8.3 Potential Impacts

The implementation of the proposal will have both temporary and permanent impacts to flora and vegetation. The potential impacts to flora and vegetation include:

- Construction phase impacts:
  - Permanent loss of native vegetation.
  - Permanent loss of GDEs.
  - Permanent loss of native vegetation within Bush Forever sites.
  - Permanent loss of TECs and PECs.
  - Permanent loss of Threatened and Priority flora.
  - Introduction and Spread of introduced weeds.
  - Introduction and Spread of *Phytophthora* Dieback.
  - Fragmentation of native vegetation.
- Operation phase impacts:
  - Spread of introduced weeds.
  - Spread of *Phytophthora* Dieback.
  - Vegetation degradation from uncontrolled access to remnant vegetation.
  - Changes to the fire regime.

8.4 Assessment of Potential Impacts

8.4.1 Permanent Loss of Native Vegetation

The proposal footprint supports a range of vegetation associations in varying degrees of condition. Nearly 80% of the vegetation is in a degraded or worse condition, including areas considered to be cleared (for example infrastructure, agriculture and industry). The remaining 20% of the vegetation is considered to be in good or better condition. Table 8.9 provides the area of impact for each vegetation condition rating within the proposal footprint.

The design of the proposal ensured that as much of the very good and better condition vegetation will be avoided. The design ensured that impacts to vegetation in degraded or worse condition (approximately 78.6% or 585.8 ha) were preferred over vegetation in good to degraded or better condition (approximately 21.4% or 159.7 ha).

Table 8.9 Clearing impacts by vegetation condition rating

Condition rating	Extent within the development envelope (ha)	Extent to be cleared in the proposal footprint (ha)	Proportion to be retained (%)[1]
Pristine	1.2	1.2	0.0
Pristine to Excellent	4.6	3.6	21.7
Excellent	63.6	53.2	16.4
Excellent to Very Good	25.4	23.3	8.3
Very Good	58.2	39.3	32.5
Very Good to Good	9.2	8.8	4.3
Good	24.3	23.5	3.3
Good to Degraded	7.6	6.7	11.8
Degraded	175.7	134.1	23.7
Degraded to Completely Degraded	56.9	34.8	38.8
Completely Degraded	464.1	359.9	22.5
Cleared (Infrastructure, industry etc.)	81.3	56.9	30.3
Total (ha)	**972.0[3]**	**745.3**	**23.4**

Source: Coffey (2015a) (Appendix C).

1. Extent retained inside development envelope but outside proposal footprint.

8.4.1.1 Loss of Vegetation Associations

The extent of disturbance within each vegetation association recorded from the proposal footprint is detailed in Table 8.10. The vegetation associations Cc[1], CcMpMr, ErCo, MpAl, Xp[2], CcEr[3], Pr, Pp, R, Rehab, FormerSettlement and all variants of Cl have not been included in Table 8.10 as they represent cleared areas or areas highly altered not representing intact native vegetation. Parts of vegetation associations in Table 8.10 that are in degraded to completely degraded condition (or poorer) are further excluded from the area of intact native vegetation to be cleared from each vegetation association. Vegetation associations Bl, BlMp, Cc[6], CcEm[1], Co, Ep, Er[3], Er[4], Er[5], ErMrMc, Mp[1], Mp[9], Mp[10], MpBl and PeAsMtMl all occur in the study area but not in the development envelope and are therefore not considered in Table 8.10.

The impact on the vegetation associations was avoided or minimised during the design process for the proposal. This included the avoidance of vegetation associations Bl, BlMp, Cc[6], CcEm[1], Co, Em[2], Ep, Er[2], Er[3], Er[4], Er[5], ErMrMc, Mp[1], Mp[9], MpBl and PeAsMtMl. Impact on the remaining vegetation associations was minimised where possible. The proposal will involve the clearing of the entire extent of three vegetation associations from the study area (see Table 8.10).

Table 8.10 Clearing impact on vegetation associations

Vegetation association	Extent in study area (ha)	Extent of intact native vegetation to be cleared within proposal footprint	Extent remaining within flora study area (%)
As	3.4	1.9	44.1
AsMlEvCl	5.4	5.3	1.9
Ba	3.7	3.5	5.4
BaBm[1]	41.7	11.2	73.1
BaBm[2]	147.6	26.2	82.2
BaBm[3]	41.9	25.8	38.4
BaBmMp	7.5	6.9	8.0
Cc/Mp	15.8	0.4	97.5
Cc[2]	7.6	1.6	78.9
Cc[3]	3.7	2.9	21.6
Cc[4]	13.4	1.4	89.6
Cc[5]	45.1	22.9	49.2
Cc[7]	4.9	2.5	49.0
CcEm[2]	92.5	27.1	70.7
CcEr[1]	9.3	2.2	76.3
CcEr[2]	20.6	2.9	85.9
CcMp	1	0.9	10.0
Em[1]	7.6	3.6	52.6
Em[2]	30.4	–	0.0
EpRi	0.9	0.8	11.1
Er[1]	8.3	1.7	79.5
Er[2]	4.8	–	0.0
Er[6]	51.8	5.2	90.0
Er[7]	4.4	<0.1	0.0
Er[8]	6.2	–	0.0
ErMp	11.7	5.8	50.4
Et[1]	13.8	3.1	77.5
Et[2]	81.9	23.7	71.1
Et[3]	20.5	4.8	76.6
Mp[2]	8.5	0.1	98.8
Mp[3]	5.3	0.4	92.5

Vegetation association	Extent in study area (ha)	Extent of intact native vegetation to be cleared within proposal footprint	Extent remaining within flora study area (%)
Mp[4]	12.5	0.8	93.6
Mp[5]	1.4	–	0.0
Mp[6]	2.7	1.3	51.9
Mp[7]	3.1	0.1	96.8
Mp[8]	9.4	5.1	45.7
MpCc	1.3	0.3	76.9
MpMr	7.1	1.3	81.7
Xp[1]	8.4	1.2	85.7
Total	**–**	**205.0**	**–**

Source: Coffey (2015a) (Appendix C).
Note: Vegetation associations Cc[1], CcMpMr, ErCo, MpAl, Xp[2], CcEr[3], Pr, Pp, R, Rehab, Former Settlement and all variants of Cl represent cleared areas or areas highly altered not representing intact native vegetation and have been excluded from this list.

8.4.1.2 Loss of Vegetation Complexes

The five vegetation complexes occurring within the proposal footprint are all above the 10% target set by the EPA and Bush Forever Strategy, while two are above the 30% threshold set by ANZECC (Table 8.11). The proposal will not result in any vegetation complex crossing a threshold into a more threatened category; that is, the proposal will not cause any vegetation complex to drop below 30%, or below 10%.

Table 8.11 Impacts on vegetation complexes at a regional level

Vegetation complex	Pre-European extent (ha)[1]	2013 extent remaining (ha)[1]	Extent to be cleared within proposal footprint (ha)[2]	Pre-European extent remaining following development of the proposal (ha)
Bassendean Complex-Central and South	87,392	24,206 (27.70%)	61.76	24,144 (27.63%)
Bassendean Complex-North Transition	17,640	16,126 (91.42%)	10.18	16,116 (91.36%)
Bassendean Complex-North	74,133	53,518 (72.19%)	69.65	53,448 (72.10%)
Southern River	57,171	11,255 (19.69%)	44.50	11,170 (19.61%)
Yanga	26,176	4,645 (17.75%)	18.94	4,626 (17.67%)

1. Pre-European extents from WALGA (2013).
2. Only considers the 205.0 ha of intact native vegetation within the proposal footprint (see Table 8.10).

8.4.2 Permanent Loss of Groundwater Dependent Ecosystems

Geomorphic wetlands (i.e. Conservation Category, Resource Enhancement and Multiple Use) occur across 349 ha of the proposal footprint (see Section 10.2.3). GDEs are intact native vegetation within geomorphic wetlands. The proposal will result in the permanent loss of 49.6 ha of GDEs, which is considered to

represent 20.9% of the mapped GDEs within the flora study area. In addition to the direct clearing of GDEs, the proposal may alter the surface and groundwater hydrology during the construction phase of the proposal. This may result in changes in composition and structure of adjacent GDEs through a change in the groundwater table or alterations to the natural surface or sub-surface water flow.

The construction of culverts and the raising of the road profile may impact on adjacent vegetation including GDEs with the creation of 'water shadows' down-flow and ponding of surface water. The shadowing and ponding of surface water is considered an issue for surface water dependent vegetation (e.g. *Hypocalymma angustifolium*). The design and construction of culverts will ensure that ponding and 'shadowing' are mitigated. The impacts to hydrology and wetlands within the proposal footprint are discussed in Section 10.6.

8.4.3 Permanent Loss of Native Vegetation within Bush Forever Sites

The proposal footprint overlaps nine Bush Forever sites (see Figure 8.5) and will impact on 128.5 ha of intact native vegetation (Table 8.12). The proposal may introduce or spread dieback and/or weeds into the Bush Forever sites.

Table 8.12 Clearing impacts on Bush Forever Sites

Site Identification	Extent of Bush Forever site (ha)	Extent to be cleared within proposal footprint (ha)[1]	Extent remaining (%)
Site 97: Kirby Road Bushland, Bullsbrook	447	3.3	99.3
Site 100: Neaves Road Creek, Bullsbrook	34.4	0.2	99.4
Site 192: Wetherell Road Bushland, Lexia/Ellenbrook	43.6	1.3	97.0
Site 198: Beechboro Road Bushland, Cullacabardee/Ballajura	483.9	30.7	93.7
Site 300: Maralla Road Bushland, Ellenbrook/Upper Swan	660.3	16.9	97.4
Site 304: Whiteman Park, Whiteman/West Swan	2,801.40	29.7	98.9
Site 307: Lightning Swamp and Adjacent Bushland, Noranda	74.9	1	98.7
Site 399: Melaleuca Park and Adjacent Bushland, Bullsbrook/Lexia	4,261.40	29.6	99.3
Site 480: Victoria Road Bushland, Malaga/Beechboro	18.9	15.9	15.9
Total	**8,841.5**	**128.5**	**98.1**

1. Considers intact native vegetation in all mapped vegetation associations.

The proposal traverses nine Bush Forever sites resulting in the fragmentation of intact native vegetation. The proposal has a significant impact on Bush Forever site 480, with only 15.9% of the site remaining at the intersection of the Tonkin and Reid highways. The proposal is constrained in this area with residential areas abutting the road reserve leaving few opportunities for avoidance of clearing of vegetation.

The separation of Bush Forever sites 198, 300, 304 and 399 is not considered to be a significant impact due to the size of the sites and the presence of large, relatively contiguous vegetation adjacent to the proposal footprint.

The proposal footprint is located along the edge of sites 192 and 307, with 1.3 ha of rehabilitated vegetation in site 192 proposed to be cleared, and 1.0 ha of roadside vegetation at site 307. The clearing of native vegetation within these Bush Forever sites 192 and 307 is not considered to significantly impact the values of the site.

Site 100 is surrounded by infrastructure and open paddocks, and the proposal footprint will dissect this site. The impact to site 97 is 3.3 ha or 0.7%. The proposal footprint will separate a small section (4.3 ha) from the remaining site. The potential impacts on native vegetation within the proposal footprint include intact native vegetation within the Bush Forever sites partially located in the proposal footprint. The impacts on native vegetation are detailed in Section 8.4.1.

In addition to the impacts associated with clearing of native vegetation within the Bush Forever sites, impacts on wetlands and GDEs within the Bush Forever sites are likely and these are considered in Section 8.4.2.

8.4.4 Permanent Removal of Threatened and Priority Ecological Communities

The proposal will impact known locations of TECs and PECs recorded in the proposal footprint. The design of the proposal footprint will ensure that there are no direct impacts to the Mound Springs SCP or the Claypans of the SCP.

The extent of each TEC and PEC within the flora study area, the development envelope and the proposal footprint has been determined (see Figure 8.4). The extent of TECs and PECs mapped from the flora study (Appendix C) does not include buffers, once these new occurrences are incorporated into the DPAW database, buffers will be determined. The design of the proposal ensured that the extent of the Claypans of the SCP within the development envelope will not be impacted.

The proposal will involve the permanent removal of parts of two TECs (SCP02 and SCP20a) and five PECs (SCP21c, SCP23b, SCP22, *Banksia* dominated woodlands on the Swan Coastal Plain and SCP24) from the proposal footprint. The clearing impacts on the TECs and PECs recorded from the study area are presented in Table 8.13.

The development envelope traverses the buffers of six locations of the TEC Mound Springs SCP and of two locations of the TEC Muchea Limestone. The proposal is not considered to impact these locations as they are located more than 1 km from the development envelope, except in the case of the location of Mound Springs SCP near Gaston Road, which is discussed in further detail below.

The development envelope that intersects the buffers of the TECs (namely the Muchea Limestone and Mound Springs SCP TECs) is generally associated with open, cleared paddocks (north of Maralla Road) and housing associated with the Ellenbrook suburb. Where the buffers intersect the development envelope, native vegetation is sparse or highly modified (for example, north of Maralla Road). The proposal is not considered to increase the impact on the TECs due to the existing level of disturbance within the buffers.

The TEC Mound Springs SCP at Gaston Road is located upslope of the proposal footprint so indirect impacts associated with groundwater and hydrology influences will not occur. During the planning study of the proposal footprint, the proposal was located to the east of the TEC to protect the groundwater quality,

which is fed from the west, north and south of the TEC. Indirect impacts to the TEC may occur if there is an impediment to surface water movement from the TEC; however, the design and construction of culverts will ensure surface water is able to move unimpeded across the landscape to the east (GHD, 2008a) (Appendix E). Impacts to this TEC are further discussed in Section 10.4.8.

Indirect impacts to the Claypans of the SCP are addressed in Section 10.4.9.

Table 8.13 Direct impacts to TECs and PECs

Ecological Community	Conservation rating	Extent within the flora study area (ha)	Extent within the development envelope (ha)	Extent within the proposal footprint (ha)[1]
Claypans of the SCP (*Casuarina obesa* association or Claypans with dense shrublands of *Melaleuca lateritia* over herbs – State PEC P1)	Critically Endangered (Commonwealth TEC) State PEC P1	9.8	0.0	0.0
Mound Springs SCP	Endangered (Commonwealth TEC) and Critically Endangered (State TEC)	1.5	0.0	0.0
SCP02	Endangered (State TEC)	1.4	1.1	0.4
SCP20a	Endangered (State TEC)	12.3	4.3	4.0
SCP21c	Priority 3 (State PEC)	178.0	78.0	64.0
SCP22	Priority 2 (State PEC)	3.4	0.3	0.1
SCP23b	Priority 3 (State PEC)	57.5	14.2	11.6
SCP24	Priority 3 (State PEC)	8.1	8.1	7.8
Banksia dominated woodlands on the Swan Coastal Plain	Priority 3 (State PEC)	488.1	174.8	62.0

1. Considers all vegetation in all mapped vegetation associations.

SCP02 (Endangered, State TEC) is known from nine occurrences with a total extent of 40.9 ha. The 2014 survey (Coffey, 2015a) recorded a potential new occurrence, which comprises 1.36 ha in size. The new occurrence has tentatively been identified as the TEC based on the results and review of the multivariate statistical analysis. Following the precautionary principle, the site is considered to be the TEC SCP02 until further assessments can be completed to determine its affinity. The proposal will involve the clearing of 0.4 ha of the SCP02 TEC.

SCP20a (Endangered, State TEC) is known from 57 occurrences and is 436 ha in extent. The 2014 survey recorded three new occurrences of the TEC, which are approximately 12.3 ha in extent. The extent of impact from the proposal footprint is approximately 4.0 ha.

SCP21c (Priority 3, State PEC) is known from 54 occurrences; however, the extent of 43 of these occurrences has not been mapped. Subsequently the current mapped extent of 310.5 ha for 11 occurrences is an under-representation of the known extent. The proposal will impact 64.0 ha of SCP21c, which is 13.1% of the known mapped extent of this PEC. SCP21c is known from 54 occurrences; however

only 11 of these have been mapped. Including surveys conducted for this study, SCP21c currently has a known mapped extent of 488.5 ha. This figure is an underrepresentation of the extent of this PEC.

SCP22 (Priority 2, State PEC) is known from approximately 45 occurrences, while the 2014 survey recorded one additional occurrence totalling 3.4 ha. The data on the extent of the previously known occurrences is not available, therefore, the overall impact is difficult to assess. The PEC SCP22 occurs across 0.1 ha of the proposal footprint and as such the proposal is not considered to have a significant impact on the PEC.

SCP23b (Priority 3, State PEC) is known from one occurrence with limited data available (DPAW, 2015) on the occurrence. The 2014 flora survey identified five new occurrences in addition to the previously known occurrence. However, as the data for the extent of the previously known occurrence is not available, the overall impact cannot be assessed. The extent of SCP23b within the flora study area was 57.5 ha, of which approximately 11.6 ha or 20.2% is located within the proposal footprint.

The proposal will impact 7.76 ha of SCP24 (Priority 3, State PEC), which is 0.76% of the known mapped extent. SCP24 is known from 33 occurrences representing 1,008 ha; however, only 16 of these have been mapped. As such the total extent of SCP24 is an underrepresentation of the extent of this PEC.

The number of occurrences and extent of the *Banksia* dominated woodlands of the Swan Coastal Plain (Priority 3, State PEC) is not currently known. The extent and final PEC description is awaiting approval from DOTE. The extent of the PEC mapped within the proposal footprint has been determined based on the presence of the two dominant Banksia species, *Banksia attenuata* and *Banksia menziesii*. The extent of the PEC within the development envelope is 174.8 ha, while the project will impact on 62.0 ha of the total 488.1 ha extent mapped within the flora study area. Approximately 12.7% of the mapped extent of the PEC will be impacted within the proposal footprint. The extent of the 'Banksia woodland of the Swan Coastal Plain' PEC does not include areas of Banksia woodland where other PEC or TEC are situated.

The condition of the extent of the TECs and PECs impacted by the proposal is provided in Table 8.14. The condition of the seven TECs or PECs to be impacted by the proposal ranged from Completely Degraded to Pristine/Excellent. Half of SCP02 is in very good condition but the remaining 0.2 ha appears to be in a degraded state or cleared. The proposal footprint will impact a total of 4.0 ha of SCP20a, the majority of which is in Excellent condition.

The majority of SCP21c to be impacted is in Good or better condition. A total of 7.69 ha of SCP24 occur in the study area, the majority of this vegetation is in Good condition. The proposal footprint will impact 10.9 ha of native vegetation of PEC SCP23b, the majority of which is in Excellent condition.

Approximately half of the Banksia dominated woodland on the Swan Coastal Plain to be impacted ranges from Very Good to Excellent condition, 12.2 ha is in degraded or worse condition. Only a small proportion is in Pristine to Excellent condition.

Table 8.14 Condition of impacted TECs and PECs

Vegetation condition	TECs		PECs				
	SCP02	SCP20a	SCP21c	SCP22	SCP23b	SCP24	Banksia SCP
Pristine to Excellent	–	–	3.4	–	–	–	0.2
Excellent	–	3.01	6.9	0.1	10.1	0.3	27.1
Excellent to Very Good	–	–	11.2	–	–	–	5.3
Very Good	0.2	0.8	23.9	–	0.8	–	9.5
Very Good to Good	–	–	5.3	–	–	0.7	<0.01
Good	–	–	8.0	–	–	6.4	4.5
Good to Degraded	–	–	–	–	–	–	3.2
Degraded	–	0.1	0.01	–	0.3	–	9.4
Degraded to Completely Degraded	–	–	4.0	–	<0.01	–	0.6
Completely Degraded	–	–	1.0	–	–	0.2	1.1
Cleared	0.2	–	0.3	–	0.5	0.2	1.2

8.4.5 Permanent Removal of Threatened and Priority Listed Flora

The clearing of intact native vegetation within the proposal footprint will not directly impact the two Threatened flora species (*Caladenia huegelii* and *Grevillea curviloba* subsp. *incurva*) recorded or the known location of Threatened *Darwinia foetida* which is located 250 m to the west of the proposal footprint near the proposed Neaves Road grade separation. The clearing for the proposal footprint will impact six of the eight priority flora recorded. Details of their extents and impacts are quantified in Table 8.15.

The known location of the threatened *Caladenia huegelii* (Grand Spider Orchid) is not within the proposal footprint. The individual recorded within the development envelope is approximately 60 m from the proposal footprint. Critical habitat for the survival of this species is the current known occupancy and areas of similar habitat surrounding known populations (DEC, 2009). The location, including surrounding similar habitat, is considered to be critical habitat (see Figure 8.1). The critical habitat for *Caladenia huegelii* within the proposal footprint is 39.2 ha or 17.2% of the flora study area.

Indirect impacts to *Caladenia huegelii* may include the introduction and proliferation of introduced weeds and dieback and activities that may indirectly impact the lifecycle of the species including impacts on the symbiotic mycorrhizal fungus or the lifecycle and movement of thynnid wasps required for pollination.

A minimum buffer of 50 m will apply between the proposal footprint and the threatened plant (Appendix C). The buffer will ensure the ecological processes occurring within the bushland are maintained and the necessary processes for the threatened plant (for example, habitat for native pollinators, maintenance of hydrological regimes) are maintained. The *Caladenia huegelii* is located within a portion of native bushland (in excess of 8.5 ha) that will be retained, ensuring the condition of the buffer and plant are maintained.

The individual recorded from the flora study area is located approximately 20 m west of Ellenbrook. The area outside of the development envelope does not provide for a larger buffer to the east of the individual due to the existing disturbed areas and the housing development. The distance between the plant and the Ellenbrook suburb to the east is not considered to be an issue because the impacts associated with the

suburban area are present and ongoing. The project will increase the protection of the plant to the east with the construction of a noise wall along the boundary of the properties abutting the project. The species survives in remnant bushland areas such as along Roe Highway Stage 7 and the bushland on the eastern side of the Murdoch railway station car park.

The records of *Grevillea curviloba* subsp. *incurva* were located in association with previously known locations (DPAW, 2014a). No new populations or individuals were recorded from the proposal footprint. The proposal will not directly disturb any known populations; however, individuals are within 10 m of the proposal footprint. The population is persisting in the degraded vegetation between the existing rail line and road. The proposal will impact 2.0 ha of degraded vegetation that is considered to be critical habitat. The degraded vegetation located along the Brand Highway verge and the rail reserve (see Figure 8.1) is considered to be critical habitat to *Grevillea curviloba* subsp. *incurva* (Phillimore and English, 2000) due to the known area of occupancy and the link the Brand Highway verge and rail reserve provides between known populations along Brand Highway and Muchea Road South. The construction of the proposal has potential for indirect impacts to *Grevillea curviloba* subsp. *incurva* due to the proximity of the road; however, impacts due to shadowing, smothering, hydrology or introduction/spread of dieback are unlikely from this proposal.

Darwinia foetida was located in association with previously known locations (DPAW, 2014a). No new populations or individuals were recorded from the proposal footprint. The population was located 250 m from the proposal footprint northwest of Neaves Road. There is no contiguous vegetation between the population of *Darwinia foetida* and the proposal footprint (see Figure 8.1). Critical habitat has not been identified for *Darwinia foetida*. However, as no populations or intact native vegetation within 200 m of the populations will be impacted, the project is not considered to impact on critical habitat for *Darwinia foetida*.

Six of the eight priority listed flora (*Millotia tenuifolia* var. *laevis* (P2)*, Poranthera moorokatta* (P2)*, Meeboldina decipiens* subsp. *decipiens* ms (P3), *Cyathochaeta teretifolia* (P3)*, Anigozanthos humilis* subsp. *chrysanthus* (P4) and *Hypolaena robusta* (P4)) are located within the proposal footprint.

The impact to *Anigozanthos humilis* subsp. *chrysanthus***,** *Hypolaena robusta* and *Poranthera moorokatta* as a result of the proposal is considered to be minor. The proportion of known individuals to be impacted in the proposal footprint represents 0.15%, 0.10% and 0.04%, respectively.

The number of known populations and individuals of *Poranthera moorokatta* is considered to be low, as it is believed to be regularly misidentified in the field. It is likely that the impact of the proposal on the number of populations is minor and the priority taxon is more widespread in intact remnant native vegetation in the Ellenbrook region.

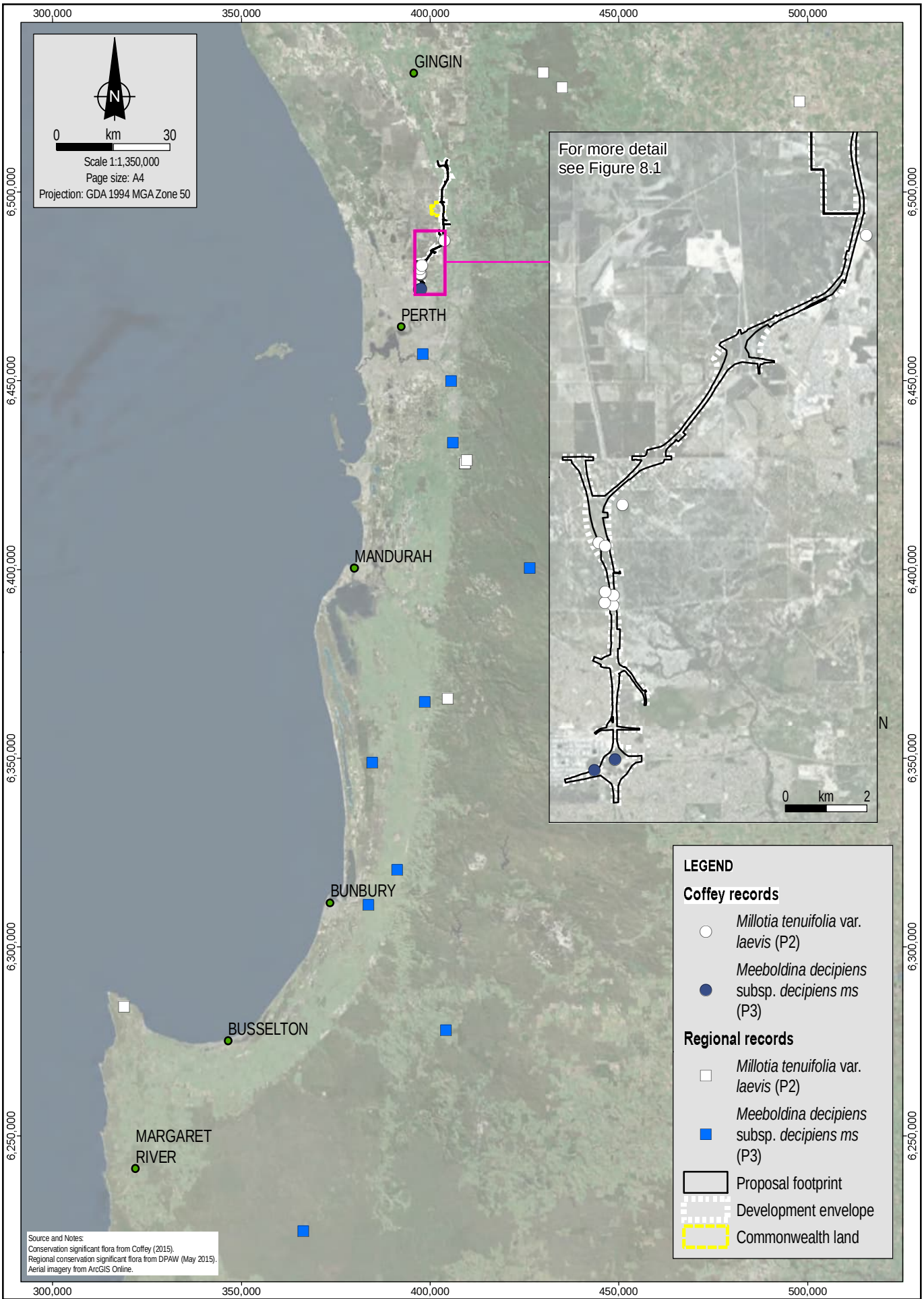
The impact to the known populations of *Millotia tenuifolia* var. *laevis* is considered to be potentially significant. *Millotia tenuifolia* var. *laevis* is a cryptic species with a wide distribution and it has not previously been recorded on the SCP. The identification of individuals in the flora study area represents the most western occurrence of this species (Figure 8.9). Previous records did not indicate the number of individuals recorded and so a conservative approach has been taken in that each record was treated as one individual. As such, this is considered the maximum potential impact. The proposal will impact on 18.8% of all known individuals and nearly 50% of the known individuals located in the flora study area, which represent a significant population as it is the first population to be recorded on the SCP.

Meeboldina decipiens subsp. *decipiens* ms has a wide distribution but the population size is unknown. Two individuals are known from one recorded population, while the other nine population records did not specify the number of individuals. In the assessment of the impact of the project on the species, a conservative approach has been taken in that each record was treated as one individual (see Figure 8.9). As such, this is considered to be the maximum potential impact on this Priority taxon.

Table 8.15 Local and regional impacts on threatened and priority flora

Species	Conservation status	Total number of known populations[1]	Number of populations known within the study area	Number of populations to be impacted within the proposal footprint	Proportion of populations to be impacted (%)	Total minimum number of known Individuals	Number of individuals within study area	Number of known individuals to be impacted within the proposal footprint	Proportion of known individuals to be impacted (%)
Caladenia huegelii	T	19	1	–	–	355	1	–	0.00
Grevillea curviloba subsp. *Incurva*	T	24	3	–	–	682	137	–	0.00
Millotia tenuifolia var. *laevis*	P2	12	4	2	16.7	16	7	3	18.8
Poranthera moorokatta	P2	4	2	1	25.0	2,508	7	1	0.04
Meeboldina decipiens subsp. *decipiens ms*	P3	12	2	2	16.7	22	11	11	50.0
Cyathochaeta teretifolia[1]	P3	30	2	–	–	1,375	30	–	–
Anigozanthos humilis subsp. *chrysanthus*	P4	18	2	1	5.6	1,334	4	2	0.15
Hypolaena robusta	P4	30	3	3	10.0	17,742	25	17	0.1
Ornduffia submersa	P4	43	1	–	–	10,297	1	–	0.00
Stylidium striatum	P4	24	1	–	–	2,965	1	–	0.00

Source: Coffey (2015a) (Appendix C).



NorthLinkWA

coffey

Date: 01.07.2015
MXD: 4483AA_03_GIS109_3
File Name: 4483AA_03_F08.09_GIS

Main Roads WA
Public Environmental Review
Perth–Darwin National Highway

Distribution of *Meeboldina decipiens* subsp. *decipiens* and *Millotia tenuifolia* var. *laevis*

Figure No: 8.9

Meeboldina decipiens subsp. *decipiens* ms were recorded from two locations in wetland habitat within the proposed Tonkin Highway and Reid Highway interchange. The two locations will be directly impacted by the proposal. These locations represent the most northerly recorded extent of this taxon and are therefore considered to be significant. The proposal will result in a 50% reduction in known individuals.

The remaining priority listed flora, *Ornduffia submersa* (P4) and *Stylidium striatum* (P4) are located outside the proposal footprint and will not be directly impacted.

An historical record of *Cyathochaeta teretifolia* (P3) was known to occur in the proposal footprint from a quadrat established and sampled for the project. The quadrat was revisited in 2014 and no individuals were recorded within the quadrat or adjacent to the quadrat. As such, the priority taxon is not considered to occur within the proposal footprint and there is no direct impact on *Cyathochaeta teretifolia*.

8.4.6 Spread of Introduced Weeds

The construction and operation phase of the proposal has the potential to result in the introduction and spread of existing introduced weeds. Remnant native bushland within the PMR is resilient to most non-invasive weeds; however, the presence of significant environmental weeds is of more concern due to the invasiveness of these weeds. Significant weeds are considered to be WONS, declared pests under Section 22 of the BAM Act and Prohibited weeds under Section 12 of the BAM Act.

During construction and maintenance activities, weeds and their seeds or vegetative material can be transported to, and within the proposal footprint through the incorrect implementation of a weed hygiene management plan. Seeds and vegetative material can be located in mud and soil attached to the undercarriage of vehicles that require appropriate cleaning and inspection prior to moving within the proposal footprint.

The boundary between the proposal footprint and the native vegetation located adjacent to the proposal footprint poses the greatest risk of weed invasion. The edges are subjected to greater levels of light, water and disturbance which allow weeds to establish and slowly out-compete native flora.

In addition to the edges, areas of high traffic and movement by vehicles, equipment and construction workers also pose a higher risk to weed invasion, with inappropriate weed hygiene measures. Once weeds are established they can be difficult to remove due to their invasiveness, competitiveness and ability to spread across the landscape. The presence of significant weeds directly impacts the integrity of intact native vegetation and can increase the likelihood of additional impacts, including fires, vegetation degradation, vermin and economic returns.

8.4.7 Spread of *Phytophthora* Dieback

Phytophthora Dieback can degrade and alter the structure of susceptible native vegetation. More than 25% of the proposal footprint is infested, and only a small area of 4.15% is considered uninfested and protectable. The current infestations (see Figure 8.8) and any additional infestations have the potential to cause significant degradation to the native vegetation, altering the structure, composition and density of the vegetation. The impact of Dieback can also severely degrade significant fauna habitat, especially Black Cockatoo feeding habitat (*Banksia* woodlands).

Dieback is spread through the movement of water and soil within the landscape via wet soil adhering to vehicle tyres/tracks and earthmoving equipment. The management of Dieback is important to ensure it does not spread into adjacent uninfested areas and protectable areas.

The movement of soil, mulch and material into and within the proposal footprint has the potential to introduce and move Dieback throughout the proposal footprint and into adjacent native vegetation. This is particularly pertinent when machinery and vehicles have been operating within Dieback infested areas without appropriate management. It is also pertinent for movement within the proposal footprint across

Dieback category boundaries. The impacts from physical disturbance to native vegetation adjacent to the proposal are considered to be low and manageable.

8.4.8 Fragmentation of Native Vegetation

The proposal footprint consists of areas of contiguous vegetation and non-contiguous vegetation. The construction and operation of the proposal has the potential to further fragment the vegetation present within the proposal footprint.

Six regional ecological linkage networks traverse the proposal footprint (see Section 8.2.9). Three (Gaston Road Bullsbrook, Raphael Road Bullsbrook and Reid Highway) of the six regional linkage networks are already highly fragmented and rely on roadside vegetation and remnant vegetation along drainage corridors to connect regionally significant bushland. The remaining three (Maralla Road Nature Reserve, Rocla mining lease area, Cullacabardee) regional linkage networks consist of large contiguous blocks of vegetation in close proximity to each other with minor fragmentation as a result of roads and developments.

The construction phase of the proposal will temporarily impede the three fragmented regional linkage networks due to vegetation clearing and the construction of the proposal. It is expected at the completion of the construction that the remaining linkages will be maintained by the revegetation and rehabilitation of the roadside vegetation (see Chapter 12).

The operation of the highway will continue to provide an impediment to the linkage network even with the successful revegetation of the roadside vegetation (see Chapter 12).

The construction phase of the proposal is considered to have a moderate impact on fragmentation within the remaining three regional linkage networks (i.e. Maralla Road Nature Reserve, Rocla mining lease area and Cullacabardee), which include large contiguous areas of native vegetation. The proposal will provide a 100 to 250 m wide impediment in key areas located at Maralla Road, Rocla mining lease area and the intact native vegetation at Cullacabardee.

The regional linkage network along Maralla Road and Cullacabardee is considered to be important for the movement of vertebrate fauna and the movement of genetic material for flora and fauna. The impact of the proposal on fauna is discussed in Chapter 9.

8.4.9 Edge Effects from Introduced Weeds and Refuse

Edge effects are identifiable as any difference in environment between the edge and the interior of a particular patch of vegetation. These edges can be referred to as ecotones where an overlap occurs between two vegetation communities. Edges are zones of overlap and interaction between different habitats or vegetation associations and their constituent elements (i.e. flora, fauna, hydrology, soils) (Beer and Fox, 1997). Two edges are created by a clearing, the natural edge and the cleared edge. Edges are expected to be created as a result of the proposal. The edges will occur between the proposal footprint and the native vegetation located adjacent to the proposal footprint.

Edges and their effects may be natural or be human induced with new edges readily created by roads, vegetation clearing, forestry and other developments (van Etten, 2014). The distance the effect spreads from the edge can be highly variable and depends on many factors such as vulnerability of edge ecosystem, degree of change in land use, intensity of this use and chance events (Murchia, 1995). Edge effects have two particular and measurable properties: (i) the distance of which the effect occurs, or at least is detectable, from the edge of the vegetation/habitat into the interior, and (ii) the degree to which the edge environment differs from the interior of the vegetation/habitat (van Etten, 2014). The scope of these edge effects widens not only to include changes to the environment adjacent to the proposal footprint, but to

include restriction on the movement for fauna, gene flow and water imposed by roads (van Etten, 2014). The restrictions on fauna and water are discussed in Chapters 9 and 10, respectively.

The impacts of edge effects on native vegetation include the physical disturbance of vegetation at the edge, the introduction of pathogens and weeds, and changes to vegetation composition. The impacts of edge effects resulting from the construction of the proposal are also detailed in Chapters 9 and 10. Edge effects are considered to be greatest where the proposal is adjacent to native vegetation. Generally, this occurs south of Maralla Road in Bullsbrook, while native vegetation is sporadic north of Maralla Road.

The native vegetation adjacent to the proposal may potentially be impacted during the construction phase due to vehicle accidents, dumping of refuse, uncontrolled third party access into adjacent vegetation, dieback and weed incursion and fire. The impacts of fire during the construction and operation phase are discussed in Section 8.4.11, while the impacts of weeds and dieback are discussed in Sections 8.4.6 and 8.4.7, respectively.

8.4.10 Uncontrolled Access

Uncontrolled access is currently contributing to the degradation of native vegetation at Maralla Road Nature Reserve, the Lexia wetlands, State Forest, Cullacabardee and the Reid Highway and Tonkin Highway interchange.

Household refuse, significant environmental weeds (i.e. declared pests listed under the BAM Act), vegetation degradation through off-road activity and Dieback have all been attributable to the uncontrolled access.

8.4.11 Fires

Native vegetation on the SCP has adapted to deal with wildfires as part of the natural ecology. Altered fire regimes (including arson, poorly managed burn-offs) can lead to the degradation of vegetation by lowering recruitment of native species, alterations to structure and an increase in weed occurrence and density.

The division of vegetation and vegetation to housing (such as that in Ellenbrook) that the proposal will create will increase the ease of access for emergency services to respond to fires. The proposal will also provide a fire break between intact native vegetation, for example, between Cullacabardee and Whiteman Park.

Fires may increase within and adjacent to the proposal footprint as a result of the construction of the proposal from incorrect disposal of cigarette butts, poor handling and storage of flammable fuels and from ‘hot works’ activities (for example, welding sparks igniting dry grass). However these risks are readily managed during construction and are unlikely to result in additional fires.

8.5 Management Measures

The mitigation hierarchy (Government of Western Australia, 2014) has been employed throughout the road planning and design phase and this assessment to ensure that:

- The locally and regionally significant vegetation located within the proposal footprint has been avoided as much as possible through the design process and specifically avoids the Mound Springs SCP and Claypans of the SCP TECs (see Chapter 4).
- Clearing is minimised to as low as practicable, i.e. the alignment and width of the development envelope has been reviewed to identify a proposal footprint that minimises clearing in very good to pristine condition vegetation and reduces the clearing of TECs and PECs.
- Where possible, vegetation will be rehabilitated. Details of rehabilitation are discussed in Chapter 12.

- Offsetting the significant residual impacts through an offset strategy (see Chapter 17).

To ensure the impact is reduced to as low as reasonably practicable, outcome-based commitments have been developed for the construction and operation aspects of the proposal. The mitigation hierarchy (Government of Western Australia, 2014) (avoid, minimise and rehabilitate/restore and offset – see Chapter 17) 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 flora and vegetation values have been avoided:

- Mound Springs SCP TEC at Gaston Road.
- Claypans of the SCP TEC adjacent to the existing Great Northern Highway.
- *Caladenia huegelii*, *Grevillea curviloba* subsp. *incurva* and *Darwinia foetida* threatened flora locations.
- *Cyathochaeta teretifolia* (P3)*, Ornduffia submersa* (P4) and *Stylidium striatum* (P4) priority flora locations.
- The alignment of the proposal was also relocated to the west of Bush Forever Site 13 (west of Sawpit Road, Bullsbrook) to avoid any direct impact to the site, including the Conservation Category Wetland (UFI 8926) within the Bush Forever site.

