Sumpland	Ellen Brook	Within 36 m
8916	REW	Palusplain	Ellen Brook	Within 92 m
9174	REW	Sumpland	Ellen Brook	Within 236 m [3]
8541	REW	Dampland	Jandakot	Within 25 m
15757	REW	Sumpland	Jandakot	Partially within
8779	REW	Sumpland	Muchea	Partially within
8801	REW	Sumpland	Muchea	Within 77 m
13387	REW	Floodplain	Muchea	Partially within
13402	REW	Sumpland	Muchea	Within 62 m
8254	MUW	Dampland	Bennett Brook	Partially within
8411	MUW	Dampland	Bennett Brook	Partially within
8438	MUW	Dampland	Bennett Brook	Within 60 m
8442	MUW	Palusplain	Bennett Brook	Within 35 m
8444	MUW	Palusplain	Bennett Brook	Within 45 m
8454	MUW	Palusplain	Bennett Brook	Within 30 m
15029	MUW	Palusplain	Bennett Brook	Partially within
15175	MUW	Palusplain	Bennett Brook	Partially within
8784	MUW	Floodplain	Ellen Brook	Within 5 m
8785	MUW	Floodplain	Ellen Brook	Partially within
8919	MUW	Sumpland	Ellen Brook	Within 98 m
8927	MUW	Palusplain	Ellen Brook	Within 96 m
15732	MUW	Palusplain	Ellen Brook/Muchea	Partially within
8447	MUW	Dampland	Jandakot	Partially within
8449	MUW	Dampland	Jandakot	Partially within
8450	MUW	Dampland	Jandakot	Partially within
8464	MUW	Sumpland	Jandakot	Partially within
13096	MUW	Sumpland	Jandakot	Completely within

Wetland (UFI[1])	Management category[2]	Wetland type	Suite	Location in relation to the proposal footprint
15030	MUW	Sumpland	Jandakot	Partially within
15200	MUW	Sumpland	Jandakot	Partially within
8936	MUW	Sumpland	Muchea	Partially within

Source: Coffey (2015d).

1. Unique feature identifier.
2. Wetland management categories as defined by Hill et al. (1996):
   Conservation Category Wetland (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.
   Resource Enhancement Wetland (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.
   Multiple Use Wetland (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%).
3. REW 9174 is included in this table due to its association with the Critically Endangered Claypans of the SCP TEC.

Flora and vegetation values of wetlands were resurveyed during the 2014 spring period and are discussed in Chapter 8.

A preliminary investigation into the stratigraphy, hydrology and vegetation of wetlands (360 Environmental, 2014b) found that most wetlands had layers of muddy sand at the surface ranging from 10 to 60 cm in depth. The mud varied from humic matter to peat to diatomaceous material. Phytoliths and silt-sized quartz also comprise part of this mud layer. Below this layer wetlands predominantly had a layer of coarse-grained quartz sand coated in iron oxides and underlain by coffee rock. Groundwater for most of the sampled wetlands was unconfined and levels changed with seasonal rain recharge patterns. Coffee rock and muddy sands retarded water infiltration and it was likely a number of wetlands perched surface and subsurface water for short periods.

Depth to watertable under the monitored wetlands varied and, at the time of sampling (end of spring/early summer), the deepest water level was greater than 3.5 m and the shallowest was 0.7 m. Groundwater recharge from rainfall was rapid, indicating rapid flow through the sandy sediments and a quick response to any changes to the water regime (360 Environmental, 2014b).

10.2.4 Ellen Brook and Twin Swamps Nature Reserves

As discussed in Section 9.4.7, the Critically Endangered Western Swamp Tortoise currently occurs at four locations, two of which (Ellen Brook Nature Reserve and Twin Swamps Nature Reserve) occur within 6 km of the proposal. The remaining two known locations of the Western Swamp Tortoise (Mogumber Nature Reserve and Moore River Nature Reserve) are located over 50 km north of the proposal and have therefore not been considered further.

The swamps within Twin Swamps Nature Reserve are fed by rainfall and surface runoff from a local catchment to the west and during the dry season water in the swamps is sustained by groundwater, which flows from west to east from the Gnangara Mound (NorthLink, 2015b) (Appendix J). Water quality varies between swamps within this nature reserve, some with good quality water and others receiving run-off from surrounding land that has relatively high levels of phosphates and nitrogen (Burbidge et al., 2010).

The swamps within Ellen Brook Nature Reserve are also fed by rainfall and surface water runoff from immediately adjoining properties. While Ellen Brook flows through the nature reserve, it is not known to interact with the swamps, nor is groundwater anticipated to feed these swamps as they are perched on a less permeable (more clayey) base. These swamps contain water from June to November during most years and are not affected by drought. Water quality within these swamps is high with little evidence of pollution (EPA, 2006c).

10.2.5 Mound Springs SCP TEC

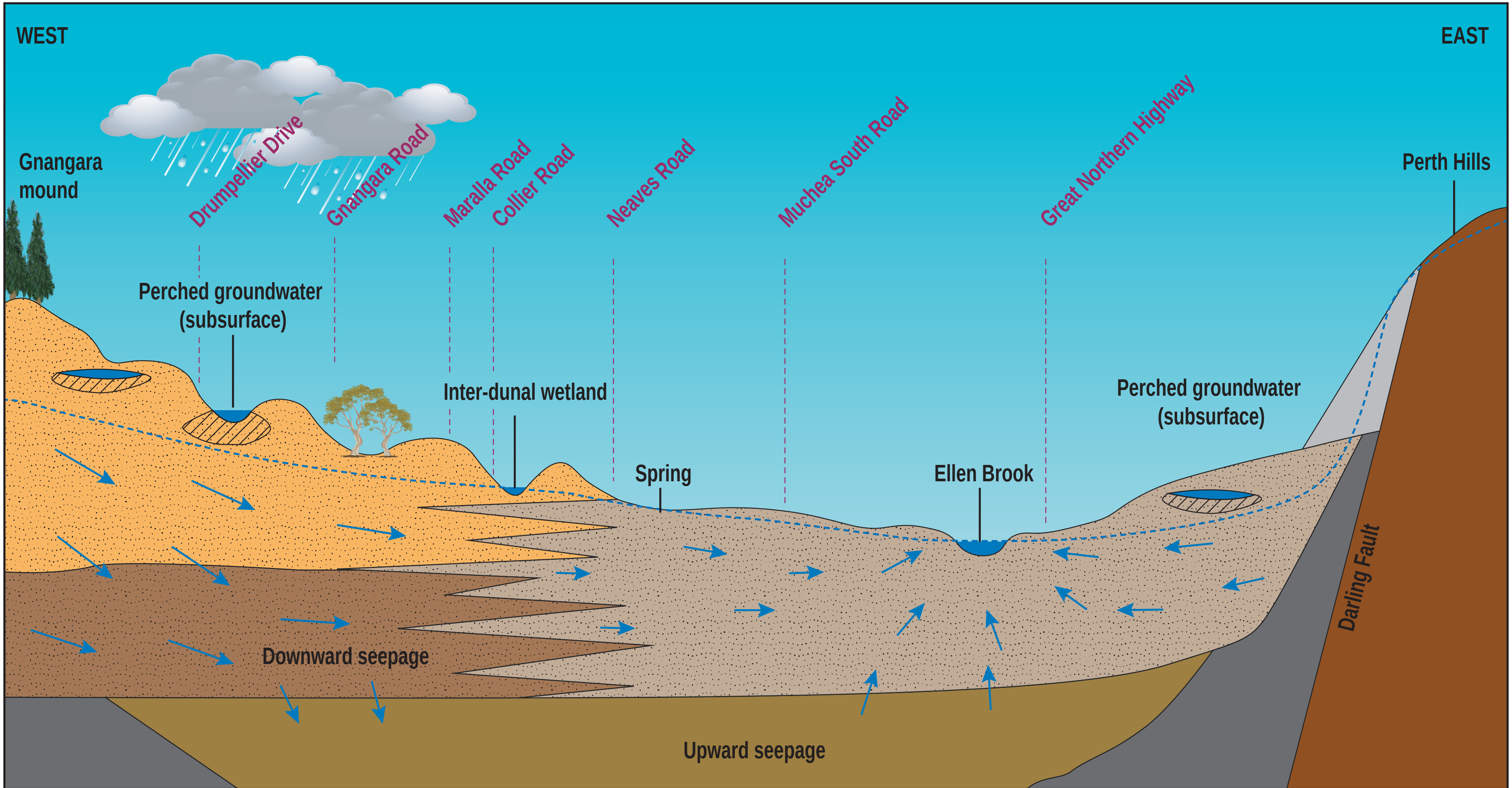
As discussed in Section 8.2.7, the proposal is located adjacent to a number of occurrences of Mound Springs SCP, a Commonwealth and State listed TEC also known as Tumulus Mound Springs (see Figure 10.2). The Mound Springs SCP TEC is characterised by continuous discharge of groundwater in raised areas of peat, which provide a stable, permanently moist series of microhabitats (CALM, 2006; DOTE, 2015).

A hydrogeological assessment of the Mound Springs SCP TEC at Gaston Road, the closest known occurrence to the proposal, was completed in 2008 following consultation with the former DEC (now DPAW). This assessment (GHD, 2008a; Appendix E) found that this Mound Springs SCP TEC has formed where the watertable is exposed at the incised land surface and is fed by the east-southeast flow of groundwater within the unconfined superficial aquifer. Dense vegetation surrounding the springs has resulted in the accumulation of peat that forms a partial confining layer. Groundwater flows through the peat through local discrete permeable zones. Most of the groundwater that discharges to the springs is contributed from a catchment zone approximately 300 to 500 m wide (north-south) and extending 500 to 1,000 m to the west. Groundwater flow direction is not considered likely to vary significantly seasonally.

10.2.6 Groundwater Occurrence, Levels and Flow

The proposal 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). A cross-sectional conceptual model of the geological and hydrogeological units along the alignment is provided as Figure 10.3.



LEGEND

# - -	Approximate conceptual setting of project		Perched groundwater		Guildford formation
----	Groundwater table		Bassendean sand		Kardinya shale (aquitard)
→	Groundwater flow direction		Crystalline rock		Mirrabooka aquifer
▨	Low permeability zone		Gnangara sand		Slope colluvium

Source: Golder 2014
Note: Not to scale

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Conceptual hydrogeological cross-section

Figure No: 10.3

The anticipated hydrogeological conditions within the proposal footprint can be broadly characterised into three hydrogeological domains (Golder, 2014) (Figure 10.4):

- 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 proposal and is one of the main hydrogeological features affecting groundwater levels within the proposal footprint (Golder, 2014).