To ensure that impacts to remaining flora and vegetation 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 205.0 ha of native vegetation will be cleared.
- A maximum of 49.6 ha of GDEs will be cleared.
- A maximum of 128.5 ha of intact native vegetation within Bush Forever sites will be cleared.
- A maximum of 4.4 ha of State listed TECs (SCP02 and SCP20a) will be cleared.
- A maximum of 145.5 ha of State listed PECs (SCP21c, SCP22, SCP23b, SCP24 and Banksia on the Swan Coastal Plain) will be cleared.

While various management measures are proposed in this PER to achieve these desired outcomes, alternative management strategies may arise with further design, investigations and project planning. MRWA is committed to achieving the environmental outcomes through 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).

MRWA's commitment to the environmental outcomes may be achieved through the implementation of the following management measures:

- Additional targeted surveys for Threatened and Priority listed flora will be undertaken prior to vegetation clearing to clearly define population boundaries, and to identify any additional populations within and adjacent to the proposal.
- Additional targeted surveys of the known populations of *Millotia tenuifolia* var. *laevis* and *Meeboldina decipiens* subsp. *decipiens* ms to clearly define populations and known individuals. The

survey results will be provided to the EPA as part of the response to submissions process to inform the EPA's assessment of the proposal.

- Progressive clearing and revegetation will occur through the life of the construction phase of the proposal.
- Delineation of an approved clearing boundary.
- Preparation and implementation of an EMP (Appendix F) to limit risk of fire, the introduction and/or spread of weeds and/or dieback and litter to protect ecosystems that supports Threatened and Priority taxa. This EMP will include a monitoring program to monitor the condition of environmentally significant vegetation along the edge of the proposal footprint (i.e. TECs, PECs and threatened flora buffers) for any indirect impacts, including significant environmental weed incursions (i.e. WONS and declared pests) and refuse.
- Develop a detailed infrastructure plan for each stage of the development prior to construction to ensure the proposal is designed within the approved development boundary ('proposal footprint') and identifies areas of native vegetation to be retained.
- Design and installation of culverts to reduce shadowing and ponding.
- Threatened and Priority listed flora and ecological communities will be demarcated outside of the proposal footprint.
- Preparation and implementation of a weed and dieback hygiene management plan including:
  - A risk assessment of potential sources and activities.
  - The identification of 'protectable' areas adjacent to the proposal footprint.
  - Requirements for hygiene washdown locations that consider risk in the surrounding landscape.
  - A program to monitor and report on compliance and corrective actions where non-compliance has occurred.
  - Quarterly auditing of washdown sites to identify weed incursions.
  - Regular walk-overs at strategic locations along the proposal footprint (i.e. in association with native vegetation) to identify and ameliorate weed incursions.
  - An auditable hygiene inspection form will be prepared to detail inspection results at the hygiene locations.
- Educational and induction material will be provided about the significant flora and ecological communities to contractors working on the construction to reduce the risk of accidental clearing.
- Revegetation will occur at the earliest opportunity within designated revegetation areas and corridors to maintain ecological linkages.
- A fence will be installed along environmentally sensitive areas to reduce the risk of unauthorised or uncontrolled access impacting on the sensitive features. Environmentally sensitive areas will include, but not limited to conservation estate, Bush Forever sites, Cullacabardee, Whiteman Park, Lexia wetlands, Dick Perry Reserve and locations of Threatened and Priority listed flora and ecological communities.
- No movement of plant (construction) or vehicles outside of the designated clearing line during construction.

In addition to the above management measures, MRWA has committed to undertaking additional vegetation surveys and analysis of the vegetation inferred to be consistent with the TEC SCP02 to determine if the vegetation is consistent with the TEC SCP02. The surveys and analysis will occur in spring 2015 with the analysis and FCT determination available shortly after the survey completion. The survey design will be prepared in consultation with DPAW. The survey results will be provided to the EPA as part of the response to submissions process to inform the EPA's assessment of the proposal.

The State listed TEC SCP20a occurs in three locations within and adjacent to the project. One location on the corner of Reid Highway and Beechboro Road North is outside the development envelope and will not be impacted by the proposal. The indirect impacts of the project on locations the TEC adjacent to the impacted areas in Whiteman Park will be managed in accordance with standard MRWA policies and procedures regarding sensitive environments on MRWA assets.

8.6 Residual Environmental Outcome

The proposal will result in the clearing of native vegetation that supports TECs, PECs, GDEs, Priority Listed flora and is located within Bush Forever sites. 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 and permanent loss of State listed TECs.
- Minor and permanent loss of State listed PECs.
- Permanent loss of native vegetation within nine Bush Forever sites.

The proposal will involve the clearing of 205.0 ha of intact native vegetation. The impact on the intact native vegetation is not considered to be significant because:

- The clearing for the proposal will not reduce the extent of the vegetation complexes to levels below 10% for constrained areas.
- Excluding three associations (AsMlEvCl, Ba and EpRi), the remaining vegetation associations recorded in the proposal footprint are represented within the broader flora study area.
- Although the proposal footprint is considered to represent high biological diversity, the biological diversity is indicative of the linear extent of the proposal extending over two landforms (Pinjarra Plain and Bassendean Dunes) and numerous geomorphic wetland types (sumplands, damplands and palusplains).
- The clearing associated with TECs will be offset.
- The offset strategy has considered the impacts of the proposal, and the impacts to TECs, PECs and Bush Forever sites have been sufficiently offset within the offset proposal.

The design of the proposal footprint has ensured that no Threatened flora will be directly impacted as a result of the proposal. The proposal may have a significant effect on critical habitat for the Grand Spider Orchid and an offset has been proposed (see Section 17.6). The proposal is not likely to have a significant effect on the Narrow Curved-leaf Grevillea as it currently exists in the road reserve where indirect impacts of dieback, erosion and weeds are readily managed. With the appropriate mitigation measures for Threatened flora the proposal is likely to meet the EPA's objectives.

Of the eight Priority Listed flora identified within the flora study area, the proposal will avoid three of them, while the impact to another three Priority taxa is considered to be minor with less than 1% of the known individuals impacted. The impact on the remaining two Priority taxa, *Meeboldina decipiens* subsp. *decipiens*

and *Millotia tenuifolia* var. *laevis*, will be managed through the successful implementation of the EMP. As such, the proposal is not likely to have a significant effect on Priority flora and is likely to meet the EPA's objectives

The impacts to flora and vegetation can be managed to meet the EPA's objective and the proposal's environmental outcomes (as outlined in Section 8.1) and are not considered to have a significant effect. The direct loss of State listed TECs, PECs and intact native vegetation within Bush Forever sites is likely to have a significant effect. However, with the appropriate mitigation measures and offsets the proposal is likely to meet the EPA's objectives. An offset proposal for these impacts is provided in Chapter 17.

A summary of the proposal's residual impact on the flora and vegetation values following the implementation of management and mitigation is provided in the following Table 8.16.

Table 8.16 Summary of residual impacts to flora and vegetation following implementation of management and mitigation measures

Aspect	Predicted impact	Management and mitigation	Residual impact
Permanent loss of native vegetation and GDEs	• Loss of native vegetation in good or better condition. • Loss of native vegetation in the local context. • Loss of GDEs. • Reduction in vegetation complexes. • Direct loss of intact native vegetation in Bush Forever sites.	• Disturbance will be restricted to the proposal footprint. • Delineation of proposal footprint. • Staged clearing and revegetation (where applicable) in accordance with infrastructure plan. • Design and implementation of culverts in line with drainage strategy to maintain GDEs adjacent to the proposal footprint. • Preparation and implementation of an EMP, including management and monitoring of intact native vegetation.	• Loss of 205.0 ha of native vegetation in degraded or better condition. • Loss of 49.6 ha of native vegetation consistent with GDEs. • Loss of 128.5 ha within Bush Forever sites.
Permanent loss of threatened and priority ecological communities	• Direct loss (i.e. clearing) of Commonwealth TECs. • Direct loss (i.e. clearing) of State TECs and PECs.	• Disturbance will be restricted to the proposal footprint. • The Commonwealth TECs, Mound Springs SCP and Claypans of the SCP will be avoided. • Finalisation of design will endeavour to avoid and minimise the impacts to State TECs and PECs within the proposal footprint. • TECs and PECs to be retained will be demarcated within and adjacent to the proposal footprint. • Preparation and implementation of an EMP, including management and monitoring of TECs, PECs and vegetated buffers.	• Loss of 4.4 ha of two State TECs: – SCP02: 0.4 ha. – SCP20a: 4.0 ha. • Loss of 145.5 ha of five State PECs: – SCP21c: 64.0 ha. – SCP22: 0.1 ha. – SCP23b: 11.6 ha. – SCP24: 7.8 ha. – Banksia Woodland on the Swan Coastal Plain: 62.0 ha.

Aspect	Predicted impact	Management and mitigation	Residual impact
Permanent loss of threatened and priority listed flora	• Direct loss (i.e. clearing) of Threatened flora. • Direct loss (i.e. clearing) of critical habitat for Threatened flora. • Direct loss (i.e. clearing) of Priority flora. • Direct loss (i.e. clearing) and/or degradation of vegetated buffers.	• Design of proposal footprint will avoid Threatened flora. • Design of proposal footprint will avoid populations of *Cyathochaeta teretifolia* (P3), *Ornduffia submersa* (P4) and *Stylidium striatum* (P4). • Additional targeted surveys for *Millotia tenuifolia* var. *laevis* and *Meeboldina decipiens* subsp. *decipiens* ms within the Ellenbrook and Tonkin and Reid Highway intersections to clearly define populations and known individuals adjacent to the proposal footprint. The survey results will be provided to the EPA as part of the response to submissions process to inform the EPA's assessment of the proposal. • Vegetated buffers will be managed and monitored. • Demarcation of Threatened and Priority flora adjacent to the proposal footprint. • Preparation and implementation of an EMP, including management and monitoring of Threatened and Priority flora including vegetated buffers.	• Loss of 39.2 ha and 2.0 ha of Critical habitat for *Caladenia huegelii* and *Grevillea curviloba* subsp. *incurva*, respectively. • Minor loss (<1% of known individuals) of three Priority taxa: – *Anigozanthos humilis* subsp. *chrysanthus* (P4): 0.15%. – *Hypolaena robusta* (P4): 0.10%. – *Poranthera moorokatta* (P2): 0.04%. • High loss (known individuals) of two Priority taxa: – *Millotia tenuifolia* var. *laevis*: 18.8%. – *Meeboldina decipiens* subsp. *decipiens* ms: 50%.
Vegetation degradation through introduction and spread of dieback and weeds	• Introduction and spread dieback. • Introduction and spread of environmentally significant weeds (WONS and declared plants and prohibited plants).	• Development and implementation of a weed and dieback management plan. • Monitoring of vegetation retained adjacent to proposal footprint. • There will be no plant and vehicle movement outside of designated clearing line during construction.	Edge effects will occur between the clearing line and areas of native bushland over time during operation. It is unlikely that, with proper management, significant edge effects will extend further than 10 m from the edge of the clearing line.

Aspect	Predicted impact	Management and mitigation	Residual impact
Fragmentation of native vegetation	• Permanent interruption of ecological linkage networks.	• Project disturbance will be restricted to the proposal footprint. • Delineation of proposal footprint. • Staged clearing and revegetation (where applicable) in accordance with infrastructure plan. • Revegetation of proposal footprint will occur in accordance with landscape management plan. • Preparation and implementation of an EMP, including management and monitoring of intact native vegetation.	• Three fragmented ecological linkage networks (Gaston Road Bullsbrook, Raphael Road Bullsbrook and Reid Highway) will be further fragmented. • Three large, mostly contiguous ecological linkage networks (Maralla Road Nature Reserve, Rocla mining lease area and Cullacabardee) will be fragmented.
Increase in uncontrolled access	• Dumping of household and construction refuse. • Introduction and spread of dieback. • Introduction and spread of significant environmental weeds. • Vegetation degradation.	• No plant and vehicle movement outside of designated clearing line during construction. • Installation of permanent fence along environmentally sensitive areas. • Access points and the PSP will be located away from extant native vegetation, where possible. If this is unavoidable, then the access points and paths will be designed to minimise the risk of uncontrolled access into significant native vegetation (i.e. Maralla Nature Reserve). • Preparation and implementation of an EMP, including management on uncontrolled access and construction refuse.	Nil. Edge effects.
Increase in wildfires	• Vegetation degradation through fires associated with the construction of the proposal.	• Risk of wildfire managed in accordance with DFES and MRWA policies and guidelines. • Preparation and implementation of an EMP, including guidance in regards to 'hot works' and storing and handling of flammable materials.	Nil.

9 TERRESTRIAL FAUNA

9.1 EPA Objective

The EPA's objective in respect of terrestrial fauna (EPA, 2014a) is to maintain representation, diversity, viability and ecological function at the species, population and assemblage level.

9.2 Existing Environment

A terrestrial fauna survey was conducted in 2014 (Coffey, 2015b) (Appendix G) and built on previous surveys (360 Environmental, 2013 and GHD, 2013c). The 2014 survey covered an area of approximately 1,028.4 ha (the 'fauna study area'). The fauna study area is approximately equivalent to the development envelope. The relationship between the fauna study area, development envelope and the proposal footprint is shown on Figure 9.1.

9.2.1 Terrestrial Vertebrate Fauna Surveys

The purpose of these fauna investigations was to identify and assess the values and significance of the fauna, fauna habitats and habitat connectivity within the proposal footprint.

A desktop assessment of State and Commonwealth databases, regional and local contextual data for the northern SCP and existing biological surveys was undertaken prior to the majority of the field surveys for the fauna study area (Coffey, 2015b) (Appendix G). The results of the desktop assessment provide a list of the expected faunal assemblage for the fauna study area.

A Level 1 survey consisting of a habitat assessment and opportunistic fauna survey was conducted within the fauna study area. This survey involved assessing and mapping the fauna habitats present and recording fauna species occurring within the fauna study area. Particular focus and survey effort was invested in identifying conservation significant fauna that occur in the fauna study area (Appendix G).

A Level 2 targeted trapping program was conducted at the same time in areas potentially containing significant fauna or their habitats, such as Whiteman Park/Cullacabardee Bushland and Maralla Road Bushland. These sites were identified in the ESD as locations where fauna movement may be impacted (EPA, 2014a). As the fauna assemblage of the SCP is well known, the trapping program was designed to identify species commonly occurring in these key areas, rather than a systematic trapping program of the whole fauna study area (Appendix G). The survey methodology used was approved by DPAW and EPA as adequate for the purpose.

The fauna study area was assessed and mapped to record the level of Black Cockatoo habitat it provides, in particular foraging, roosting and breeding habitat. Black Cockatoos breed in large tree hollows that are found in trees usually more than 200 years old (DSEWPAC, 2012c). Trees of suitable species that have a diameter at breast height (DBH) of over 500 mm are classified as potential breeding trees. The location and details of potential breeding trees were recorded and assessed for the presence of hollows. A Black Cockatoo habitat assessment covering the presence and mapping of Black Cockatoo foraging and breeding habitat, including the presence of potential breeding trees, was also conducted in an area of State Forest and Class A Nature Reserve (89.7 ha) west of Ellenbrook within the proposal footprint (360 Environmental, 2013).

A fauna movement survey was conducted at Maralla Road Bushland and Whiteman Park/Cullacabardee Bushland. Tracks adjacent to the trapping sites were used to identify fresh animal tracks and allow them to be sorted into fauna class and number of movements. Only ground dwelling native species were recorded

during the survey as these are the target species for any potential fauna movement corridors. The data collected was analysed using ARC GIS Hot Spot analysis to identify areas of high fauna traffic and importance. This data was used to recommend appropriate locations and types of fauna movement corridors (bridges, underpasses etc.) or mechanisms (Coffey, 2015b) (Appendix G).

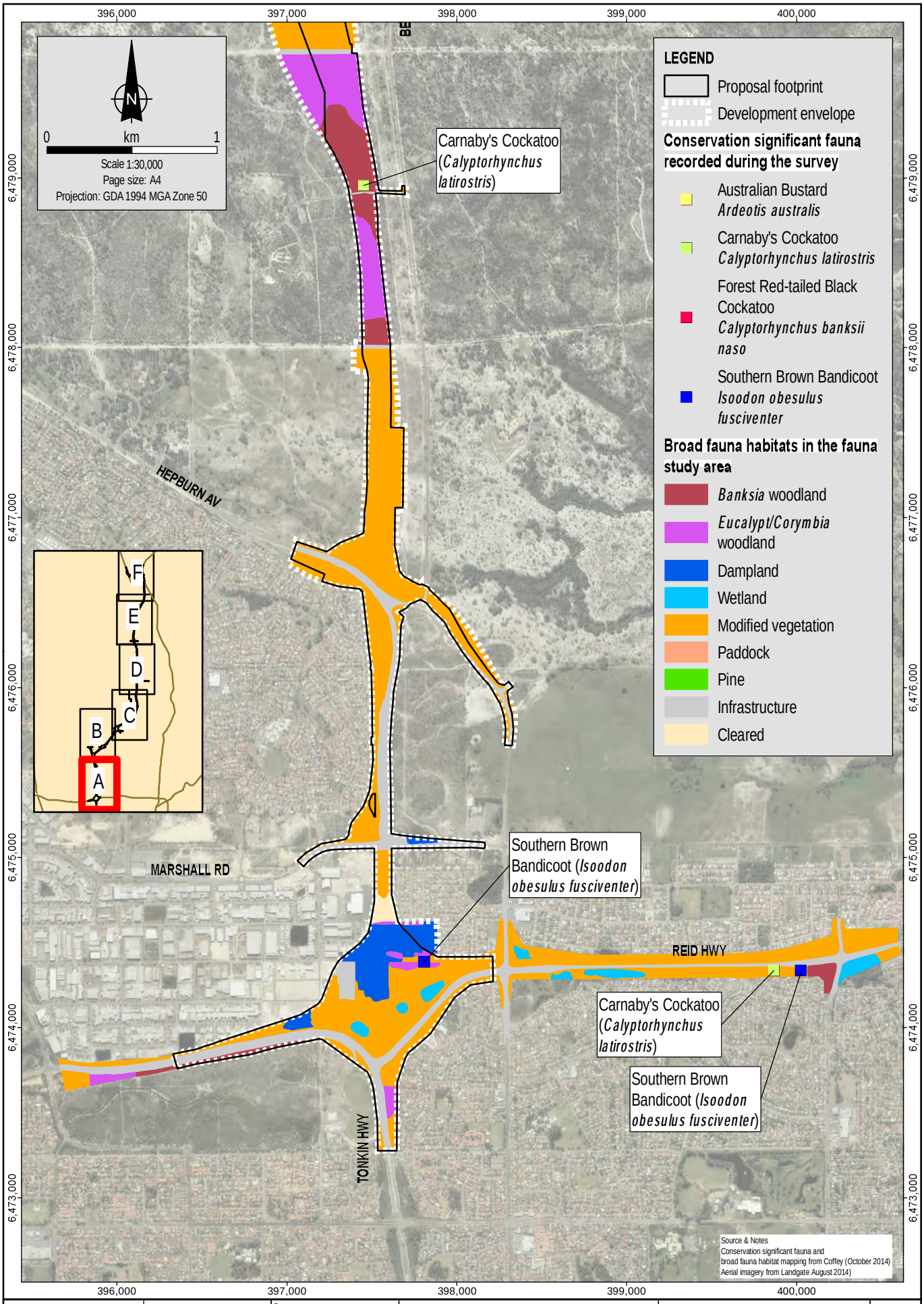
Once the proposal footprint was confirmed, any additional areas outside of the initial fauna study area requiring surveying were identified. A Level 1 fauna assessment and a Black Cockatoo habitat assessment was conducted within these additional areas (Coffey, 2015c).

9.2.2 Fauna Habitats

A total of four natural fauna habitats were recorded in the proposal footprint, including Banksia Woodland, Eucalypt/Corymbia Woodland, Dampland and Wetland habitats. These habitats were defined based upon existing landforms, the fauna value they provide and the vegetation mapping from the flora survey (Coffey, 2015a). The fauna habitat mapping differs slightly from the vegetation community types from Section 8.2 as mapping was undertaken at a different scale. The total area of natural habitats is 159.3 ha, equating to approximately 21.4% of the proposal footprint. A further three secondary fauna habitats were recorded, namely Modified Vegetation, Paddock and Pine Plantation (Figure 9.1 and Table 9.1). Although the secondary fauna habitats do not support the full fauna assemblage, they provide limited habitat to some species. A total of 514.9 ha of secondary fauna habitats was recorded in the proposal footprint, equating to approximately 69% of the proposal footprint. In addition, 71.5 ha was classified as cleared areas or infrastructure, which equates to approximately 9.6% of the proposal footprint.

Table 9.1 Fauna habitats of the proposal footprint

Habitat type	Area (ha)	Habitat value
Natural fauna habitats		
Banksia Woodland	81.7	Moderate
Eucalypt/Corymbia Woodland	43.1	High
Dampland	19.0	Moderate
Wetland	15.5	Moderate
Secondary fauna habitats		
Modified Vegetation	208.2	Low
Paddock	255.7	Low
Pine Plantation	51.0	Low
Nil habitats		
Infrastructure/cleared	71.5	Nil
Total	**745.7**	–



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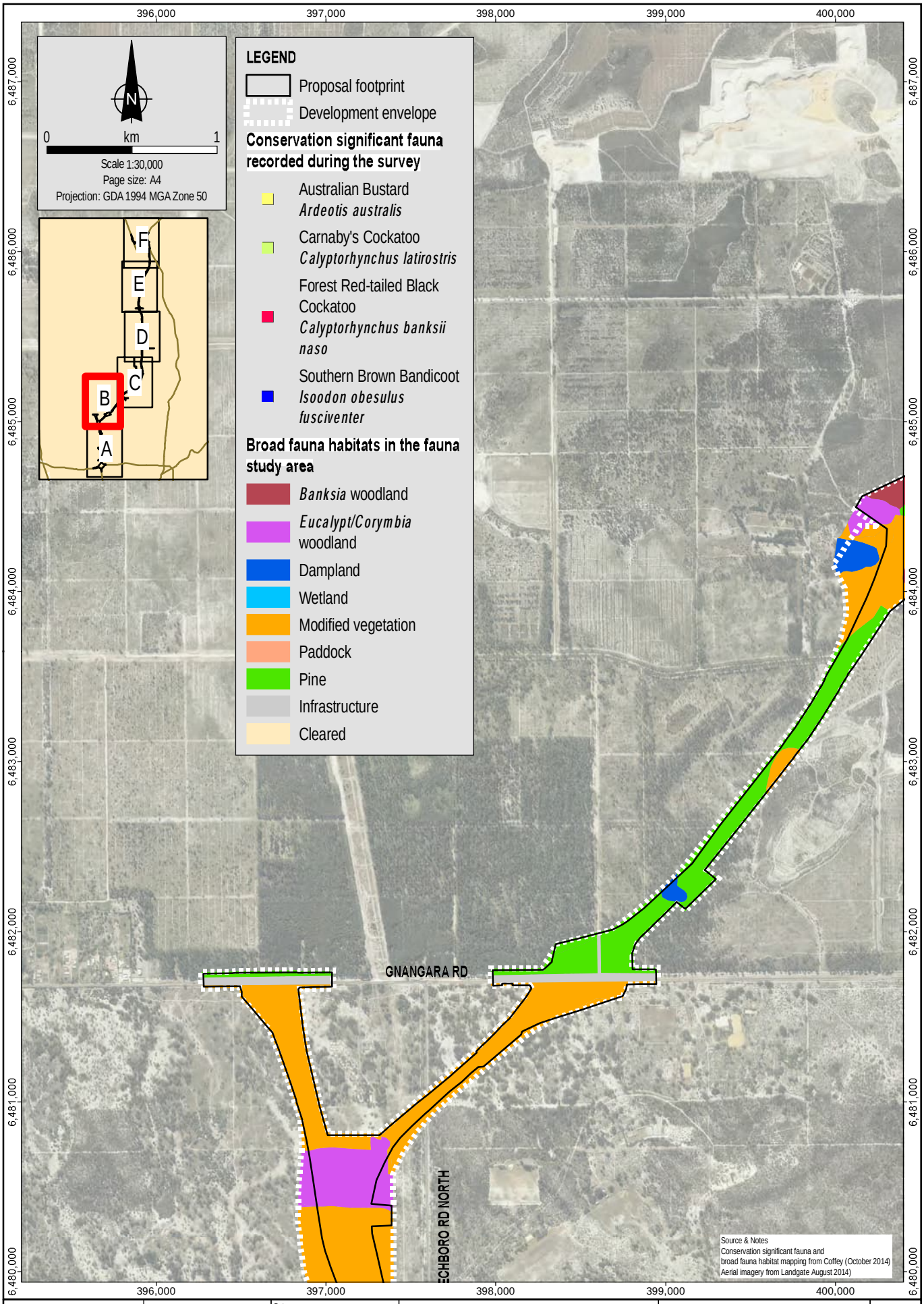

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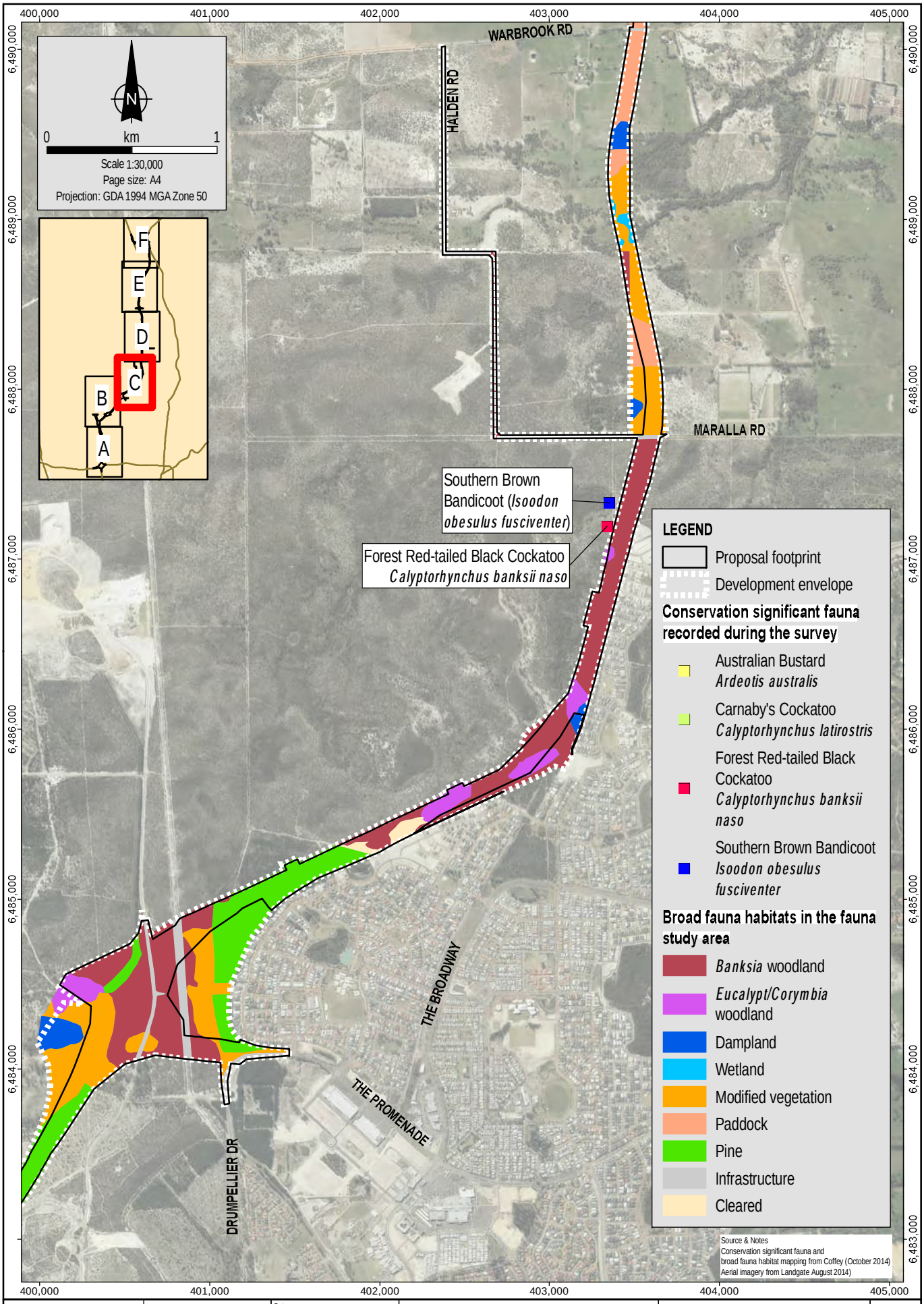

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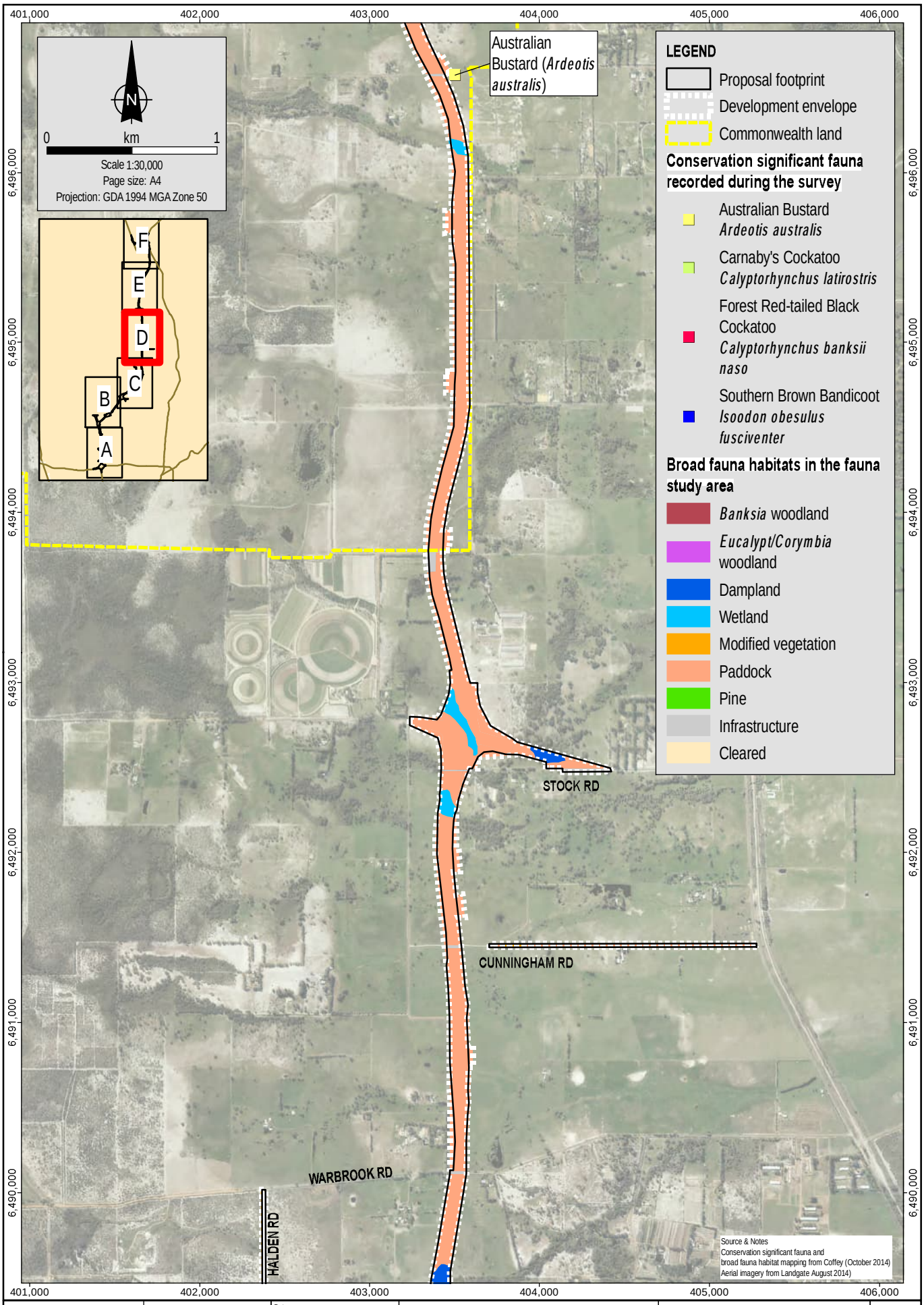

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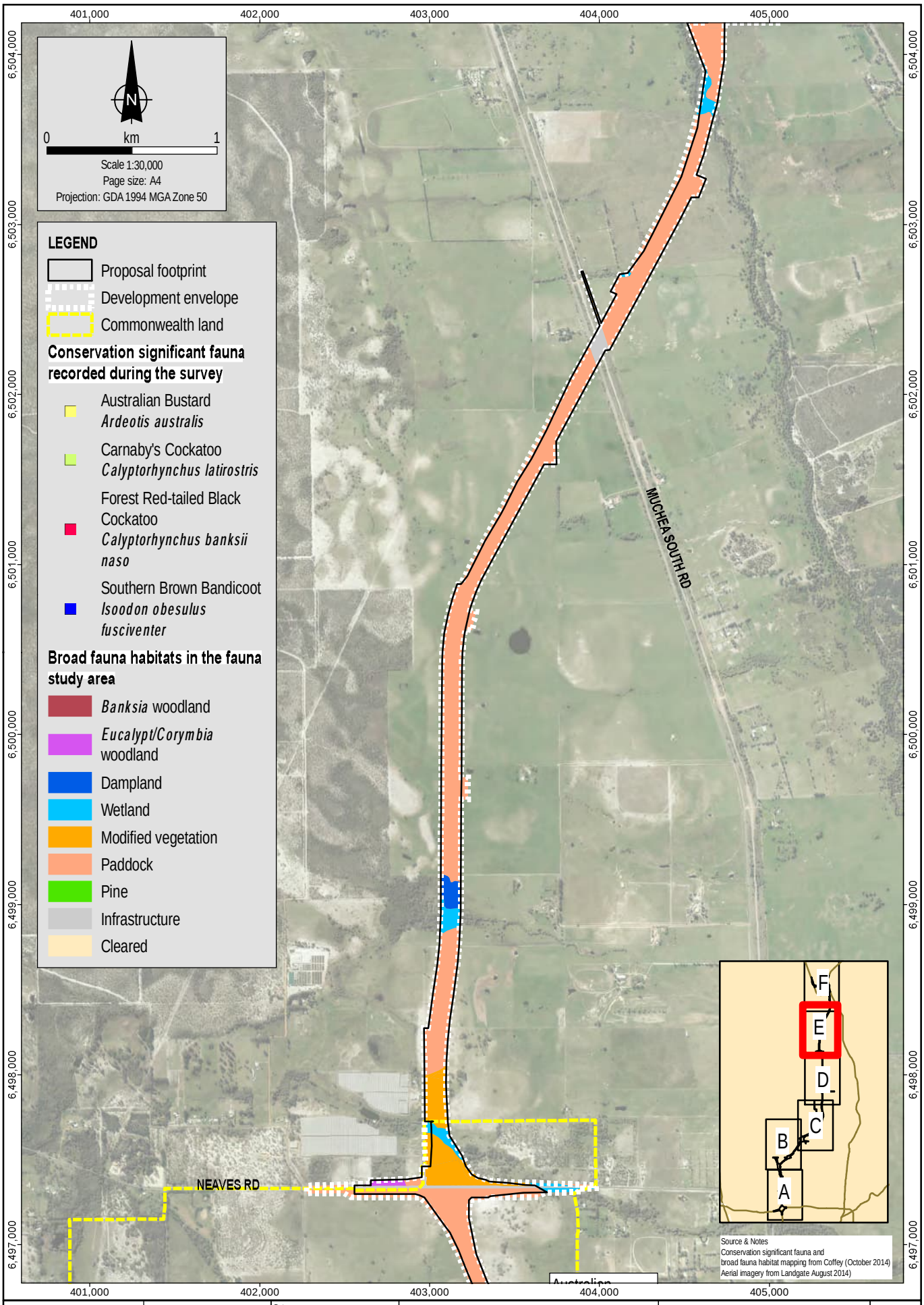
Date: 05.06.2015
MXD: 4483AA_03_GIS086_2
File Name: 4483AA_03_F9.1D_GIS

Main Roads WA
Public Environmental Review
Perth–Darwin National Highway

Fauna habitat mapping and conservation significant fauna
Map 4 of 6

Figure No:
9.1D



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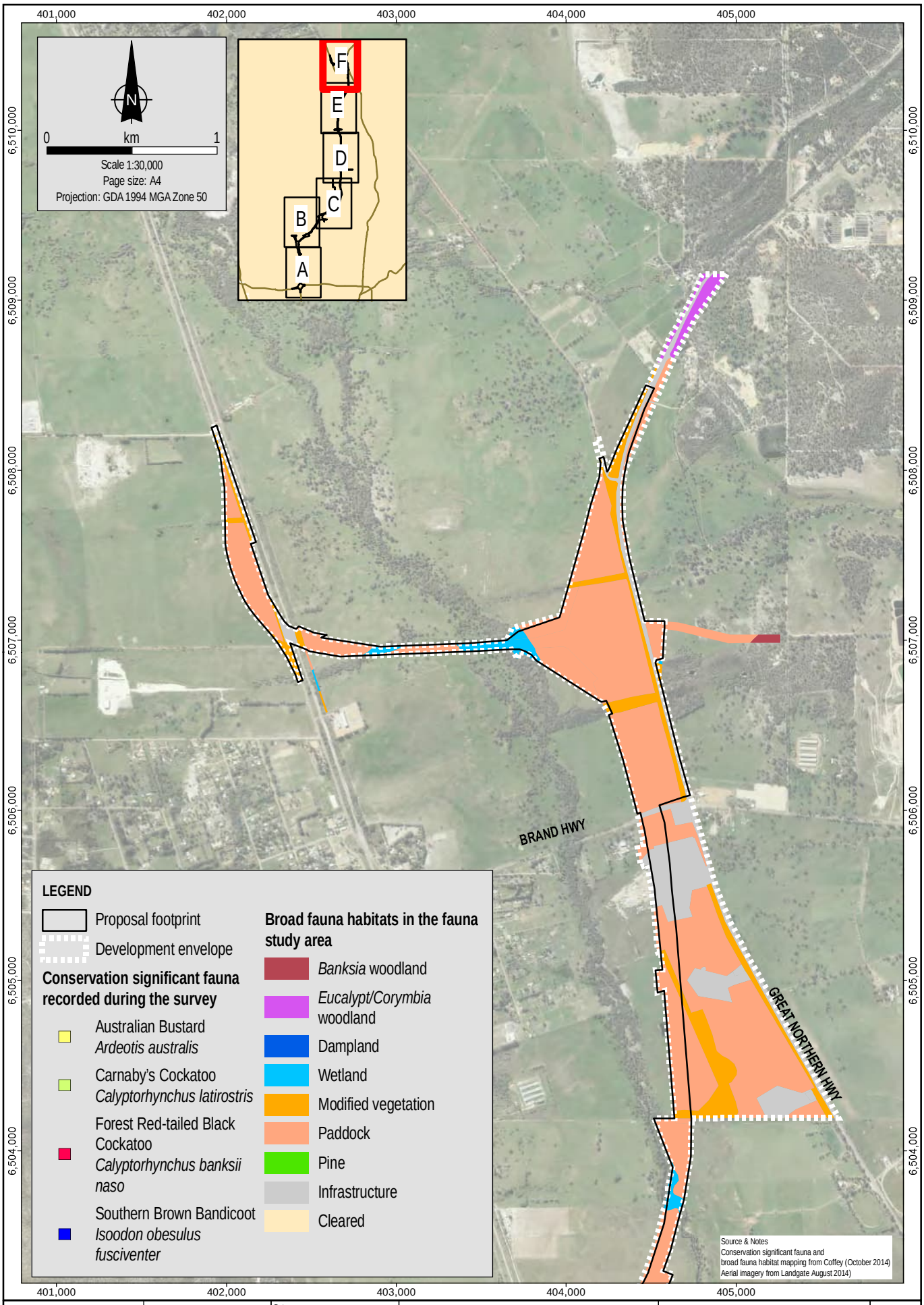
Fauna habitat mapping and conservation significant fauna
Map 5 of 6

Figure No:
9.1E



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9.2.2.1 Banksia Woodland

The vegetation of this habitat type is typified by *Banksia attenuata* and *Banksia menziesii* low woodland with occasional *Eucalyptus todtiana* over mixed shrubs dominated by *Eremaea pauciflora*, *Scholtzia involucrata* and *Leucopogon conostephioides* over isolated sedges and rushes. The Banksia Woodland habitat is the most extensive fauna habitat in the proposal footprint (81.7 ha, or 11.0%) and is predominantly located south of Maralla Road. The vegetation condition ranged from degraded to pristine with current impacts including weeds, feral animals, rubbish, tracks, recent fire damage and dieback. The majority of this habitat type was classified as being in very good to excellent condition, in particular the sections associated with Cullacabardee and Maralla Road Bushland (Coffey, 2015b) (Appendix G).

9.2.2.2 Eucalypt/Corymbia Woodland

The vegetation of this habitat type is typified by *Eucalyptus marginata* and/or *Corymbia calophylla* woodland over occasional *Banksia attenuata* and *Banksia menziesii* over *Xanthorrhoea preissii* shrubland over mixed low shrubs over sedges and rushes. The Eucalypt/Corymbia Woodland habitat (43.1 ha, 5.8%) is predominantly located south of Maralla Road. The vegetation condition ranged from good to excellent with existing impacts including weeds, feral animals, rubbish, tracks, recent fire damage and dieback. The majority of this habitat type was classified as being in very good to excellent condition, in particular the sections associated with Cullacabardee and Maralla Road Bushland (Coffey, 2015b) (Appendix G).

9.2.2.3 Dampland

The vegetation of this habitat type is characterised by occasional *Eucalyptus rudis* trees over *Melaleuca preissiana* and/or *Melaleuca rhaphiophylla* low woodland over occasional heath scrub dominated by *Pericalymma* spp., *Astartea* spp. and *Melaleuca* spp. over sedges and rushes. The Dampland habitat type (19 ha, 2.5%) is an area where moisture collects and during the winter months it becomes seasonally waterlogged. The vegetation condition ranged from completely degraded to pristine with impacts including weeds, feral animals, rubbish and tracks. The majority of this habitat type was classified as being in very good condition with some degraded sections north of Maralla Road (Coffey, 2015b) (Appendix G).

9.2.2.4 Wetland

The vegetation of this habitat type is characterised by *Eucalyptus rudis* and *Melaleuca preissiana* woodland over mixed shrubs over sedges and rushes with surface water expression. The Wetland habitat (15.5 ha, 2.1%) is typically small lakes and ephemeral creeks. As such, it provides habitat to some aquatic species, but not for fauna that require deep lakes or large wetland habitats such as rivers, swamps and large lakes. This habitat does not contain the shallow margins that migratory wading birds prefer as foraging habitat. The term 'Wetland' is used here in a fauna habitat context and differs from the definition of a wetland referred to in Section 10.2.3. The vegetation condition of the Wetland habitat ranged from completely degraded to very good with existing impacts including weeds, feral animals, rubbish and tracks. The majority of this habitat type was classified as being in degraded condition (Coffey, 2015b) (Appendix G).

9.2.2.5 Secondary habitats

Secondary fauna habitats often provide conduits between areas of more suitable habitat and act as an ecological linkage. Secondary fauna habitats comprise about 514.9 ha (69%) of the proposal footprint.

All secondary habitats have had the original vegetation structure disrupted and contain a high level of impact from clearing, weeds, feral animals, rubbish and tracks (Coffey, 2015b) (Appendix G).

9.2.3 Black Cockatoo Habitats

Based on the distribution maps in the EPBC Act Referral Guidelines for the Three Threatened Black Cockatoo Species (DSEWPAC, 2012c) two of the three species of Black Cockatoo are expected to occur in the proposal footprint, namely Carnaby's Cockatoo (*Calyptorhynchus latirostris*) and the Forest Red-tailed

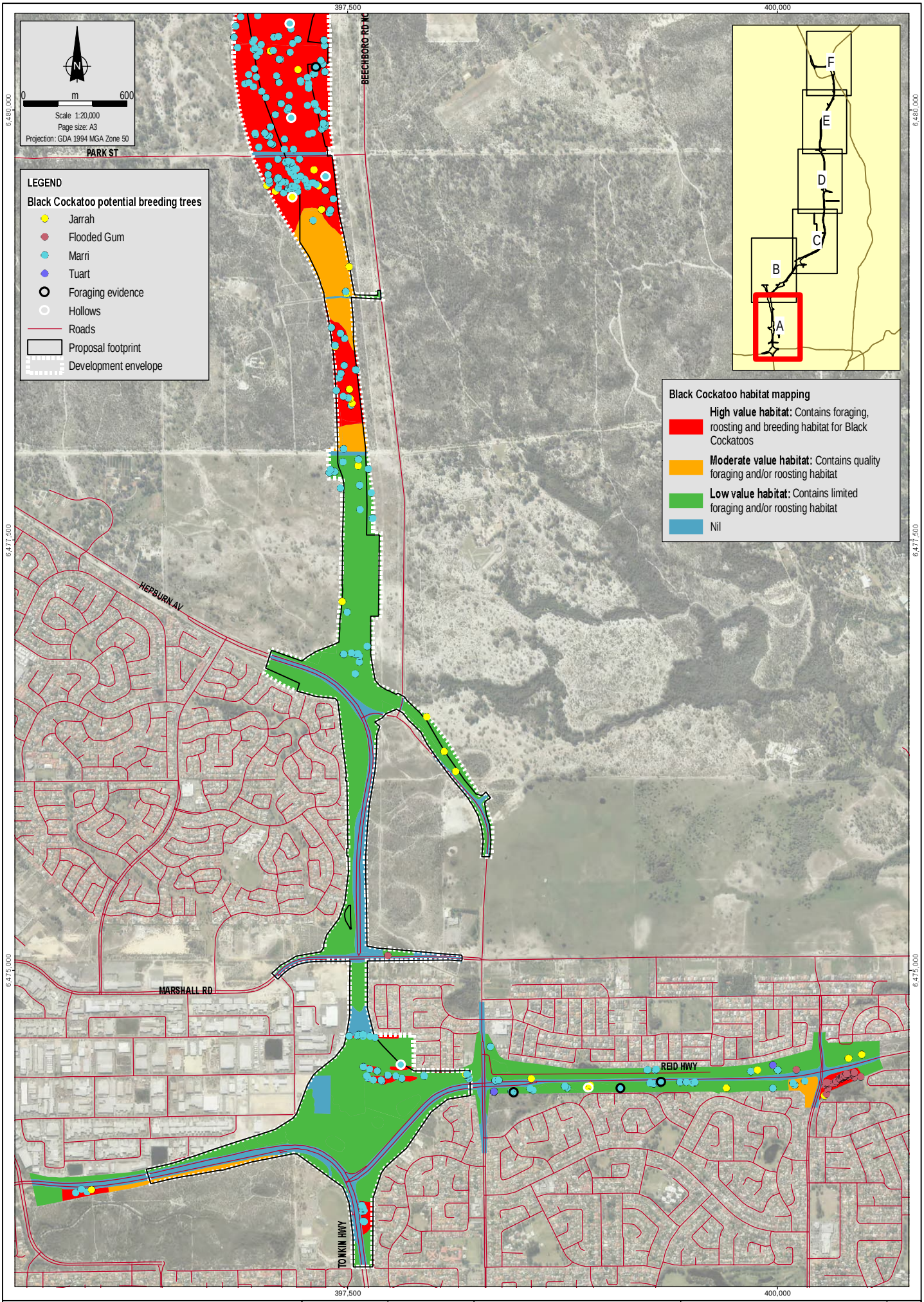
Black Cockatoo (*Calyptorhynchus banksii naso*). The proposal footprint is just outside of the northern distribution for the Baudin's Cockatoo (*Calyptorhynchus baudinii*) and it was therefore classified as possibly occurring. Collectively, the Carnaby's Cockatoo and Forest Red-tailed Black Cockatoo are referred to as 'Black Cockatoos'.

The Pine Plantations in the proposal footprint are part of the Forest Products Commission (FPC) plantation, which is currently being harvested and will not be replanted. Harvesting of a portion of Pines in the proposal footprint has occurred since the survey was undertaken in 2014. The remaining portion of Pines in the proposal footprint (51 ha) is intended to be cleared in the near future for purposes not related to the proposal. Accordingly, the entire Pine Plantation habitat recorded in the proposal footprint has not been classified as foraging or roosting habitat.

The proposal footprint was assessed to determine the quality of Black Cockatoo habitat it provides, in particular foraging, roosting and breeding habitat (Figure 9.2 and Table 9.2). Foraging, roosting and breeding habitat are not independent of each other and overlaps exist between all three habitats.

Table 9.2 Black Cockatoo habitats of the proposal footprint

Habitat	Black Cockatoo habitat			
	High value (contains potential breeding, roosting and foraging habitat)	Moderate value (contains quality foraging habitat)	Low value (contains limited foraging habitat)	Nil value (contains no habitat)
Eucalypt/Corymbia woodland	43.1	–	–	–
Banksia Woodland	–	81.7	–	–
Dampland	–	–	19	–
Wetland	12.9	–	2.6	–
Modified Vegetation	64.1	–	144.1	–
Pine Plantation	–	–	–	51
Paddock	–	–	255.7	–
Cleared/infrastructure	–	–	–	71.5
Total (hectares)	**120.1**	**81.7**	**421.4**	**122.5**



Source & Notes
Black cockatoo and tree mapping from Coffey (2015).
Aerial imagery from Landgate (August 2014).

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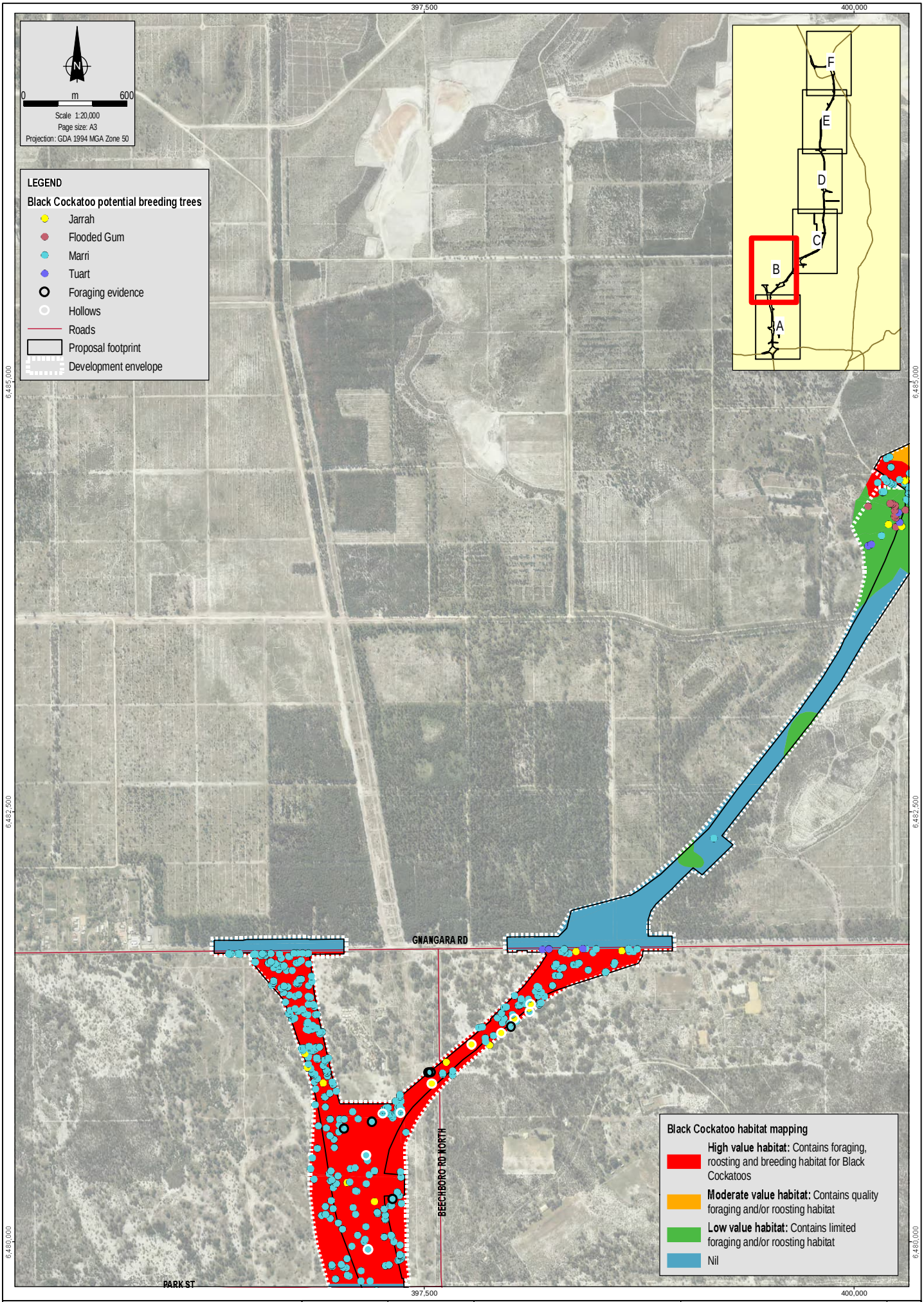
Black Cockatoo habitat mapping
Map 1 of 6

Figure No: 9.2A



Source & Notes
Black cockatoo and tree mapping from Coffey (2015).
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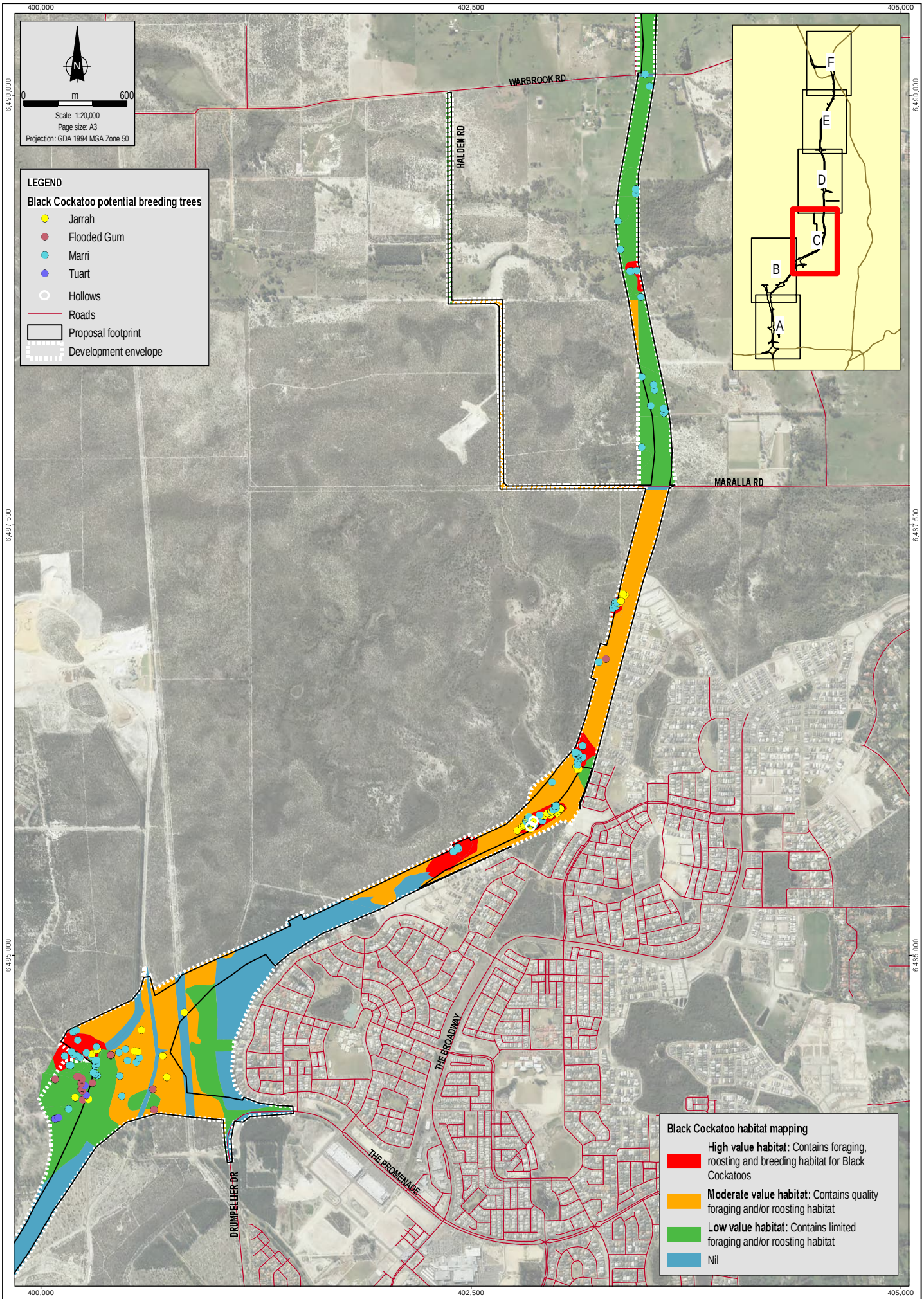
Black Cockatoo habitat mapping
Map 2 of 6

Figure No: 9.2B



Source & Notes
Black cockatoo and tree mapping from Coffey (2015).
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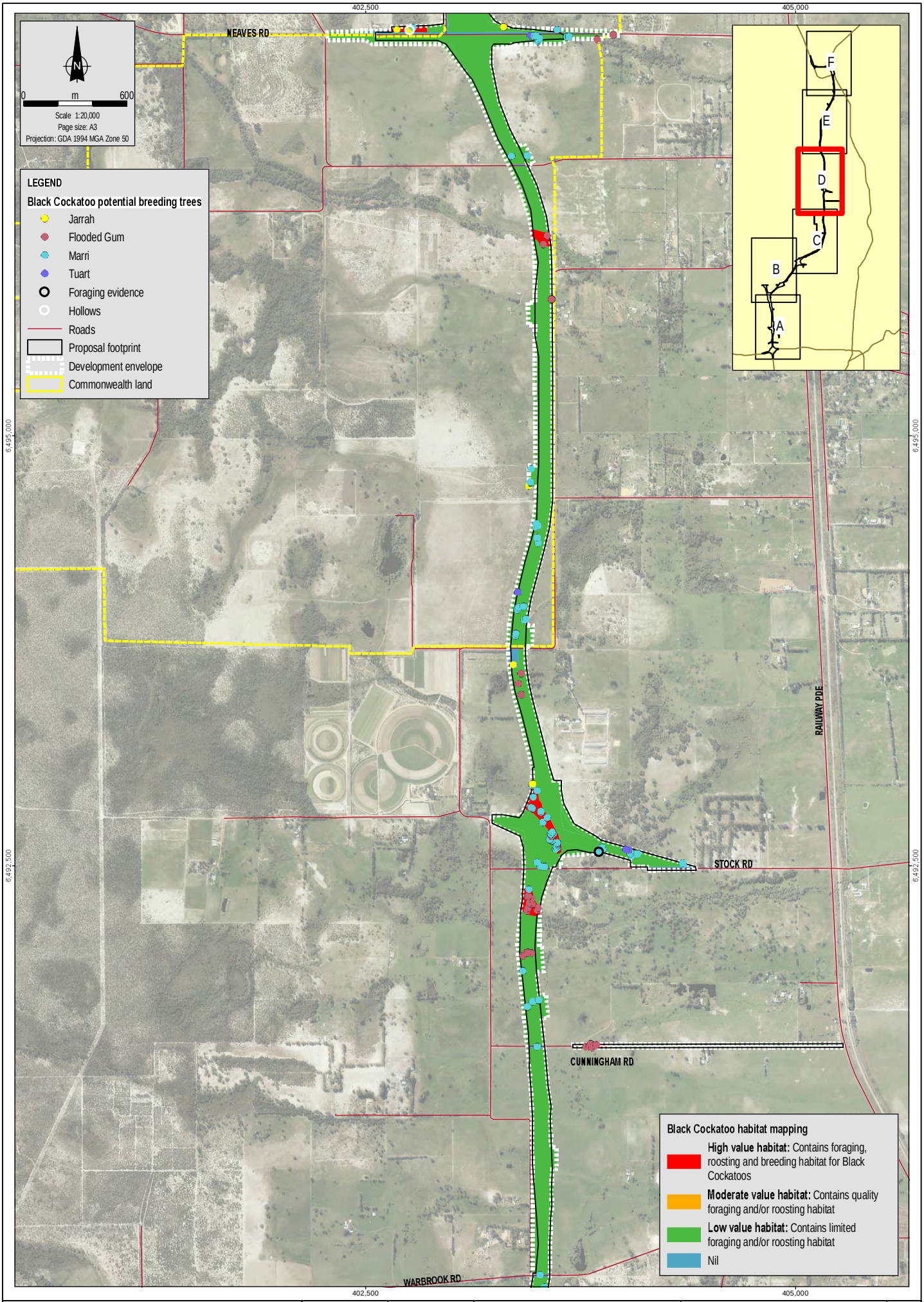
Black Cockatoo habitat mapping
Map 3 of 6

Figure No: 9.2C



Source & Notes
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Aerial imagery from Landgate (August 2014).

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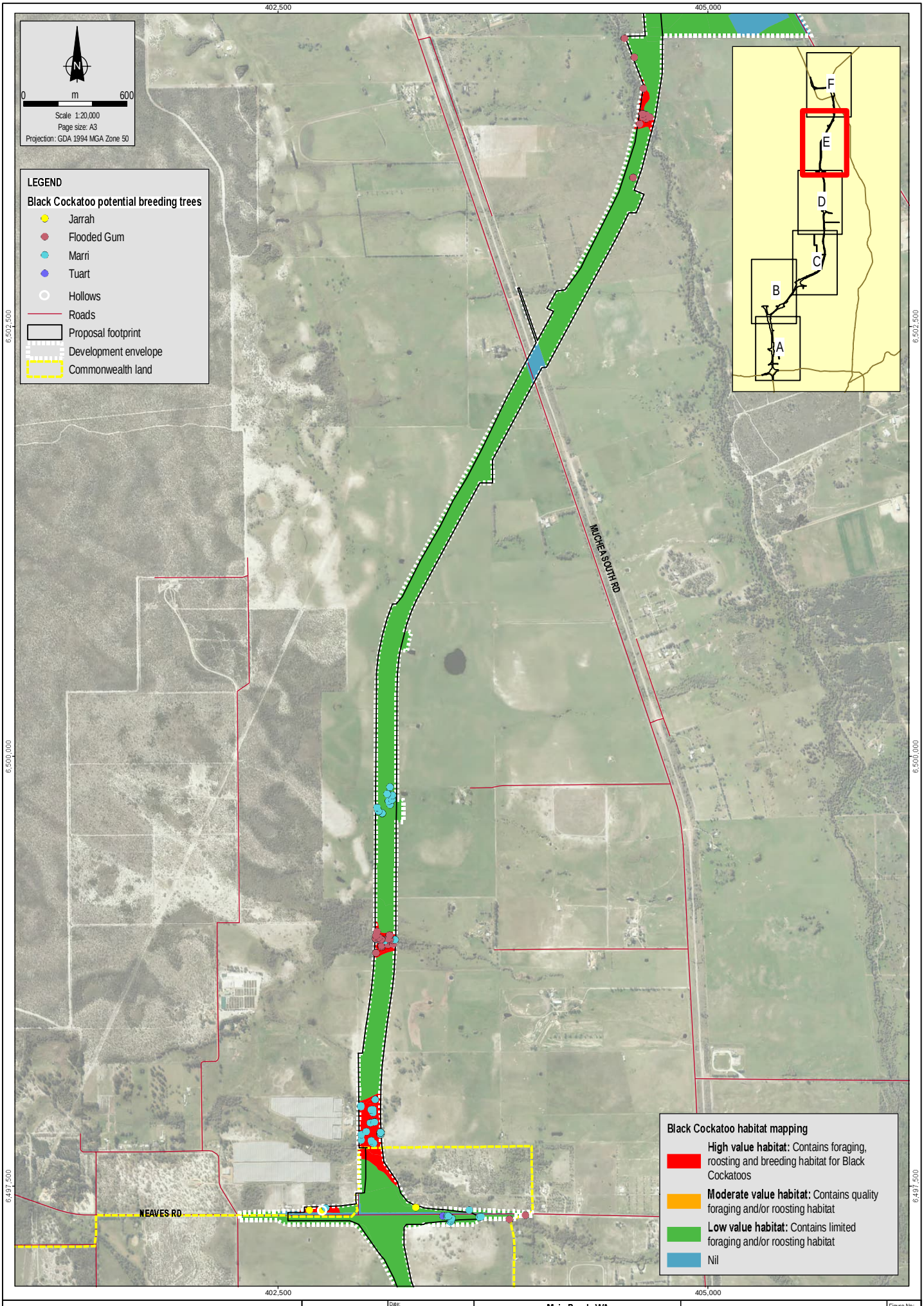
Black Cockatoo habitat mapping
Map 4 of 6

Figure No: 9.2D



Source & Notes
Black cockatoo and tree mapping from Coffey (2015).
Aerial imagery from Landgate (August 2014).

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Date: 05.06.2015
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File Name: 4483AA_03_F9.2E_GIS

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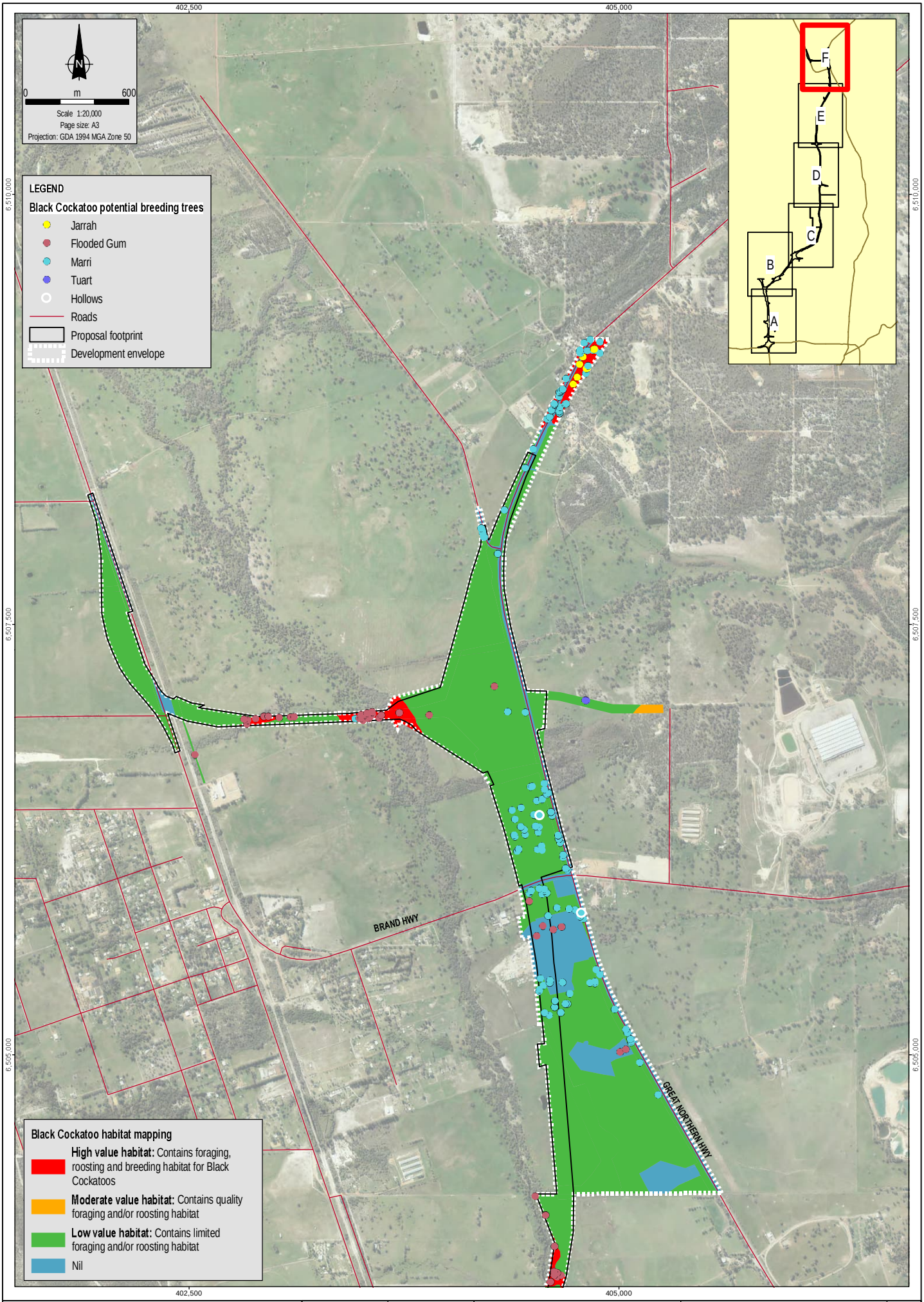
Black Cockatoo habitat mapping
Map 5 of 6

Figure No: 9.2E



Source & Notes
Black cockatoo and tree mapping from Coffey (2015).
Aerial imagery from Landgate (August 2014).

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Black Cockatoo habitat mapping
Map 6 of 6

Figure No: 9.2F

9.2.3.1 Foraging Assessment

The two species of Black Cockatoo from the vicinity of the proposal footprint have different foraging requirements. Carnaby's Cockatoo can be described as a generalist, foraging on a wide range of plant species, including *Eucalyptus* sp., *Corymbia* sp., *Allocasuarina* sp., *Banksia* sp. and other proteaceous trees and shrubs (DSEWPAC, 2012c). Forest Red-tailed Black Cockatoos have a more specific diet consisting of *Eucalypt* sp., *Corymbia* sp. and *Allocasuarina fraseri*. Habitats where these plant species are dominant were classified as providing foraging habitat for each species. Areas of High and Moderate value Black Cockatoo habitat have been classified as quality foraging habitat for Carnaby's Cockatoos, whereas areas of High value Black Cockatoo habitat have been classified as quality foraging habitat for Forest Red-tailed Black Cockatoos. As such, 201.8 ha of quality Carnaby's Cockatoo foraging habitat (classified as providing High and Moderate value Black Cockatoo habitat) and 120.1 ha of quality Forest Red-tailed Black Cockatoo foraging habitat (classified as High value Black Cockatoo habitat) was recorded in the proposal footprint (Figure 9.2).

There were 21 species of foraging resources and eight records of Black Cockatoo foraging evidence observed in the proposal footprint (upon Marri nuts and Banksia cones) (Coffey, 2015b).

9.2.3.2 Roosting Assessment

The Eucalypt/Corymbia Woodlands and Wetland habitats with stands of tall trees provide potential roosting habitat for Black Cockatoos (58.6 ha) (see Figure 9.2).

A desktop search for known roost sites was completed for the proposal footprint using data from the Great Cocky Count (Burnham et al., 2010). No known roost sites occur in the proposal footprint and none were recorded during the survey. Three major roost site locations have been recorded in the Pine Plantations to the west of the proposal footprint in the Gnangara region. All sites are within 10 km of the proposal footprint and have between 64 and 542 Carnaby's Cockatoos using these roost locations (Burnham et al., 2010).

9.2.3.3 Breeding Assessment

The proposal footprint contains 737 trees that have a DBH over 500 mm. The majority of these trees are Marri (574), followed by Flooded Gum (90), Jarrah (68) and Tuarts (5). The EPBC Act Referral Guidelines for the Three Threatened Black Cockatoo Species (DSEWPAC, 2012c) states, "in a woodland stand with trees of suitable diameter at breast height, all trees of all ages and size are potentially important for maintaining breeding in the long term" and, as such, the Eucalypt/Corymbia Woodland, Modified Vegetation and Wetland habitats with stands of suitably sized trees and species are classified as potential breeding habitat and mapped as High value (120.1 ha) (see Figure 9.2).

For hollows to be of use to Black Cockatoos they should have dimensions of at least 12 cm entrance size (Groom, 2011; Johnstone et al., 2013). A total of 13 trees that contained suitable sized hollows were recorded within the proposal footprint (see Figure 9.2). There are no known breeding records for Black Cockatoos in the proposal footprint or its vicinity.

9.2.4 Fauna Assemblage

A desktop assessment of database searches and relevant surveys identified 360 species of fauna that have been previously recorded in the vicinity of the proposal footprint (Appendix G). This includes four invertebrate, five fish, 14 amphibian, 64 reptile, 232 bird and 41 mammal species. It should be noted that the species list from the desktop assessment includes historic records of species that have since become locally extinct and species that have been recorded in the general region, but are vagrants and are generally not found in the area because of a lack of suitable habitat.

A more recent assessment of the fauna assemblage of the Gnangara Sustainability Strategy (GSS) study area suggests that there is a total of 304 species of fauna currently existing in the vicinity of the proposal footprint. This includes 13 amphibians, 64 reptiles, 217 birds and 10 mammals (native non-bat mammals) (Wilson and Valentine, 2009). The reduction in the number of birds and mammals in recent data compared with the historical data corresponds with findings that these two faunal groups have been impacted to a greater extent by urban development (How and Dell, 2000; Wilson and Valentine, 2009; Government of Western Australia, 2000b). There is no data to suggest any historical changes to distribution and abundance of amphibians and reptiles (How and Dell, 2000).

The changes to fauna assemblage are caused by the impact of European settlement such as the loss of habitat, fragmentation of habitat, feral predators, changed fire regimes, climate change and the spread of *Phytophthora* dieback. However, there is a lack of the quantitative data on the level of impact these threats currently pose (Wilson and Valentine, 2009). Despite these impacts, the persistence of the majority of the original reptile assemblage in Perth's remnant bushlands suggests that many of the ecosystem processes remain intact (How and Dell, 2000).

The objective of the field surveys was to sample terrestrial vertebrate fauna. As such, a systematic survey for the invertebrates and fish of the fauna study area was not conducted. Conservation significant invertebrates and fish species identified in the desktop assessment were assessed on their likelihood of occurrence in the fauna study area based on the habitats present, current distribution and relevance of previous records. The DEC conducted a terrestrial invertebrate biodiversity assessment for the GSS, which identified three conservation significant invertebrates as currently occurring on the northern SCP (Wilson and Valentine, 2009). Of these, only the Priority 4 listed Graceful Sun Moth (*Synemon gratiosa*) occurs in close proximity (within 10 km) of the proposal footprint.

A total of four conservation significant invertebrate species and one conservation significant fish species were identified in the desktop assessment; however, none of them were considered likely to occur in the fauna study area (Appendix G).

Short range endemics (SRE) are species of animal (predominantly Invertebrates) that have a restricted distribution of less than 10,000 km^2 (Harvey, 2002). The desktop review did not identify any conservation significant SREs in the vicinity of the proposal footprint. The Mound Springs SCP TEC located adjacent to the proposal footprint was identified as a location of potential SRE habitat (Wilson and Valentine, 2009). However, the proposal avoided this site during earlier planning studies and will not impact this site. The lack of restricted landforms or habitats and the presence of vegetation units that are contiguous and widespread outside of the proposal footprint limits the likelihood of SREs being confined to the development area (EPA, 2009). Survey methodology focusing on terrestrial vertebrate fauna was reviewed and endorsed by the OEPA. As such, no specific SRE survey was required to comply with the ESD.

A total of 97 species were recorded during both the Level 1 opportunistic survey and Level 2 trapping survey, including one fish, six amphibian, 19 reptile, 62 bird and nine mammal species (Table 9.3) (Appendix G). Of the 97 species recorded during the survey, nine species were introduced.

Table 9.3 Summary of fauna assemblage

Fauna group	Species identified in desktop review	Species recorded in proposal footprint during 2014 survey
Invertebrates	4	0
Fish	5	1
Amphibians	14	6
Reptiles	64	19
Birds	232	62
Mammals	41	9
Total	**360**	**97**

9.2.5 Conservation Significant Fauna

From the database searches a total of 67 conservation significant fauna species listed under the EPBC Act, WC Act or DPAW's Priority listing, have been recorded in the vicinity of the proposal footprint. These include four invertebrate, one fish, four reptile, 47 bird and 11 mammal species. These species were assessed for their likelihood to occur, reviewing each species' current distribution, habitat requirements/relevance and location and age of previous records in the vicinity of the proposal footprint.

Four conservation significant fauna were recorded in the proposal footprint during the survey (Appendix G) (see Figure 9.1):

- Carnaby's Cockatoo (*Calyptorhynchus latirostris*) listed as Endangered (EPBC Act) and Schedule 1 (WC Act).
- Forest Red-tailed Black Cockatoo (*Calyptorhynchus banksii naso*) listed as Vulnerable (EPBC Act) and Schedule 1 (WC Act).
- Australian Bustard (*Ardeotis australis*) listed as Priority 4 (DPAW Priority list).
- Southern Brown Bandicoot (*Isoodon obesulus fusciventer*) listed as Priority 5 (DPAW Priority list).

A further seven species of conservation significance are considered likely to occur in the proposal footprint:

- Great Egret (*Ardea alba*) listed as Migratory (EPBC Act) and Schedule 3 (WC Act).
- Cattle Egret (*Ardea ibis*) listed as Migratory (EPBC Act) and Schedule 3 (WC Act).
- Rainbow Bee-eater (*Merops ornatus*) listed as Migratory (EPBC Act) and Schedule 3 (WC Act).
- Western Carpet Python (*Morelia spilota imbricata*) listed as Schedule 4 (WC Act).
- Jewelled Sandplain Ctenotus (*Ctenotus gemmula*) listed as Priority 3 (DPAW Priority list).
- Black-striped Snake (*Neelaps calonotos*) listed as Priority 3 (DPAW Priority list).
- Western Brush Wallaby (*Macropus irma*) listed as Priority 4 (DPAW Priority list).

9.2.6 Locally and Regionally Significant Fauna

Fauna of local and regional significance for the proposal are defined as species that have distributions restricted to the SCP or species whose populations/distributions have declined on the SCP since European settlement (Government of Western Australia, 2000b; Wilson and Valentine, 2009). Locally or regionally significant species are not listed under Commonwealth or State legislation or under DPAW's Priority species list.

A total of 22 species considered to be locally or regionally significant were recorded within the proposal footprint during the survey. These include:

- Common species with distributions restricted to the SCP (as defined in Wilson and Valentine, 2009): One amphibian *Crinia insignifera* and two reptiles *Ctenophorus adelaidensis* and *Hemiergis quadrilineata*.
- Species that are rare on the SCP but common elsewhere (as defined in Government of Western Australia, 2000b): Two reptiles *Varanus tristis* and *Parasuta gouldii*.
- Species that are habitat specialists with a reduced distribution on the SCP (as defined in Government of Western Australia, 2000b): Nine birds including the Common Bronzewing, Splendid Fairy-wren, White-browed Scrubwren, Weebill, Western Thornbill, Yellow-rumped Thornbill, Scarlett Robin, Hooded Robin and Grey Shrike-thrush.
- Wide-ranging species with reduced populations on the SCP (as defined in Government of Western Australia, 2000b): Eight birds including the Emu, Brown Goshawk, Little Eagle, Wedge-tailed Eagle, Brown Falcon, New Holland Honeyeater, Western Little Wattlebird and Black-faced Woodswallow.

9.2.7 Fauna Movement Survey

A specific fauna movement survey (see Appendix G) conducted on the vehicle tracks directly adjacent to the Maralla Road Bushland (approximately 500 m in length) and Whiteman Park/Cullacabardee Bushland (approximately 1,800 m in length) was used to identify areas of high fauna traffic (Figure 9.3). This survey identified fresh animal tracks and sorted them into fauna class and frequency of movement. This data will be used to recommend the appropriate locations and types of fauna movement corridors or mechanisms. Only ground dwelling native species were recorded during the fauna movement survey as these are the target species for any potential fauna movement corridors.

A total of 255 fauna crossings were recorded at the Whiteman Park/Cullacabardee Bushland during the survey with the vast majority of records belonging to Western Grey Kangaroos (83%) followed by Bobtail Skinks (12%). Smaller skinks (3%), snakes (1.5%) and a Goanna (0.5%) were also recorded crossing the track at this location, but in much lower numbers. Analysis of the Whiteman Park/Cullacabardee site indicated a total of nine hotspots (99% confidence interval), two located north of Baal Road and seven concentrated towards the southern section of the track (see Figure 9.3).

A total of 99 fauna crossings were recorded at the Maralla Road Bushland during the survey with the vast majority of records belonging to Western Grey Kangaroos (70%) followed by Bobtail Skinks (26%), smaller Skinks (2%), an Emu (1%) and a Goanna (1%). Analysis of the Maralla Road site had shown that two hotspots (99% confidence interval) were recorded along the track. One hotspot was located adjacent to the Dampland habitat and the other halfway along the track towards Maralla Road (see Figure 9.3).