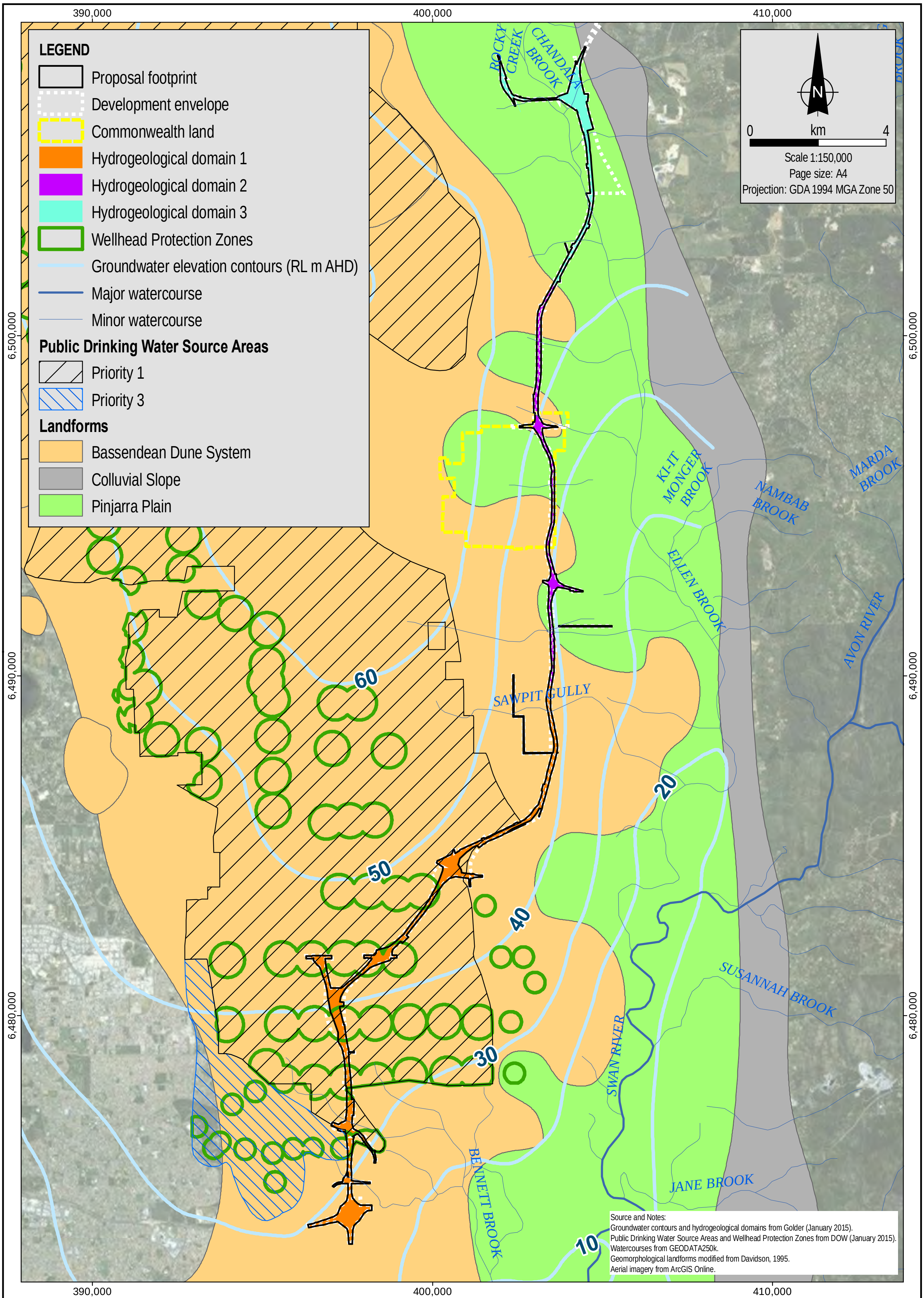
Groundwater levels within the proposal footprint experience a seasonal high following the wet season (around September/October) and are at a seasonal low around April/May. The extent of seasonal variation depends on the hydraulic conductivity of the geological unit, but generally a seasonal fluctuation of about 2 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 proposal footprint 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 Hydrogeological Domain 3 groundwater generally flows from the Perth Hills and Darling Scarp in a southwest direction with discharge into Ellen Brook (see Figure 10.4; Golder, 2014).

10.2.7 Groundwater Quality

Groundwater quality varies across the proposal footprint and is affected by existing and historic land use, local geology, recharge and discharge zones and fluctuations in the groundwater level (both seasonal and long term trends) (Golder, 2014).

Groundwater quality within the superficial aquifer is generally good with salinity generally less than 1,000 mg/L, and less than 500 mg/L within the proposal footprint (DOW, 2010 cited in Golder, 2014). Salinity will generally be higher further from the crest of the Gnangara Mound and can be brackish to saline (greater than 1,000 mg/L) in the clay of the Guildford Formation along Ellen Brook (DOW, 2012; DOW, 2009a; Davidson 1995 all cited in Golder, 2014).



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Generally the groundwater is acidic with pH ranging between 4 and 6 and the calcium carbonate content in the Bassendean Sands is low, resulting in groundwater having little acid buffering capacity. Within the proposal footprint pH may be higher near outcrops of Muchea Limestone, which would buffer acidic waters (Golder, 2014).

Nutrient levels vary across the superficial aquifer and are closely associated with land use. Natural nitrate levels in the superficial aquifer are generally less than 1 mg/L (Davidson, 1995 cited in Golder, 2014). However, nitrate concentrations have become elevated in the superficial aquifer due to human activity with the highest concentrations associated with horticultural areas. Phosphate concentrations are also generally higher than would be naturally expected with elevated levels associated with fertilisers, animal waste and septic waste. Within the proposal footprint nitrate levels would generally be expected to be below 10 mg/L. Phosphate levels within the proposal footprint would generally be expected to be low (less than 0.3 mg/L) south of Maralla Road and increase toward Ellen Brook to greater than 3 mg/L (DOW, 2012 cited in Golder, 2014).

10.2.8 Groundwater Users

Groundwater from the Gnangara Mound is used to support domestic, environmental, recreational, commercial (horticulture and agriculture) and industrial needs. The Gnangara Mound is currently the most significant source of groundwater for the Perth region as well as a vital part of groundwater dependent ecosystems. The groundwater of the superficial aquifer within the proposal footprint is, therefore, of considerable importance to local users and to the Perth region as a whole.

This is demonstrated by the level of protection offered to the Gnangara Mound through the proclamation of the Gnangara UWPCA under the *Metropolitan Water Supply Sewerage and Drainage Act 1909*. The proposal intercepts a number of priority areas and protection zones of this UWPCA as depicted in Figure 10.4, including:

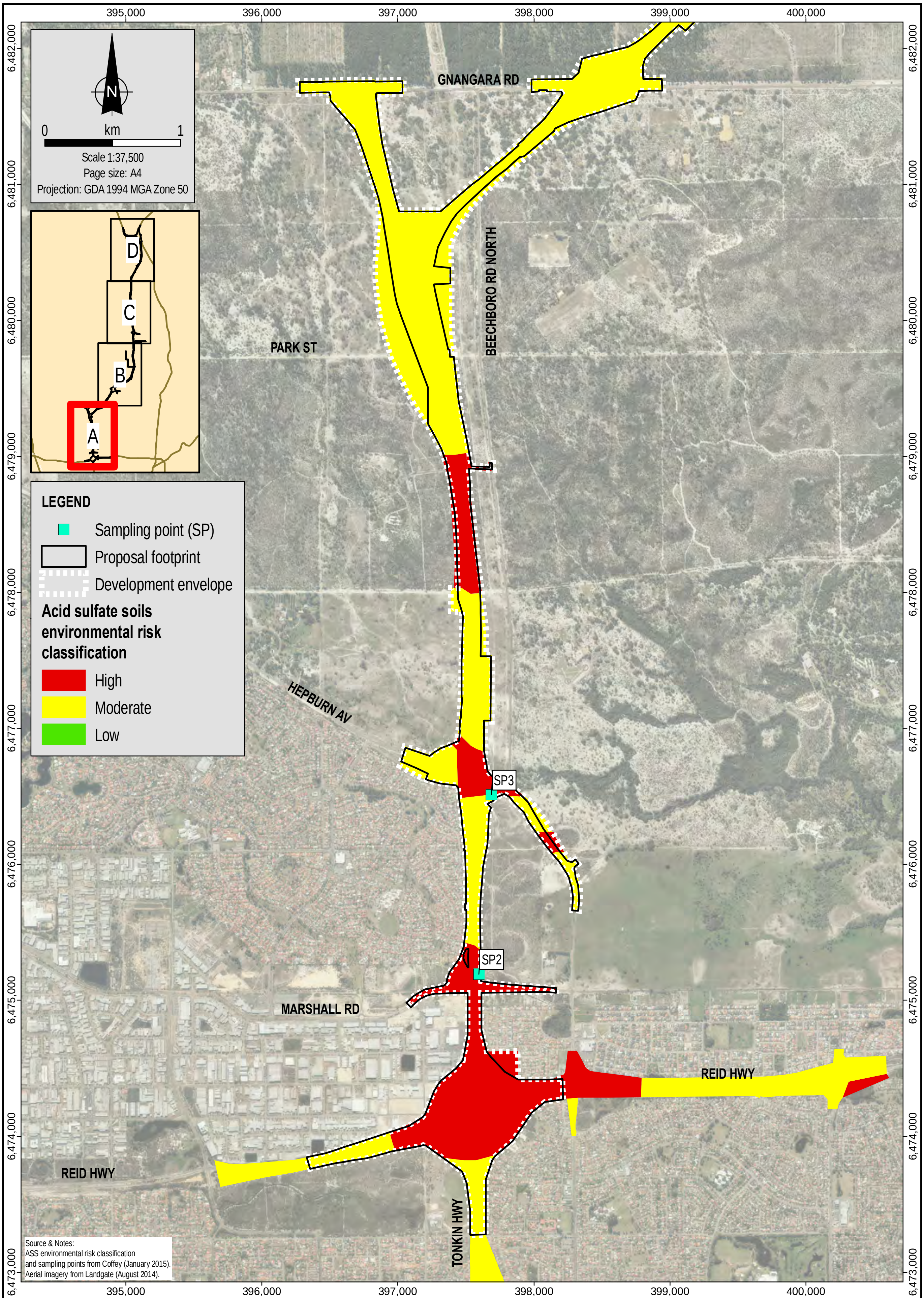
- Priority 1 area – areas that are managed to ensure no degradation of the drinking water source occurs. These areas contain the greatest restrictions on land use and activity and aim to avoid all risks to the drinking water source.
- Priority 3 area – areas where management of risk to water sources from catchment activities are targeted. These are principally areas where existing land use co-exists with water supply sources.
- Eight Wellhead Protection Zones (WHPZ) – circular zones established around groundwater production wells to protect drinking water sources from contamination. In Priority 1 areas WHPZ have a radius of 500 m, in Priority 2 and 3 areas the radius is 300 m. Special conditions, such as restrictions on storage and use of chemicals, may apply within these zones (DOW, 2006c).

10.2.9 Acid Sulfate Soils

Acid sulfate soils (ASS) are soils that contain iron sulfides, predominantly pyrite. The formation of pyrite requires the presence of iron (naturally available from sediments), sulfur (S) (usually from seawater or sediments of marine origin) and organic matter.

A preliminary investigation into the potential presence of ASS was undertaken in accordance with the guideline, *Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes* (DEC, 2013b). The full ASS investigation report (Coffey, 2015e) is provided as Appendix K.

The potential for ASS occurrence was assessed using a tailored ASS risk mapping process. This involved mapping soils within the proposal footprint as having a low, medium or high risk of ASS occurrence, taking into consideration site elevation, geology, groundwater depth and wetland presence and classification, in addition to DER ASS risk mapping. The results of this assessment are illustrated on Figure 10.5.



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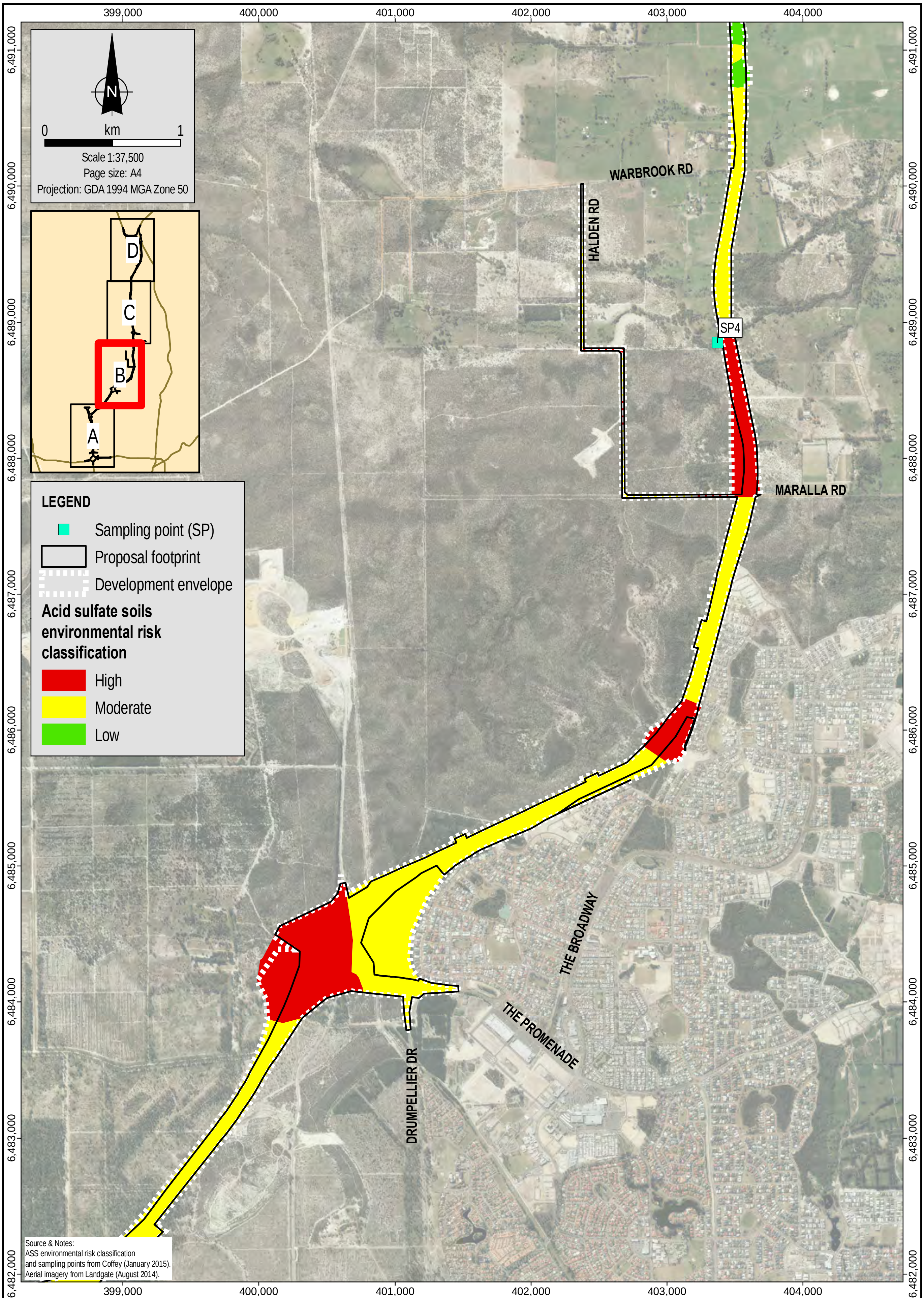
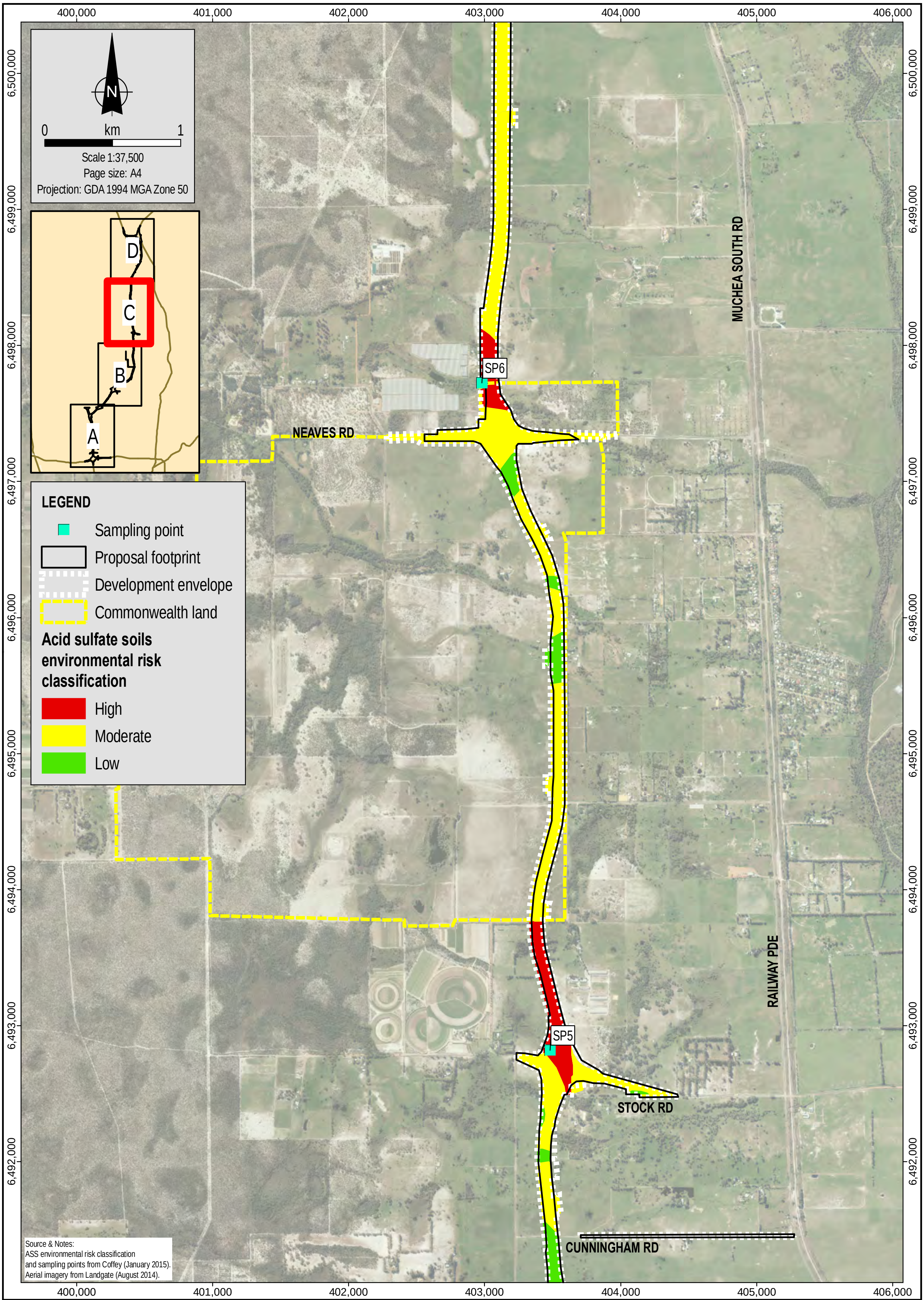
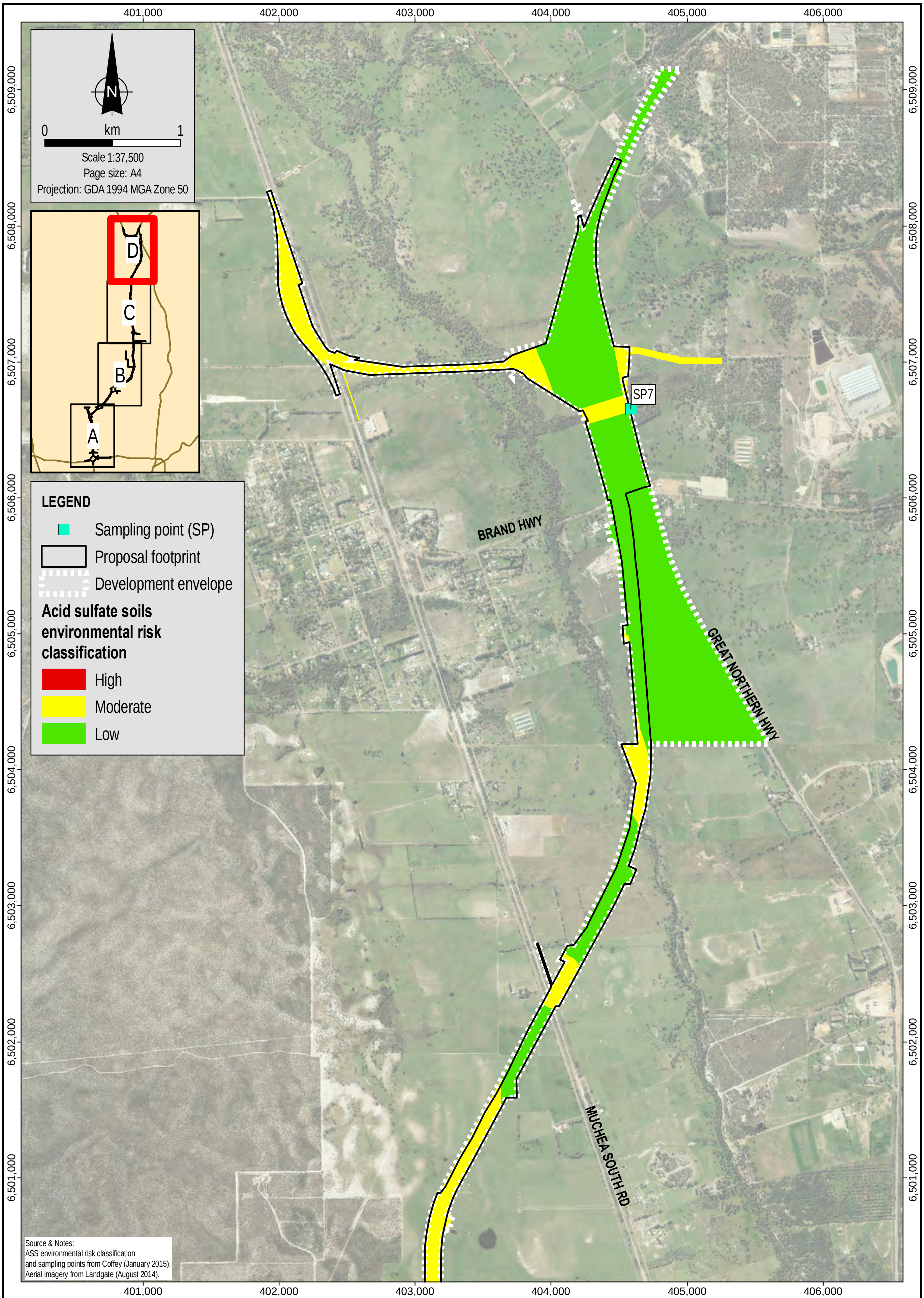


NorthLinkWA	coffey	Date: 18.06.2015 MXD: 4483AA_03_GIS084_2 File Name: 4483AA_03_F10.5B_GIS	Main Roads WA Public Environmental Review Perth–Darwin National Highway	Acid sulfate soils environmental risk classification Map 2 of 4	Figure No: 10.5B



NorthLinkWA	coffey	Date: 03.06.2015 MXD: 4483AA_03_GIS084_2 File Name: 4483AA_03_F10.5C_GIS	Main Roads WA Public Environmental Review Perth–Darwin National Highway	Acid sulfate soils environmental risk classification Map 3 of 4	Figure No: 10.5C



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Acid sulfate soils environmental risk classification
Map 4 of 4

Figure No: 10.5D

Preliminary soil sampling also identified that of the seven sites sampled from within areas mapped as high risk of ASS occurrence, two sampling locations exceeded the DER net acidity criterion of 0.03% S (see Figure 10.5) confirming the presence of ASS within the proposal footprint.

Areas of particular concern, in relation to the occurrence of ASS include:

- Watercourse crossings.
- Low-lying areas and wetlands.
- Areas of light grey to grey sands typical of 'Bassendean Sands'.
- Silty or peaty soils.
- Areas containing iron-cemented organic rich sands (coffee rock).

10.3 Potential Impacts

The following impacts on existing hydrological regimes and inland water quality may occur during the construction phase:

- Altered surface water runoff volumes from vegetation clearing.
- Altered surface water flow from earthworks (e.g. cut and fill) and crossing/impounding of waterways and wetlands.
- Temporary changes to local groundwater levels as a result of drawdown of local aquifers during construction (e.g. any dewatering during construction and groundwater abstraction for use as construction water).
- Altered groundwater flow paths associated with subsurface compaction.
- Altered water quality, associated with:
  - Liberation of sediments during ground disturbing activities.
  - Disturbance to potential ASS.
  - Accidental spills and releases.
- Impact to groundwater users (Gnangara Mound).
- Impact to wetlands and EPP lakes.
- Impact to Ellen Brook and Twin Swamps Nature Reserves (and the Western Swamp Tortoise).
- Impacts to Mound Springs SCP TEC.
- Impacts to Claypans of the SCP TEC.
- Impact to Ellen Brook.

The following impacts to existing hydrological regimes and inland water quality may occur during the operation phase:

- Altered surface water runoff volumes from road surface.
- Changes to local groundwater levels associated with infiltration basins.
- Altered water quality associated with road runoff and accidental spills and releases.

- Impact to groundwater users (Gnangara Mound).
- Impact to wetlands and EPP lakes.
- Impact to Ellen Brook and Twin Swamps Nature Reserves (and the Western Swamp Tortoise).
- Impacts to Mound Springs SCP TEC.
- Impact to Ellen Brook.