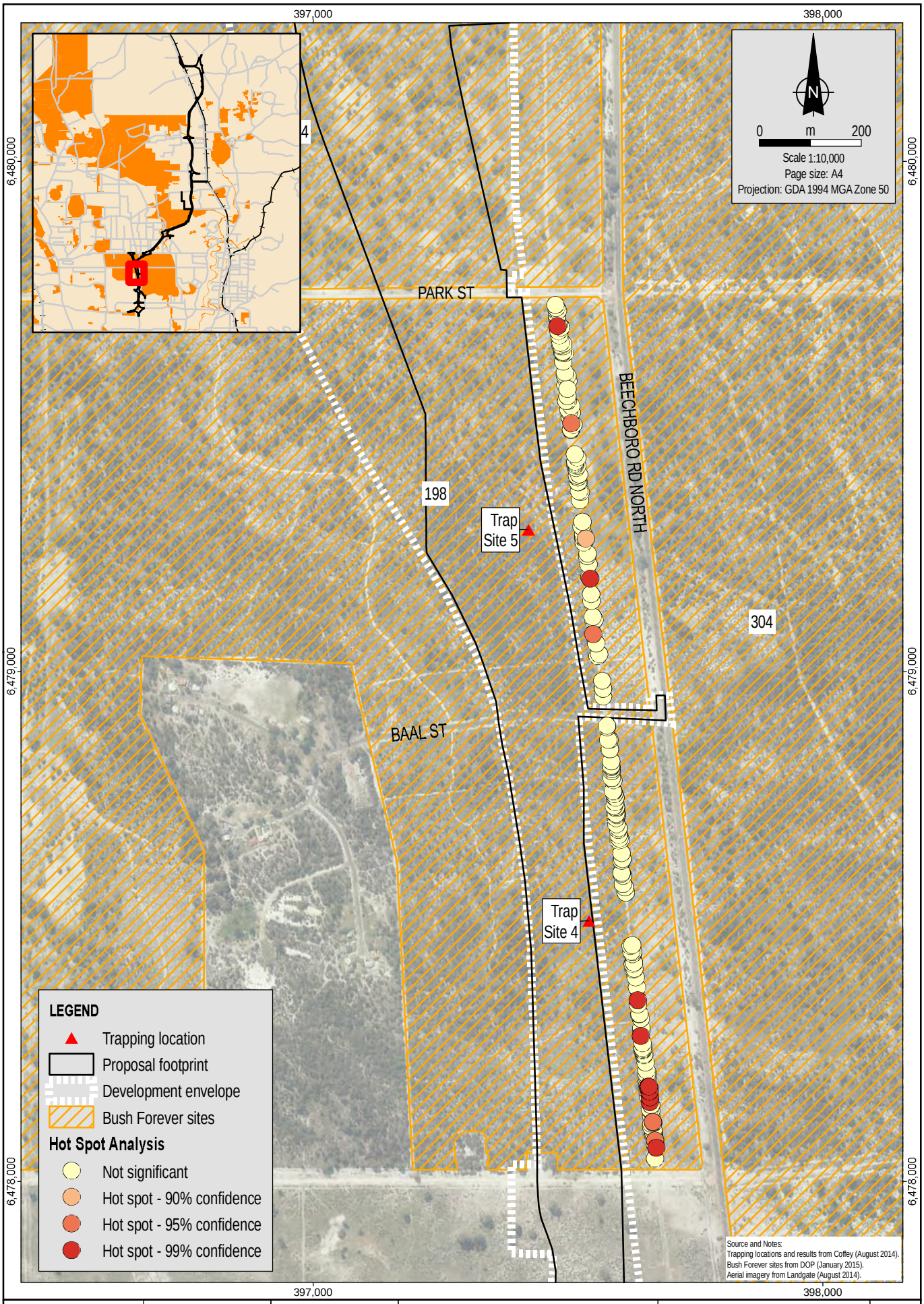
9.2.8 Ecological Connectivity

A combination of aerial photographs, ground-truthing, assessment of the Perth regional ecological linkages report (Brown et al., 2009) and consultation with the OEPA was used to identify areas of importance in regards to ecological linkages. The main areas of focus included Maralla Road Bushland and Whiteman Park/Cullacabardee Bushland, which have been previously identified as an "existing or potential bushland/wetland linkage" (Government of Western Australia, 2000). A number of priority listed ground dwelling fauna have previously been recorded in the surrounding area, namely the Jewelled Sandplain Ctenotus, Southern Brown Bandicoot and Western Brush Wallaby. These sites were surveyed for their potential to provide ecological linkages and encourage safe fauna movement.

The proposal is located within an existing road reserve at Maralla Road Bushland (Government of Western Australia, 2000b). This site provides an ecological linkage to Bush forever sites 300 and 301 in the east and 300 and 399 to the west (Government of Western Australia, 2000b). The section of vegetation that exists between the Ellenbrook Estate and Maralla Road acts as a bottleneck that restricts access to large areas of native vegetation in both an eastern and western direction, including Melaleuca Park Bushland, Ellenbrook Nature Reserve and Walyunga National Park (Figure 9.4).

The Cullacabardee Bushland forms part of an ecological linkage with the greater Whiteman Park Nature Reserve (Government of Western Australia, 2000b), which extends both east and west of the proposal (see Figure 9.4).

The Dampland and Eucalypt/Corymbia Woodland at the Tonkin Highway/Reid Highway intersection (Micro Gardens Park) maintains a level of ecological connectivity between Lightning Swamp Bushland, Malaga Regional Space and Koondoola Regional Bushland to the west, and Point Reserve to the east. This site has been identified as being part of a "regionally significant fragmented bushland/wetland linkage" (Government of Western Australia, 2000b). Diggings attributed to the conservation significant Southern Brown Bandicoot (P5) were recorded in the Micro Gardens Park and the road reserve near the Reid Highway/Altone Road intersection (see Figure 9.1). Although heavily degraded, the vegetation of the road reserve provides an ecological linkage between areas of suitable habitat.



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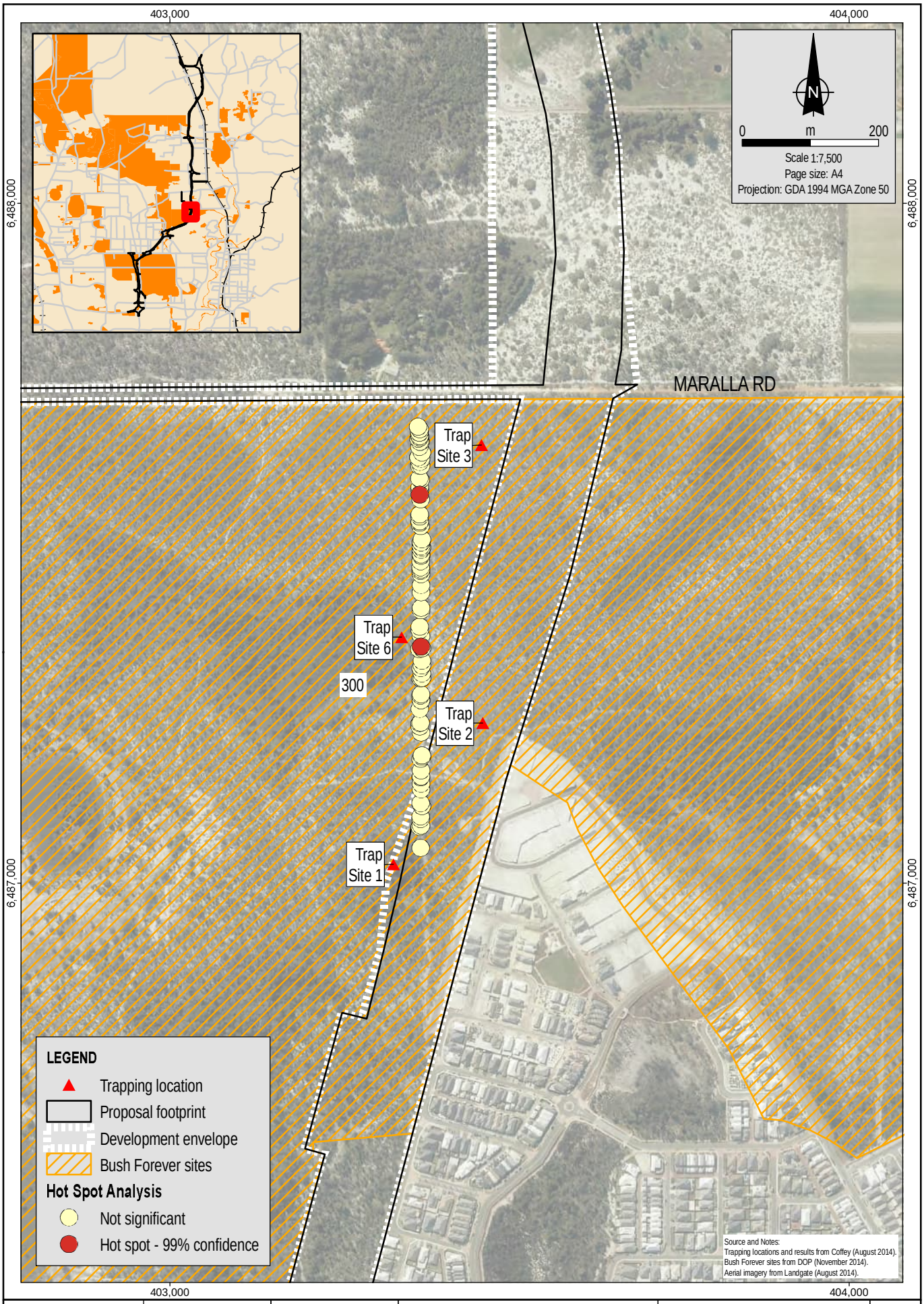

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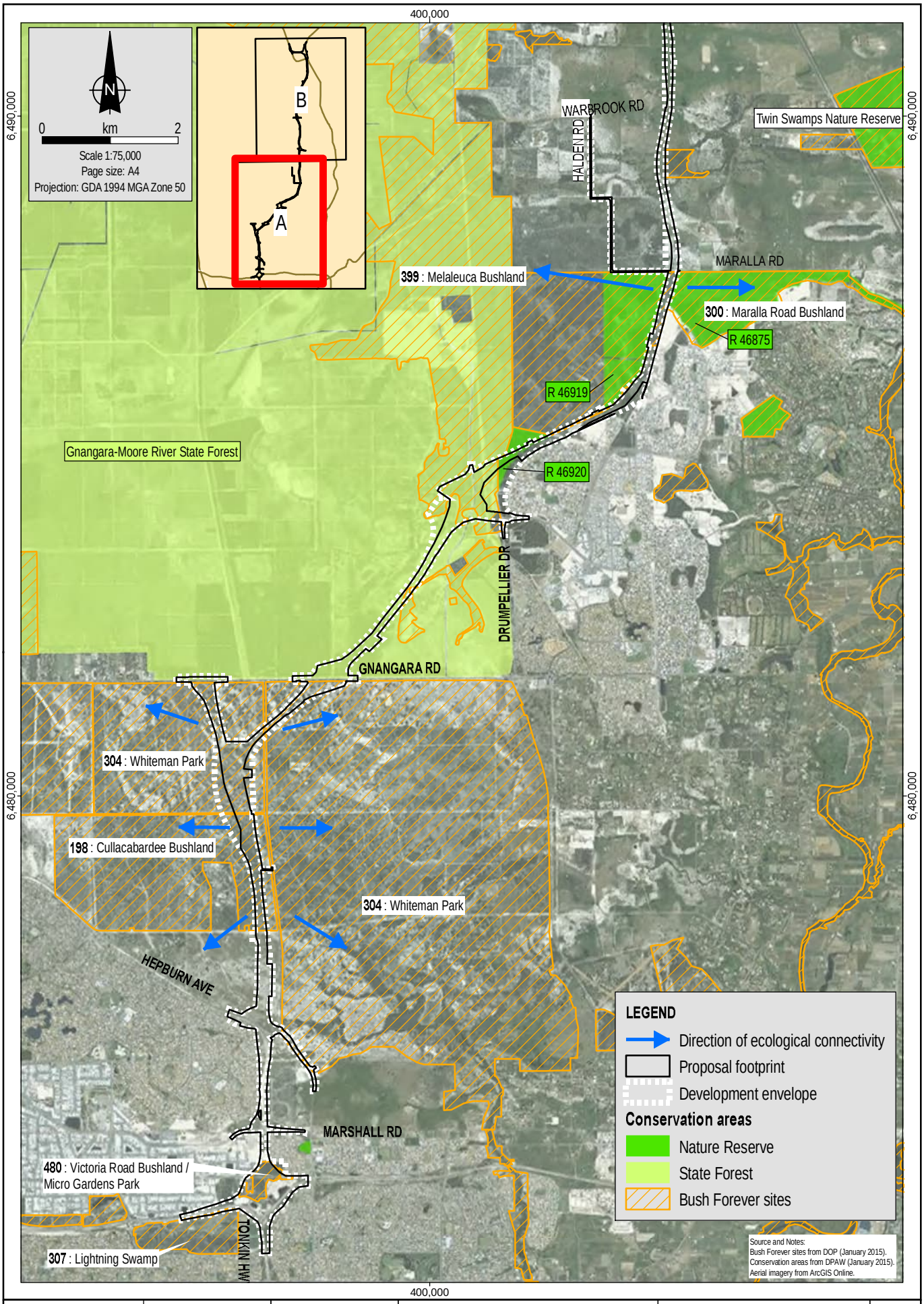

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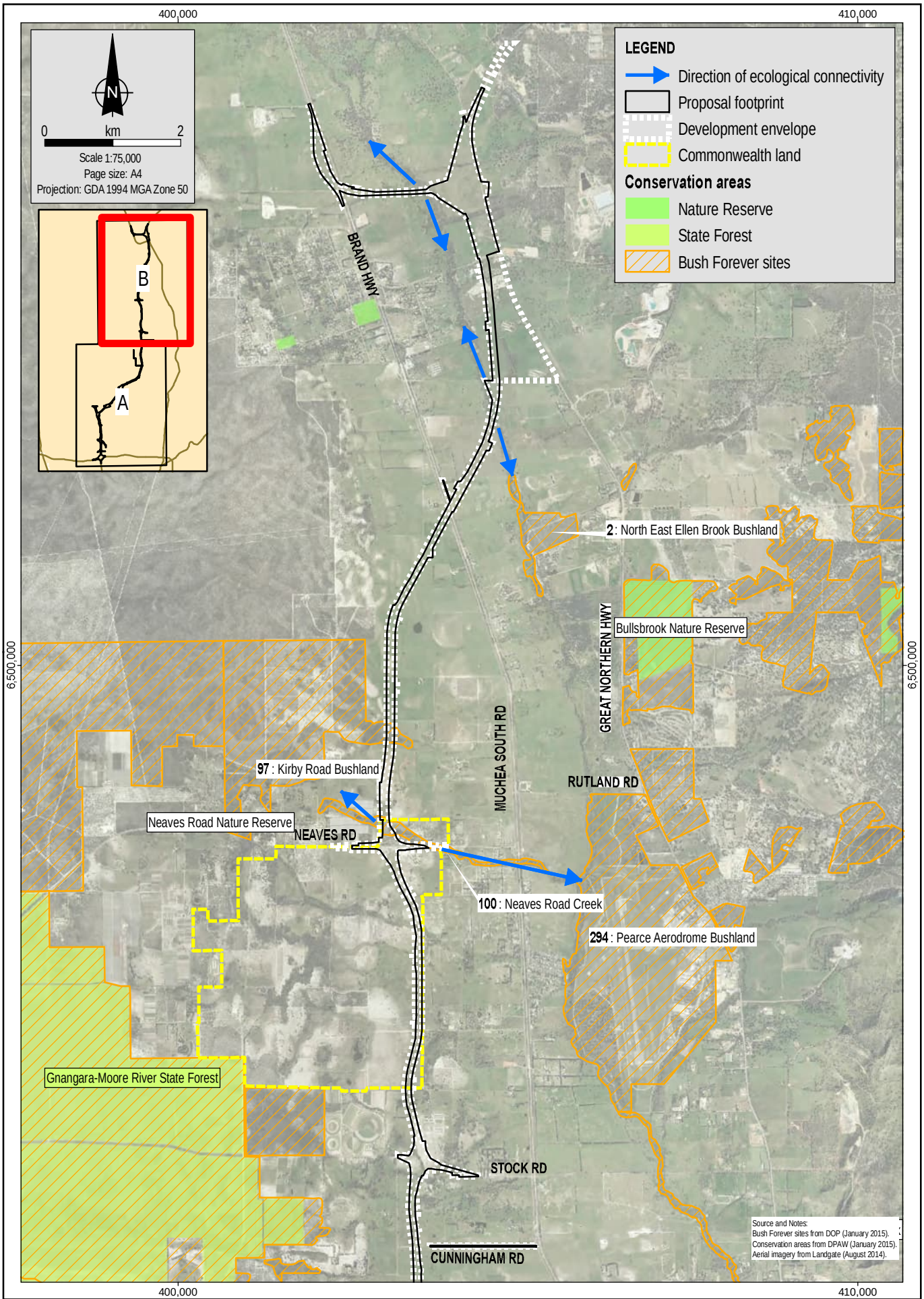

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9.3 Potential Impacts

The proposal has the potential to impact a number of fauna habitats, fauna assemblages and conservation significant fauna during the construction and operation phases.

The following impacts are anticipated during the construction phase:

- Habitat loss due to vegetation clearing.
- Habitat fragmentation due to vegetation clearing.
- Disturbance to waterbirds (including migratory species) from impacts to wetlands.
- Fauna mortalities primarily due to clearing activities.
- Feral predation of displaced fauna by Red Foxes and Cats.
- Accidental fire during construction activities.
- Light and noise as a result of machinery and construction activities.

The following impacts are anticipated during the operation phase:

- Habitat fragmentation.
- Severing of ecological connectivity.
- Fauna mortalities from fauna/vehicle interactions.
- Feral predation by Red Foxes and Cats.
- Habitat degradation, edge effects, weeds, dieback, rubbish and vehicle tracks.
- Increased risk of bushfires due to greater human access to areas of vegetation.
- Light and noise as a result of vehicles along the PDNH.
- Altered surface and groundwater hydrology resulting in habitat degradation.

9.4 Assessment of Potential Impacts

9.4.1 Habitat Loss and Habitat Fragmentation

Due to the localised impact of vegetation clearing and the cumulative impact of the urbanisation of the SCP, habitat loss during construction is considered a major threatening process expected from the proposal. The impact of habitat loss on conservation significant fauna at a local and regional scale is provided in Table 9.4.

As a result of the extended, linear nature of the proposal, habitat fragmentation and the related loss of ecological connectivity is considered a potential significant impact that requires mitigation. Fragmented habitats have an increased risk of loss of genetic diversity and ecological diversity (QDMR, 2000). Along with an increased risk of vehicle collisions and a higher susceptibility to impacts such as fire, disease and predation this could lead to localised extinction (QDMR, 2000). Due to their restricted dispersal abilities, ground dwelling fauna are more likely to be impacted by habitat fragmentation and the loss of ecological connectivity.

Table 9.4 Local and regional context of habitat loss for conservation significant fauna

Species	EPBC Act Conservation significance	State Conservation Significance	Habitat loss due to the proposal	Proportion of habitat loss at a local scale[1]	Proportion of habitat loss at a regional scale[2]
Carnaby's Cockatoo	Endangered	Schedule 1	201.8 ha foraging habitat	2.6%	0.2% at a regional scale 0.04% at a bioregional scale[3]
			58.6 ha roosting habitat	Cannot be calculated	Cannot be calculated
			120.1 ha potential breeding habitat	Cannot be calculated	Cannot be calculated
Forest Red-tailed Black Cockatoo	Vulnerable	Schedule 1	120.1 ha foraging habitat	1.6%	0.1% at a regional scale 0.03% at a bioregional scale[3]
			58.6 ha roosting habitat	Cannot be calculated	Cannot be calculated
			120.1 ha potential breeding habitat	Cannot be calculated	Cannot be calculated
Great Egret	Migratory	Schedule 3	15.5 ha of potential habitat	Cannot be calculated	Cannot be calculated
Cattle Egret	Migratory	Schedule 3	271.2 ha of potential habitat	Cannot be calculated	Cannot be calculated
Rainbow Bee-eater	Migratory	Schedule 3	367.5 ha of potential habitat	4.8%	0.4%
Western Carpet Python		Schedule 4	124.8 ha of potential habitat	1.6%	0.1%
Jewelled Sandplain Ctenotus		Priority 3	81.7 ha of potential habitat	1.1%	0.1%
Black-striped Snake		Priority 3	124.8 ha of potential habitat	1.6%	0.1%
Western Brush Wallaby		Priority 4	124.8 ha of potential habitat	1.6%	0.1%
Southern Brown Bandicoot		Priority 5	19.0 ha of potential habitat	Cannot be calculated	Cannot be calculated

Note: Values that cannot be calculated are due to the lack of information pertaining to the local or regional scale of the specific habitat requirements of that species.

1. Local scale represents the extent of all Bush Forever sites within 1 km of the proposal footprint.
2. Regional scale represents the extent of all Bush Forever sites within 10 km of the proposal footprint.
3. Bioregional scale represents the amount of Black Cockatoo habitat on the SCP.

A total of 159.3 ha of natural fauna habitats will be impacted by the proposal (21.4% of the proposal footprint). The majority of the proposal footprint occurs on secondary fauna habitats and areas classified as infrastructure/cleared. As such, the remaining 586.4 ha (78.6%) of the proposal footprint offers limited/no habitat to fauna. It is expected that the entire proposal footprint will cleared of vegetation and hence all fauna habitats identified in the proposal footprint (see Table 9.1) will be removed.

The 159.3 ha of natural vegetation expected to be cleared is distributed over the majority of the proposal footprint thus dispersing the expected impacts. The proposal will result in a loss of habitat at a local scale, but due to its linear nature, similar surrounding habitat will remain. There are 13 Bush Forever sites located within 1 km of the proposal footprint that collectively contain approximately 7,649 ha of native vegetation (Government of Western Australia, 2000b). The clearing of 159.3 ha of natural vegetation equates to a 2.1% loss at a local scale.

At a regional scale the fauna habitats present in the proposal footprint are common and widespread in the SCP. Approximately 101,000 ha of remnant native vegetation occurs in the GSS (Brown et al., 2009), a 2,200 km^2 section of the northern SCP that includes the proposal and its regional surrounds. The remnant native vegetation of the GSS contains habitats similar to those found in the proposal footprint (Banksia Woodland, Eucalypt/Corymbia Woodland, Dampland and Wetland habitats) and additional habitats that are not represented in the proposal footprint (Wilson and Valentine, 2009). The 159.3 ha of native vegetation to be cleared in the proposal footprint represents approximately 0.2% of the remnant native vegetation in a regional context.

9.4.1.1 Impact on Carnaby's Cockatoo (*Calyptorhynchus latirostris*) and Forest Red-tailed Black Cockatoo (*Calyptorhynchus banksii naso*)

The total population of Carnaby's Cockatoo is approximately 40,000 individuals (Garnett et al., 2011) with approximately 8,000 to 10,000 birds on the northern SCP (Johnstone and Kirkby, 2011). Habitat loss is a known threatening process for this species (DOTE, 2015).

The proposal footprint is situated at the northern extent of the Forest Red-tailed Black Cockatoo's current range (DSEWPAC, 2012c). The total estimated population for this species is approximately 10,000 to 15,000 birds, with the breeding population being as low as 10 to 20% (Johnstone and Kirkby, 2011).

9.4.1.2 Impact on Black Cockatoo Foraging Habitat

The proposal will result in the loss of approximately 201.8 ha (excluding Pine Plantation) of quality foraging habitat for Carnaby's Cockatoos and 120.1 ha of quality foraging habitat for Forest Red-tailed Black Cockatoos (excluding Pine Plantation). Areas adjacent to the proposal footprint such as East Wanneroo, Gnangara and Whiteman Park have been identified as important sites for Carnaby's Cockatoo on the SCP (Johnstone and Kirkby, 2011).

The clearing of foraging habitat in the proposal footprint equates to a loss of approximately 2.6% of the local Carnaby's Cockatoo habitat available within 1 km of the proposal footprint and 0.2% of the regional habitat available within 10 km of the proposal footprint (based upon habitat within Bush Forever sites). There are approximately 474,000 ha of suitable Carnaby's Cockatoo habitat on the SCP (Johnston, 2013). The clearing of 201.8 ha of Carnaby's Cockatoo foraging habitat through the proposal represents 0.04% of the available habitat in a bioregional context.

The clearing of foraging habitat in the proposal footprint equates to a loss of approximately 1.5% of the local Forest Red-tailed Black Cockatoo habitat available within 1 km of the proposal footprint and 0.1% of the regional habitat available within 10 km of the proposal footprint (based upon habitat within Bush Forever sites). The clearing of 120.1 ha of Forest Red-tailed Black Cockatoo foraging habitat through the proposal represents 0.03% of the available habitat in a bioregional context.

The impact on both Black Cockatoo species from the proposal was assessed against the Significant Impact Guidelines 1.1 (DOTE, 2013) in Chapter 16. The proposal will impact critical habitat for the Carnaby's Cockatoo and the Forest Red-tailed Black Cockatoo, which constitutes a significant impact (DPAW, 2013a; Chapman, 2007).

9.4.1.3 Impact on Black Cockatoo Roosting Habitat

The Eucalypt/Corymbia Woodlands and Wetland habitats with stands of tall trees are classified as potential roosting habitat for Black Cockatoos. Black Cockatoos show roost site fidelity and will revisit suitable roost sites (DSEWPAC, 2012c). Due to the absence of significant roost sites in the proposal footprint, limited impacts to roosting habitats are expected. Approximately 58.6 ha of potential roosting habitat is expected to be cleared for the proposal.

9.4.1.4 Impact on Black Cockatoo Breeding Habitat

The Eucalypt/Corymbia Woodland, Modified Vegetation and Wetland habitats with stands of suitably sized trees (118.2 ha) are classified as potential breeding habitat and are mapped as high value. In total 120.1 ha of potential breeding habitat for Black Cockatoos is expected to be cleared for the proposal.

The proposal footprint contains 737 trees that have a DBH over 500 mm. A total of 13 trees that contained suitably sized hollows were located throughout the proposal footprint. All 737 trees of suitable size, including the 13 trees with suitable sized hollows, are expected to be cleared for the proposal.

As the proposal footprint is not known as a current breeding site, the impact on Black Cockatoo breeding is not immediate.

9.4.1.5 Impact on the Great Egret (*Ardea alba*)

The Great Egret has been previously recorded at Lightning Swamp, Whiteman Park, Bennett Brook, Waltham Reserve and Malaga Regional Open Space, which are all directly adjacent to the proposal footprint (DPAW, 2014c).

The Great Egret occurs throughout Australia with Western Australian populations occurring across the greater part of the state, except the arid eastern interior (Johnstone and Storr, 1998). The Great Egret inhabits mostly shallow fresh lakes, pools in rivers, lagoons, lignum swamps, clay pans and samphire flats, large dams and sewage ponds (Johnstone and Storr, 1998). The Wetland habitats of the proposal footprint provide suitable habitat for this species. As such, approximately 15.5 ha of suitable habitat for this species will be cleared by the proposal.

This species is not considered susceptible to habitat fragmentation effects as it is highly mobile (DOTE, 2014d) and no significant nesting sites are known from the SCP. As such, impacts to this species are likely to be limited to local scale habitat loss.

Based upon the Significant Impact Guidelines 1.1 (DOTE, 2013), the proposal footprint does not support an ecologically significant proportion of this species, contain critical habitat, occur at the limit of this species' range or occur within an area where this species is declining. As such, the proposal will not create a significant impact to this relatively common and widespread species.

9.4.1.6 Impact on the Cattle Egret (*Ardea ibis*)

The Cattle Egret has been previously recorded from the Lake Joondalup area, which is approximately 10 km west of the proposal footprint (DPAW, 2014d).

A Cattle Egret was recorded foraging in pastures adjacent to the proposal footprint during the survey period. The Cattle Egret inhabits pastures, garbage tips, crops, wetlands, tidal flats and drains (Pizzey and Knight, 2007). The Wetland and Paddock habitat types provide suitable habitat for this species. As such, approximately 271.2 ha of suitable habitat for this species is expected to be cleared by the proposal.

The Cattle Egret occurs in the wetter parts of WA and also in Northern and Eastern Australia, New Zealand and Southeast Asia (Johnstone and Storr, 1998). Due to its cosmopolitan distribution and mobile nature, this species will not be impacted as a result of loss of habitat.

Based upon the Significant Impact Guidelines 1.1 (DOTE, 2013), the proposal footprint does not support an ecologically significant proportion of this species, contain critical habitat, occur at the limit of this species' range or occur within an area where this species is declining. As such, the proposal will not create a significant impact to this relatively common and widespread species.

9.4.1.7 Impact on the Rainbow Bee-eater (*Merops ornatus*)

The Rainbow Bee-eater is one of the most widespread bird species in Australia (Barrett et al., 2003) occurring across the country in a range of habitats. This species has previously been recorded on numerous occasions in the vicinity of the proposal footprint (DPAW, 2014c, d).

The Rainbow Bee-eater is considered likely to occur in the proposal footprint across all fauna habitat types including the secondary habitat type of Modified Vegetation. A total of 367.5 ha of suitable habitat for this species will be impacted by the proposal. This equates to a loss of approximately 4.8% of the local habitat available within 1 km of the proposal footprint and 0.4% of the regional habitat available within 10 km of the proposal footprint (based upon habitat within Bush Forever sites).

Due to the common occurrence, widespread distribution and mobile nature of this species, the impact due to loss of suitable habitat in the proposal footprint is expected to be negligible.

Based upon the Significant Impact Guidelines 1.1 (DOTE, 2013), the proposal footprint does not support an ecologically significant proportion of this species, contain critical habitat, occur at the limit of this species' range or occur within an area where this species is declining. As such, the proposal will not create a significant impact to this relatively common and widespread species.

9.4.1.8 Impact on the Western Carpet Python (*Morelia spilota imbricata*)

The Western Carpet Python has previously been recorded (from only one record) approximately 15 km west of the proposal footprint (GHD, 2013c). Habitat destruction is a known threatening process for the Western Carpet Python (Pearson, 2005; DEC, 2012b).

It is a widespread subspecies that occurs across the southern portion of Western Australia (Bush et al., 2010). As such, the loss of suitable habitat from the proposal is expected to be negligible at a regional scale.

This species requires large areas of undisturbed bushland (Bush et al., 2007) and as such the most likely location for it to occur in the proposal footprint is the Banksia Woodland and Eucalypt/Corymbia Woodland of the Maralla Road Bushland. A total of 124.8 ha of suitable habitat for this species will be impacted by the proposal. This equates to a loss of approximately 1.6% of the local habitat available within 1 km of the proposal footprint and 0.1% of the regional habitat available within 10 km of the proposal footprint (based upon habitat within Bush Forever sites).

Only one record of this species has occurred in the vicinity of the proposal footprint (GHD, 2013a). This is an isolated record with no additional records in the vicinity (DPAW, 2014d). As such, the loss of ecological connectivity, habitat loss and fragmentation from the proposal is unlikely to significantly impact this species.

9.4.1.9 Impact on the Jewelled Sandplain Ctenotus (*Ctenotus gemmula*)

There have been recent records of the Jewelled Sandplain Ctenotus occurring in bush associated with the proposal footprint such as Whiteman Park and Maralla Road Bushland (Bush et al., 2010).

This species is scarce on the SCP as it is the northern extent of its range (Bush et al., 2010). Populations also occur along the south coast of WA from Rocky Lake to Toolina Cove (Storr et al., 1999). Even though the occurrence of this species is scarce on the SCP the proposal is unlikely to impact this species at a regional level due to its extended distribution.

The Jewelled Sandplain Ctenotus is considered likely to occur in the Banksia Woodland of the proposal footprint. A total of 81.7 ha of suitable habitat for this species will be cleared by the development of the proposal. This equates to a loss of approximately 1.1% of the local habitat available within 1 km of the proposal footprint and 0.1% of the regional habitat available within 10 km of the proposal footprint (based upon habitat within Bush Forever sites). Impacts to this species from the loss of habitat, loss of ecological connectivity and habitat fragmentation are expected to be restricted to a local scale.

9.4.1.10 Impact on the Black-striped Snake (*Neelaps calonotos*)

The Black-striped Snake occurs only along the SCP with the bulk of this species' known distribution occurring in the Perth region. However, there have been recent records of this species further north near Dongara and Eneabba, suggesting it has a broader distribution (Bush et al., 2010). This species inhabits coastal dunes and Eucalypt/Banksia Woodlands (Bush et al., 2010) and it has been recorded directly adjacent to the proposal footprint in Ellenbrook and Muchea (DPAW, 2014d).

Even though this species has a limited distribution, the loss of suitable habitat in the proposal footprint is expected to be negligible at a regional scale due to the widespread occurrence of suitable habitat.

A total of 124.8 ha of suitable habitat for this species (Banksia Woodland and Eucalypt/Corymbia Woodland of the proposal footprint) will be cleared by the development of the proposal. This equates to a loss of approximately 1.6% of the local habitat available within 1 km of the proposal footprint and 0.1% of the regional habitat available within 10 km of the proposal footprint (based upon habitat within Bush Forever sites).

As this species is a ground dwelling reptile with limited dispersal abilities, cumulative habitat fragmentation is a risk to the local populations of this species. Impacts to this species from the loss of habitat, loss of ecological connectivity and habitat fragmentation are expected to occur at a local scale.

9.4.1.11 Impact on the Australian Bustard (*Ardeotis australis*)

This species was recorded on a road reserve adjacent to the proposal footprint in Bullsbrook (see Figure 9.1) and has also previously been recorded at Whiteman Park (Coffey, 2015c).

The Australian Bustard is a wide-ranging species that occurs over the majority of Australia apart from the southwest and southeastern areas. It inhabits open grass plains, low shrublands and grassy open woodlands (Ziembicki, 2010).

The Australian Bustard is a highly nomadic species and the records are of vagrant individuals rather than populations occurring in the vicinity of the proposal footprint. As such, significant impacts to this species from the proposal will not occur.

9.4.1.12 Impact on the Western Brush Wallaby (*Macropus irma*)

The Western Brush Wallaby has previously been recorded in Whiteman Park, Cullacabardee and Ellenbrook, all of which are adjacent to the proposal footprint (DPAW, 2014c).

This species occurs in southwestern Australia from Kalbarri in the north to Cape Arid in the south (Woinarski et al., 2014). As such, the loss/impact upon suitable habitat in the proposal footprint is expected to be negligible at a regional scale. The Banksia Woodland and the Eucalypt/Corymbia Woodland around Cullacabardee and Maralla Road Bushlands provide suitable habitat for this species. As such, approximately 124.8 ha of potential habitat will be impacted by the proposal. This equates to a loss of approximately 1.6%

of the local habitat available within 1 km of the proposal footprint and 0.1% of the regional habitat available within 10 km of the proposal footprint (based upon habitat within Bush Forever sites).

Impacts to this species from the loss of habitat, loss of ecological connectivity and habitat fragmentation are not expected to be significant and only occur at a local scale.

9.4.1.13 Impact on the Southern Brown Bandicoot (*Isoodon obesulus fusciventer*)

This species has previously been recorded in Aveley, Beechboro, Bullsbrook, Whiteman, Caversham and Ellenbrook, all of which are all adjacent to the proposal footprint (DPAW, 2014c). Three individuals were captured at trap site 6 (next to the proposal footprint) during the trapping program and diggings were recorded at Micro Gardens Park and in the road reserve alongside Reid Highway (see Figure 9.1).

The West Australian subspecies is distributed along the coast from Guilderton to Esperance (DPAW, 2014d). As such, the impacts to this species at a regional level from the proposal are not considered significant and are unlikely to alter the conservation significance of this species.

A total of 19 ha of suitable habitat (classified as Dampland habitat) will be impacted by the development of the proposal. Local populations of this species are likely to be impacted by this development, as they are a ground dwelling species with poor dispersal abilities and are predominantly found in the restricted environs of the Dampland habitats. In particular the population recorded at Micro Gardens Park may be affected as there are restricted dispersal opportunities in the area and the majority of the vegetation in this area will be cleared. The population size in the Dampland habitat in the Maralla Road Bushland is unknown; however, due to this habitat occurring adjacent to the proposal footprint the species will potentially be affected by habitat fragmentation.

9.4.1.14 Impact on Locally and Regionally Significant Fauna

All of the locally and regionally significant fauna recorded in the proposal area are considered common either on the SCP or within other portions of their distributions. As such, the proposal will not increase the level of significance of these species. Impacts to these species due to the loss of habitat in the proposal footprint are expected to be negligible at a regional scale due to the widespread occurrence of suitable habitat for these species.

Impacts to these species from the loss of habitat, loss of ecological connectivity and habitat fragmentation caused by the proposal are restricted to the local scale and not expected to be significant.

9.4.2 Fauna Mortalities

The proposal will bisect areas of intact vegetation in particular around the Whiteman Park/Cullacabardee Bushland and Maralla Road Bushland. There is considerable potential for an increase in vehicle/fauna interactions during the operation phase of this proposal.

For common animals, particularly smaller species, road mortalities do not exert a significant pressure on population dynamics or conservations status (QDMR, 2000). However, for large fauna, particularly those with restricted and declining distributions and those that have repeated and regular contact with roads, there is evidence that road mortalities can significantly impact populations (QDMR, 2000). As such, populations of the Western Brush Wallaby and the Southern Brown Bandicoot are more susceptible to the effects of road mortalities during the operation phase of the proposal than the more common species. Birds of prey and other scavenging fauna will be attracted to road kill and may themselves fall victim to vehicle collisions.

Black Cockatoo species often forage on roadside vegetation and due to their large size have a tendency to fly low, particularly after take-off. This characteristic means these species are susceptible to vehicle collisions (Saunders et al., 2011).

Fauna mortalities are expected to occur during the construction phase as machinery clears trees and vegetation. This may particularly include species that reside in trees and hollows. Ground dwelling fauna are at higher risk of mortality during the construction phase due to their limited ability to disperse away from habitats as they are being cleared.

9.4.3 Feral Predation

During both the construction and operation phases the clearing of native vegetation, habitat degradation and fencing along the perimeter may lead to increased predation from Red Foxes and Cats. The movement of introduced predators is often facilitated through the clearing of natural vegetation (QDMR, 2000). Both the Red Fox and Cat were regularly recorded in the fauna survey (Coffey, 2015b). Ground dwelling native fauna are most at risk of increased predation as the level of protection provided by current fauna habitats will be decreased through vegetation clearing.

9.4.4 Habitat Degradation

During its operation phase the proposal will potentially increase degradation to the surrounding fauna habitats, including creating new areas of edge effects. Edge effects occur when fragmented habitats are further degraded by indirect impacts. By creating greater human access to fauna habitats the proposal may lead to an increase in anthropogenic factors such as rubbish, the spread of weeds and dieback, off-road vehicle access and chemical pollution. These impacts can be cumulative and result in the degrading of fauna habitats and their ability to support the resident fauna populations.

Habitat degradation is a known threatening process for both the Carnaby's Cockatoo and the Forest Red-tailed Black Cockatoo (DOTE, 2014e, 2015).

Factors involved in habitat degradation are already prevalent in the vicinity of the proposal footprint with rubbish, weeds, dieback, off road vehicle access all being recorded in the proposal footprint during the survey (Coffey, 2015b). As the proposal will not be the sole source of the factors creating habitat degradation, the extent and significance of impacts from the proposal on fauna habitats and the fauna assemblage they support is difficult to assess. However, the proposal is likely to constitute a small negative cumulative effect in degrading fauna habitats.

Edge effects will potentially be increased along areas of significant habitat such as Maralla Road Bushland and Whiteman Park/Cullacabardee Bushland, adding to the impacts already present. The proposal is likely to create a small negative cumulative effect in these areas by degrading the surrounding fauna habitats.

9.4.5 Altered Fire Regimes

Fires are a natural part of many ecosystems in Australia; however, the increased frequency, intensity and duration of manmade fires can cause impacts through habitat loss or fragmentation (temporary) or direct fauna mortalities. The proposal may increase the risk of accidental and deliberately lit fires (during the operation phase) as the proposal allows greater access into areas of native vegetation, including areas of significant habitat such as Maralla Road Bushland and Whiteman Park/Cullacabardee Bushland.