10.4 Assessment of Impacts

10.4.1 Altered Surface Water Runoff Volumes

The proposal is generally being built over existing permeable ground (i.e. sandy soils) with a high hydraulic connectivity. Coupled with the separation distance to groundwater in the order of two or more metres, little natural runoff occurs in the northern section of the alignment during common rainfall events. In the northern section of the alignment these soils are subject to seasonal waterlogging and inundation due to a higher watertable, which decreases the ability for rainfall to infiltrate and results in increased runoff during the winter months.

Vegetation generally reduces stormwater runoff volumes by capturing rainfall in its canopy and releasing water into the atmosphere through evapotranspiration. In addition, tree roots and leaf litter create soil conditions that promote infiltration of rainwater into the soil. As a result, clearing of vegetation during construction may have a localised increase in surface water runoff volumes; however, this impact is likely to be negligible given the area of vegetation loss (approximately 205 ha) is equivalent to only 0.2% of the combined 95,260 ha of catchments in which the proposal is located.

During the operation phase, the road pavement will have a much lower permeability and will result in a localised increase in runoff volumes. Where this runoff is not appropriately managed it may collect alongside the road, particularly in low-lying areas including wetlands. Where this water cannot infiltrate (i.e. due to the presence of clays/peat) this may result in waterlogging or increased levels of standing water, impacting vegetation condition and structure.

10.4.2 Altered Surface Water Flow

As described in Section 10.2.1 and depicted in Figure 10.1, the proposal footprint crosses through three different drainage zones: the urban zone, P1 zone and palusplain zone. In any of these areas the construction of the road embankment may fill an area that currently conveys flowing water or disconnect areas of standing water (i.e. wetlands); however, it is particularly critical in the northern palusplain zone where, as well as numerous small ephemeral streams, there are likely to be areas of sheet flow that may be impacted. The waterway of Ellen Brook is also present in this zone and is crossed by the proposal and existing Brand Highway.

Through the interdunal area of the P1 zone there is generally little existing surface flow, with the exception of the tributary to Mussel Brook near Hepburn Avenue. Wetlands exist within the P1 zone and are typically expressions of groundwater rather than areas collecting significant surface runoff.

Within the urban zone, surface water flows are generally controlled through formalised drainage systems such as the Water Corporation's Victoria Road Branch Drain and the Emu Swamp Main Drain, which both cross the proposal.

Where insufficient drainage structures (i.e. culverts) are provided this can lead to retention of water upstream of the embankment (often referred to as waterlogging or inundation) and a decrease in the water received downstream of the embankment (often referred to as 'water shadow').

10.4.3 Altered Water Quality

During construction, water quality could be affected by the liberation of sediments, disturbance of ASS and or the accidental spill and/or release of hydrocarbons and other chemicals. These contaminants, once liberated, could pass along surface water flow paths and enter surface water features (e.g. Ellen Brook and its tributaries or surrounding wetlands) or infiltrate into groundwater systems (i.e. Gnangara Mound).

During operation, water quality could be affected by polluted road run-off. Typical non-point source contaminants from roads include gross litter and particulates, nutrients, heavy metals and elemental compounds (i.e. nickel, copper, zinc, cadmium and lead), and hydrocarbons (asphalt, diesel and petrol). These are washed off the road surface during rainfall events that generate surface runoff and have the potential to pollute adjacent soils, surface water (i.e. Ellen Brook and its tributaries or surrounding wetlands) and groundwater systems.

Potential point sources of water pollution from the proposal are spills of hydrocarbons or other chemicals resulting from road traffic accidents. This includes the potential loss of petrol, diesel and other engine fluids from damaged engines or fuel tanks, as well as other pollutants spilt from damaged loads.

Water pollution can impact the quality of public drinking water sources, degrade and alter habitats/vegetation structure, adversely affect aquatic life and reduce the aesthetic value of water bodies for recreational users.

10.4.4 Changes to Local Groundwater Level and Flow

The impacts on local groundwater levels and flows during and following construction are expected to be minimal as the road surface is generally several metres above the design maximum groundwater level (i.e. the maximum groundwater level surface anticipated along the alignment during the design life of the proposal) for the majority of the alignment. No cuttings will be made below the design maximum groundwater level.

10.4.4.1 Construction Dewatering

Temporary dewatering may be required in some areas to facilitate deep excavations such as the construction of bridge footings and relocation or protection of utility services. Dewatering will reduce groundwater levels in the proximity to these specific construction activities, which may impact groundwater dependent ecosystems. The preferred method for dewatering is the use of well-point spears, involving the extraction of water via series of spears and reinjection back into the aquifer, where possible as close to the abstraction point as practical; however, dewatering methods may need to be altered based on local conditions. Dewatering is unlikely to exceed six weeks in any one location. An assessment of required drawdown of groundwater levels to enable the construction of bridge footings found that no dewatering would be required if the construction works were undertaken during drier months, when groundwater levels are at a minimum (NorthLink, 2015c) (Appendix L). However, if footings are constructed during wetter months, then dewatering may be required at eight locations. In this case, the analysis indicates that dewatering for six weeks would result in drawdown ranging from 0.1 to 0.9 m and a drawdown radius of influence (i.e. the distance from the excavation to where drawdown is zero) of 160 to 490 m centred on the dewatering point. Should dewatering be required, impacts on groundwater levels are anticipated to be minor and short-term and within usual seasonal variation.

10.4.4.2 Construction Groundwater Abstraction

Construction of the proposal will require a supply of water for construction purposes at various locations along the alignment. While construction water requirements will not be known until detailed final design work has been carried out, construction water will be sourced from existing bores in accordance with existing licences where possible. Where existing bores or licences are unavailable, new bores may need to be constructed and licenced in accordance with DOW requirements.

Preliminary analysis has been conducted using generalised hydrogeological models for each of the three hydrogeological domains given that bore locations have not yet been determined (NorthLink, 2015c) (see Appendix L). For each hydrogeological domain, the model produced estimates of groundwater level drawdown and radius of influence for various pumping rates and durations. The analysis was based on several assumptions that were in turn based on the known hydrogeological properties of each domain. Hydrogeological Domains 1 and 2 were considered similar enough to analyse together, with estimated drawdown of between 1.1 and 6.7 m at the well for pumping rates of 5 and 30 L/s respectively (assuming continuous pumping for 12 months). The maximum radius of influence, which depends on pumping duration but not pumping rate, was about 1.5 km. For bores located in Hydrogeological Domain 3, achievable pumping rates are significantly lower due to lower hydraulic conductivity and the confined nature of the aquifer. Drawdown estimations at the well are between 1.6 and 8.2 m for pumping rates of 1 and 5 L/s respectively. However, the maximum radius of influence is larger at about 7.8 km after 12 months, albeit in the confined aquifer and not the groundwater table.

Operational requirements for bores will likely be less than that assumed by the modelling, e.g. a bore might operate for six months at 10 L/s for 10 hours on weekdays only. When determining the number and location of new bores, therefore, the following factors will be taken into account:

- Rates of water abstraction.
- Bore operating regimes and durations.
- Hydrogeology of bore locations.
- Expected groundwater drawdown and resulting indirect impacts to environmental values (e.g. wetlands).
- Existing groundwater licence allocations.

An iterative assessment of a planned bore’s predicted drawdown against a detailed hydrogeological model will allow for the adjustment of the bore’s location or operational parameters to ensure that drawdown impacts to sensitive environmental receptors such as nearby wetlands can be avoided completely or minimised to within acceptable thresholds. Acceptable thresholds for relevant sensitive environmental receptors will be related to the magnitude of drawdown expected and are defined in later sections of this chapter relevant to those receptors.

Due to the presence of the clayey Guildford Formation layer in Hydrogeological Domain 3 and the lack of adequate water resources at the surface, construction water bores in the northern portion of the proposal are likely to target a sand aquifer beneath the clayey Guildford Formation or the deeper Mirrabooka aquifer. The Guildford Formation acts as an aquitard, limiting the effects to the groundwater table from drawdown in deeper aquifers. Impacts to sensitive environmental receptors at the surface that rely on the groundwater table are therefore likely to be negligible (NorthLink, 2015c).

Due to the progressive nature of the construction works, abstraction from any one bore will be limited to a particular stage of development, limiting the distance from the bore at which groundwater is drawn down and resulting in short-term and localised impacts.

10.4.4.3 Road Embankment Compaction

An issue raised during the Drainage Reference Group workshops was the compaction of soils during road embankment construction and the effect this could have on soil permeability and thus the movement of groundwater.

To assess the potential impact of road embankment compaction a basic steady-state two-dimensional numerical groundwater model was developed based on conservative theoretical worst-case scenarios, as detailed geotechnical investigation data was not available at the time (NorthLink, 2015d) (Appendix M). The model was based on the geology of northern parts of the proposal footprint north of Maralla Road (Hydrogeological Domain 3 – see Figure 10.4), where the presence of a shallow clay layer beneath a thin surface layer of sand is most likely to restrict groundwater flow if the sand layer becomes compacted. Within this model two key variables were altered:

- The thickness of the sand layer between the underside of the compacted road embankment foundation and the top of a clay layer; and
- The hydraulic conductivity of the compacted road embankment foundation.

Based on conservative but realistic values for these parameters, the results of the modelling are presented as generalised scenarios in Table 10.4.

Table 10.4 Modelled changes to groundwater levels from embankment compaction

	2 m sand thickness scenario	1 m sand thickness scenario	Base case scenario
Thickness of sand layer between embankment foundation and underlying clay layer	2 m	1 m	0.5 m
Maximum potential change in groundwater level:			
• Immediately upstream.	+0.08 m	+0.15 m	+0.12 to +0.23 m
• 150 m downstream.	–0.10 m	–0.10 m	–0.10 m
• 300 m downstream.	–0.10 m	–0.10 m	–0.10 m

Source: Golder (2015) (see Appendix M).

The scenarios in Table 10.4 apply only in areas where the modelled geology (a thin surface layer of sand above a clay layer) exists. The majority of the proposal is not located over this type of geology and therefore no hydrological changes as a result of compaction are expected.

The northern portion of the alignment, where clay associated with the Guildford Formation may be close to the surface, is the only area where hydrological changes from road embankment compaction may occur. Preliminary geotechnical investigations have encountered clay or low permeability soils with less than 1 m of sand cover only in the section of the proposal north of a point about 1 km south of Muchea South Road (Golder, 2015). In other areas where clay has been encountered, there is generally more than 1 m of sand cover.

In the northern portion of the alignment, groundwater levels on the upstream side of the embankment could rise by up to 0.23 m in the base case scenario. This means where the depth to groundwater is already less than 0.23 m, groundwater could theoretically reach the surface up to 40 m upstream of the embankment, in the absence of other mitigation measures. This does not, however, take into account the changed flow regime that resulting from groundwater being liberated as surface water, and 40 m of ponding on the upstream side is therefore likely to be an overestimate. Furthermore, the analysis predicts groundwater level rises to become even smaller as the sand layer thickness increases, dropping to 0.15 m for a 1 m sand layer and only 0.08 m for a 2 m sand layer. Groundwater level decreases downstream of the embankment would be up to 0.1 m in all scenarios. In all cases, any groundwater level changes will be well within usual seasonal variations.

The construction of an embankment directly onto clay (i.e. a scenario where the sand layer thickness is less than 0.5 m) is likely to be avoided by design engineers due to the resulting introduction of embankment stability issues. A no-sand or limited sand scenario such as this is likely to be associated with either a natural drainage channel or localised depression, in which case surface water is already likely to be present prior to road construction, especially during the wetter months, and where drainage structures would already be planned.

The potential impacts to groundwater levels described above are where groundwater flow is perpendicular to the road alignment but could be less where the alignment is not parallel to Ellen Brook and groundwater contours. In addition, changes to groundwater flow and levels are likely to be negligible where appropriate drainage structures are in place (e.g. culverts), maintaining hydraulic connectivity across the embankment. Similar approaches were used on the Perth to Bunbury Highway, which was also constructed on sand and palusplain wetland systems. Post-construction monitoring of that project found that hydraulic conductivity was maintained across the road, with little to no effect on groundwater levels either side of the road observed (GHD, 2012).

The absence of clay layers in Hydrogeological Domains 1 and 2 means that the compaction effects on groundwater described in this section are not expected to occur. In Hydrogeological Domain 3, changes to groundwater levels are limited to specific scenarios in mostly cleared areas only, with any changes being small and within seasonal variations.