Fire and its associated habitat loss, including the destruction of suitable breeding hollows, is listed as a threat to Carnaby's Cockatoo and Forest Red-tailed Black Cockatoo (Cale, 2003; DOTE, 2014e).

9.4.6 Impact from Light and Noise

The artificial lighting, mechanical noise and road noise caused during the construction and operation phases of the proposal may impact fauna in the vicinity of the proposal. The extent of effect of these impacts is difficult to assess as the impact from these is relatively unknown (QDMR, 2000). These impacts may disrupt the natural behaviour of fauna in the close vicinity to the proposal. Impacts to fauna behaviour can include the disorientation of migratory or nocturnal fauna, increased levels of physiological stress, the avoidance of habitats close to the proposal and the abandoning of previously used roost or nest sites. The

impacts to fauna, including those to populations in the Maralla Road Bushland and Whiteman Park/Cullacabardee Bushland, from light and noise are considered to be minimal considering the prevalence of similar impacts surrounding the proposal footprint.

9.4.7 Impacts from Changes to Hydrological Conditions

The proposal may disrupt the surface flow of water or lower local ground water levels. This could affect groundwater-dependent vegetation particularly around Wetland and Dampland habitats, in turn causing habitat degradation and reducing the ability of these habitats to support fauna such as the Great Egret, Cattle Egret and Southern Brown Bandicoot.

Seven groundwater dependent plant species that are known foraging and breeding resources for Black Cockatoos were recorded in the proposal footprint:

- *Banksia attenuata* – groundwater dependent facultative).
- *Banksia ilicifolia* – groundwater dependent (obligate).
- *Banksia littoralis* – groundwater dependent (obligate).
- *Banksia menziesii* – groundwater dependent (facultative).
- *Corymbia calophylla* – groundwater dependent (facultative).
- *Eucalyptus rudis* – groundwater dependent (obligate).
- *Eucalyptus todtiana* – groundwater dependent (facultative).

Disruption to the hydrological regime due to the development is unlikely to significantly impact the productivity and survival of these plant species, and is therefore unlikely to reduce the amount or quality of Black Cockatoo foraging and breeding resources in the local area. Impacts to the hydrological regime will be temporary in nature during construction, and the extent of the hydrological change is unlikely to impact these deep rooted groundwater dependent species.

The critically endangered Western Swamp Tortoise occurs at only four locations. Two of these (Ellen Brook Nature Reserve and Twin Swamps Nature Reserve) are within 6 km of the proposal footprint.

Due to the close proximity of the proposal footprint to sensitive habitat (the Twin Swamps Nature Reserve and Ellen Brook Nature Reserve) and the conservation significance of this species, an analysis on the potential impact to these habitats from changes to hydrological conditions was undertaken. The potential impacts to Western Swamp Tortoise habitat and groundwater dependent vegetation are addressed further in Chapter 10.

9.4.8 Impact on Ecological Connectivity

As the proposal is an extended linear development, the loss of ecological connectivity is a major potential impact affecting the fauna values of areas surrounding the alignment. The proposal predominantly extends north-south, potentially limiting the ecological connectivity in an east/west direction. For the majority of the proposal footprint, the loss of ecological connectivity is not an issue as the final preferred alignment occupies already highly impacted areas (modified vegetation, cleared areas, paddocks etc.) or abuts existing infrastructure (Ellenbrook and Malaga housing estates). Whiteman Park/Cullacabardee Bushland, Maralla Road Bushland and the areas surrounding Micro Gardens Park were identified as being at risk of loss of ecological connectivity.

Impacts created by fragmented ecosystems include:

- Restricted dispersal – Potential loss of territory and inability to find a mate, due to the increased size of roads and volume of traffic in the area.

- Loss of genetic diversity – Potential for the limiting of gene flow between populations, which can lead to an increased risk of inbreeding and a higher susceptibility to impacts such as disease, droughts and fires.
- Loss of ecological diversity – Local extinctions of specific species could reduce the faunal assemblage of the remnant vegetation in the area, which can lead to a reduction in functionality within an ecosystem.
- Increased risk of vehicle collision – Higher levels of traffic on surrounding roads and wider stretches of roads can lead to increased fauna mortalities.
- Higher susceptibility to impacts – Impacts such as fire, disease and feral predation can lead to localised extinction.

Impact on Maralla Road Ecological Connectivity

The Maralla Road Bushland forms part of an ecological linkage in an east-west direction including Bush Forever sites 300, 301 and 399, Ellenbrook Nature Reserve and Walyunga National Park. The maintenance of ecological connectivity at the Maralla Road site is important due to the bottleneck that occurs between Ellenbrook Estate and Maralla Road, which is only 500 m wide (see Figure 9.3). This ecological linkage is one of the few existing on the eastern side of the SCP that connects to the Darling Range and is seen as a linkage of high importance (Brown et al., 2009).

Almeria Parade, Maralla Road, cleared agricultural land and the Ellenbrook housing estate are the existing causes of the restriction in ecological connectivity at a local level. The proposal will create a further barrier to ecological connectivity, primarily in an east-west direction.

The proposal intersects a portion of approximately 500 m of native vegetation at this site (Banksia Woodland and Eucalypt Woodland) (see Figure 9.3). A number of priority listed ground dwelling fauna have previously been recorded in the surrounding area, namely the Jewelled Sandplain Ctenotus, Southern Brown Bandicoot and Western Brush Wallaby. The populations of these species and the faunal assemblage of the surrounding areas will potentially be impacted by the development unless connectivity can be maintained.

Impact on Whiteman Park/Cullacabardee Bushland Ecological Connectivity

The Cullacabardee Bushland forms part of an ecological linkage with the greater Whiteman Park Nature Reserve, which extends both east and west of the proposal and has previously been identified as an "existing or potential bushland/wetland linkage" (Government of Western Australia, 2000b).

The native vegetation occurring through the core areas of Whiteman Park (including Cullacabardee Bushland) has been identified as providing connectivity between the coast and the hills (east-west) and north-south directions (Brown et al., 2009). The proposal will create a barrier, cutting ecological connectivity in an east-west direction and to a lesser degree the north-south direction. Beechboro Road North, Gnangara Road, degraded vegetation, vehicle tracks and the fences either side of the road already create barriers to ecological connectivity at a local level, particularly for ground dwelling fauna.

The proposal intersects a portion of a strip of approximately 1,800 m of native vegetation at this site (Banksia Woodland and Eucalypt Woodland) (see Figure 9.3). A number of priority listed ground dwelling fauna have been previously recorded in the surrounding area, namely the Jewelled Sandplain Ctenotus, Southern Brown Bandicoot and Western Brush Wallaby. The populations of these species and the faunal assemblage of the surrounding areas will potentially be impacted by the development.

Impact on Micro Gardens Park Ecological Connectivity

The Dampland and Eucalypt/Corymbia Woodland at the Tonkin Highway/Reid Highway intersection (Micro Gardens Park) maintains a level of ecological connectivity between Lightning Swamp Bushland, Malaga Regional Space and Koondoola Regional Bushland to the west and Point Reserve to the east (see Figure 9.3). This site has been identified as being part of a "regionally significant fragmented bushland/wetland linkage" (Government of Western Australia, 2000b). Diggings attributed to the Southern Brown Bandicoot were recorded in the Micro Gardens Park and the road reserve near the Reid Highway/Altone Road intersection (see Figure 9.3). Although heavily degraded, the vegetation of the road reserve provides an ecological linkage between areas of suitable habitat.

The proposal will require the clearing of some of the roadside vegetation along Tonkin Highway and Reid Highway. This will impact the resident fauna in this area by restricting/cutting the ecological linkage along approximately 4.5 km of the existing roadside vegetation that occurs between the remnant bushland in the area. The ecological linkages present are already limited due to the presence of numerous roads and the degraded nature of roadside vegetation. The level of ecological linkage still maintained is unknown; however, the presence of Southern Brown Bandicoot diggings (see Figure 9.1) and other fauna recorded using the roadside vegetation suggests that it provides some level of ecological linkage.

9.5 Mitigation and Management

To reduce the proposal's impacts to existing fauna values, the mitigation hierarchy (i.e. avoid, minimise, rehabilitate and offset) discussed in Chapter 7 has been applied during proposal design and in the development of appropriate mitigation and management strategies and offsets.

To avoid ecologically sensitive areas, the road alignment and design has been altered throughout the planning of the proposal (for further information also refer to Chapters 3 and 4).

To avoid impacts to habitat for the Critically Endangered Western Swamp Tortoise at Twin Swamps Nature Reserve, the interchange at Warbrook Road was relocated to Stock Road.

To avoid an area containing a high concentration of Black Cockatoo breeding trees, the width of the proposal footprint was reduced between Baal Street and Gnangara Road (see Figure 4.3). The updated proposal footprint design reduced the number of breeding trees cleared from 410 to 342 (a reduction of 68 breeding trees).

The proposal alignment predominantly follows existing infrastructure, cleared areas or secondary habitats, which reduces impacts to existing fauna habitats. A total of 586.4 ha or 78.6% of the proposal footprint occurs on these disturbed areas that offer little or no habitat for fauna.

Through design efficiencies the proposal design has been reduced from 1,028.4 ha (fauna study area/ development envelope) to about 745.7 ha in size (proposal footprint), which equates to a 282.7 ha reduction. The smaller design footprint reduces impacts to natural fauna habitats by a total of 49.6 ha across the alignment (Table 9.5).

Table 9.5 Reduction of impacts per habitat type

Habitat type	Area in study area (ha)	Area in proposal footprint (ha)	Impact reduction (%)
Natural fauna habitats			
Banksia Woodland	96.3	81.7	15.2%
Eucalypt/Corymbia Woodland	63.7	43.1	32.3%
Dampland	27.1	19.0	29.9%
Wetland	21.8	15.5	28.9%
Secondary habitats			
Modified Vegetation	303.0	208.2	31.3%
Paddock	331.6	255.7	22.9%
Pine Plantation	69.9	51.0	27.0%
Infrastructure/cleared	115.0	71.5	37.8%
Total	**1,028.4**	**745.7**	**27.5%**

To ensure that impacts to the remaining fauna 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 201.8 ha of Carnaby's Cockatoo foraging habitat; 120.1 ha of Forest Red-tailed Black Cockatoo foraging habitat; and 120.1 ha of breeding habitat (inclusive of 737 potential breeding trees) and 58.6 ha of roosting habitat for both Black Cockatoo species will be removed.
- A maximum of 159.3 ha of natural fauna habitat will be removed.
- Ecological connectivity will be maintained across the PDNH alignment.
- The occurrence of fauna mortality, associated with vegetation clearing, vehicle interaction will be minimised during construction and operation.

While various management measures are proposed in this PER to achieve these desired outcomes, alternative management strategies may arise with further design, investigations and project planning. MRWA is committed to achieving environmental outcomes through 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).

An EMP will be developed and implemented prior to construction and will include measures for mitigating and managing impacts to fauna values particularly in regard to the clearing of vegetation, use of fauna spotters, risk of fire, spread of weeds and dieback, light and noise impacts and the use of fauna fencing.

The mitigation and management strategies summarised below can be applied to achieve the above environmental commitments for fauna values.

9.5.1 Habitat Loss and Habitat Fragmentation

The following mitigation/management measures will reduce the impacts of habitat loss and habitat fragmentation:

- A total of 21 fauna underpasses and two bridges are planned to be constructed in key locations along the alignment. Refer to Section 9.5.8 for details.
- During construction, boundary fencing or flagging will be used to delineate extent of clearing so clearing outside of the specified boundary will not occur.
- Clearing to occur only within construction footprint in Maralla Road Bushland and Whiteman Park/Cullacabardee Bushland where ecological connectivity is paramount.
- An offset site in Chittering has been purchased to offset the impacts of habitat loss from the proposal and includes 673.5 ha of Black Cockatoo habitat. A summary of the fauna values of the offset site is contained in Chapter 17.
- Retain or rehabilitate roadside vegetation, especially along the Reid Highway section of the proposal footprint to help facilitate fauna movement between local habitats.

9.5.2 Habitat Degradation

The following mitigation/management measures will reduce the impacts of habitat degradation:

- Implement an EMP (Appendix F) to limit the risk of fire, spread of weeds and dieback, rubbish and vehicle tracks caused during construction.
- Retain and translocate hollow logs to surrounding habitats. Logs are an important refuge site for many animal species and take a long time to be created.

9.5.3 Feral Predation

The following mitigation/management measures will reduce the impacts of feral animal predation:

- Retain and translocate hollow logs to surrounding habitats. Logs are an important refuge site for many animal species and provide shelter against predation.
- The use of furniture (objects to provide shelter) in fauna underpasses to reduce risk of predation.
- Revegetation as close to fauna underpasses as possible to reduce risk of predation.
- The use of multiple fauna underpasses close to each other to reduce the risk of predators taking advantage of the funnelling effect of underpasses on fauna.

9.5.4 Fauna Mortalities

The following mitigation/management measures will reduce the impacts of fauna mortalities during the construction and operation phases of the proposal:

- A total of 21 fauna underpasses and two bridges are planned to be constructed in key locations along the alignment. Details on these are covered in Section 9.5.8.
- The use of Banksia and other Black Cockatoo foraging resources will be limited as part of revegetation activities within 10 m of the road. Having foraging resources close to the road will create a higher chance of vehicle impact on these species.
- Clearing to occur outside of spring wherever possible, to minimise impacts to the breeding cycle of resident fauna e.g. nesting birds. If clearing is conducted during spring fauna spotters must be present.
- A trapping and translocation program will be conducted for ground dwelling fauna in areas of native vegetation prior to clearing. Fauna will be released in comparable habitat outside of the construction footprint.

- Fauna spotters will be present during the clearing of native vegetation to help translocate any fauna to adjacent suitable habitat and minimise any mortalities.
- Fauna fencing will be installed on both sides of the road in areas north of Hepburn Avenue along the alignment to a minimum of 100 m north of Maralla Road (Figure 9.5) to restrict fauna access to the road. The fauna fence design will be consistent with MRWA Drawing No. 200331-110 (1,800 mm high and dug into the ground 500 mm). The design of fauna fencing restricts medium to large ground dwelling fauna from obtaining access to the road and guides them to safe crossing points at the fauna underpass locations.
- Fauna escape ramps will be installed a minimum of every 200 m in sections containing fauna fencing. Fauna escape ramps are one-way devices that allow trapped animals safe egress from the road reserve. The ramps are required to be a 1,500 mm high to prevent fauna access in the wrong direction.
- A 40 km/h speed limit will be enforced within the construction zone to mitigate against animal strikes.
- All fauna injured during the construction period will be taken to an authorised veterinarian or wildlife carer.
- Fauna warning signs will be installed in areas where native vegetation occurs next to the roadside.

9.5.5 Altered Fire Regimes

The following mitigation/management measures will reduce the impacts of altered fire regimes:

- The risk of fire will be managed by minimising fuel load and controlling ignition sources through the implementation of an EMP and an emergency response procedure.
- Impacts from fire during the operation phase of the proposal will be managed by the inclusion and maintenance of firebreaks.
- The proposal will act as a firebreak and the footpaths and access tracks will allow greater access for fire fighters.

9.5.6 Light and Noise

Impacts to fauna from light and noise are difficult to quantify. The following precautionary measures will minimise the level of impact form light and noise:

- Lights will be directed towards construction activities to limit the amount of light spill to surrounding habitats.
- Where possible low level lighting will be used during the construction phase of the proposal. Artificial screening will be employed along areas adjacent to native vegetation.
- The road lighting will consider AS 4282 ‘Control of the Obtrusive Effects of Outdoor Lighting’ and road lighting will comply with AS 1158 ‘Road Lighting’ to reduce impacts from light pollution.

395,000

400,000

6,480,000

6,475,000

LEGEND

- Proposal footprint
- Development envelope

Fauna underpass

- Box culvert (1,200 x 1,200 mm)
- Dual use culvert
- Sections including fauna fencing (1,800mm high)
- Bush Forever sites

N

0 km 1

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Page size: A4
Projection: GDA 1994 MGA Zone 50

GNANGARA RD

PARK ST

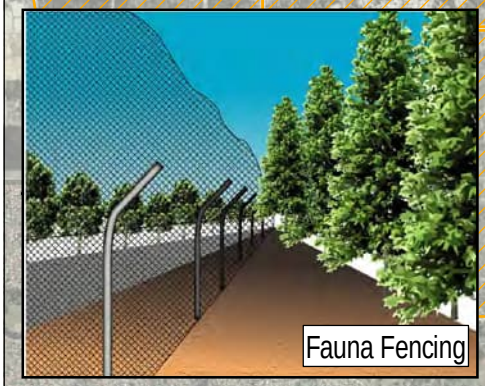
HEPBURN AV

BEECHBORO RD NORTH

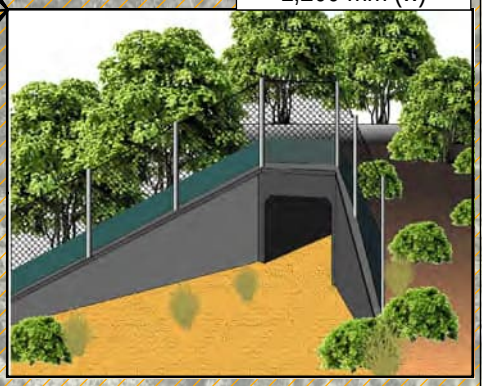
MARSHALL RD

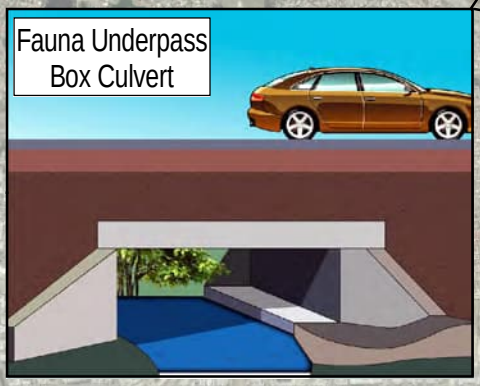
REID HWY

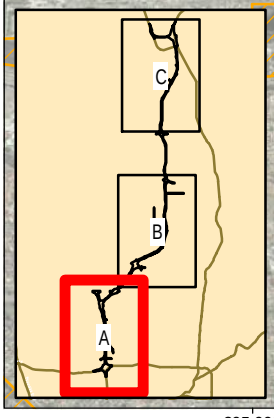
TONKIN HWY



6 x Fauna Underpass
Box Culvert
1,200 mm (h)
1,200 mm (w)

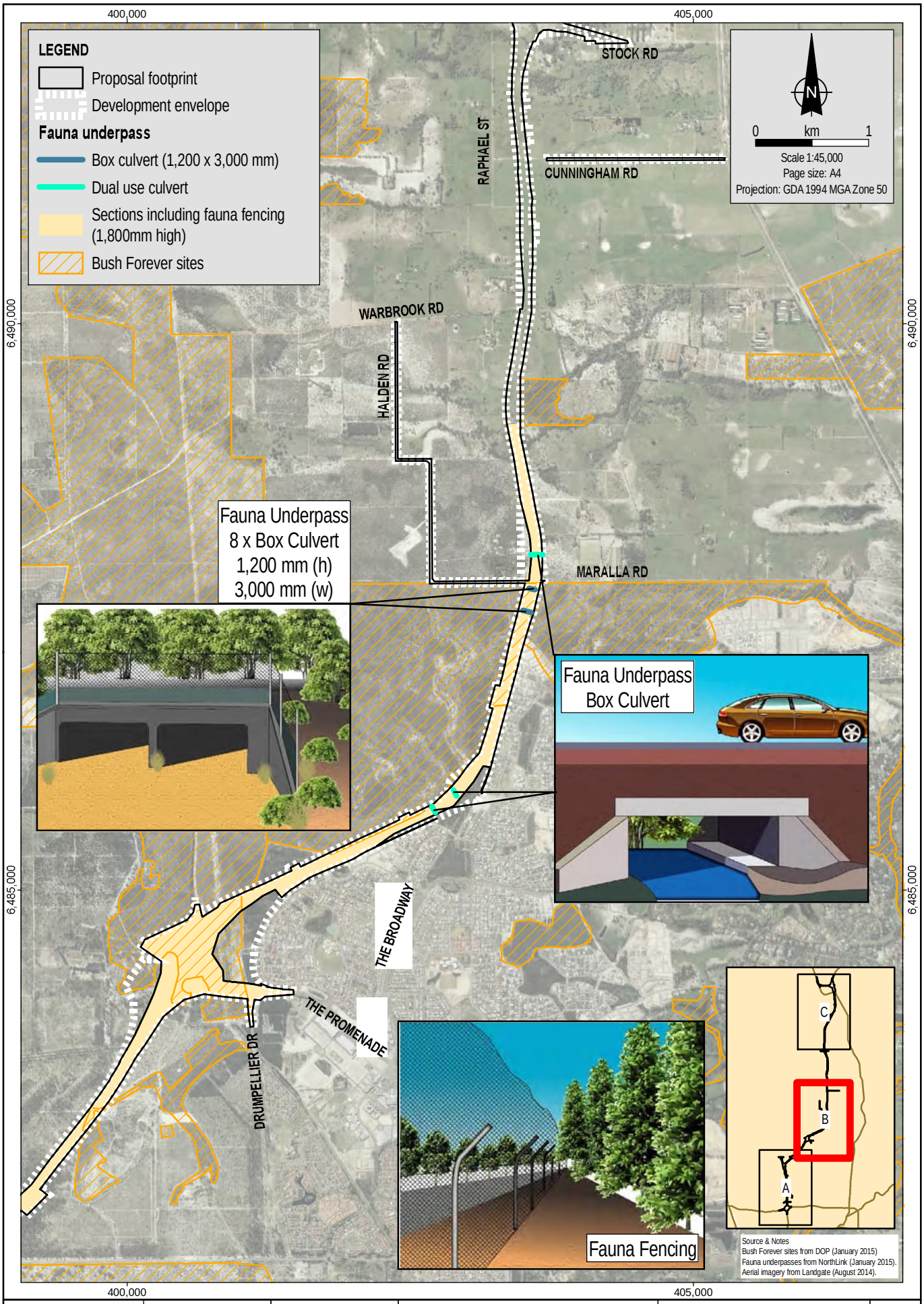






Source & Notes
Bush Forever sites from DOP (January 2015)
Fauna underpasses from NorthLink (January 2015).
Aerial imagery from Landgate (August 2014).

NorthLinkWA / coffey	Date: 18.06.2015 MXD: 4483AA_03_GIS076_2 File Name: 4483AA_03_F009.5A_GIS	Main Roads WA Public Environmental Review Perth–Darwin National Highway	Proposed fauna underpass locations Map 1 of 3	Figure No: 9.5A



NorthLinkWA	coffey	Date: 18.06.2015 MXD: 4483AA_03_GIS077_2 File Name: 4483AA_03_F9.5B_GIS	Main Roads WA Public Environmental Review Perth–Darwin National Highway	Proposed fauna underpass locations Map 2 of 3	Figure No: 9.5B

400,000

405,000

6,505,000

6,500,000

N

0 km 1

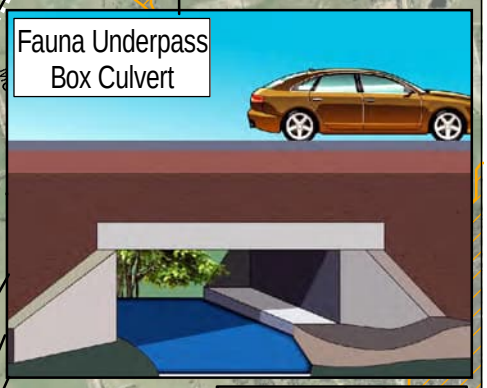
Scale 1:45,000
Page size: A4
Projection: GDA 1994 MGA Zone 50

BRAND HWY

GREAT NORTHERN HWY

NEAVES RD

Fauna Underpass
Box Culvert

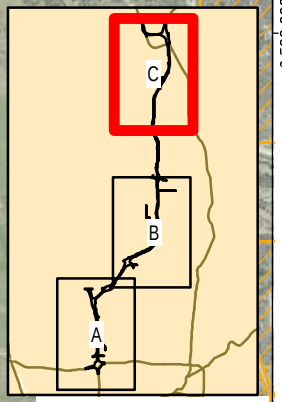


LEGEND

- Proposal footprint
- Development envelope
- Commonwealth land

Fauna underpass

- Bridge
- Dual use culvert
- Bush Forever sites



Source & Notes
Bush Forever sites from DOP (January 2015).
Fauna underpasses from NorthLink (January 2015).
Aerial imagery from Landgate (August 2014).

NorthLinkWA	coffey	Date: 18.06.2015 MXD: 4483AA_03_GIS078_2 File Name: 4483AA_03_F9.5C_GIS	Main Roads WA Public Environmental Review Perth–Darwin National Highway	Proposed fauna underpass locations Map 3 of 3	Figure No: 9.5C

9.5.7 Changes to Hydrological Conditions

Hydrological impacts and the associated management measures for hydrological conditions are discussed in Chapter 10. There is no significant impact expected for the Western Swamp Tortoise or habitats at Twin Swamp Nature Reserve and Ellen Brook Nature Reserve from alteration of hydrology.

9.5.8 Underpass Design

The underpass locations, sizes and designs have been selected based upon a combination of the following factors:

- The hotspot data obtained from the fauna movement survey.
- Topography – fauna underpasses are not effective unless they are at or slightly below ground level and do not contain a high gradient.
- Information gathered from relevant studies and reports (Bamford, 2011; MRWA, 2010; QDMR, 2000).
- Design that is consistent with MRWA Design of Fauna Underpass document (MRWA, 2010).
- Advice from fauna underpass expert for Western Australia (Chambers, pers. comm.).

Underpass dimensions differ at each location based upon the fauna recorded or expected to occur in the vicinity, as well as the need to limit human interaction, in particular access by four wheel drive vehicles and motorbikes (Table 9.6 and Figure 9.5). Human interference has been identified as a key factor in the reduction of use of fauna underpasses (Bamford, 2011). Fauna underpasses with a height of 1,200 mm are of sufficient size that large animals such as an adult Western Grey kangaroos will readily use the structure, while limiting human access (Chambers, pers. comm.). As such, both the Whiteman Park/Cullacabardee and Maralla Road Bushland sites will have 1,200 mm high underpasses installed, due to the abundance of Western Grey Kangaroo records in the fauna movement survey. Multiple underpass locations are proposed at each site to help facilitate populations on either side of the proposal and to facilitate escape routes in case of fire, flooding or other impacts at one location (QDMR, 2000). Multiple locations ensure that even if an impact occurs on one location, ecological connectivity will still be maintained.

Table 9.6 Summary of fauna underpass design and locations

Location	Underpass design	Dimensions (height x width) (mm)	Length (from opening to opening)	Comments
Hepburn Ave	Dual Purpose Drainage/fauna culvert	Minimum of 300 x 300	Sections of 80 m, 20 and 15 m	Under the PDNH alignment
Cullacabardee Bushland	Box Culvert	1,200 x 1,200	82 m	Under the PDNH alignment
Cullacabardee Bushland	Dual Purpose Drainage/fauna culvert	Minimum of 300 x 300	80 m	Under the PDNH alignment
Cullacabardee Bushland	Box Culvert	1,200 x 1,200	80 m	Under the PDNH alignment
Cullacabardee Bushland	Box Culvert	1,200 x 1,200	Sections of 65 m and 50 m	Under the PDNH alignment

Location	Underpass design	Dimensions (height x width) (mm)	Length (from opening to opening)	Comments
Whiteman Park	Box Culvert	1,200 x 1,200	65 m	Under the PDNH alignment
Whiteman Park	Box Culvert	1,200 x 1,200	Sections of 65 m and 15 m	Under the PDNH alignment
Whiteman Park	Box Culvert	1,200 x 1,200	Sections of 65 m and 15 m	Under the PDNH alignment
Ellenbrook	Dual Purpose Drainage/fauna culvert	Minimum of 300 x 300	65 m	Under the PDNH alignment
Ellenbrook	Dual Purpose Drainage/fauna culvert	Minimum of 300 x 300	65 m	Under the PDNH alignment
Maralla Road Bushland	2 x Box Culvert	1,200 x 3,000	70 m	Location of dual underpasses
Maralla Road Bushland	2 x Box Culvert	1,200 x 3,000	70 m	Location of dual underpasses
Maralla Road Bushland	2 x Box Culvert	1,200 x 3,000	70 m	Location of dual underpasses
Maralla Road Bushland	2 x Box Culvert	1,200 x 3,000	70 m	Location of dual underpasses
Bullsbrook	Dual Purpose Drainage/fauna culvert	Minimum of 300 x 300	Sections of 70 m and 30 m	Under the PDNH alignment
Bullsbrook	Dual Purpose Drainage/fauna culvert	Minimum of 300 x 300	85 m	Under the PDNH alignment
Bullsbrook	Dual Purpose Drainage/fauna culvert	Minimum of 300 x 300	75 m	Under the PDNH alignment
Bullsbrook	Dual Purpose Drainage/fauna culvert	Minimum of 300 x 300	Sections of 40 m and 12 m	Under the PDNH alignment
Bullsbrook/Muchea	Bridge	Unknown	Unknown	Bridge over Ellen Brook, includes fauna friendly design
Muchea	Dual Purpose Drainage/fauna culvert	Minimum of 300 x 300	80 m	Under the PDNH alignment
Muchea	Bridge	Unknown	Unknown	Bridge over Ellen Brook, includes fauna friendly design

To ensure the fauna underpasses will be effectively utilised, the final designs will be completed in consultation with a fauna underpass specialist. The final underpass designs will contain the following features known to encourage use by fauna and reduce the risk of predation (Bamford, 2011; QDMR, 2000):

- Objects for fauna to shelter on or in (furniture) will be installed.
- Where possible openings (sky lights) to allow natural light through will be constructed.
- Revegetation close to the underpass openings will be undertaken using local species.
- Natural flooring such as sand or gravel to help drain water. Fauna tend to avoid underpass locations with surface water present.
- The final 10 to 15 m of fauna fencing is angled towards the underpass opening.

Due to the significance of the ecological linkage at Maralla Road Bushland, wider underpasses have been planned to provide an increased openness ratio. The openness ratio relates to the length, height and width ratio. Higher openness ratios provide greater effectiveness for fauna use (QDMR, 2000). The portion of the proposal that intersects the Maralla Road Bushland runs parallel to a steep dune system. As fauna underpasses are most effective if they are at or slightly below ground level and do not have a steep gradient (QDMR, 2000), the dune system has limited the viable underpass locations to two areas. As such, each location will have fauna underpasses built in pairs (two 3,000 mm x 1,200 mm underpasses side by side) with a 10 to 20 m gap followed by another pair of underpasses. In total, eight underpasses (four pairs of underpasses) will be installed in the Maralla Road Bushland (see Figure 9.5).

To assess the effectiveness of the fauna underpasses, monitoring of the Maralla Road and Whiteman Park/Cullacabardee sites will be undertaken. A minimum of two surveys to identify the size of the population of fauna species most likely to use the underpasses (Western Grey Kangaroos, Southern Brown Bandicoots and Bobtail Skinks etc.) will be completed at least six months prior to construction. Monitoring of the fauna underpasses for a minimum of a year post construction will be completed. If fauna underpasses are deemed not to be effective, management options such as greater rehabilitation of surrounding vegetation and the installation of underpass furniture will be considered as a minimum.

The portion of the proposal intersecting with the Whiteman Park/Cullacabardee Bushland has a total of six fauna underpasses planned. As the site is located close to urban developments a smaller 1,200 mm x 1,200 mm underpass will be used. This will still allow for use by adult Western Grey Kangaroos and Western Brush Wallabies (recorded in the vicinity), but restrict passage by vehicles and bikes. The combination of underpasses and the cul-de-sac of Beechboro Road North would allow access between Cullacabardee Bushland and Whiteman Park. Underpass locations have been selected based on data from the fauna movement survey, road design and topography of the surrounding area.

The roadside vegetation alongside of the Tonkin/Reid Highway facilitates fauna movements between the remnant bushland in the vicinity. The proposal will intersect the Micro Garden Parks habitat reducing east and west fauna movement. Where the proposal design allows, roadside vegetation will be retained or revegetation undertaken to allow for fauna movements to continue.

To help facilitate fauna movement in other sections of the proposal, a total of nine dual use culverts are planned. These culverts act as both drainage culverts and fauna underpasses and use a design with either a raised ledge or separate raised culvert, to give fauna a dry passage while maintaining water flow. The size of the dual use culverts will be based on the drainage requirements of each culvert, but will allow for a minimum of a 300 mm raised ledge or pipe. Drainage lines are conduits for fauna movement as the thick vegetation associated with them provides shelter (MRWA, 2010). Two bridges will be created over Ellen Brook (see Figure 9.5). Bridges will be designed to be of sufficient height to allow fauna passage along the drainage line.

9.6 Residual Environmental Impact

Of the potential impacts identified, habitat loss and habitat fragmentation (including the associated loss of ecological connectivity) are the major residual impacts. These impacts can be readily managed to meet the EPA's objectives (as outlined in Section 9.1).

The proposal is likely to have a significant effect on both Black Cockatoo species (Carnaby's and Forest Red-tailed) based upon the Significant Impact Guidelines 1.1 (DOTE, 2013). However, with the appropriate mitigation measures (see Section 9.5) and offsets (see Chapter 17) the proposal is not expected to have an unacceptable effect on either Black Cockatoo species and will meet the EPA's objectives. A summary of impacts and mitigations for the proposal is covered in Table 9.7.

9.6.1 Habitat Loss

The proposal will result in the clearing of 159.3 ha of native fauna habitat, including 81.7 ha of Banksia Woodland, 43.1 ha of Eucalypt/Corymbia Woodland, 19 ha of Dampland habitat and 15.5 ha of Wetland habitat. The 159.3 ha of natural vegetation in the proposal footprint is distributed over a large distance (approximately 38 km) thus spreading the expected impacts. The design of the proposal has predominantly followed existing infrastructure, cleared areas or secondary fauna habitats (78.6% of the proposal footprint). The remaining portions of the proposal contain natural habitat (21.4%).

Approximately 201.8 ha of quality Carnaby's Cockatoo foraging habitat, 120.1 ha of quality Forest Red-tailed Black Cockatoo foraging habitat, 58.6 ha of Black Cockatoo roosting habitat, 737 trees with a DBH over 500 mm and 118.2 ha of potential Black Cockatoo breeding habitat will be impacted. These impacts will reduce the availability of foraging, roosting and future breeding resources at the local scale. However, the proposal footprint is not within the current breeding range of both Black Cockatoo species and no significant roost site locations have been recorded in the proposal footprint.

The proposal will clear Black Cockatoo habitat, including vegetation that provides food resources and roosting sites in the non-breeding season for the Carnaby's Cockatoo and Marri and Jarrah Woodland in an area of the southwest of WA that receives more than 600 mm of annual average rainfall. Under the critical habitat criteria in the recovery plan for the Carnaby's Cockatoo and the Forest Red-tailed Black Cockatoo both of these actions constitute a significant impact (DPAW, 2013a; Chapman, 2007). However, with the appropriate mitigation measures and offsets the proposal is not expected to have an unacceptable effect on either Black Cockatoo species and will meet the EPA's objectives (outlined in Section 9.1).

Due to the widespread distribution of the migratory avifauna (Rainbow Bee-eater, Great Egret and Cattle Egret) and non-reliance on habitats specific to the proposal, impacts to these species are not likely to be significant.

Vegetation clearing will result in the loss of habitat for species of ground dwelling conservation significant fauna, including the Black Striped-snake (124.8 ha), Jewelled Sandplain Ctenotus (81.7 ha), Western Brush Wallaby (124.8 ha) and Southern Brown Bandicoot (19 ha). These are the most likely species to be directly impacted by the proposal. Due to their limited dispersal ability they are more likely to be impacted by habitat fragmentation, road mortalities and loss of suitable habitat. The implementation of fauna underpasses, environmental management plan and fauna-proof fencing will lessen the impact to these species during the construction and operation phases of the proposal. The impact to ground-dwelling conservation significant fauna is not likely to be significant.

9.6.2 Ecological Connectivity

The loss of ecological connectivity is a potential issue, especially around Micro Gardens Park, Cullacabardee Bushland and the Maralla Road Bushland. Resident fauna populations at these locations will be affected by an increased risk of vehicle collisions and a higher susceptibility to impacts such as fire, disease and

predation which could lead to localised extinction. The 21 planned fauna underpasses and two bridges along the alignment will allow for the maintenance of ecological connectivity. Although fauna movements will be adversely impacted, the implementation of the appropriate size, location and design of fauna underpasses, in particular around the Maralla Road and Whiteman Park/Cullacabardee Bushlands, will lessen this impact to the lowest practicable level.

9.6.2.1 Maralla Road Bushland

The maintenance of ecological connectivity at the Maralla Road site is important due to the bottleneck that occurs between Ellenbrook Estate and Maralla Road. This location restricts access in both an east and west direction towards Bush Forever sites 300, 301 and 399, Ellenbrook Nature Reserve and Walyunga National Park. The proposal will inevitably cause a restriction on fauna movement throughout this area. The installation of eight (four dual) underpasses of 3,000 mm x 1,200 mm with appropriate design features will allow the maintenance of some level of ecological connectivity through this area.

9.6.2.2 Whiteman Park/Cullacabardee Bushland

The Cullacabardee Bushland forms part of an ecological linkage with the greater Whiteman Park Nature Reserve (Government of Western Australia, 2000b) that extends both east and west of the proposal. As the proposal intersects a portion of approximately 1,800 m of this site, fauna underpasses had to be spread out to ensure ecological connectivity was maintained along the entire distance. The installation of six underpasses of 1,200 mm x 1,200 mm with appropriate design features will allow the maintenance of some level of ecological connectivity through this area.

9.6.2.3 Micro Gardens Park

The ecological connectivity around the Micro Gardens Park area (Tonkin and Reid Highway intersection) is already highly disrupted by the current road network and infrastructure. However, through roadside vegetation maintained along the corridor some ecological linkage can occur. The level of linkage currently maintained is unknown, but a number of ground dwelling fauna species were recorded in the roadside vegetation including the diggings of the conservation significant Southern Brown Bandicoot (P5). The proposal will result in the loss of the majority of the roadside vegetation through this area with the widening of many of the roads. Where the proposal design allows, roadside vegetation will be retained or revegetation undertaken to allow for fauna movements to continue. Due to design restrictions of connecting with existing infrastructure (multiple large roads through the intersection) ecological connectivity could not be maintained through the use of underpasses.

Table 9.7 Summary of residual impacts to terrestrial fauna following implementation of management and mitigation measures

Type of impact	Predicted impact	Management and mitigation	Residual impact
Habitat loss	• Loss of fauna habitat from clearing vegetation. • Removal of Black Cockatoo habitat.	• Avoidance of ecologically sensitive areas in design and a reduction in the proposal footprint design. • An EMP will be developed and implemented. • During construction use boundary fencing or flagging will be used.	• Loss of 159.3 ha of natural fauna habitat. • Loss of Black Cockatoo habitat: – 201.8 ha Carnaby's Cockatoo foraging habitat. – 120.1 ha Forest Red-tailed Black Cockatoo foraging habitat. – 58.6 ha roosting habitat. – 120.1 ha potential breeding habitat (including 737 potential breeding trees). • Loss of conservation significant habitat: – 15.5 ha Great Egret habitat. – 271.2 ha Cattle Egret habitat. – 367.5 ha Rainbow Bee-eater habitat. – 81.7 ha Jewelled Sandplain Ctenotus habitat. – 124.8 ha Black Striped-snake, Western Carpet Python and Western Brush Wallaby habitat. – 19 ha Southern Brown Bandicoot habitat.

Type of impact	Predicted impact	Management and mitigation	Residual impact
Habitat fragmentation	• Loss of ecological connectivity leading to increased risk of loss of genetic diversity and ecological diversity, increased risk of vehicle collisions and a higher susceptibility to impacts such as fire, disease and predation.	• Retain as much roadside vegetation as possible, especially along the Tonkin/Reid Highway section of the proposal footprint. • A total of 21 fauna underpasses and two bridges are planned to be constructed in key locations along the alignment. • Fauna underpass monitoring program will be developed.	• Fragmentation to fauna habitats will increase due to the proposal. However, the inclusion of fauna underpasses allows the maintenance of ecological connectivity to the greatest practicable extent.
Habitat degradation	• Increased spread of weeds and dieback. • Increased occurrence of rubbish dumping and vehicle tracks. • Edge effects.	• Implement an environmental management plan to limit spread of weeds and dieback, rubbish and vehicle tracks caused during construction. • Retain and translocate hollow logs to surrounding habitats.	• The proposed measures will limit the impacts created by weeds, dieback, vehicles tracks and rubbish during construction. These impacts are already common and widespread through the region and the proposal is unlikely to be the only cause of these impacts. • There will be edge effects where the alignment abuts native vegetation.