10.4.4.4 Infiltration Basins

During the operation phase it is anticipated that localised and temporary changes to groundwater levels in the areas surrounding the infiltration basins will occur due to the collection of surface water runoff from the road, particularly during high rainfall events.

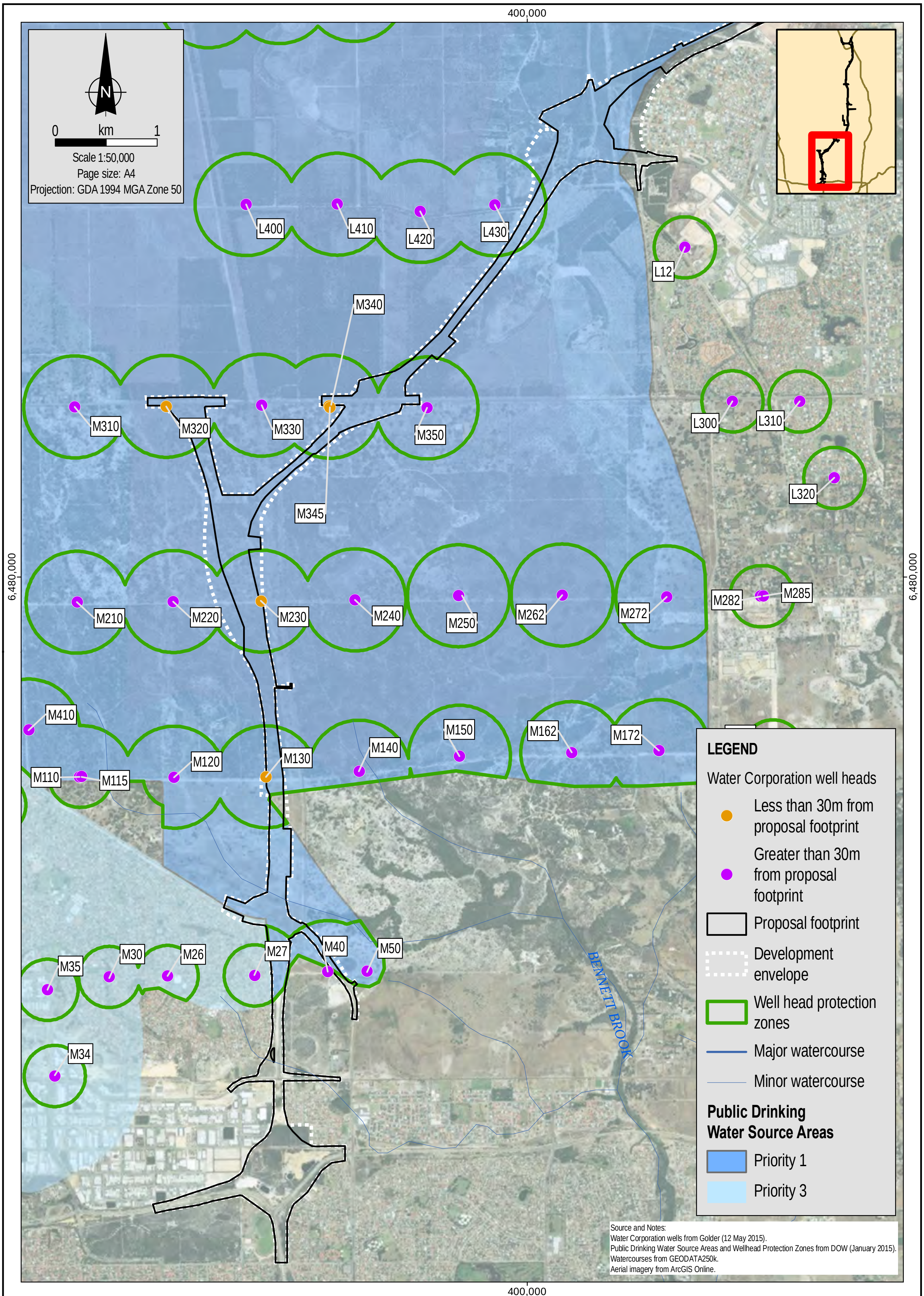
10.4.5 Impact to Groundwater Users (Gnangara Mound)

The development envelope intercepts 10 WHPZs associated with the following 12 Water Corporation wells: L430, M340, M345, M350, M320, M330, M220, M230, M130, M27, M40 and M50 (Figure 10.6). Four of these wells occur within 10 m of the proposal footprint (M320, M340, M230 and M130) and are within 15 to 30 m of the existing road network. The remaining wells are situated 30 m or more from the proposal footprint. None of the Water Corporation wells will be directly impacted by the proposal.

As discussed in Sections 10.4.1 and 10.4.2 construction and operation impacts on surface water runoff volumes and surface water flow will be localised and negligible and are not anticipated to have a significant impact on the Gnangara Mound and its users.

Construction impacts that have the potential to impact the Gnangara Mound include water pollution, dewatering and construction water abstraction. A detailed investigation of dewatering requirements has not yet been undertaken. However, it is not expected that any interchanges located within the Priority 1 area will require dewatering. As discussed in Section 10.4.4.1, any dewatering could result in localised and temporary lowering of groundwater levels and would first require approval from the Department of Water under the *Rights in Water and Irrigation Act 1914*, a process that requires consideration of existing groundwater user licence allocations., Construction water will be fit-for-purpose (i.e. non-potable), unless this is not available.

Water pollution is also the primary potential impact to the Gnangara Mound during operation, as discussed in Section 10.4.3.



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Public Environmental Review
Perth–Darwin National Highway | Water Corporation wells and wellhead protection zones | Figure No: 10.6

10.4.6 Impact to Wetlands and EPP Lakes

The proposal will result in both direct and indirect impacts to wetlands and EPP lakes. Construction impacts include the permanent loss and/or degradation of wetlands, changes to wetland hydrological regimes and altered water quality. Operational impacts may also impact wetland hydrological regimes and alter water quality.

Impacts relating to the loss and degradation of wetland vegetation are considered separately in Section 8.4.2.

This assessment is supported by the PDNH Wetland Assessment (Coffey, 2015d) (Appendix I) and Swan Valley Bypass - General Stratigraphy, Wetland Hydrology and Wetland Vegetation (360 Environmental, 2014b).

10.4.6.1 Permanent Loss and/or Degradation of Wetlands

During proposal definition and alignment studies, the principle of impact avoidance and minimisation to significant environmental values was applied. Complete avoidance of wetlands (particularly CCW and REW) proved difficult given the concentration of wetlands within and surrounding the alignment. During the more recent studies, the DOD requested realignment of a section of the proposal to the east to avoid impacts to its landholdings. This realignment was considered, but impacts to DOD's landholdings could not be completely avoided without unreasonable impact to a CCW (UFI 8914) and two REWs (UFIs 8916 and 8915). As a result, the road was aligned as far east as possible to minimise impact to DOD landholdings, without impacting these three wetlands. Furthermore, the interchange at The Promenade was redesigned to avoid REW 8541. An additional 2.8 ha of CCW and 4.5 ha of REW within the development envelope have been avoided.

This section details the direct impacts of the proposal on wetlands. According to the geomorphic wetland mapping, approximately 42.7% (315.9 ha) of the proposal footprint has been mapped as occurring in association with a wetland. This includes approximately 4.6% mapped as CCWs (Table 10.5). Indirect hydrological impacts to remnant portions of wetlands directly impacted by the project are discussed in Section 10.4.6.3.

Table 10.5 Summary of the extent of each wetland category within the proposal footprint

Wetland category	Extent of wetland within proposal footprint (ha)	Proportion of proposal footprint
Conservation Category	14.8	2.0%
Resource Enhancement	14.0	1.9%
Multiple Use	320.2	43.0%
Total	**349.0**	**46.8%**

Source: Coffey (2015d).

Table 10.6 details direct impacts to wetlands within the proposal footprint. A total of 25 individual wetlands occur within the proposal footprint and will be wholly or partially cleared and filled, including five CCWs, four REWs and 14 MUWs (Coffey, 2015d) (see Figure 10.2). Impacts to significant ecological features associated with these wetlands are identified and assessed separately in Chapters 8 and 9.

The proposal will clear 287.3 ha associated with 14 MUWs within the proposal footprint (see Tables 10.5 and 10.6). This equates to 90.9% of the wetlands mapped within the proposal footprint.

Table 10.6 Wetlands within the proposal footprint

Wetland	Category	Extent of wetland	Extent of wetland within proposal footprint	
		(ha)	(ha)	(%)
8416	CCW	2.4	0.1	5.5
8773	CCW	3.18	0.39	12.3
8792	CCW	0.9	0.9	100.0
8909	CCW	0.39	0.004	1.0
15028	CCW	4.4	0.5	12.0
15033	CCW	9.9	7.4	74.7
15260	CCW	68.4	5.5	8.0
8779	REW	20.3	0.4	1.8
13387	REW	27.3	0.3	1.1
15752	REW	239.6	0.9	0.4
15757	REW	34.0	12.3	36.2
8254	MUW	11.6	2.1	17.9
8411	MUW	2.6	0.4	15.7
8447	MUW	15.9	9.7	60.8
8449	MUW	5.0	0.2	4.3
8450	MUW	96.5	3.2	3.3
8464	MUW	14.2	6.3	44.5
8785	MUW	2.2	0.6	25.2
8936	MUW	14.7	2.2	15.1
13096	MUW	0.3	0.3	100.0
15029	MUW	51.3	18.5	36.2
15030	MUW	6.8	3.7	54.8
15175	MUW	74.1	4.6	6.2
15200	MUW	28.0	1.6	5.6
15732	MUW	13,744.4	266.8	1.7
Total		**14,474.8**	**318.4**	**–**

Source: Coffey (2015d).

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 further in this PER.

Four REWs partially located within the proposal footprint (UFIs 8779, 13387, 15752 and 15757) will be directly impacted by the proposal (see Tables 10.5 and 10.6 and Figure 10.2).

Approximately 0.3 ha (1.1%) of REW 13387 will be directly impacted by the upgrading (i.e. widening) of an existing local road that traverses this wetland. This impact is minor in scale and not considered to be a significant impact given the current existence of the local road and the degraded nature of the landscape (Coffey, 2015d).

REW 15757 has been significantly impacted and modified by historical clearing, residential and industrial development and existing fragmentation by Marshall Road and Hepburn Avenue. Approximately 12.3 ha (36.2%) of this wetland will be directly impacted by the proposal, associated with the construction of the interchange at Marshall Road. The proposal 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. The development of the light industrial zone and the upgrade of Hepburn Avenue would have required the infilling and compaction of soils in the local area. Impacts to the wetland are considered to be minor given the scale of the impact and the current condition of the wetland (Coffey, 2015d).

Similar to REW 15757, the remaining two REWs (15752 and 8779) have been completely cleared and no longer support any native vegetation (Coffey, 2015d). The proposal will impact approximately 0.9 ha (0.4%) and 0.4 ha (1.8%) of the mapped extent of REW 15752 and REW 8779 respectively. REW 15752 is located around and to the east of Beechboro Road North, with the proposal involving the upgrade and integration of Beechboro Road North with the proposal. REW 8779 is located north of Neaves Road in open paddocks with only occasional scattered trees. Impacts to both of these wetlands are not considered to be significant given the minor scale of the impact and their existing condition (Coffey, 2015d).

As detailed in Tables 10.5 and 10.6 and on Figure 10.2, seven CCWs (8416, 8773, 8792, 8909, 15028, 15033 and 15260) will be directly impacted by the proposal.

The proposal will impact 7.4 ha (approximately 74.7%) of the mapped extent of CCW 15033. A small portion (less than 1 ha) of this wetland has already been impacted by historical clearing and development in Milly Court, Malaga. The remaining 2.5 ha of this CCW will be retained, but will be subject to secondary impacts associated with the highly urbanised surroundings (including edge effects, uncontrolled access, dumping of refuse). The clearing of 74.7% of this CCW is considered to be a significant impact (Coffey, 2015d).

The clearing of 5.5 ha of CCW 15260 (8.0% of the mapped extent) is considered to be a minor impact. The clearing will also sever a small area of this CCW (1.2 ha) to the east of the alignment, which may indirectly reduce the conservation values of the remnant extent of this wetland (Coffey, 2015d).

CCW 8792 is located entirely within the proposal footprint. While the size (0.9 ha) of the CCW and thus scale of the impact in the broader context of the proposal's impact on wetlands is fairly minor, the total loss of this CCW is considered to be a significant impact (Coffey, 2015d).

A total of 0.1 ha of CCW 8416 occurs within the proposal footprint and will be directly impacted by the proposal. This impact is considered to be minor given the scale of the impact (only 5.5% of the CCW's mapped extent), the degraded condition of this wetland and as Beechboro Road North potentially provides an existing barrier to hydrological flow (Coffey, 2015d).

A total of 0.5 ha of CCW 15028 will be directly impacted by the proposal. This impact, while minor in the context of the total area to be impacted by the proposal, is considered to be significant as this will result in the complete loss of this wetland, given that the remainder of the mapped extent has already been impacted by clearing and industrial development (Coffey, 2015d).

A total of 0.4 ha of CCW 8773 occurs within the proposal footprint and will be directly impacted as a result. This impact is considered to be minor given the scale of the impact (only 12.5% of the CCW's mapped extent) and that most of the directly impacted portion of this wetland is good to degraded, degraded or very degraded.

CCW 8909 is located adjacent to the proposal footprint, with only 40 m^2 of the mapped extent of the wetland inside the proposal footprint. Due to the small size of directly affected wetland, this impact is considered negligible.

In consideration of the criterion used by DPAW to determine if a wetland should be recognised as a conservation category wetland (DPAW, 2013d), the above impacts to CCWs are considered to be of regional significance if (Coffey, 2015d):

- 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%.

Impacts on consanguineous suites within the proposal footprint are set out in Table 10.7.

Table 10.7 Extent of proposal impacts on consanguineous suites associated with each impacted CCW

Consanguineous suite	Impacted CCWs	Total area of CCW in consanguineous suite (ha)	% CCW in consanguineous suite	Direct loss of CCWs associated with the proposal (ha)	% CCW in consanguineous suite following proposal impacts
Bennett Brook	8416, 15260	2,490.8	7.7	5.6	7.6
Ellen Brook	8773, 8909	437.6	3.1	0.4	3.1
Jandakot	8792, 15028, 15033	4,378.9	21.3	8.8	21.2

Source: DPAW (2013d).

The local scale of the proposal's impact on CCWs 8416 and 15260 within the Bennett Brook consanguineous suite (5.6 ha) is considered to be minor given that the proportion of CCW within the Bennett Brook consanguineous suite will only be reduced from 7.7% to 7.6%. However, given that the proportion of CCWs within this consanguineous suite is already below 10%, this impact could be significant from the perspective of regional representation within the Bennett Brook consanguineous suite (Coffey, 2015d).

The local scale of the proposal's impact on CCWs 8773 and 8909 within the Ellen Brook consanguineous suite (0.4 ha) is also minor given that the proportion of CCW within the Ellen Brook consanguineous suite will remain virtually unchanged. However, as with the Bennett Brook consanguineous suite, less than 10% of the Ellen Brook consanguineous suite remains and this impact could therefore be considered significant from a regional representation perspective (Coffey, 2015d).

The scale of the proposal's impact on CCWs 8792, 15028 and 15033 within the Jandakot consanguineous suite (8.8 ha) is also minor given that the proportion of CCW within the Jandakot consanguineous suite will only be reduced from 21.3% to 21.2%. As the proportion of CCWs within the Jandakot consanguineous suite is well above 10%, clearing of CCWs within the Jandakot consanguineous suite is not considered to be significant from the perspective of regional representation within the Jandakot consanguineous suite (Coffey, 2015d).

10.4.6.2 Permanent Loss and/or Degradation of EPP Lakes

Of the five EPP lakes identified in Table 10.2, only three EPP lakes have the potential to be directly impacted by the proposal. The mapped boundaries of EPP lakes 439 and 441 partially occur within the proposal footprint (0.44 ha and 0.12 ha respectively). The boundaries of these lakes appear to be associated with CCW 8664, CCW 8800 and REW 8801, 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 (Coffey, 2015d).

EPP lake 450 is mapped in association with the MUW 8785 and is partially located within the Cooper Road and Stock Road interchange (see Figure 10.2). An earlier wetland assessment determined that, as a result of large-scale clearing and grazing by cattle, the condition of this wetland is generally degraded and intensive management would be required to improve the regeneration and condition of associated vegetation (GHD, 2009). Construction will involve the clearing and infilling of a very minor portion (0.04 ha or 3.1%) of the mapped extent of this lake (Coffey, 2015d).

10.4.6.3 Changes to Hydrological Regimes and Water Quality

As discussed in Sections 10.4.1 to 10.4.4, both the construction and operation of the proposal have the potential to impact existing hydrological regimes and water quality, and thus the health and condition of wetlands and EPP lakes. Tables 10.2 and 10.3 list wetlands and EPP lakes in close proximity to the proposal footprint that have the potential to be indirectly impacted by the proposal. Wetlands most likely to be indirectly impacted are those directly adjacent to the proposal footprint, particularly remnant portions of wetlands indirectly impacted by the proposal.

Potential hydrological impacts that may impact wetlands and EPP lakes during construction include:

- Localised increase in stormwater runoff from cleared catchments.
- Short-term and localised lowering of groundwater levels in the immediate vicinity of any dewatering activities.
- Changes to surface water and groundwater flows associated with the construction and compaction of the road embankment.
- Contamination associated with the:
  - Oxidation of potential ASS during earthworks and/or dewatering.
  - Liberation of exposed soils following clearing during heavy rainfall.
  - An accidental spill of a harmful substance during maintenance and/or operation of plant and machinery.
- Loss of conservation values where functioning of the remaining parts of a CCW is impaired.

Potential hydrological impacts that may impact wetlands and EPP lakes during operation include:

- Localised increase in stormwater runoff from the road pavement.
- Localised and temporary increase in groundwater levels below infiltration basins, following rainfall.
- Contamination associated with:
  - Polluted road runoff.
  - An accidental spill of harmful substance by a road user.

As discussed in Sections 10.4.1 and 10.4.2, construction and operation impacts on surface water runoff volumes and surface water flow will be localised and negligible and are not anticipated to have any real impact on wetlands or EPP lakes. During construction, however, some wetlands that are partially within the proposal footprint (see Table 10.3) may experience indirect impacts to the parts of those wetlands that will remain outside the proposal footprint. The proposal will sever CCW 15260 in its southeast corner, leaving a

1.15 ha section between the proposal and Beechboro Road North. It is unlikely that this portion of CCW 15260 will continue functioning as a CCW and as such this is considered to be a significant impact. No indirect impacts are expected to CCW 15028, located at the Tonkin Highway/Reid Highway interchange, as historical clearing has already resulted in the loss of all parts of this wetland outside the proposal footprint (see Section 10.4.6.1). Similarly, the northwestern portion of CCW 15033 has already been cleared, while the northeastern portion outside the proposal footprint is considered large enough to retain ecological function. Indirect impacts to other wetlands are negligible and are not expected to result in loss of ecological function (CCWs 8416, 8773, 8802 and 8909 and REWs 8779, 9174, 13387, 15727 and 15752), due to the size of the remaining portions and/or that the related direct impacts are to parts of wetlands that are already degraded or completely degraded.

Changes in groundwater flow and levels either side of the road embankment may impact the existing hydrological regime of neighbouring wetlands. As described in Section 10.4.4.3, compaction of the road embankment foundation within 0.5 m of any occurrence of clay may alter groundwater flows where not appropriately managed, resulting in a small rise in groundwater level upstream of the embankment and a decrease in groundwater levels downstream of the embankment. Preliminary geotechnical investigations have encountered clay or low permeability soils with less than 1 m of sand cover only in the section of the proposal north of a point about 1 km south of Muchea South Road (Golder, 2015).

Although REW 9174 (which is also associated with the Critically Endangered Claypans of the SCP TEC) is located in an area where clay has been found within 1 m of the ground surface, it is outside the 40 m likely upstream zone of impact of any compaction-related changes to surface water levels and flows. The use of methods such as the installation of drainage structures or importation of material to increase the thickness of the free-draining layer is expected to make any impacts from compaction to wetlands highly unlikely in any of the compaction scenarios described in Table 10.4.

The existing hydrological regime of wetlands may also be impacted by the short-term and localised lowering of the groundwater table associated with dewatering and water abstraction activities during construction (as discussed in Section 10.4.4). Of the eight locations identified as potentially requiring dewatering to enable bridge footing construction, only dewatering at the Tonkin Highway/Reid Highway interchange could result in drawdown at nearby wetlands, potentially having an indirect impact on the current extents of CCW 15028 and CCW 15033 (NorthLink, 2015c). However, as identified in Section 10.4.6, the proposal is already expected to result in the total loss of CCW 15028, and the remaining part of CCW 15033 is likely to be outside the drawdown radius of influence and therefore not affected by dewatering. No indirect impacts to EPP Lakes, REWs or any other CCWs are expected as a result of drawdown associated with dewatering.

As described in Section 10.4.4.2, the location and number of construction water abstraction bores proposed to be used (new and existing) will be assessed against a detailed hydrogeological model. Hydrogeological modelling will account for the proposed parameters of the bore (e.g., pumping rate, hours of operation, duration of operation etc.) as well as the hydrogeology of the proposed bore site (e.g., groundwater abstraction in Hydrogeological Domain 3 is expected to have limited impact on the groundwater table). Preferentially, each construction water bore required will be sited such that no wetlands are located within the modelled drawdown radius of influence for the bore, thereby avoiding indirect hydrological impacts to wetlands as a result of drawdown. For logistical reasons it may not always be possible to site a bore such that no wetlands occur within its drawdown radius of influence, e.g. due to transportation costs or the availability of groundwater licence allocations. In these cases, the operating parameters of bores will be limited such that modelled changes to groundwater levels at wetlands remain within usual seasonal variations for those wetlands. Monitoring bores may be used to confirm impacts to groundwater levels during the operation of construction water abstraction bores. As such, impacts to wetlands from changes to hydrological regimes resulting from drawdown are expected to be short-term and localised.

Furthermore, the health and condition of wetlands may be impacted by contaminated surface water and/or groundwater (as discussed in Section 10.4.3) if not appropriately managed.

10.4.7 Impact to Ellen Brook and Twin Swamps Nature Reserves

During proposal definition and alignment studies, the interchange at Warbrook Road was relocated to Stock Road to avoid any potential impacts on Twin Swamps Nature Reserve, following consultation with the DEC. A key concern raised during stakeholder consultation was the potential indirect impact of the proposal on the critically endangered Western Swamp Tortoise habitat within Twin Swamps and Ellen Brook Nature Reserves (see Section 9.4.7). As a result of these concerns two position papers were prepared to assess the potential impacts of the proposal on each of these habitats (Appendices J and N).

A review of surface drainage patterns has found that surface flows east of the proposal footprint split to the south and north of the local Twin Swamps Nature Reserve surface water catchment and, therefore, will not flow into Twin Swamps (see Appendix J). Furthermore, subsurface compaction modelling (discussed in Section 10.4.4.3) indicates that, given the expected sandy nature of the surrounding soils and the separation distance of Twin Swamps from the proposal (2.6 km), groundwater levels at Twin Swamps are not expected to be impacted by the construction of the road embankment.

Given that Twin Swamps are fed by groundwater, a change in groundwater quality due to the construction and presence of the road (over less than 500 m length of the alignment) could potentially impact water quality in Twin Swamps. The level of impact would depend on the type of contaminant and its concentration (resulting from a spill for example), the effectiveness of emergency response procedures in the case of a spill and how well road runoff is managed (i.e. whether it is passed through vegetated swale before infiltrating into the groundwater system). Furthermore, the risk of contaminated groundwater from the proposal reaching and impacting Twin Swamps is very low and manageable, given the natural attenuation that would occur of the analyte/contaminant over the estimated 60-year travel period in groundwater from the road to Twin Swamps (see Appendix J).

Drawdown from any dewatering required at the Stock Road interchange during construction is not expected to alter groundwater levels at Twin Swamps. In addition, the use of detailed hydrogeological modelling and methods for siting bores described in Sections 10.4.4.2 and 10.4.6.3 will ensure that Twin Swamps is not impacted by construction water drawdown.