Type of impact	Predicted impact	Management and mitigation	Residual impact
Fauna mortalities and feral predation	• Increased risk of fauna mortalities from vehicle collision. • Potential for fauna to be killed or injured during vegetation clearing. • Increased predation of fauna due to loss of shelter.	• Inclusion of fauna fencing and fauna underpasses in appropriate areas. • Retention and translocation of hollow logs to provide shelter against predation. • The use of furniture in fauna underpasses. • Revegetation close to fauna underpasses and the use of multiple fauna underpasses to reduce the risk of predation. • Fauna warning signs on road to alert drivers of the potential risk. • Trapping and translocation program to be completed prior to construction. • Use of fauna spotters during clearing.	• The installation of fauna fencing and underpasses in areas most likely to contain fauna will assist species in having a safe passage across the alignment. • The implementation of a trapping and translocation program and the use of fauna spotters will reduce the risk and harm to fauna during vegetation clearing. • Inevitable fauna mortalities will occur during the construction and operation phases of the proposal, the management measures will lessen the risk and number of incidences.
Altered fire regime	• Increased frequency, intensity and duration of fires started by unnatural causes.	• The risk of fire will be managed by minimising fuel load and controlling ignition sources during construction through the implementation of an EMP and an emergency response procedure. Impacts from fire during the operation phase of the proposal will be managed by the inclusion and maintenance of firebreaks.	• With appropriate management plans and the inclusion and maintenance of firebreaks the risk of fire and its potential damage will be reduced.

Type of impact	Predicted impact	Management and mitigation	Residual impact
Noise and light	• Impacts may disrupt the natural behaviour of fauna in the close vicinity to the proposal, including disorientation of migratory or nocturnal fauna, increased physiological stress, the avoidance of habitats close to the proposal and the abandoning of previously used roost or nest sites.	• Lights will be directed towards construction activities to limit the amount of light spill to surrounding habitats. • Where possible low level lighting will be used and artificial screening will be employed. • The road lighting will comply with AS 1158 'Road Lighting' and consider AS 4282 'Control of the Obtrusive Effects of Outdoor Lighting' to reduce impacts from light pollution.	• Impacts to fauna from light and noise are difficult to quantify. Precautionary measures will be implemented to minimise the level of impact they potentially provide.
Hydrological alteration	• Potential for groundwater and surface water flows to be disrupted leading to habitat degradation for water dependent vegetation.	• Fauna impacts from the drainage and groundwater alterations will be managed under the hydrological impacts outlined in Chapter 10.	• The flow of surface and ground water will not be severely impacted by the proposal. Habitat degradation due to altered hydrological flows is expected to be negligible.

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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.

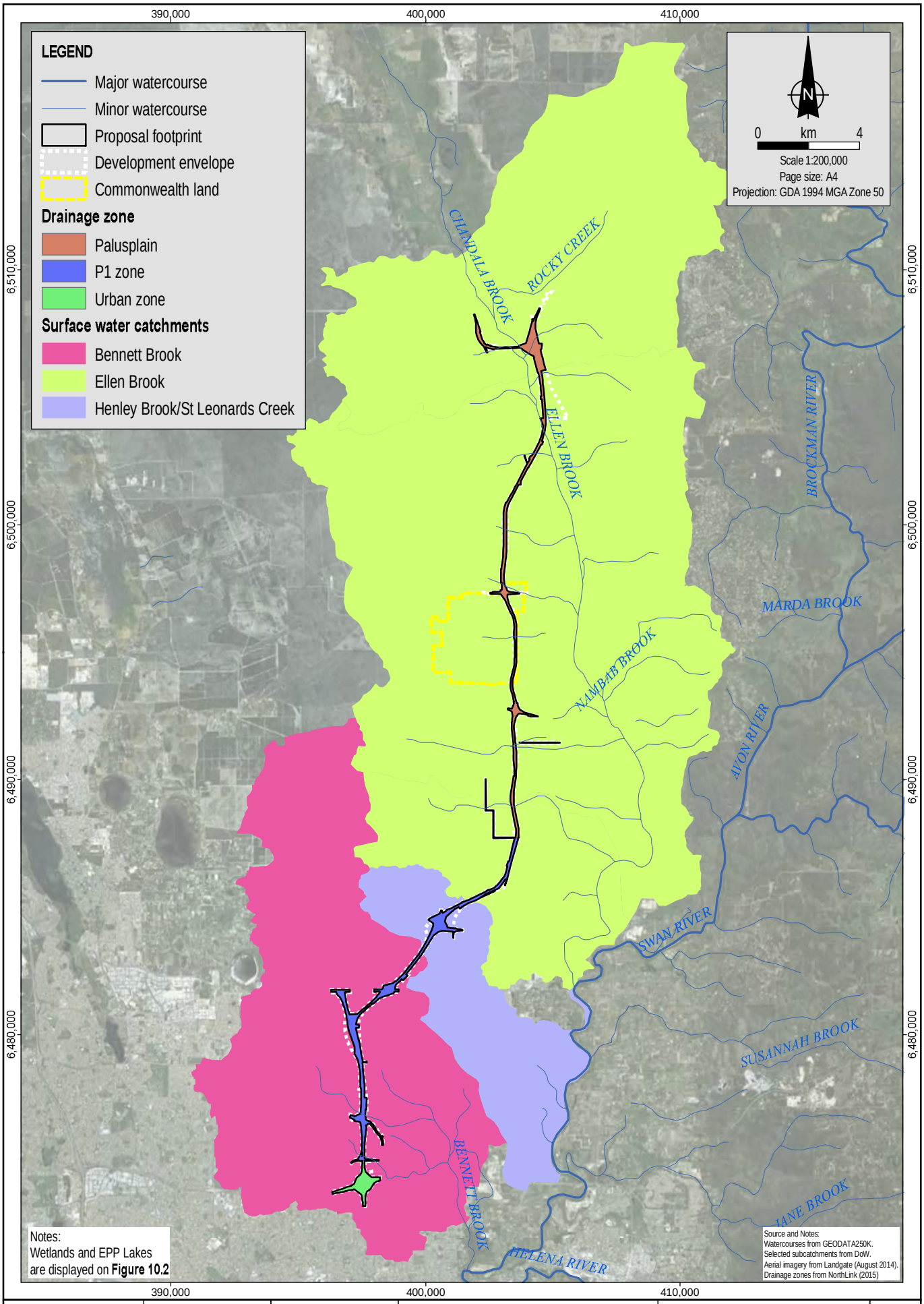
10.2 Existing Environment

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).



NorthLinkWA	coffey	Date: 05.06.2015 MXD: 4483AA_03_GIS031_2 File Name: 4483AA_03_F10.1_GIS	Main Roads WA Public Environmental Review Perth–Darwin National Highway	Surface water features	Figure No: 10.1

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

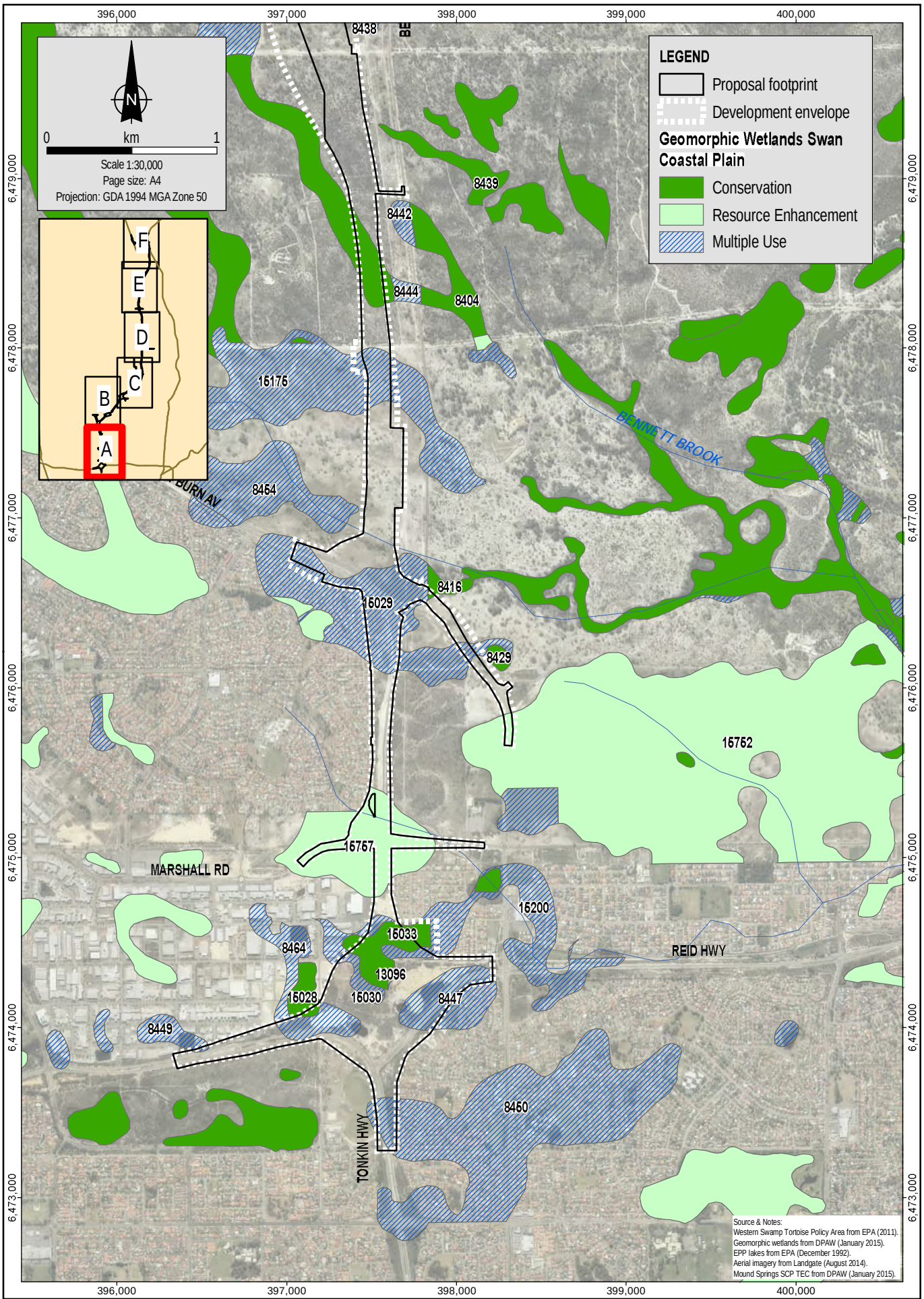
Drainage zone	Drainage characteristics
Urban zone	This zone lies within a predominantly urbanised landscape with extensive formal drainage systems. Soils are typically Bassendean Sand with isolated areas of peaty clay swamp deposits and the groundwater level is generally within 1 to 10 m of the surface.
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

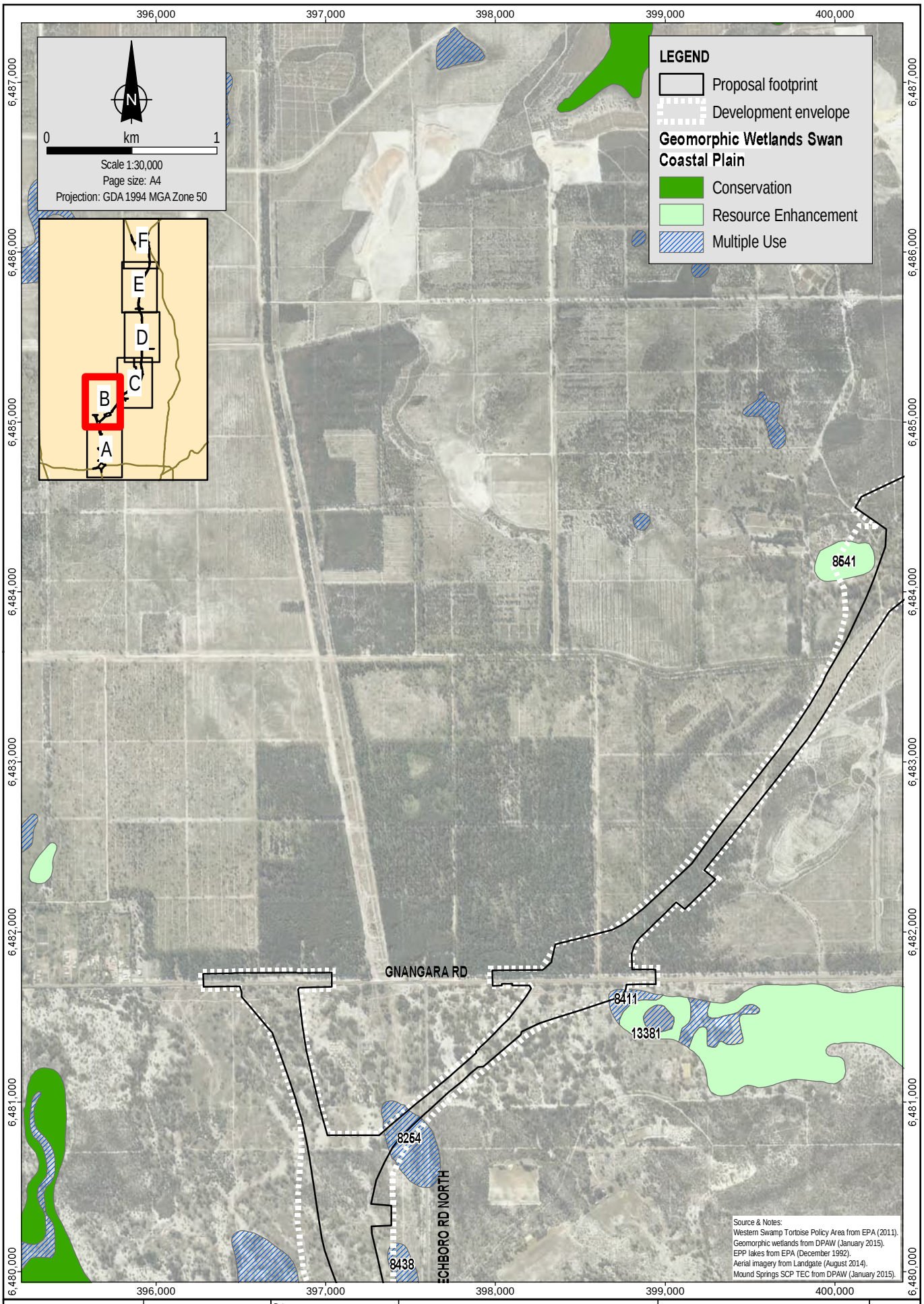
The Environmental Protection (Swan Coastal Plain Lakes) Policy 1992 (1992 Lakes EPP) protects the environmental values of lakes on the Swan Coastal Plain (SCP). The 1992 Lakes EPP made the filling, draining, excavating, polluting and clearing of these lakes an offence unless authorised by the EPA. Lakes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



NorthLinkWA	coffey	Date: 05.06.2015 MXD: 4483AA_03_GIS112_2 File Name: 4483AA_03_F10.2A_GIS	Main Roads WA Public Environmental Review Perth–Darwin National Highway	Geomorphic wetlands and EPP lakes Map 1 of 6	Figure No: 10.2A



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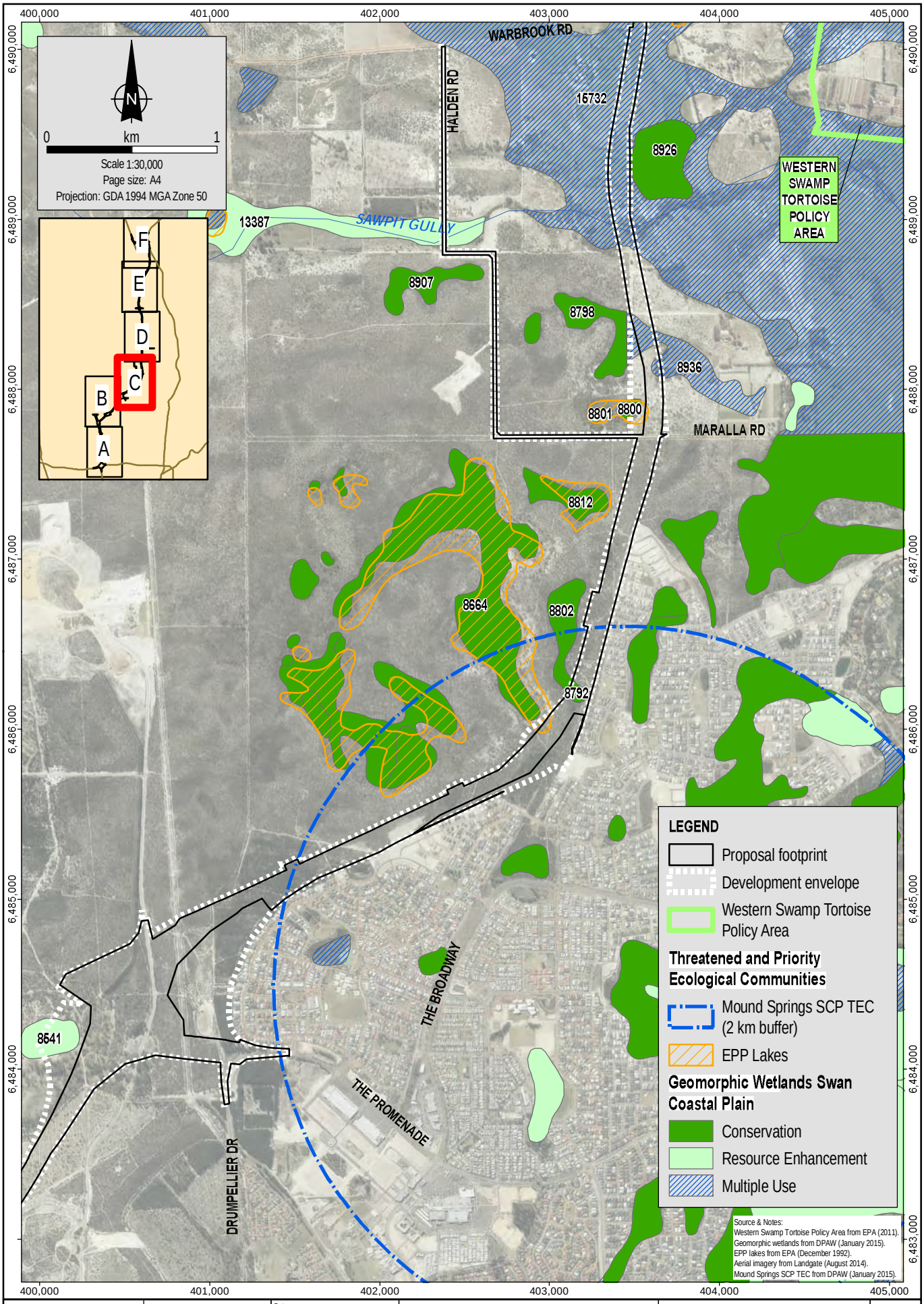

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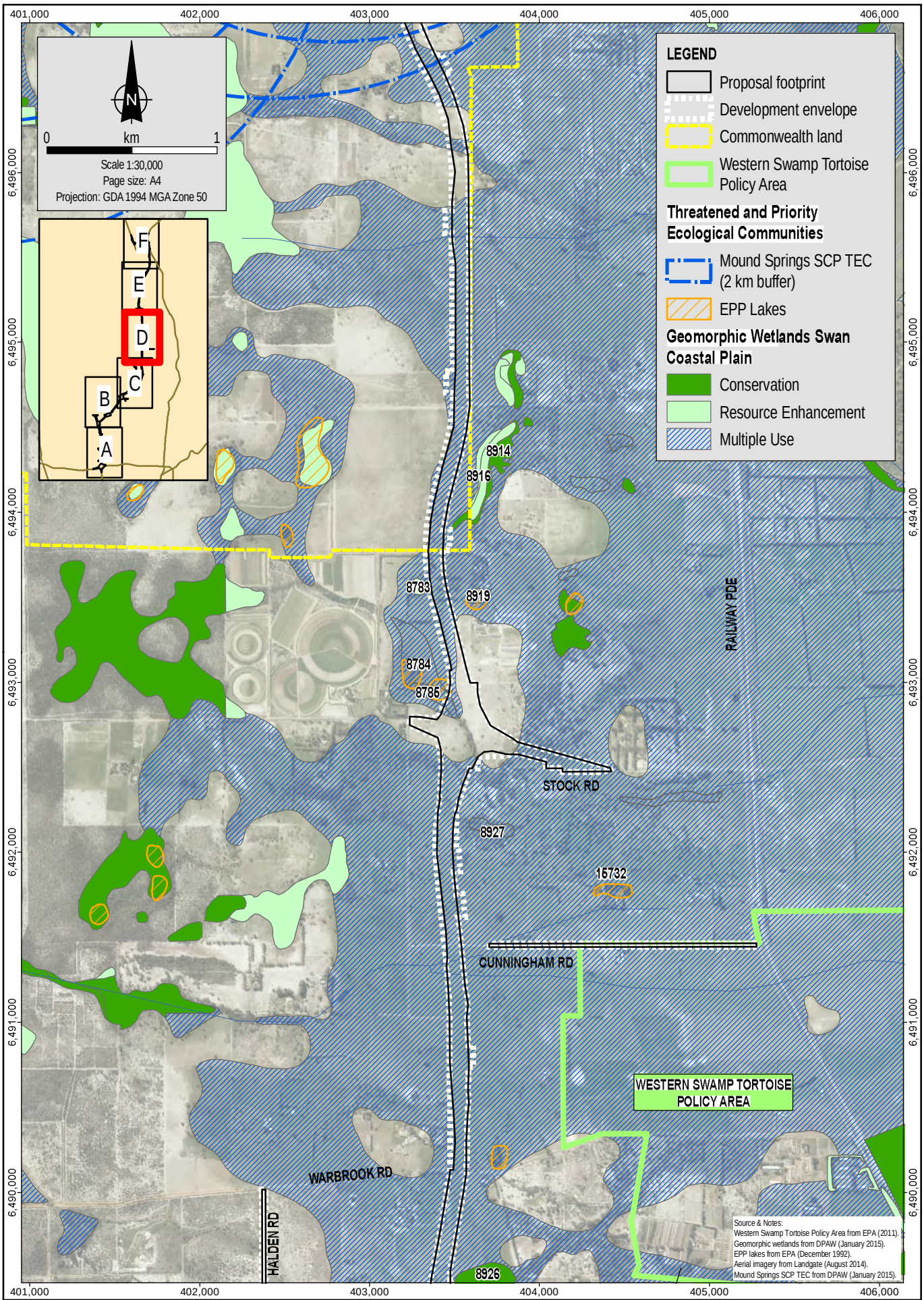

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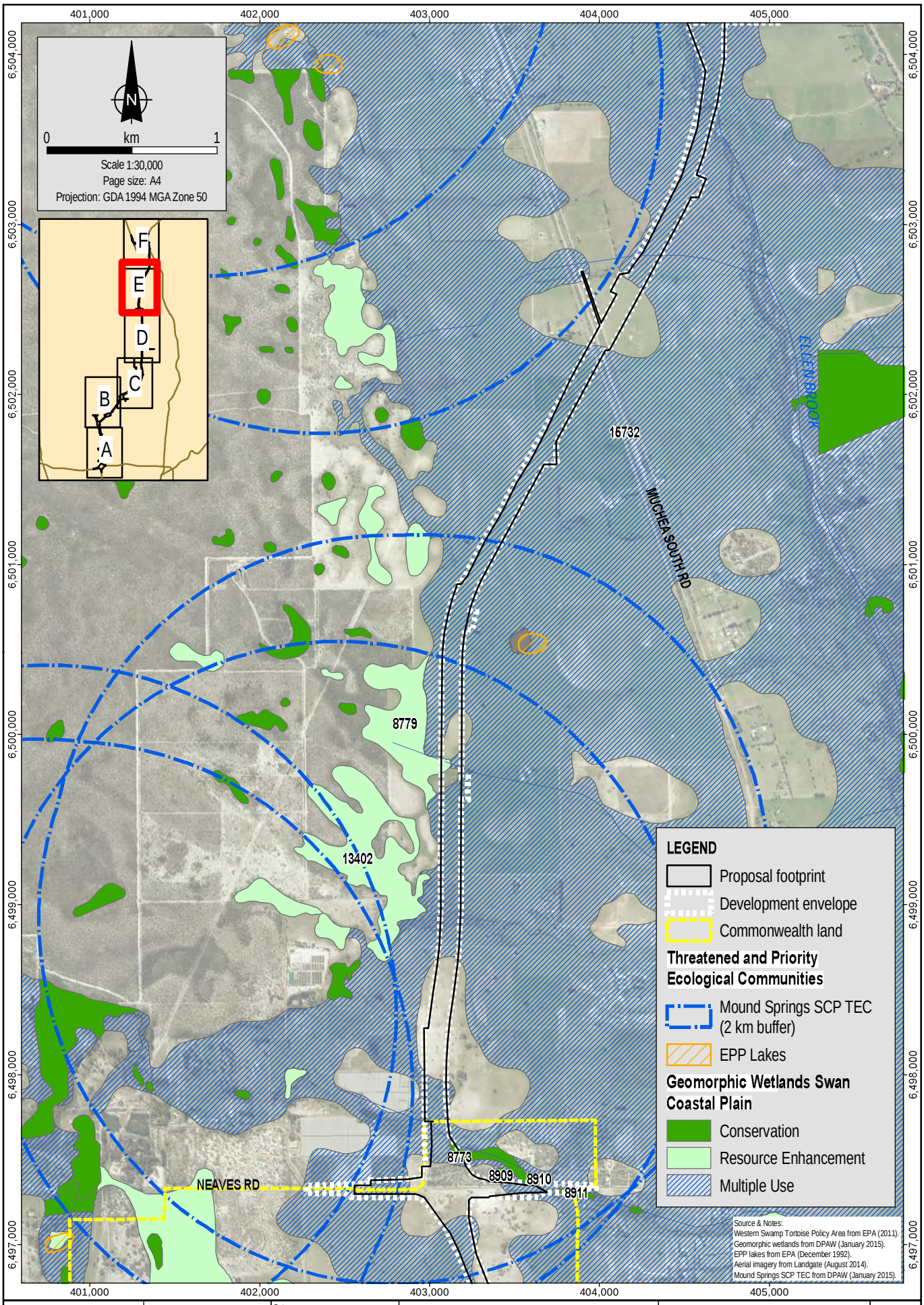

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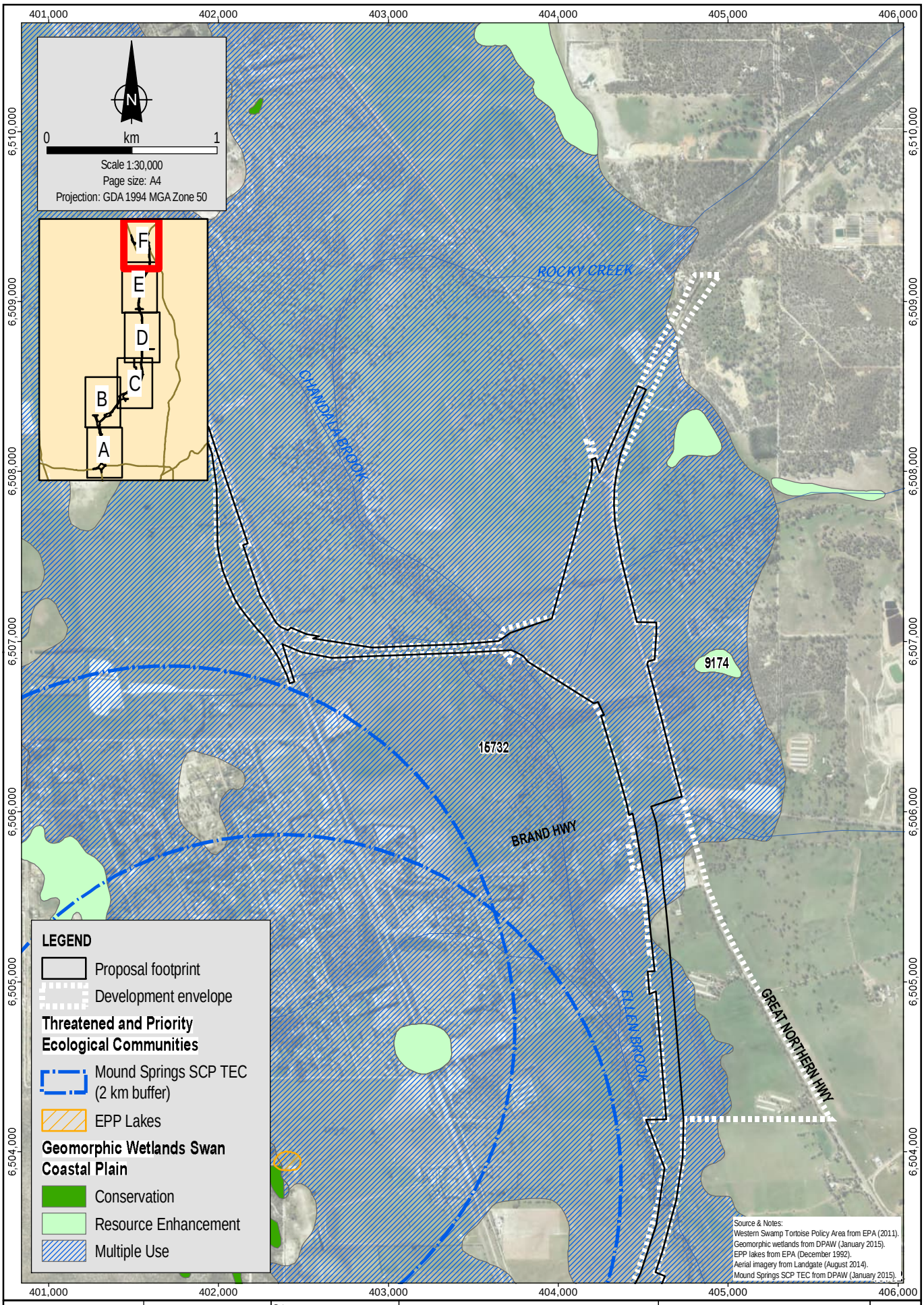
Geomorphic wetlands and EPP lakes
Map 5 of 6

Figure No:
10.2E



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Public Environmental Review
Perth–Darwin National Highway

Geomorphic wetlands and EPP lakes
Map 6 of 6

Figure No:
10.2F

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

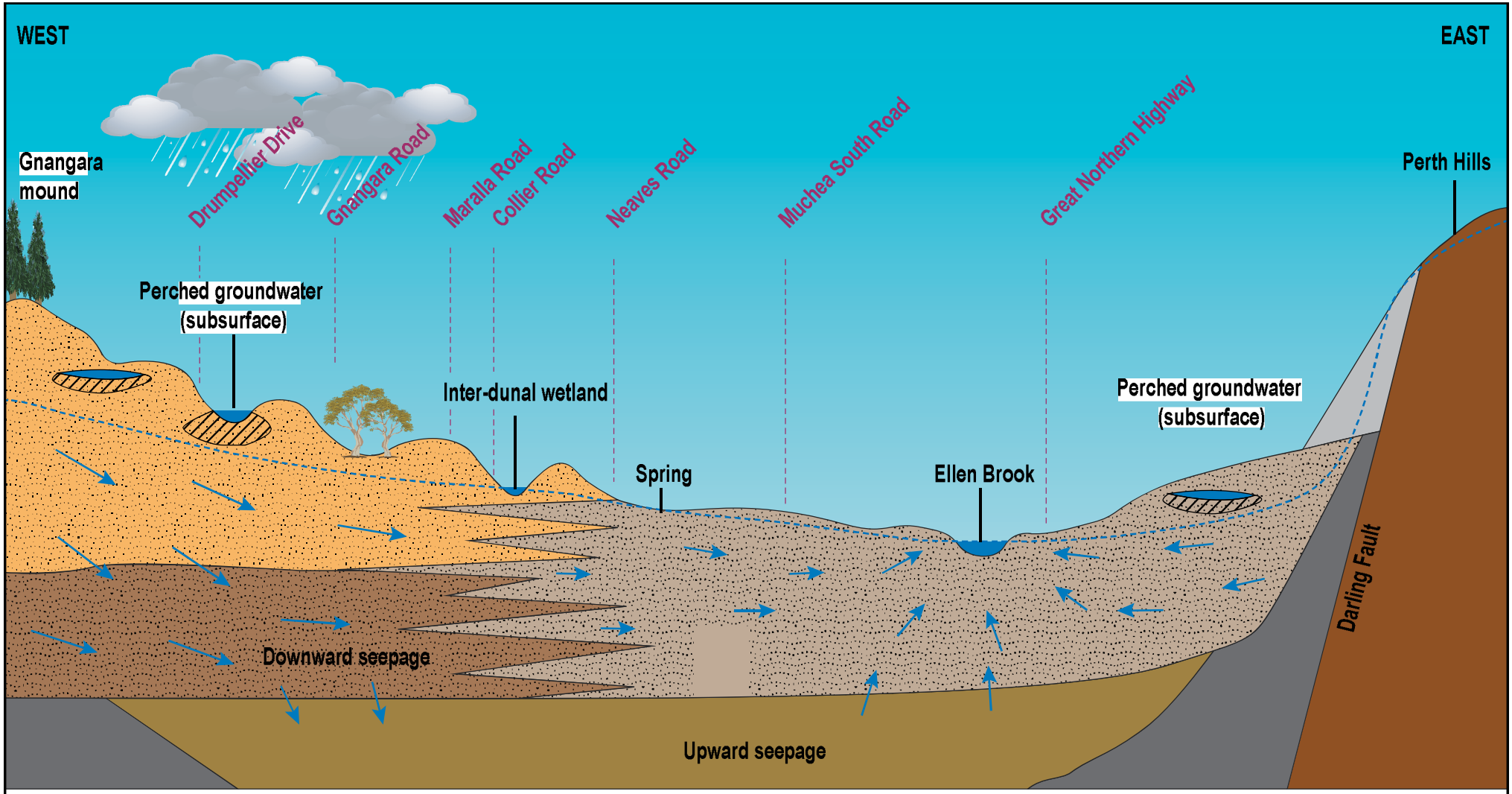
As discussed in Section 8.2.7, the proposal is located adjacent to a number of occurrences of Mound Springs SCP, a Commonwealth and State listed TEC also known as Tumulus Mound Springs (see Figure 10.2). The Mound Springs SCP TEC is characterised by continuous discharge of groundwater in raised areas 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
- ---- Groundwater table
- → Groundwater flow direction
- ▨ Low permeability zone
- Perched groundwater
- Bassendean sand
- Crystalline rock
- Gnangara sand
- Guildford formation
- Kardinya shale (aquitard)
- Mirrabooka aquifer
- Slope colluvium

Source: Golder 2014 Note: Not to scale	coffey	Date: 22.06.2015 File Name: 4483_03_F10.03_GL_4	Main Roads WA Public Environmental Review Perth–Darwin National Highway	NorthLinkWA	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).