Ellen Brook Nature Reserve is dissected by the ephemeral waterway after which it is named. The section of the reserve to the south of this waterway contains the ephemeral swamp habitat for the Western Swamp Tortoise. This swamp is formed by a perched groundwater on a clay lens fed predominantly by direct rainfall rather than surface flows from outside the reserve or Ellen Brook itself (which is 4 m lower in the landscape). Furthermore this swamp is not believed to be directly connected to the superficial groundwater aquifer (NorthLink, 2015e) (see Appendix N).

As a result, the proposal is not anticipated to have any impact on the swamp within Ellen Brook Nature Reserve. Runoff from the proposal is not anticipated to reach the swamp as it will either infiltrate within the road reserve or enter surface drainage flow paths, which will be intercepted by Ellen Brook, preventing any surface water flow from reaching the swamp. Furthermore, the swamp is not likely to be impacted by any contaminated groundwater resulting from the proposal as groundwater flows from the proposal would be intercepted by Ellen Brook before they could reach the swamp (see Appendix N).

10.4.8 Impact to Mound Springs SCP TEC

During proposal definition and alignment studies the proposal was realigned to the east to avoid direct impacts to the Mound Springs SCP TEC at Gaston Road (see Figure 10.2). The Interim Recovery Plan for this TEC (CALM, 2006) flags the importance of hydrological processes in terms of both quality and quantity of water, given that some of the fauna species present within this TEC have no dormant stages and depend on the maintenance of a permanent supply of fresh water, as do many inhabitant vascular and non-vascular plant species.

The hydrogeological assessment of this Mound Springs SCP TEC (GHD, 2008a) identified that it was most likely to be impacted by changes in groundwater level and associated spring flow and/or changes in water quality as a result of the proposal.

The relocation of the road 60 m to the east and down gradient of this Mound Springs SCP TEC has significantly reduced the potential hydrogeological impacts of the proposal, as any contamination in groundwater resulting from either the construction or operation of the proposal (discussed in Section 10.4.3) will move in an easterly direction, away from this Mound Springs SCP TEC. The presence of the road may, however, act as a barrier to surface drainage where there is insufficient drainage capacity through the road embankment, impeding surface water flow away from this Mound Springs SCP TEC and resulting in the pooling of water between this Mound Springs SCP TEC and the proposal.

As this Mound Springs SCP TEC occurs within Hydrogeological Domain 2, no impacts to water regimes at this Mounds Spring SCP TEC from road embankment compaction are expected (see Section 10.4.4.3).

This Mound Springs SCP TEC is unlikely to be impacted by the short-term and localised lowering of the groundwater table associated with dewatering activities during construction, given that the nearest potential dewatering location is the interchange at Stock Road, over 6 km to the south (as discussed in Section 10.4.4.1). In addition, the use of detailed hydrogeological modelling and methods for siting bores described in Sections 10.4.4.2 and 10.4.6.3 will ensure that this Mound Springs SCP TEC is not impacted by drawdown from construction water abstraction.

A number of other occurrences of Mound Springs SCP TEC occur within the vicinity of the proposal although they have greater separation distances from the proposal (see Figure 10.2) and so are less likely to be impacted. Like the Gaston Road Mound Springs SCP TEC, the majority of these Mound Springs SCP TECs lie to the west, up gradient of the proposal and so are also unlikely to be impacted by any potential contamination off the road. The only occurrence of Mound Springs SCP TEC to the east of the proposal is not anticipated to be impacted, as the majority of surface water from the road adjacent to Ellenbrook estate in which this Mound Springs SCP TEC occurs will flow away from the proposal. However, this Mound Springs SCP TEC occurrence is more susceptible to receiving contaminated groundwater from the proposal.

10.4.9 Impact to Claypans of the SCP TEC

As discussed in Section 10.4.4.2, where clay was found to occur within 0.5 m of the road embankment foundation and the watertable is within 0.23 m of the ground surface, the compaction of a road embankment adjacent to the Claypans of the SCP TEC, if not appropriately managed, could result in a slight rise in groundwater levels. Given that “the vegetation suite is dependent on the wetlands filling and drying at appropriate times of the year” (TSSC, 2012), any ponding of surface water or rise in groundwater level could be a significant impact on the TEC. However, as described in Section 10.4.4.3, the use of methods such as the installation of drainage structures or importation of material to increase the thickness of the free-draining layer is expected to reduce any impacts from compaction to the Claypans of the SCP TEC in all of the compaction scenarios defined in Table 10.4. Although it is recognised that “any change to the hydrological functioning of the community will significantly alter it such that it is unlikely to remain part of the ecological community" (TSSC, 2012), any changes to groundwater levels are likely to be negligible and therefore not enough to affect the hydrological functioning of the TEC.

The existing hydrological regime of the Claypans of the SCP TEC may be impacted by the short-term and localised lowering of the groundwater table associated with dewatering and water abstraction activities during construction (as discussed in Section 10.4.4). Construction of bridge footings at the Muchea interchange (intersection of Great Northern Highway and new Brand Highway) would require dewatering resulting in drawdown of 0.1 m if conducted in wetter months. However, dewatering would not be required if the construction work is undertaken during the drier months, and therefore no drawdown impacts to the TEC would be expected. In addition, the use of detailed hydrogeological modelling and methods for siting construction water abstraction bores described in Sections 10.4.4.2 and 10.4.6.3 will ensure that this TEC is not impacted by drawdown from construction water abstraction.

10.4.10 Impact to Ellen Brook

Earthworks and piling during construction may liberate sediments, disturb ASS and impact bank stability (see Section 10.4.3). Clearing of vegetation along the banks may also result in changes to surface water flow (see Section 10.4.2). However, as footings for the bridge over Ellen Brook (south of Muchea) will be constructed using piling methods, no dewatering impacts to Ellen Brook are expected to occur.

During operations the proposal may impact Ellen Brook as a result of increased surface water volumes from the road surface and changes to water quality as discussed in Sections 10.4.1 and 10.4.3 respectively.

10.5 Mitigation and Management

To reduce the proposal's impacts to existing hydrological regimes and inland water quality, the mitigation hierarchy (i.e. avoid, minimise, rehabilitate/restore and offset; see Chapter 7) has been applied during proposal design and in the development of appropriate mitigation and management strategies and offsets.

As discussed throughout this chapter, the following significant hydrological values have been avoided: Mound Springs SCP TEC at Gaston Road, Claypans of the SCP TEC, one CCW (UFI 8914) and three REWs (UFIs 8916, 8915 and 8541). The interchange at Warbrook Road was also relocated to Stock Road to avoid any potential impacts on Twin Swamps Nature Reserve. In addition, 2.8 ha of CCW and 4.5 ha of REW within the development envelope have been avoided by the proposal footprint.

To ensure that impacts to the remaining hydrological values present within and in close proximity to the proposal footprint are minimised and that the relevant EPA objectives can be met, MRWA commits to the following outcomes:

- A maximum of 14.8 ha of CCW and 14.0 ha of REW will be removed.
- No adverse change in the condition of remaining wetlands, Ellen Brook, Mound Springs SCP TEC and Claypans of the SCP TEC.
- No adverse impact on groundwater quality or availability of the Gnangara Mound.

While various management measures are proposed in this PER to achieve these desired outcomes, alternative management strategies may arise with further design, investigations and proposal planning. MRWA is committed to achieving environmental outcomes through the implementation of appropriate management measures that are relevant to specific conditions on site, and which may vary from those described in this document. This approach is consistent with the Environmental Assessment Guideline for Recommending Environmental Conditions (EPA, 2013a).

One of the leading controls in the mitigation and management of hydrological impacts associated with the proposal is the implementation of the proposal's drainage strategy during design and construction.

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 developed in consultation with the DOW and in accordance with the DOW's principles of water resource management, as detailed in the Stormwater Management Manual for Western Australia (DOW, 2004) and the Decision Process for Stormwater Management in Western Australia (DOW, 2009c).

As discussed in Section 10.2.1 the drainage strategy has defined and characterised three different drainage zones (see Table 10.1 and Figure 10.1) and established specific objectives and management strategies for each zone in consideration of their varying geographic and hydrologic characteristics. A brief description of each zone's key drainage objectives is provided in Table 10.8 and the drainage strategy is provided as Appendix H.

Table 10.8 Key drainage objectives

Drainage zone	Key drainage objectives
Urban zone	Primary objective is flood mitigation for both the road and adjacent properties. Another important objective is to maintain/improve the water quality of the receiving waters.
P1 zone	Primary objective is protection (both water quality and quantity) of the Gnangara Groundwater Mound with a particular focus on the WHPZs around the extraction bores and the maintenance of groundwater recharge. Other important objectives are the protection of wetlands and flood mitigation for development adjacent to the proposal.
Palusplain	Primary objective is to maintain existing hydrology/surface flow as much as possible, whilst protecting wetlands and Ellen Brook.

This strategy has influenced the design of the proposal and informed a number of the relevant hydrological mitigation and management strategies summarised below that can be applied to achieve the above environmental commitments:

- An EMP will be developed and implemented during construction and will include measures for mitigating and managing hydrological impacts particularly in regard to the generation, storage, handling and release of pollutants (including total suspended solids (TSS), ASS, hydrocarbons and chemicals), including an emergency spill response procedure.
- A drainage management and monitoring plan will be developed and implemented, including a groundwater monitoring procedure to ensure impacts to Gnangara Mound are being appropriately managed.
- A wetland management and monitoring plan will be developed and implemented, including a groundwater monitoring procedure to ensure impacts to wetlands (including Ellen Brook) are being appropriately managed.
- A detailed infrastructure plan will be prepared for each stage of the development prior to construction to ensure that the proposal is designed and constructed in accordance with the drainage strategy. This will include details of key proposal elements including locations and dimensions (e.g. culverts, bioretention swales, infiltration basins) and, where possible, identify any areas of CCW and REW that can be retained following final design.
- The road surface will be constructed above the design maximum groundwater level.
- Design and locate culverts to maintain surface water flows, including maintaining hydraulic connectivity between areas of wetland intersected/fragmented by the proposal.

- Maintain hydraulic connectivity of groundwater upstream and downstream of the road embankment where clay is present within 0.5 m of the road embankment foundation through the installation of culverts where surface flows are anticipated.
- Promote runoff for small rainfall events onto the ground as close to the source as possible for infiltration, through the most appropriate infiltration drainage mechanism (i.e. vegetated/grassed swales/verge, bioretention swales, soak well type pits and retention/detention basins). The selection of an appropriate drainage mechanism is dependent on whether the section of the alignment is kerbed or unkerbed and its location and proximity to sensitive values (e.g. WHPZs, wetlands and Ellen Brook). These infiltration mechanisms will also assist in the removal of contaminants through settling, filtering process and/or biological action.
- Construction laydown areas and stockpiles (including storage of hazardous materials and refuelling activities) will be located outside the WHPZs and 50 m from all CCWs, Mound Springs SCP TECs and Claypans of the SCP TEC to mitigate potential water quality impacts.
- Bridge construction at Ellen Brook will be undertaken during periods when Ellen Brook is at low flow. All construction works will be completed outside the low flow area to prevent impacts to surface water flow during construction and bridge footings will be piled. The location of bridge infrastructure (i.e. pilings) outside the low flow area means that impacts to surface water flow during operation will only occur during periods of high flow.
- Following final design and the definition of likely soil disturbance, a detailed ASS investigation will be undertaken to inform the development of an ASS Management Plan.
- Following final design and identification of appropriate water abstraction locations (where not in accordance with an existing bore/licence) an investigation into water abstraction requirements will be undertaken to understand the extent and scale of associated impacts on groundwater.
- Construction water abstraction bores will be sited and operated such that drawdown impacts to environmentally sensitive receptors are within the usual seasonal variations of groundwater levels for those receptors, unless further studies into those receptors' ecological water requirements (EWRs) show impacts to be insignificant. Monitoring bores may be used to monitor groundwater levels and verify hydrogeological modelling.
- Where practical, construction of bridge footings will be scheduled during summer to avoid dewatering requirements.. If dewatering is required, dewatering methods (e.g. well-point spears) that minimise the radius of influence in confirmed areas of ASS and on sensitive receptors (e.g. wetlands) will be utilised.
- Any dewatering and abstraction of construction water will be undertaken in accordance with approved licences under the *Rights in Water and Irrigation Act 1914*. A dewatering management plan (including ASS management) will be developed and implemented in support of any application for dewatering and a groundwater licence operating strategy will be developed and implemented as necessary to support the supply of construction water.
- The use of spread footings in final design will be considered where sands are deemed suitable to support structures at raised interchanges, to minimise the extent of any anticipated disturbance to ASS.
- Interference with beds and banks associated with bridge construction over Ellen Brook and direct impacts to wetlands from road construction will be undertaken in accordance with an approved permit under the *Rights in Water and Irrigation Act 1914*.