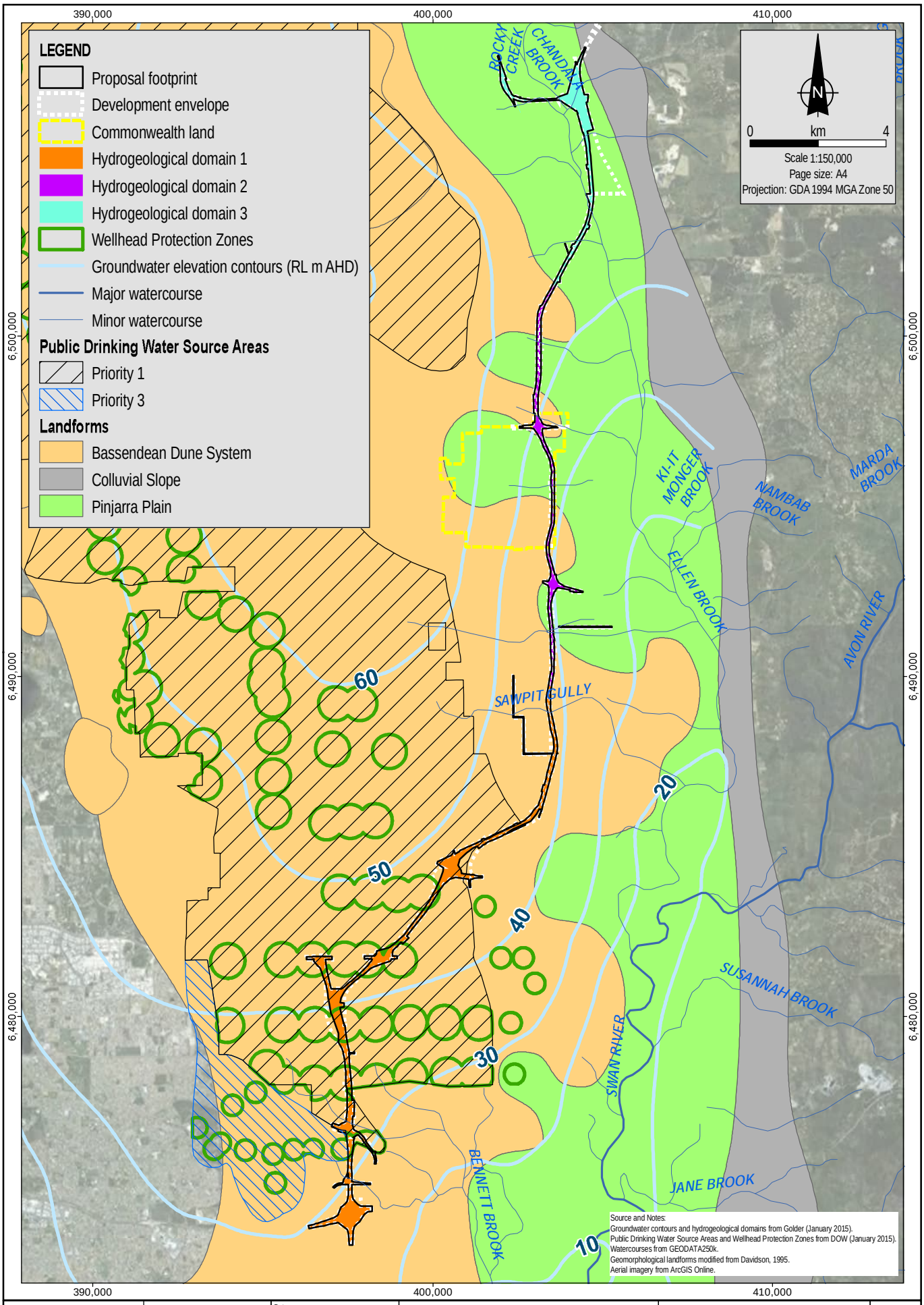
Groundwater levels within the proposal footprint experience a seasonal high following the wet season (around September/October) and are at a seasonal low around April/May. The extent of seasonal variation depends on the hydraulic conductivity of the geological unit, but generally a seasonal fluctuation 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:

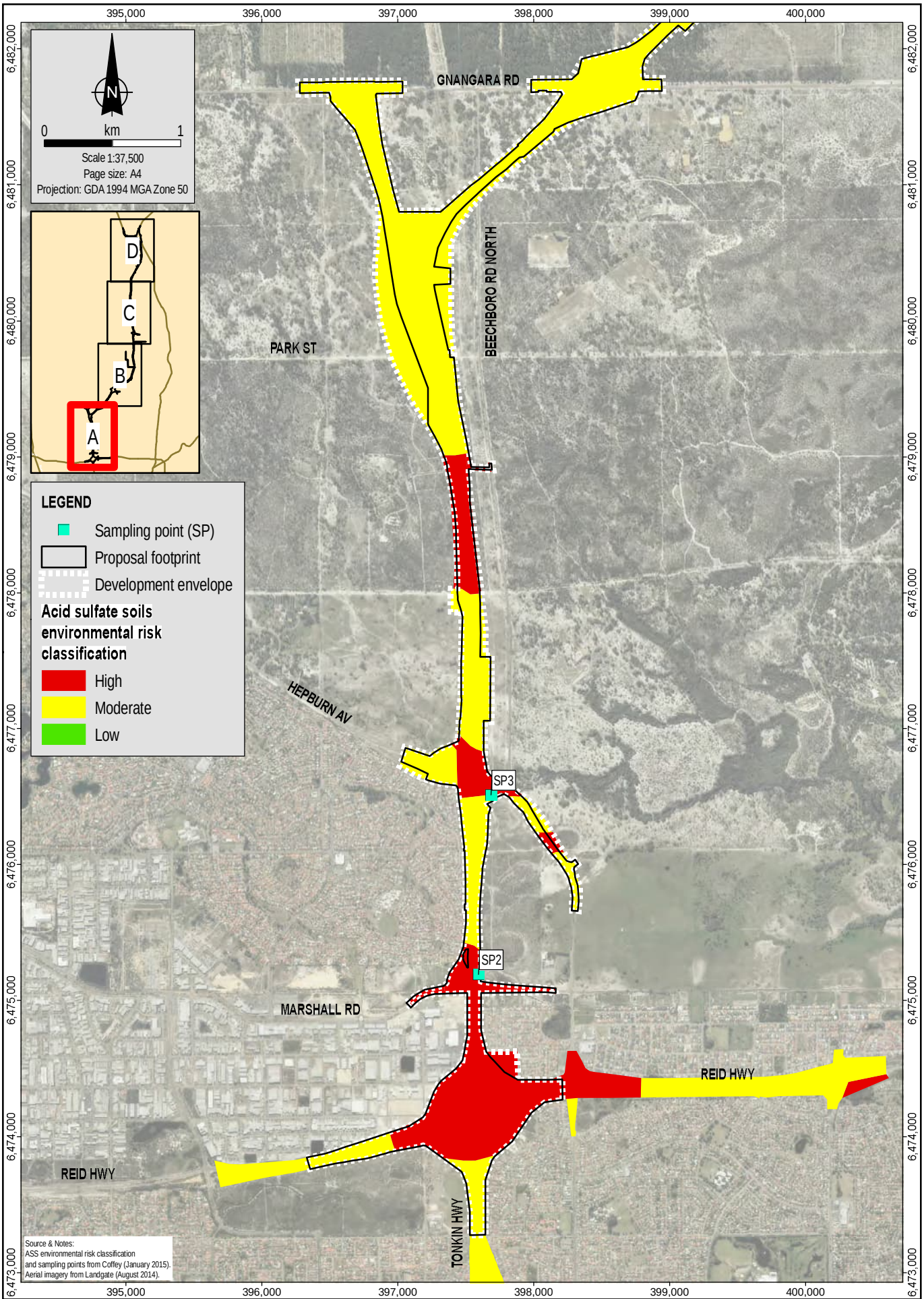
- Priority 1 area – areas that are managed to ensure no degradation of the drinking water source occurs. These areas contain the greatest restrictions on land use and activity and aim to avoid all risks to the drinking water source.
- Priority 3 area – areas where management of risk to water sources 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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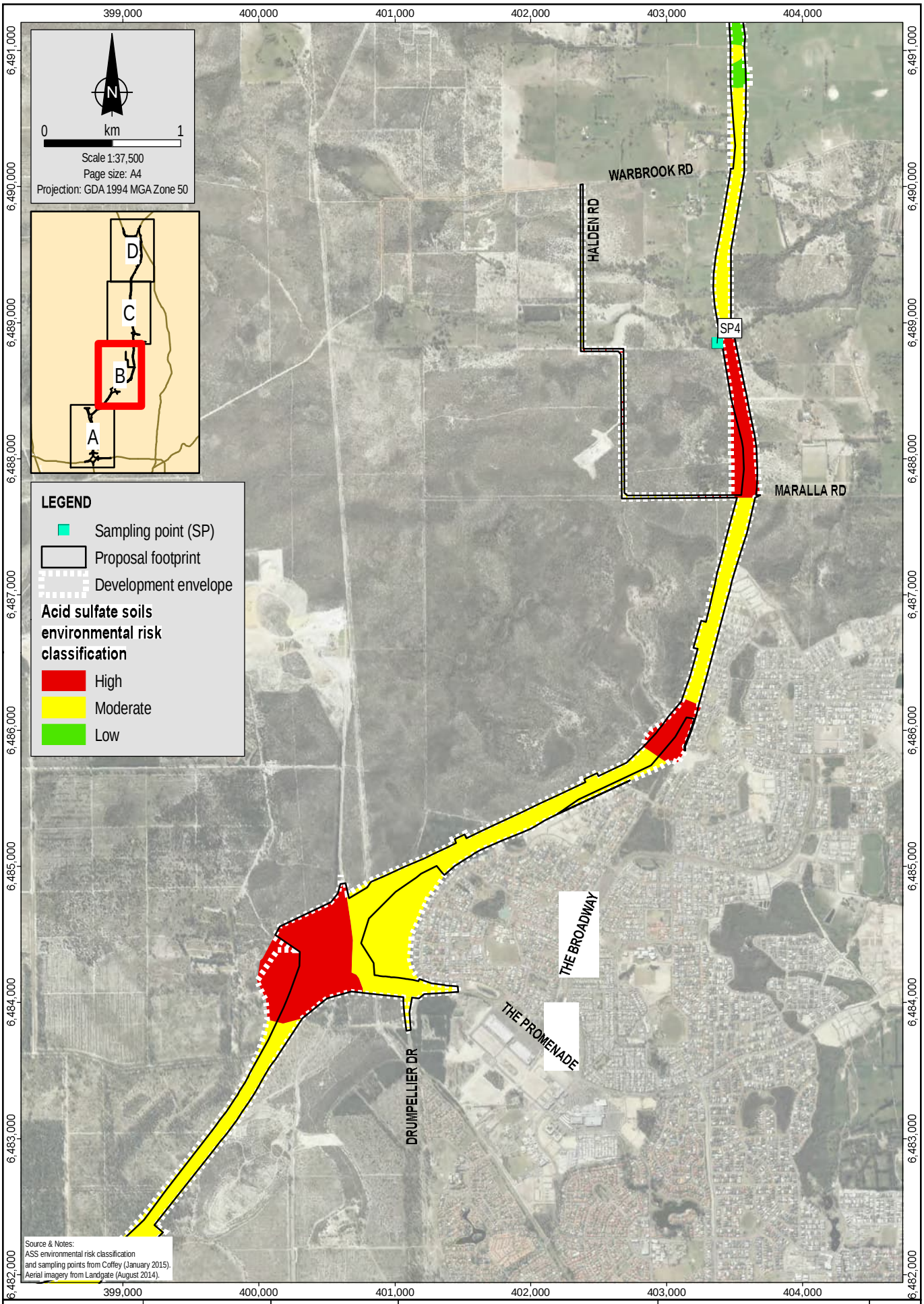
Main Roads WA
Public Environmental Review
Perth–Darwin National Highway

Acid sulfate soils environmental risk classification
Map 1 of 4

Figure No: 10.5A



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Date: 18.06.2015
MXD: 4483AA_03_GIS084_2
File Name: 4483AA_03_F10.5B_GIS

Main Roads WA
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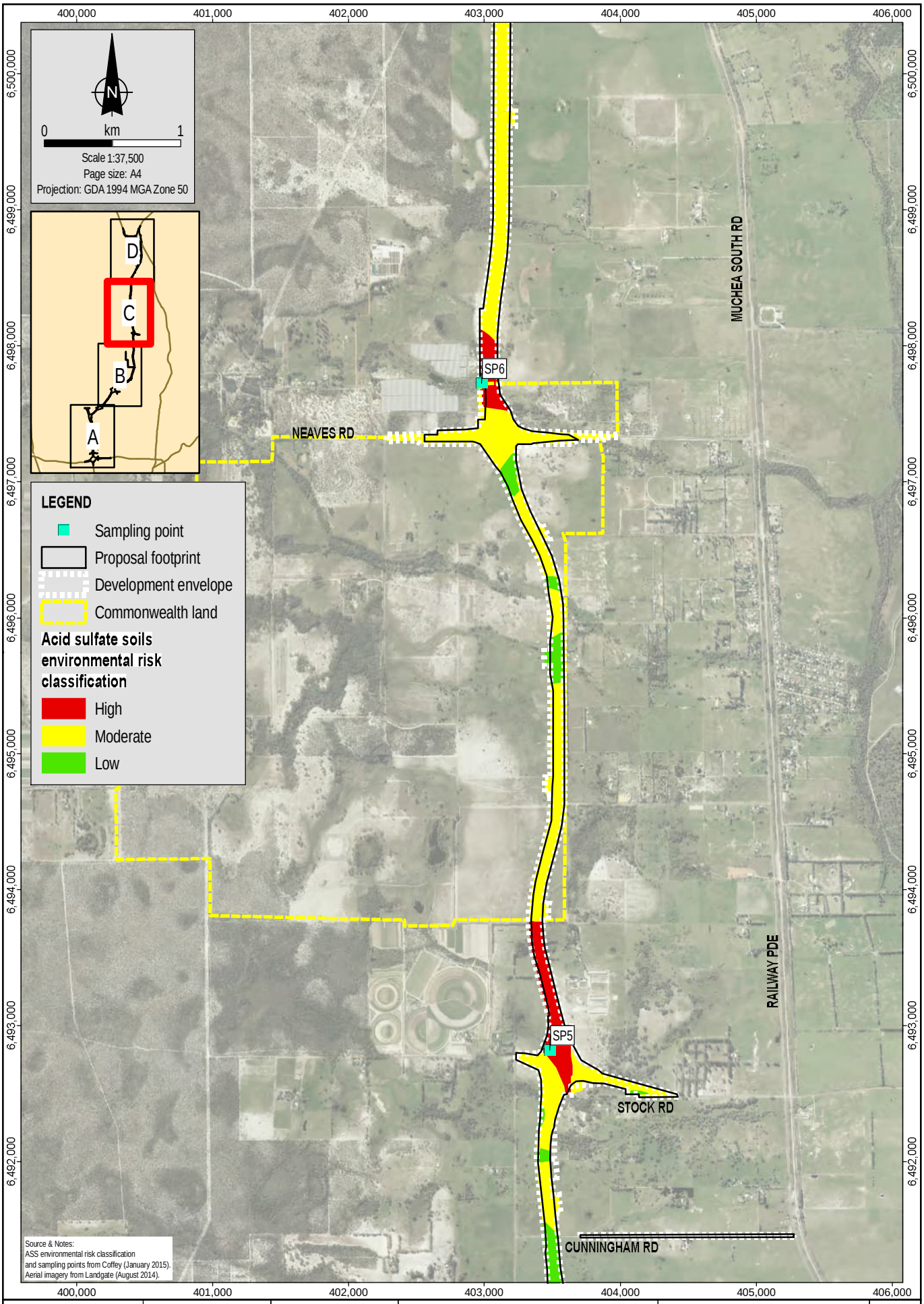
Acid sulfate soils environmental risk classification
Map 2 of 4

Figure No: 10.5B



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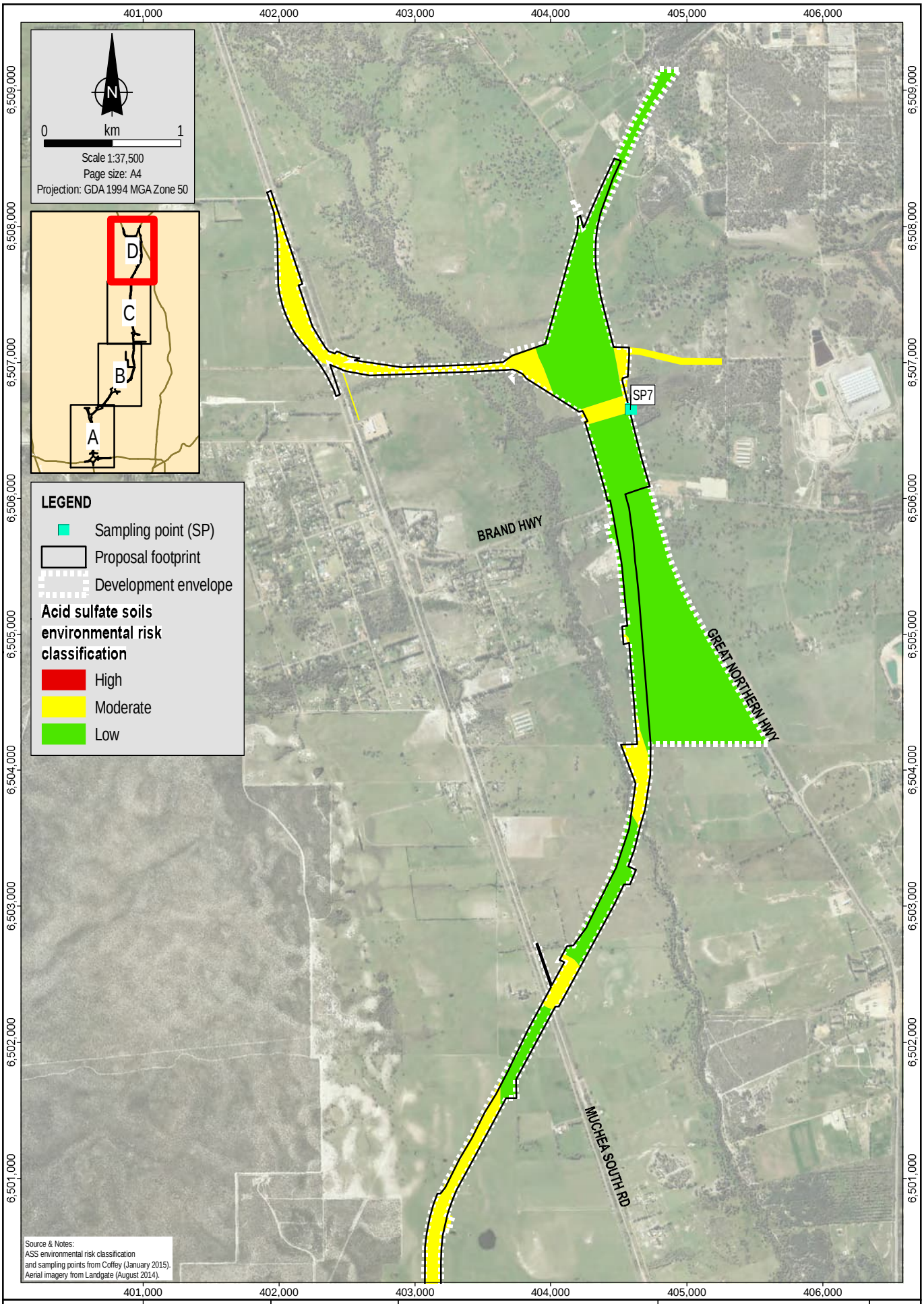

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File Name: 4483AA_03_F10.5D_GIS

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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.

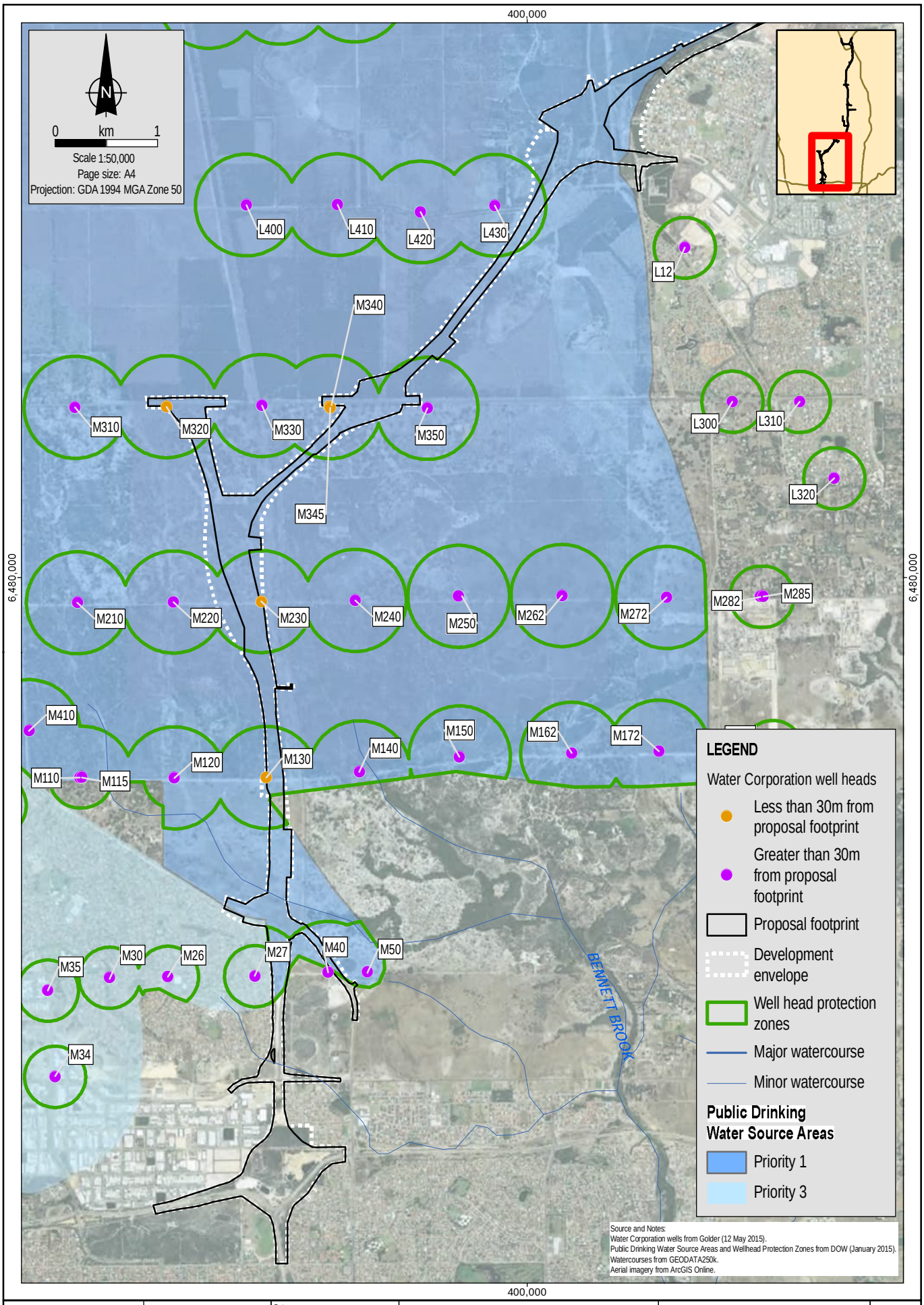
10.4.5 Impact to Groundwater Users (Gnangara Mound)

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.



NorthLinkWA	coffey	Date: 09.07.2015 MXD: 4483AA_03_GIS106Prob_3 File Name: 4483AA_03_F10.6_GIS	Main Roads WA 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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11 AMENITY (NOISE AND VIBRATION)

11.1 EPA Objective

The EPA's objective relating to amenity (EPA, 2015a) is to ensure that impacts from noise and vibration are reduced to as low as reasonably practicable.

11.2 Existing Environment

Noise monitoring was conducted in accordance with the Australian Standard 2702:1984 Acoustics – Methods for the Measurement of Road Traffic Noise and occurred during the period of September to December 2014 (Lloyd George Acoustics, 2015a).

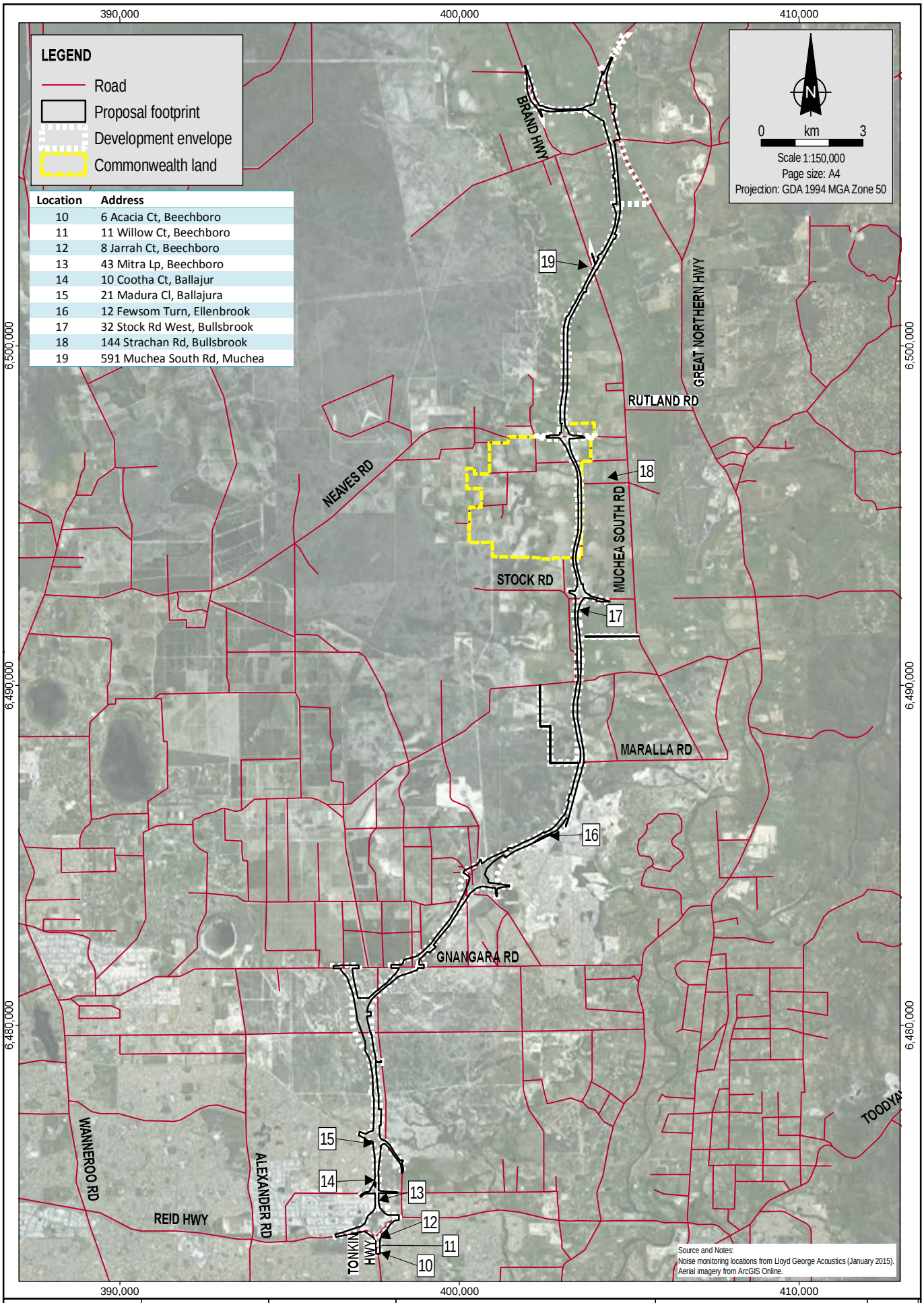
Noise monitoring was undertaken at nine locations from just south of Reid Highway to Muchea (Figure 11.1) and results are detailed in Table 11.1.

Table 11.1 Noise monitoring locations

Site No.	Address	Average weekday noise level (dB)		
		$LA_{10,18\ hour}$	$LA_{eq\ (Day)}$	$LA_{eq\ (Night)}$
10	6 Acacia Court, Beechboro	57.1	54.9	50.9
11	11 Willow Ct, Beechboro	53.9	52.2	48
12	8 Jarrah Court, Beechboro	51.6	50.6	45.5
13	43 Mitra Loop, Beechboro	50.9	50.1	52.8
14	10 Cootha Court, Ballajura	47.8	47.4	43.2
15	21 Madura Close, Ballajura	50.3	49.4	47.0
16	12 Fewson Turn, Ellenbrook	45.6	49.1	44.1
17	32 Stock Road West, Bullsbrook	51.1	54.2	48.2
18	144 Strachan Road, Bullsbrook	45.6	47.7	43.2
19	591 Muchea South Road, Muchea	52.1	50.7	49.3

Noise measurements were used to determine the differences between the $L_{A10,18\ hour}$ and $L_{Aeq\ (Day)}$ or $L_{Aeq\ (Night)}$ noise descriptors, as well as to determine if the day or night period traffic noise is dominant when compared to SPP 5.4 criteria.

The difference between the $L_{Aeq\ (Day)}$ and $L_{Aeq\ (Night)}$ results was shown to be between 4 dB and 7 dB. The daytime noise levels were found to increase more than the night levels, correlating with an increase in traffic volumes. It is assumed for this proposal that daytime traffic noise levels will be more than 5 dB above the night-time traffic noise levels. Therefore, the day time noise levels have been compared against SPP 5.4 noise criteria.



NorthLinkWA

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Date: 29.06.2015
MXD: 4483AA_03_GIS087_2
File Name: 4483AA_03_F11.1_GIS

Main Roads WA
Public Environmental Review
Perth–Darwin National Highway

Noise monitoring locations

Figure No: 11.1

11.3 Noise Level and Vibration Criteria

11.3.1 Construction Noise Criteria

Noise from construction sites is managed under Regulation 13 of the Environmental Protection (Noise) Regulations 1997 (Noise Regulations). Any construction noise made between 7.00 a.m. to 7.00 p.m. Monday to Saturday (excluding public holidays) is exempt from assigned noise limits, provided the works are being carried out in accordance with AS 2436:2010 – Guide to Noise and Vibration Control on Construction, Demolition and Maintenance sites. If work is to be conducted outside of these times a noise management plan will be prepared in accordance with Regulation 13 of the Noise Regulations.

11.3.2 Traffic Noise Criteria

State Planning Policy 5.4 Road and Rail Transport Noise and Freight Considerations in Land Use Planning (SPP 5.4) defines the traffic noise criteria relevant to the operation of the proposal (Government of Western Australia, 2009). Note that the Noise Regulations do not apply to traffic noise. SPP 5.4 outdoor noise criteria are shown in Table 11.2. SPP 5.4 is relevant to this proposal, as this proposal involves a:

- Proposed new major road project in the vicinity of existing or future noise-sensitive land uses.
- Proposed major redevelopment of existing road infrastructure in the vicinity of existing or future noise-sensitive land uses.

Where the proposal is being constructed in an area where there is no existing traffic noise (i.e. greenfield site), there is an expectation that the SPP 5.4 "target" should be achieved where reasonable and practical. For other sites, efforts should be made to achieve the "limit". Where the "target" can be met, no further mitigation measures under SPP 5.4 are required.

Where it is not possible to achieve the "limit", best practicable noise mitigation measures should be implemented. These measures should balance noise benefit, cost, feasibility, community preferences, amenity, safety, security and conflict with other policies. This may include measures to achieve the required indoor noise criteria, if the limit can't be achieved outside a noise sensitive premise.

Table 11.2 SPP 5.4 outdoor noise criteria

Period	Target	Limit
Day (6am to 10pm)	55 dB $L_{Aeq\ (Day)}$	60 dB $L_{Aeq\ (Day)}$
Night (10pm to 6am)	50 dB $L_{Aeq\ (Night)}$	55 dB $L_{Aeq\ (Night)}$

Source: State Planning Policy 5.4 Road and Rail Transport Noise and Freight Considerations in Land Use Planning (Government of Western Australia, 2009).

11.3.3 Construction Vibration Criteria

In Western Australia there are no vibration criteria that are applicable to construction vibration.

11.4 Potential Impacts

During the construction and operation phases of the proposal, potential impacts from excessive noise and vibration include:

- Sleep disturbance.
- Hearing impairment.
- Community annoyance.

- Reduced amenity.
- Reduced learning capacity.
- Changed behaviour in the use of public areas.
- Hearing protection requirement.
- Vibration, leading to structural damage (only expected during construction).

11.5 Assessment of Potential Impacts

11.5.1 Construction Noise and Vibration

Due to its temporary and variable nature, noise and vibration impacts from the construction activities are difficult to assess or model. Impacts during this phase are of a temporary nature and are likely to be more prevalent where construction activities occur in close proximity to residential areas. A list of construction activities likely to generate noise and vibration include, but are not limited to:

- Clearing of vegetation and topsoil.
- Earthworks.
- Operating machinery and generators.
- Construction of structures.
- Drilling and pile driving.
- Transporting of cut, fill and materials.

Increases in noise may impact the rest and recreational activities of the surrounding community especially if construction activities are undertaken at night. The noise and vibration associated with construction activities can cause particular annoyance to the community due to its tonality, modulation and impulsiveness.

Noise sensitive premises along the proposal footprint that are likely to be impacted most as a result of construction activities are:

- Between Tonkin/Reid Highway interchange and Hepburn Avenue, including the suburbs of Noranda, Beechboro, Malaga and Ballajura.
- Cullacabardee.
- Cyrenian House.
- Ellenbrook.
- Rural residential properties north of Ellenbrook.

11.5.2 Operation Noise and Vibration

A noise assessment was undertaken in accordance with the SPP 5.4.

The noise impact assessment (Lloyd George Acoustics, 2015b) (Appendix O) considered the likely traffic noise emissions resulting from the proposal on sensitive receivers. Modelled impacts took into account:

- Types of vehicles using the road infrastructure. Vehicles were classed as either heavy or non-heavy and each was allocated different source heights above road levels to represent the engine and exhaust height.

- Topographical data was considered in the modelling and integrated into the existing proposal site characteristics (i.e. existing property fences). Buildings were incorporated into the model as they can provide barrier attenuation when located between a source and receiver.

Modelled noise was compared to the policy criteria outlined in Table 11.2. The results of the noise modelling (both with and without proposed noise walls) are depicted in Figures 11.2 and 11.3 as follows:

- Properties where noise levels are predicted to be above the noise target of 55 dB $L_{Aeq,}$ but below the noise limit of 60 dB L_{Aeq}.
- Properties where the noise level will be above the 60 dB L_{Aeq} noise limit.

The noise modelling depicted in Figure 11.3 includes:

- Proposed noise walls between Reid Highway and Hepburn Avenue to ensure, where practicable, that all noise sensitive premises have resultant noise levels below the day limit criterion of 60 dB L_{Aeq}, as this area is not considered a greenfields area.
- Proposed noise walls between Hepburn Avenue and Ellenbrook to ensure, set at a maximum of 5 m where practicable, that all noise sensitive premises have traffic noise levels below the day target criterion of 55 dB L_{Aeq}.
- A maximum noise wall height of 5 m.

With a 5 m high limit on noise walls, all properties between Hepburn Avenue and Ellenbrook will have traffic noise levels below the limit and the majority will be below the target.

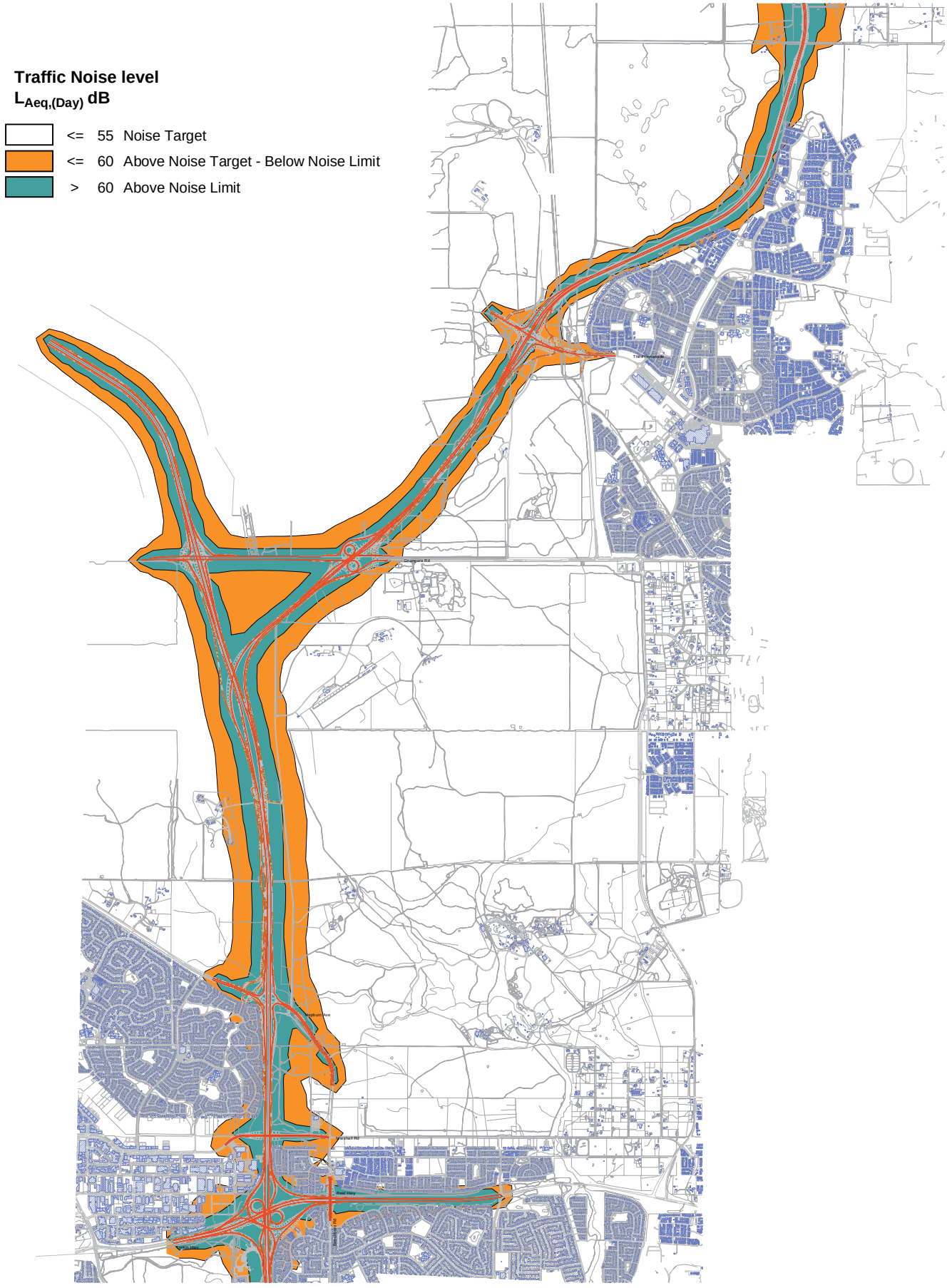
Rural residential properties north of Ellenbrook where noise levels are likely to exceed the day target criteria of 55 dB L_{Aeq} are presented in Figure 11.4. At these locations, it is not practicable or reasonable to construct noise walls. Noise sensitive receivers north of Ellenbrook will receive facade treatments and screen walls to minimise visual and acoustic impacts. It is estimated that eight receivers may require facade protection. During operations vibration from traffic is unlikely to be detectable and will not result in vibration impacts to humans or damage buildings and structures.

11.6 Management Measures

To reduce the noise and vibration impacts resulting from the proposal, the mitigation hierarchy (i.e. avoid, minimise, rehabilitate/restore and offset) discussed in Chapter 7 has been applied during proposal design and in the development of appropriate mitigation and management strategies and offsets.

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 appropriate management measures that are relevant to specific conditions on site, and which may vary from those described in this document.

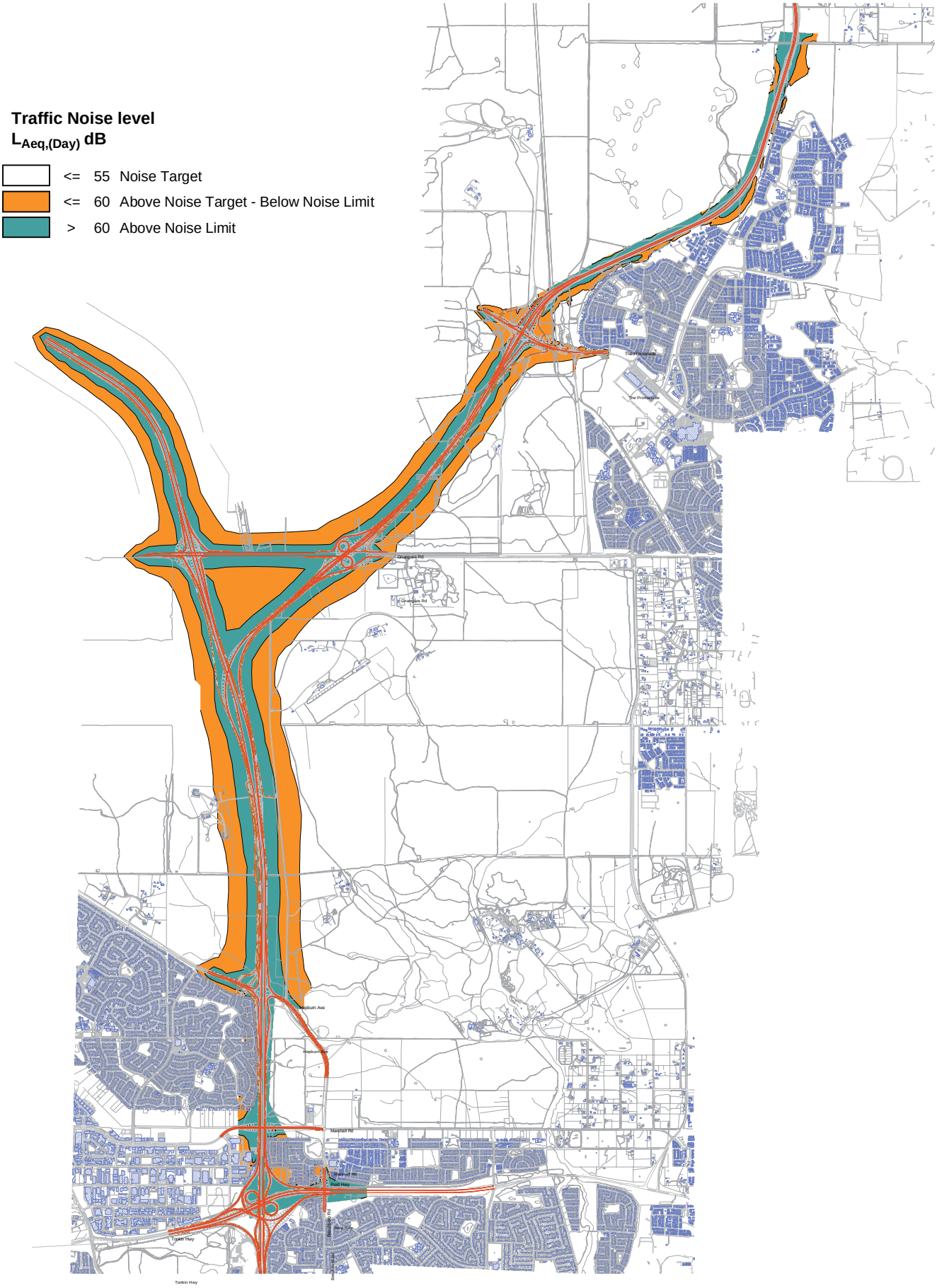
This approach is consistent with the Environmental Assessment Guideline for Recommending Environmental Conditions (EPA, 2013a).