10.6 Residual Impacts

With the exception of the direct loss of wetlands and in consideration of the proposal's outcome-based commitments, it is expected that the proposal will be managed so that only the following minor residual impacts are anticipated:

- Minor localised alteration to ephemeral surface water flows.
- Temporary and localised lowering of groundwater levels from dewatering and water abstraction during construction.
- Temporary and localised increase in groundwater levels at infiltration basins.

The proposal has been designed to ensure drainage across the site is maintained as close as practicable to the pre-development condition. Bridges will be constructed over Ellen Brook and culverts will be used to manage flows beneath the road along minor drainage lines and local surface flow paths.

Compaction of the road embankment is not likely to have any significant impact on groundwater flows or levels. Hydraulic connectivity upstream and downstream of the embankment can be maintained by installing culverts where surface flows are anticipated.

A number of infiltration systems will be provided along the alignment to manage surface water runoff and poor water quality created by the impervious road surface. Infiltration systems mimic the natural water cycle by promoting the percolation of surface runoff and infiltration into the groundwater system. A residual effect of these infiltration systems is localised groundwater mounding following rainfall.

Water pollution from the road can also be managed through the implementation of best practice management measures in relation the generation, storage, handling and release of pollutants (including TSS, ASS, hydrocarbons and chemicals), including an emergency spill response procedure.

Construction dewatering and construction water abstraction may result in localised and temporary drawdown of groundwater levels. Following final design and identification of water abstraction locations (where not in accordance with an existing bore/licence), an investigation into water abstraction requirements will be undertaken to understand the extent and scale of associated impacts on groundwater. Construction water abstraction bores will be sited and operated such that drawdown impacts to environmentally sensitive receptors are within the usual seasonal variations of groundwater levels for those receptors, unless further studies into those receptors' ecological water requirements show impacts to be insignificant. Any dewatering and abstraction of construction water will be undertaken in accordance with approved licences and associated management plans, which will be developed in consideration of the outcomes of this investigation to ensure impacts to sensitive values are appropriately managed.

These impacts can all be readily managed to meet the EPA's objectives and the proposal's environmental commitments (as outlined in Sections 10.1 and 10.5). As such, the impacts to surface and groundwater hydrology are not deemed to be significant.

As discussed in Section 10.4.6, the direct loss of wetlands is in some cases considered to be of local significance. However, as the proposal (i.e. clearing and infilling of these wetlands) will be managed to ensure that surrounding hydrological regimes and ecosystem function is maintained (i.e. through the installation of culverts), it is considered that the proposal is likely to meet the EPA's objectives. Furthermore the offset of direct and indirect impacts to CCWs (Chapter 17) will ensure the EPA's objectives are met.

A summary of the proposal's residual impacts on existing hydrological regimes and inland water quality following the implementation of mitigation and management measures proposed in support of the proposal's environmental commitments is provided in the following Table 10.9.

Table 10.9 Summary of residual impacts to hydrological processes and inland waters quality following implementation of management and mitigation measures

Aspect	Predicted impacts	Management and mitigation	Residual impacts
Vegetation removal and earthworks associated with excavation of road cuttings, construction of bridge foundations and piling	Localised increase in stormwater runoff from cleared catchments, liberation of exposed soils and changes to surface water drainage patterns.	• Provision of bridge crossings over Ellen Brook, built outside the low flow channel. • Bridge construction at Ellen Brook will be undertaken during periods when Ellen Brook is at low flow and bridge footings will be piled. • Preparation and implementation of an EMP, which will include localised stormwater management practices during construction. • Preparation and implementation of a drainage management and monitoring plan.	Minor localised alteration to ephemeral surface water flows.

Aspect	Predicted impacts	Management and mitigation	Residual impacts
	Short-term lowering of groundwater levels in the immediate vicinity of any dewatering/construction water abstraction, altering the condition and health of the Gnangara Mound, Ellen Brook, Mound Springs SCP TEC, Claypans of the SCP TEC and surrounding wetlands.	• The road surface will be constructed above the design maximum groundwater level. • Following final design and identification of appropriate sources of construction water (where not in accordance with an existing bore/licence) an investigation into water abstraction requirements will be undertaken to understand the extent and scale of associated impacts on groundwater. • Construction water abstraction bores will be sited and operated such that drawdown impacts to environmentally sensitive receptors are within the usual seasonal variations of groundwater levels for those receptors unless further studies into those receptors' ecological water requirements show impacts to be insignificant. Monitoring bores may be used to monitor groundwater levels and verify hydrogeological modelling. • Where practical, construction of bridge footings will be scheduled during summer to avoid dewatering requirements. If dewatering is required, dewatering methods (e.g. well-point spears) that minimise the radius of influence on sensitive receptors (e.g. wetlands) will be utilised. • Any dewatering and abstraction of construction water will be undertaken in accordance with approved licences and associated dewatering management plan and/or groundwater licence operating strategy. • Preparation and implementation of a drainage management and monitoring plan, including a groundwater monitoring procedure. • Preparation and implementation of a wetland management and monitoring plan.	Temporary and localised lowering of groundwater levels.

Aspect	Predicted impacts	Management and mitigation	Residual impacts
	Oxidation of potential ASS during dewatering and excavation of road cuttings, associated contamination of surface water and groundwater and altered condition and health of the Gnangara Mound, Ellen Brook, Mound Springs SCP TEC, Claypans of the SCP and surrounding wetlands.	• The road surface will be constructed above the design maximum groundwater level. • Undertake a detailed ASS investigation following detailed design and the definition of likely soil disturbance. • Where practical reduce dewatering timeframes and use dewatering methods (e.g. well-point spears) that minimise the radius of influence in confirmed ASS areas. • Dewatering, water abstraction and/or interference of bed and banks will be undertaken in accordance with approved licences and associated dewatering management plan and/or groundwater licence operating strategy. • Preparation and implementation of an EMP, including an ASS management procedure. • Consider the use of spread footings in final design, where sands are deemed suitable to support structures at raised interchanges, to minimise the extent of any anticipated disturbance to ASS. • Preparation and implementation of a drainage management and monitoring plan, including a groundwater monitoring procedure. • Preparation and implementation of a wetland management and monitoring plan.	Nil.
	Direct loss (i.e. filling and impounding) of wetlands.	• Disturbance will be restricted to the proposal footprint. • Finalisation of design will endeavour to avoid and minimise impacts to CCWs and REWs within the proposal footprint. Where any areas of CCW and REW can be retained these will be identified within a detailed infrastructure plan prior to construction. • Preparation and implementation of a wetland management and monitoring plan.	• Complete loss of one CCW (0.9 ha) and partial loss of an additional six CCWs (13.9 ha). • Partial loss of four REWs (14.0 ha). • Partial loss of EPP Lake 450 (0.04 ha).

Aspect	Predicted impacts	Management and mitigation	Residual impacts
	Water pollution associated with spills and increased levels of TSS in stormwater runoff, altering the condition and health of the Gnangara Mound, Ellen Brook, Mound Springs SCP TEC, Claypans of the SCP TEC, Twin Swamps Nature Reserve and surrounding wetlands.	• Construction laydown areas and stockpiles (including storage of hazardous materials and refuelling activities) will be located outside the WHPZs and 50 m from all CCWs, Mound Springs SCP TECs and Claypans of the SCP TEC to mitigate potential water quality impacts. • Preparation and implementation of an EMP, including localised stormwater management practices and measures relating to the generation, storage, handling and release of pollutants (including TSS, hydrocarbons and chemicals), including an emergency spill response procedure. • Preparation and implementation of a drainage management and monitoring plan, including a groundwater monitoring procedure. • Preparation and implementation of a wetland management and monitoring plan.	Nil.
	Loss of conservation values where functioning of the remaining parts of a CCW is impaired.	• Construction laydown areas and stockpiles (including storage of hazardous materials and refuelling activities) will be located outside the WHPZs and 50 m from all CCWs, Mound Springs SCP TECs and Claypans of the SCP TEC to mitigate potential water quality impacts. • Preparation and implementation of an EMP, including localised stormwater management practices and measures relating to the generation, storage, handling and release of pollutants (including TSS, hydrocarbons and chemicals), including an emergency spill response procedure. • Preparation and implementation of a drainage management and monitoring plan, including a groundwater monitoring procedure. • Preparation and implementation of a wetland management and monitoring plan.	• Loss of ecosystem function in a portion of CCW isolated by the proposal (1.2 ha).

Aspect	Predicted impacts	Management and mitigation	Residual impacts
Placement of fill, compaction of embankment foundations and other earthworks	Road embankment will act as a barrier to surface water flows, leading to retention of water upstream and decrease in water received downstream, potentially altering the condition and health of Ellen Brook, Mound Springs SCP TEC, Claypans of the SCP TEC and surrounding wetlands.	• Design and construction of the proposal in accordance with the drainage management strategy, including the location of culverts to maintain surface water flows.	Nil.
Physical presence of road	Localised increase in stormwater runoff from road pavement and temporary changes to groundwater levels in the areas surrounding the infiltration basins.	• Design and construction of the proposal in accordance with the drainage strategy, including promotion of runoff for small rainfall events onto the ground as close to source as possible for infiltration, through the most appropriate infiltration drainage mechanism.	Localised and temporary increase in groundwater levels at infiltration basins, following rainfall.

Aspect	Predicted impacts	Management and mitigation	Residual impacts
	Water pollution from stormwater runoff altering the condition and health of the Gnangara Mound, Ellen Brook, Mound Springs SCP TEC, Claypans of the SCP TEC and surrounding wetlands.	• Design and construction of the proposal in accordance with the drainage strategy, including selection of appropriate infiltration drainage mechanisms along the alignment, including: – Provision of bioretention basins where the road passes within a WHPZ and within 50 m of a CCW, REW, Mound Springs SCP TEC and/or Claypans of the SCP TEC. – Provision of a vegetated retention/detention basin for road runoff within 400 m of the Ellen Brook. • Preparation and implementation of an EMP, including an emergency spill response procedure. • Preparation and implementation of a drainage management and monitoring plan, including a groundwater monitoring procedure. • Preparation and implementation of a wetland management and monitoring plan.	Nil.
Operation and maintenance of plant and machinery during construction	An accidental spill of harmful substance entering surface or ground waters, altering the condition and health of the Gnangara Mound, Ellen Brook, Mound Springs SCP TEC, Claypans of the SCP TEC and surrounding wetlands.	• Construction laydown areas and stockpiles (including storage of hazardous materials and refuelling activities) will be located outside the WHPZs and 50 m from all CCWs, Mound Springs SCP TECs and Claypans of the SCP TEC to mitigate potential water quality impacts. • Preparation and implementation of an EMP, including measures relating to the generation, storage, handling and release of pollutants (including hydrocarbons and chemicals), surface water management (e.g. use of settlement basins and silt curtains) and an emergency spill response procedure. • Preparation and implementation of a drainage management and monitoring plan, including a groundwater monitoring procedure. • Preparation and implementation of a wetland management and monitoring plan.	Nil.

Aspect	Predicted impacts	Management and mitigation	Residual impacts
Vehicle collision and/or spillage of hazardous waste	An accidental spill of harmful substance entering surface or ground waters, altering the condition and health of the Gnangara Mound, Ellen Brook, Mound Springs SCP TEC, Claypans of the SCP TEC, Twin Swamps Nature Reserve and surrounding wetlands.	• Design and construction of the proposal in accordance with the drainage strategy, including selection of appropriate infiltration mechanisms along the alignment. • Preparation and implementation of an EMP, including measures relating to the generation, storage, handling and release of pollutants (including hydrocarbons and chemicals) and an emergency spill response procedure. • Preparation and implementation of a drainage management and monitoring plan, including a groundwater monitoring procedure. • Preparation and implementation of a wetland management and monitoring plan.	Nil.

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