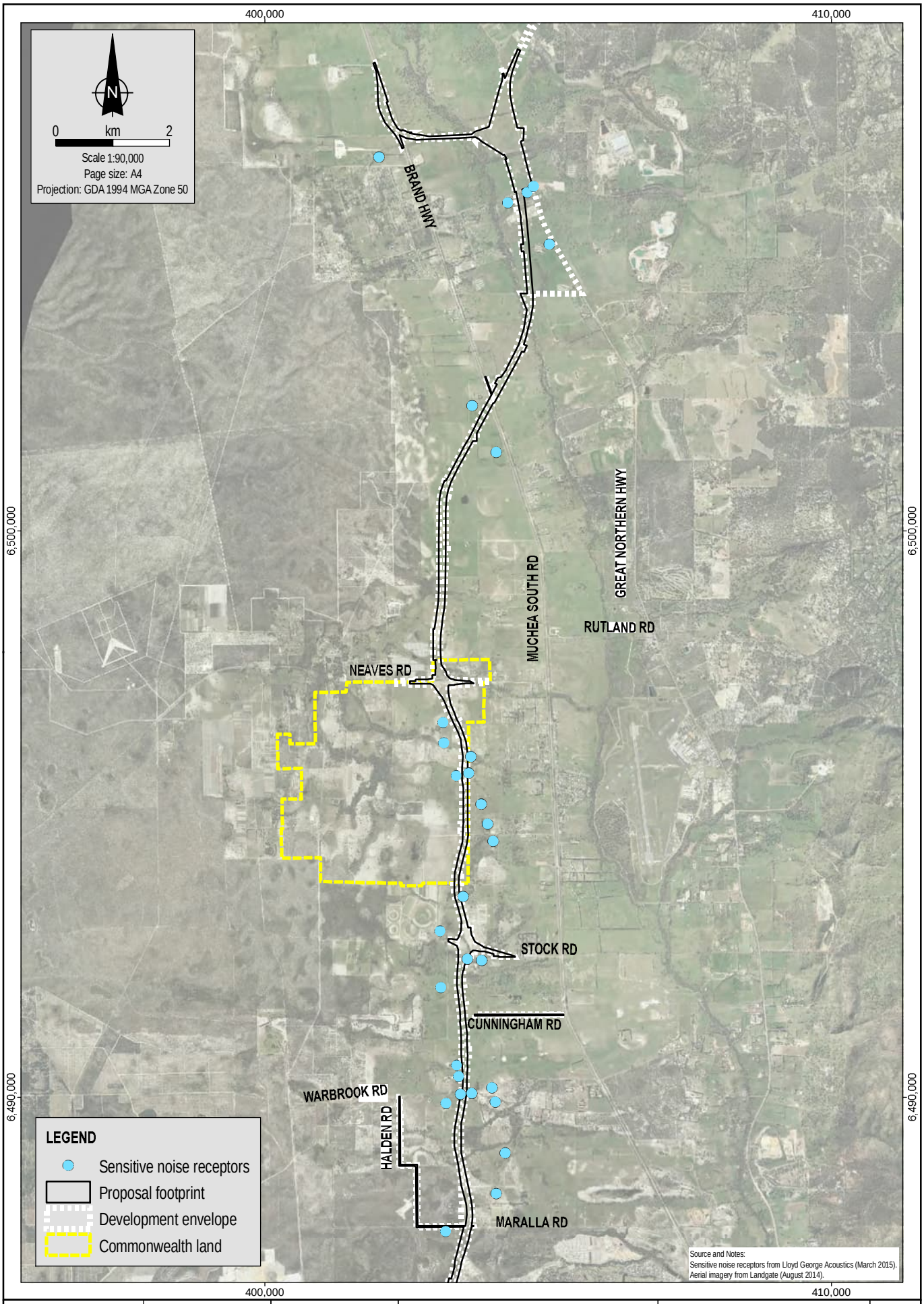
coffey	Date: 25.03.2015	Main Roads WA	NorthLinkWA	Predicted noise levels (without noise walls)	Figure No: 11.2
	File Name: 4483AA_03_F11.02_GIS_GL	Public Environmental Review Perth–Darwin National Highway			

Traffic Noise level
$L_{Aeq,(Day)}$ dB

	<=	55	Noise Target
	<=	60	Above Noise Target - Below Noise Limit
	>	60	Above Noise Limit



coffey	Date: 02.07.2015	Main Roads WA	NorthLinkWA	Predicted noise levels (with noise walls)	Figure No: 11.3
	File Name: 4483AA_03_F11.02_GIS_GL_2	Public Environmental Review Perth–Darwin National Highway			



NorthLinkWA	coffey	Date: 03.06.2015 MXD: 4483AA_03_GIS101_2 File Name: 4483AA_03_F11.4_GIS	Main Roads WA Public Environmental Review Perth–Darwin National Highway	Sensitive noise receptors north of Ellenbrook	Figure No: 11.4

11.6.1 Construction Noise and Vibration

Construction noise will comply with Regulation 13 of the Noise Regulations.

A Construction Noise and Vibration Management Plan (CNVMP) will be developed for any out of hours works (outside of 7.00 a.m. to 7.00 p.m. Monday to Saturday) in accordance with the Environmental Protection (Noise) Regulations 1997, to the satisfaction of DER and relevant local government authorities. The CNVMP will be developed prior to construction to ensure all works are carried out in accordance with AS 2436:2010 - Guide to Noise and Vibration control on Construction, Demolition and Maintenance sites, and will include the following mitigation/management measures:

- Using equipment with low noise levels and maintaining noise control devices on equipment.
- Using broadband reversing alarms on construction equipment.
- Taking precautionary measures to avoid vibration damage to buildings near work sites.
- Vibration will not exceed a particle velocity of 5 mm/s during construction.
- A dilapidation survey will be undertaken prior to construction.
- Providing a 24-hour noise and vibration complaint hotline during construction and maintaining a complaints register.
- Obtaining necessary approval to work outside of normal working hours, if required.
- Providing public notification where receptors may be impacted by construction noise and/or vibration, particularly when works will occur outside normal working hours.
- Minimising the amount of night-time traffic and construction adjacent to residential areas.
- Undertaking noise and vibration monitoring during construction in response to complaints or at potentially affected locations to alert operators of exceedances of noise and vibration limits.

11.6.2 Operation Noise

Management of noise during the operation phase will require the following to be developed during the final design of the proposal and will be implemented prior to the end of construction:

- Locating the road infrastructure as far to the west within the road reserve as far as is practicable, in the vicinity of Ellenbrook, to minimise noise impacts.
- Using the quietest practical road surface.
- Constructing noise walls to a maximum height of 5 m at noise sensitive premises adjacent to the alignment between Reid Highway and Hepburn Avenue to ensure noise levels do not exceed the noise limit of 60 dB L_{Aeq} at these premises. The location of noise walls are indicated in Figure 11.3.
- Constructing noise walls to a maximum height of 5 m at noise sensitive premises adjacent to the alignment between Hepburn Avenue and Ellenbrook with the aim to ensure noise levels do not exceed the noise target of 55 dB L_{Aeq} at these premises, as far is reasonably practicable. Noise walls will be a constructed of material with a surface density exceeding 15 kg/m^2. The location of noise walls are indicated in Figure 11.3.
- Should the construction of noise walls not result in achieving the noise target of 55 dB L_{Aeq} at noise sensitive receptors between Hepburn Avenue and Ellenbrook, efforts will be made to achieve the noise limit of 60 dB L_{Aeq}.

- Where the road is located within 100 m of residential properties north of Ellenbrook, a visual screening wall will be constructed of 2.4 m in height.
- Façade protection packages will be implemented at identified properties north of Ellenbrook where noise levels are likely to exceed the day limit criteria of 60 dB L_{Aeq}. The level of treatment provided will be determined on a case-by-case basis in consultation with affected property owners and is likely to consist of 6 mm thick glazing to windows (see Figure 11.4).

11.7 Residual Impact

Noise and vibration impacts will be localised and temporary during the construction phase of the proposal. With the implementation of mitigation and management measures the effects are expected to be manageable and within the requirements of the Noise Regulations. As such, construction noise and vibration is likely to meet the EPA's objective.

For areas between Reid Highway and Hepburn Avenue the noise limit of 60 dB L_{Aeq} can be achieved through the construction of noise walls. Implementation of appropriate mitigation measures will therefore achieve noise limits as prescribed in State Planning Policy 5.4. As such, the proposal is likely to meet the EPA's objective along this section of the development envelope.

For areas between Hepburn Avenue and Ellenbrook, achieving the noise target of 55 dB L_{Aeq} may not be achievable at all noise sensitive receptors through the construction of noise walls (to a maximum height of 5 m). However, the noise limit of 60 dB L_{Aeq} will not be exceeded at any noise sensitive receptors along this section of the proposal. As such, the proposal is likely to meet the EPA's objective along this section of the development envelope.

It is expected that the daytime noise target of 55 dB L_{Aeq} will not be achieved at eight rural residential properties north of Ellenbrook due to limitations on noise wall locations. All reasonable and practicable management measures will be implemented to meet the EPA's objectives in respect of noise north of Ellenbrook.

A summary of the proposal's residual impacts on amenity following the implementation of mitigation and management measures is provided in Table 11.3.

Table 11.3 Summary of residual noise impacts following implementation of management and mitigation measures

Aspect	Predicted impacts	Management and mitigation	Residual impacts
Construction noise and vibration	Changes in amenity for local communities.	A CNVMP will be developed for any out of hours works, prior to construction, to ensure all works are carried out in accordance with AS 2436:2010 - Guide to Noise and Vibration control on Construction, Demolition and Maintenance sites, and will include the following mitigation/management measures: • Using equipment with low noise levels and maintaining noise control devices on equipment. • Using broadband reversing alarms on construction equipment. • Taking precautionary measures to avoid vibration damage to buildings near work sites. • Ensure construction vibration does not exceed 5 mm/s. • Providing a 24-hour noise complaint hotline during construction. • Obtaining necessary approval to work outside of normal working hours, if required. • Providing public notification where receptors may be impacted by construction noise and/or vibration, particularly when works will occur outside normal working hours. • Minimising the amount of night-time traffic and construction adjacent to residential areas. • Conducting a dilapidation survey prior to construction. • Undertaking noise and vibration monitoring during construction in response to complaints or at potentially affected locations to alert operators of exceedances of noise and vibration limits.	Noise and vibration impacts will temporarily occur during the construction phase of the proposal. With the implementation of mitigation and management measures the effects are expected to be manageable and within the requirements of the Noise Regulations.

Aspect	Predicted impacts	Management and mitigation	Residual impacts
Road traffic using PDNH	Changes in amenity for local communities.	• Locating the highway as far to the west of Ellenbrook as practicable. • Using the quietest practical road surface. • Constructing noise walls to a maximum height of 5 m adjacent to noise sensitive premises between Reid Highway and Ellenbrook and of a material with a surface density exceeding 15 kg/m^2. • Should the construction of noise walls not result in achieving the noise target of 55 dB LAeq at noise sensitive receptors between Hepburn Avenue and Ellenbrook, efforts will be made to achieve the noise limit of 60 dB L_{Aeq}. • Constructing screening walls of a maximum height of 2.4 m at noise sensitive premises north of Ellenbrook. • Where the limit can't be achieved north of Ellenbrook, facade treatments will be applied to reduce indoor noise.	For brownfields areas between Reid Highway and Hepburn Avenue the proposal will achieve the noise limits of 60 dB L_{Aeq} prescribed in State Planning Policy 5.4. For greenfields areas between Hepburn Avenue and Ellenbrook the proposal will achieve the noise target of 55 dB L_{Aeq} at noise sensitive receptors where practicable, while achieving the noise limit of 60 dB L_{Aeq} at remaining noise sensitive receptors where 55 dB L_{Aeq} cannot be achieved. Mitigation measures will not achieve the 55 dB LA_{eq} target for eight rural residential properties north of Ellenbrook. Façade treatment will be provided to achieve indoor noise targets, but will not necessarily reduce external noise.

12 REHABILITATION AND DECOMMISSIONING

12.1 EPA Objective

The EPA's objective for rehabilitation and decommissioning is to ensure that premises are decommissioned and rehabilitated in an ecologically sustainable manner (EPA, 2015a).

It should be noted that the proposal itself is intended to provide permanent infrastructure and is unlikely to be closed and decommissioned. However, at the completion of construction some areas will require revegetation and this term has been used throughout the PER.

12.2 Landscaping Objectives

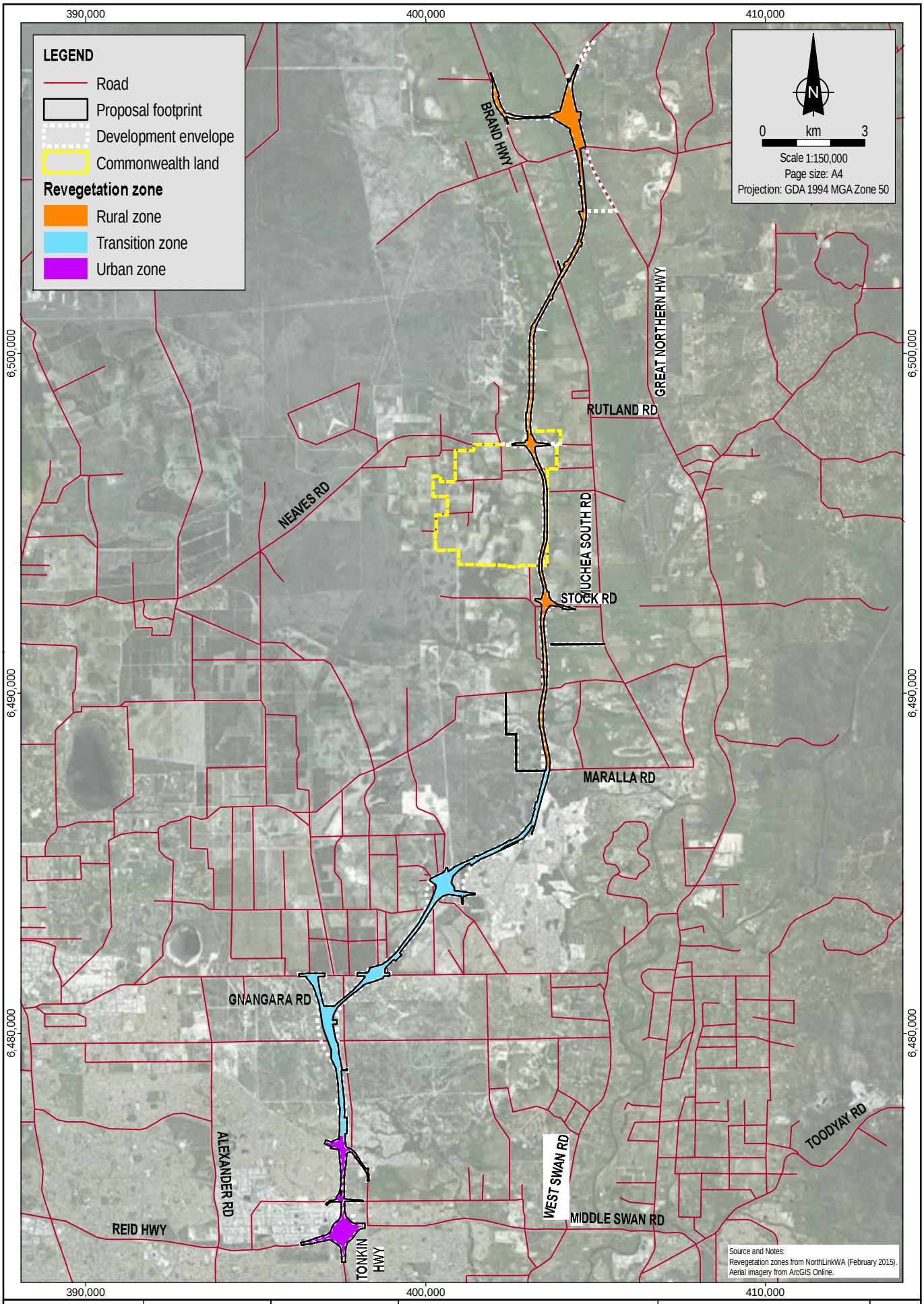
Appropriate landscaping forms part of the revegetation plan. The landscaping, urban design and aesthetics planning objectives that will be implemented for the proposal include:

- Provide a landscape consistent with the vegetation types and classes of the proposal footprint.
- Provide an urban experience for road users, creating a 'journey' through the road corridor.
- Provide a road corridor development with high quality urban design and aesthetic structures.
- Provide a soft landscaped road alignment in keeping with the varied site context of the corridor.
- Provide landscape and urban design treatments that are sustainable and maintainable.
- Provide landscape and urban design treatments that provide amenity for adjoining landholders and provide management of the roadway's visual impacts.

12.3 Revegetation Strategy

The revegetation strategy considers the existing landscapes of the proposal footprint, which have been divided into three zones according to the current vegetation and land use along the alignment. Revegetation will focus on using native provenance vegetation in each of these zones that are suited to the surrounding landscape characteristics and land use. Starting at the northernmost section of the proposal, the landscaping types and extent are as follows (Figure 12.1):

- Rural zone – The northern boundary of the proposal footprint to Maralla Road. This zone is commonly characterised by arid landscapes with pasture grass, where large portions of land have been cleared of native vegetation. Revegetation will use pasture species and drainage swales will be planted with native reeds and sedges to link with watercourses and reduce pollutant build-up from road runoff as per the drainage strategy developed for the proposal (BG&E, 2015) (Appendix H).
- Transition zone – Maralla Road to Hepburn Avenue. This zone, particularly around the Ellenbrook area, contains pockets of pristine vegetation, including woodland vegetation such as Banksia (see Figure 8.3). Revegetation will match adjoining woodland vegetation and existing Banksia woodland will be protected and retained.



NorthLinkWA	coffey	Date: 05.06.2015 MXD: 4483AA_03_GIS096_2 File Name: 4483AA_03_F12.1_GIS	Main Roads WA Public Environmental Review Perth–Darwin National Highway	Revegetation zones Figure No: 12.1

- Urban zone – Hepburn Avenue to the southern boundary of the proposal footprint. This zone contains existing transport corridors with vegetation consisting of mid to low grassland. Revegetation will complement existing vegetation with plantings of Marri and Grass trees. Species that complement the road corridor and its structural elements will be selected. Plant selection will be used to contribute to headlight screening, noise attenuation, distant views and mitigation of visual impacts where practicable.

The revegetation strategy for each of the three zones is outlined below.

12.3.1 Rural Zone Revegetation

The revegetation strategy for the rural zone includes (Figure 12.2):

- Verge batter landscaping to focus on dry grassing and tree planting.
- Revegetation treatments to reinforce provenance species adjacent to wetlands and watercourses. Roadside swales will incorporate limited revegetation with native provenance wetland species.
- Landscaping along this section will consist predominantly of tree planting to reinforce and complement the existing character.
- The species suggested to be used for revegetation in the rural zone include *Xanthorrhoea preissii*, *Melaleuca rhaphiophylla*, *Corymbia calophylla* and *Eucalyptus wandoo*.

12.3.2 Transition Zone Revegetation

The revegetation strategy for the transition zone includes (Figure 12.3):

- Utilising native provenance species for revegetation wherever possible.
- Ensuring planting themes reflect native vegetation types of adjacent areas, with emphasis on characteristic species in new landscaping.
- Concentrating wetland planting in roadside swales and where drainage systems (i.e. existing wetlands, drainage and creek lines) within the proposal footprint are located.
- Ensuring provenance in planting mixes adjacent to ecologically significant retained bushland.
- Ensuring revegetation landscaping provides connectivity between remnant bush landscapes.

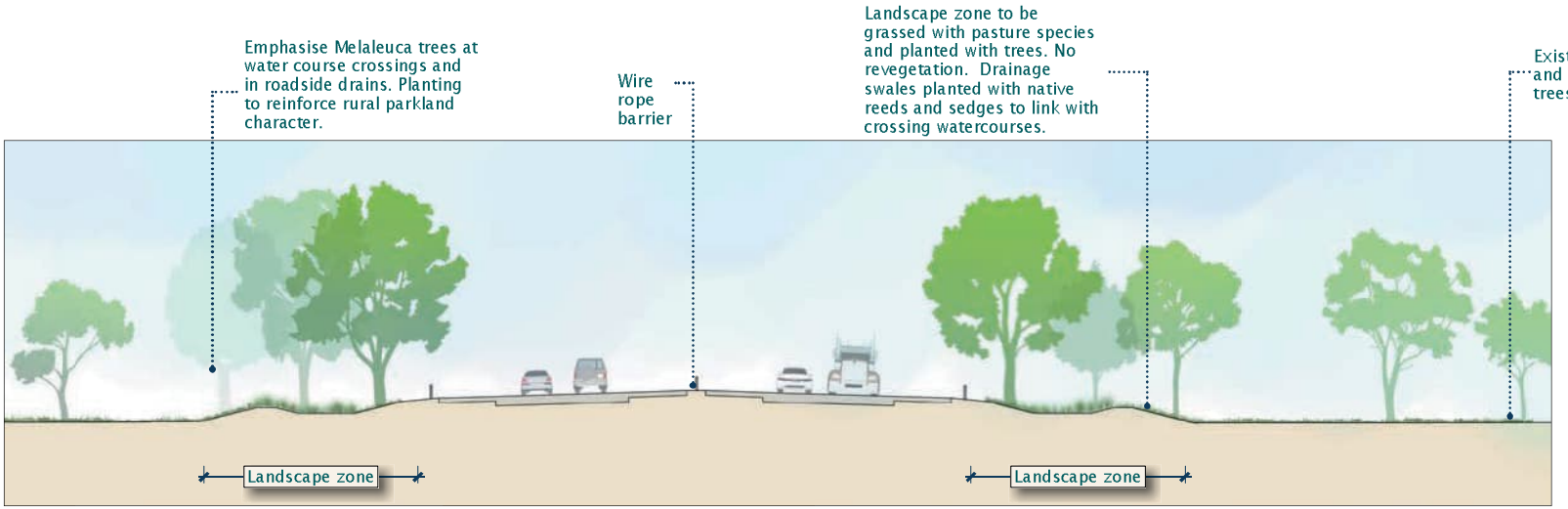
The species suggested for revegetation in the transition zone include *Xanthorrhoea preissii, Melaleuca, rhaphiophylla, Corymbia calophylla, Banksia attenuata* and *Banksia menziesii*.

12.3.3 Urban Zone Revegetation

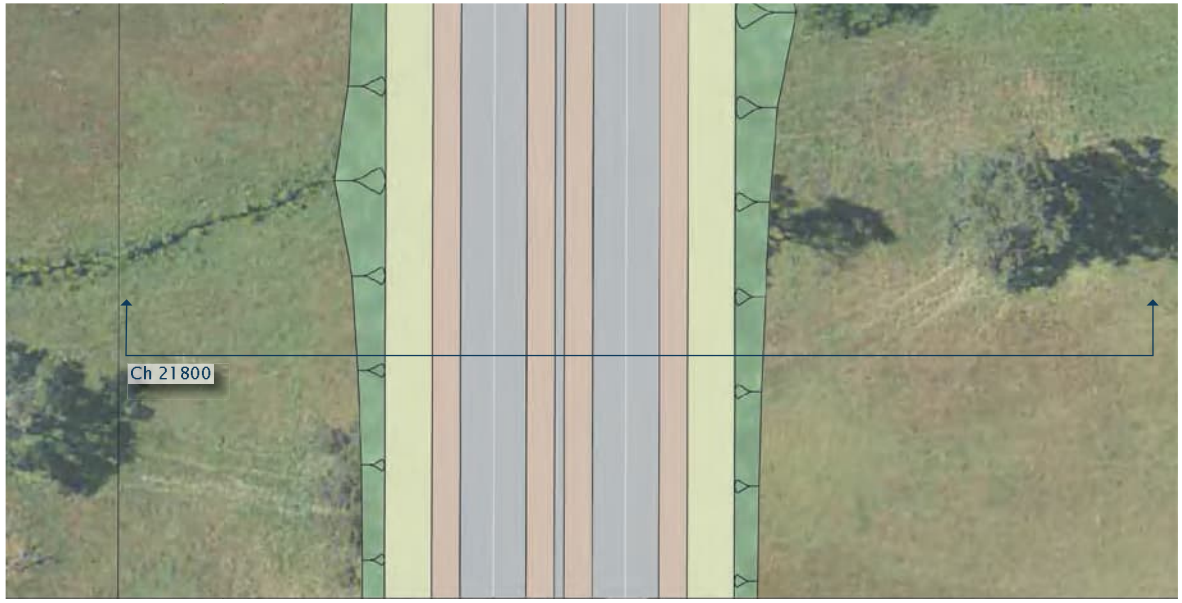
The revegetation strategy for the urban zone includes (Figure 12.4):

- Selecting species to complement road corridor and its structural elements. Plant selection will be used to contribute to headlight screening, noise attenuation, distant views and mitigation of visual impacts where practicable.
- Combining revegetation treatments using provenance native species with horticulturally proven cultivars to enhance amenity in focal zones and ensure robust performance.
- Ensuring provenance in planting mixes adjacent to ecologically significant retained bushland including that found in the Reid/Tonkin Interchange and remnant wetlands.

The species suggested for revegetation in the urban zone include *Xanthorrhoea preissii, Melaleuca, rhaphiophylla, Corymbia calophylla, Banksia attenuata, Banksia menziesii, Eucalyptus gomphocephala, Eucalyptus todtiana* and *Eucalyptus marginata*.



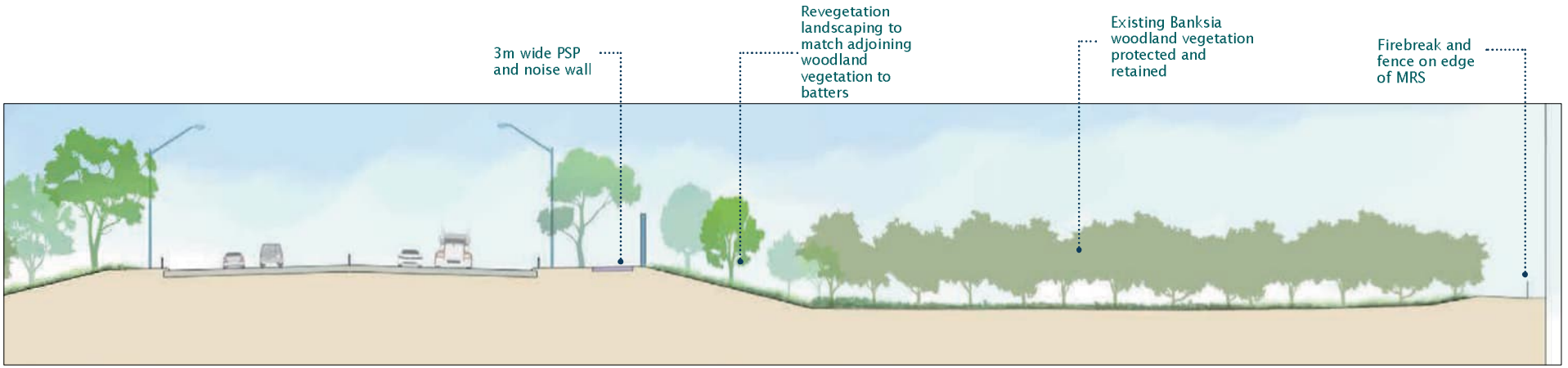
Preliminary Section 1:300



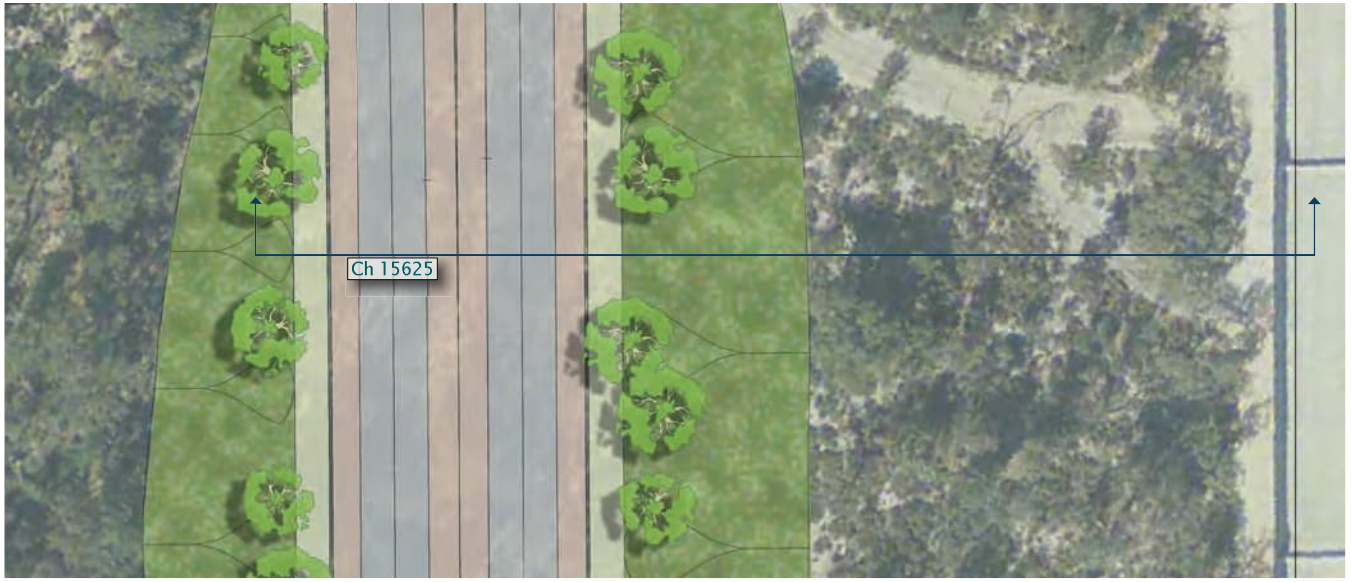
Roadway Treatments - 1:500

Key Plan - Central

Note: Drawing is not to scale and is for illustrative purposes only.	coffey	Date: 07.07.2015 File Name: 4483_P03_F12.02_GL_5	Main Roads WA Public Environmental Review Perth–Darwin National Highway	NorthLinkWA	Illustrative plan for revegetation (Rural zone)	Figure No: 12.2



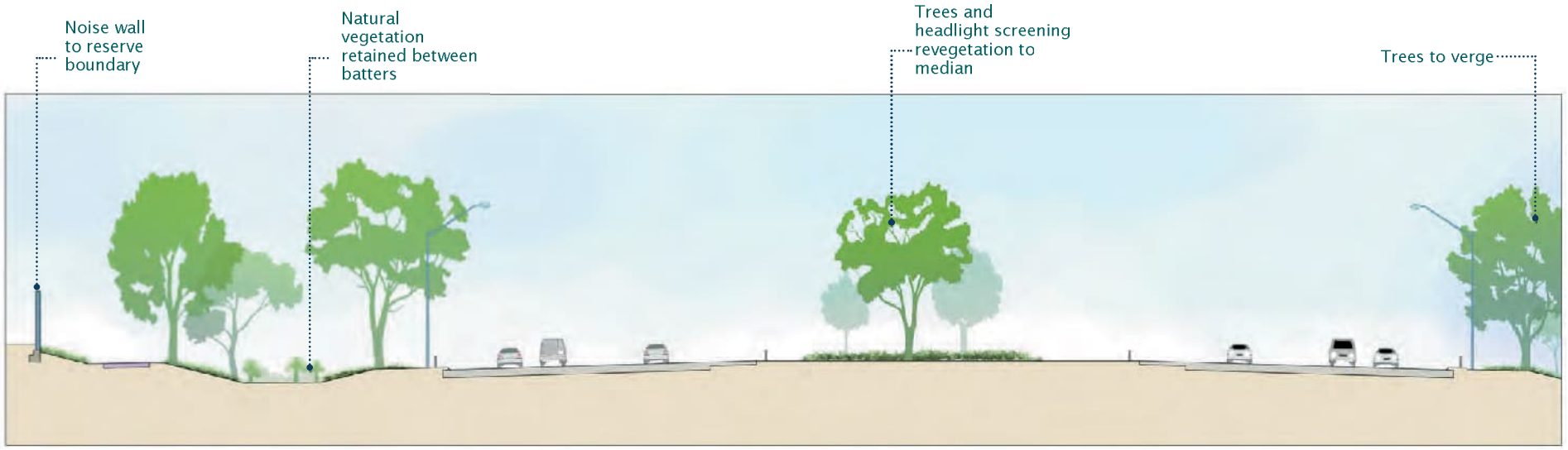
Preliminary Section 1:300



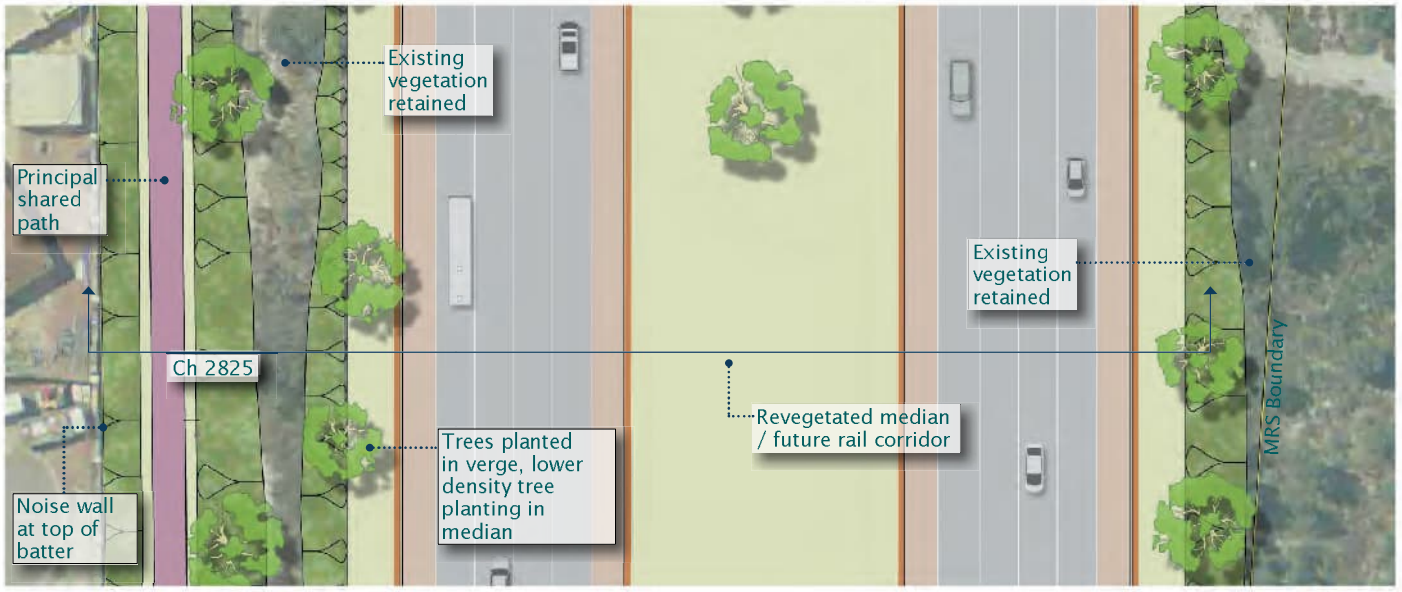
Roadway Treatments - Type 5 - 1:500

Key Plan - Central

Note: Drawing is not to scale and is for illustrative purposes only.	coffey	Date: 13.02.2015 File Name: 4483_P03_F12.03_GL_3	Main Roads WA Public Environmental Review Perth–Darwin National Highway	NorthLinkWA	Illustrative plan for revegetation (Ellenbrook)	Figure No: 12.3



Preliminary Section 1:300



Key Plan - South

Landscape 2 - 1:500

Note: Drawing is not to scale and is for illustrative purposes only. Railway is shown only to illustrate future possible use of central median and is not proposed as part of this proposal.	coffey	Date: 18.06.2015 File Name: 4483_P03_F12.04_GL_6	Main Roads WA Public Environmental Review Perth–Darwin National Highway	NorthLinkWA	Illustrative plan for revegetation (Reid Highway - Hepburn Avenue)	Figure No: 12.4

12.3.4 Revegetation Setbacks and Placement

Revegetation for the proposal will be in compliance with MRWA Vegetation Placement within the Road Reserve Doc. No. 6707/022 (MRWA, 2013b). This guide outlines the recommended setbacks and clearance requirements from all driving surfaces and at intersections and crossings, that apply to all revegetation or landscaping associated with new road construction.

Restrictions apply to the placement of vegetation near road infrastructure, in particular, to maintain road safety. These rules also minimise ongoing maintenance to control vegetation growth and maintain a standard amenity level for road users. The proposal will incorporate these restrictions when undertaking revegetation, in particular, the consideration of a roadside maintenance zone and a clear zone.

The roadside maintenance zone can be variable in width and is maintained on both sides of the roadway to retain clear sightlines and lateral clearances from the roadway and for functional off road drainage. The clear zone is a safety zone adjacent to both sides of the roadway used to maintain clearance to utilities and to help reduce the severity of accidents if vehicles run off the road. Restrictions apply for trees and fixed objects within this band of variable width.

12.4 Potential Impacts

Failure to rehabilitate a proposal site or poor site rehabilitation can have a number of impacts on the environment (Government of Western Australia, 2014) including:

- Reduction in the quality and quantity of habitats.
- Reduction in ecosystem functions.
- Impacts to adjacent natural vegetation and the economic value of sites.
- Contaminated water from road runoff into swales.

12.5 Mitigation and Management

To ensure that impacts to rehabilitation present within the proposal footprint are minimised and that the relevant EPA objectives can be met, MRWA commits to the following outcomes:

- All areas of temporary disturbance will be revegetated by the re-establishment of a cover of vegetation suited to the location.
- Rehabilitation of the road verge will improve the amenity of the site, the stability of unpaved surfaces and promote ecological sustainability.

While various management measures are proposed in this PER to achieve these desired outcomes, alternative management strategies may arise with further design, investigations and project planning. MRWA is committed to achieving environmental outcomes through 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).

The following mitigation and management strategies have been developed to achieve the above commitments and have been informed by relevant MRWA environmental guidelines and corporate procedures:

- An EMP will be developed and implemented during construction.

- A detailed revegetation plan will be developed outlining a clear timeframe for mitigation and management measures, monitoring actions and completion targets.
- Retain topsoil for placement on areas where revegetation will be undertaken. In the absence of adequate topsoil, suitable growth medium will be used. If additional topsoil is required, materials must be contaminant and weed free.
- Dieback hygiene procedures will be implemented to ensure no cross-contamination of dieback free material occurs.
- Weed hygiene procedures will be implemented to minimise the risk of introducing weeds into rehabilitated areas.
- Conserving and where possible chipping good quality vegetation, during clearing, for reuse as mulch.
- Treating or disposing unsuitable topsoil and cleared vegetation during the clearing works.
- Landscaping will be undertaken in accordance with the landscaping types and extent present in the proposal footprint (rural zone, transition zone and urban zone).
- Local provenance native species that represent the floristic formations of the proposal footprint will be selected for revegetation.
- Scheduling rehabilitation progressively where practicable. Timing of activities will, however, be dependent on optimal seasons.
- Ongoing maintenance will form part of the regional Maintenance Program and will be the responsibility of the Asset Manager.

12.6 Residual Impacts

At a minimum, revegetation will achieve roadside stability and minimise ongoing maintenance.

Revegetation will, in the long term, enhance the ecological function of vegetation immediately adjacent to the proposal footprint and assist in conservation of local biodiversity values.

Successful revegetation will assist in meeting community expectations relating to local amenity and aesthetics.

Implementation of the revegetation strategy and associated management measures will meet the EPA's objective to ensure that the proposal footprint is rehabilitated in an ecologically sustainable manner, consistent with agreed outcomes and land uses, and without unacceptable liability to the State.

A summary of the proposal's residual impacts on revegetation following the implementation of mitigation and management measures is provided in the following Table 12.1.

Table 12.1 Summary of residual impacts on revegetation following implementation of management and mitigation measures

Aspect	Predicted impacts	Management and mitigation	Residual impacts
Failure to rehabilitate a proposal site or poor site rehabilitation	Reduction in the quality and quantity of habitats, ecosystem function and adjacent natural vegetation.	• An EMP will be developed and implemented during construction, which includes a detailed revegetation plan, outlining a clear timeframe for mitigation and management measures, monitoring actions and completion criteria. • Topsoil will be retained and vegetation removed (topsoil materials must be contaminant and weed free). • Dieback hygiene procedures will be implemented. • Weed hygiene procedures will be implemented, to minimise the risk of introducing weeds into rehabilitated areas. • Conserving and where possible chipping good quality vegetation, during clearing, for reuse as mulch. • Treating or disposing unsuitable topsoil and cleared vegetation during the clearing works. • Landscaping will be undertaken in accordance with the landscaping types and extent present in the proposal footprint (rural zone, transition zone and urban zone). • Local provenance native species that represent the floristic formations of the proposal footprint will be selected for revegetation. • Scheduling rehabilitation progressively where practicable. Timing of activities will however be dependent on optimal seasons. • Ongoing maintenance will form part of the regional Maintenance Program and will be the responsibility of the Asset Manager.	• Achievement of roadside stability and minimised ongoing maintenance. • Enhancement of the ecological function of vegetation immediately adjacent to the proposal footprint and assist in conservation of local biodiversity value.

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13 ABORIGINAL HERITAGE

13.1 EPA Objectives

The EPA's objective for heritage is to ensure that historical and cultural associations, and natural heritage, are not adversely affected (EPA, 2015a).

Aboriginal heritage was not identified in the ESD by the EPA as a preliminary key environmental factor. However, heritage was identified as one of two other environmental factors which require consideration in the PER. In addition, MRWA recognises the significance of Aboriginal heritage and a survey was commissioned in this regard. A desktop study, followed by a field survey and consultation, was carried out in accordance with the *Aboriginal Heritage Act 197*2 (AH Act) and Guidance Statement No. 41 Assessment of Aboriginal Heritage (Amergin, 2014, 2015) (Appendices P and Q).

13.2 Existing Environment

The proposal is located on a combination of alluvial soils and Bassendean sands, both of which have been identified as having higher numbers of archaeological sites than other areas on the Swan Coastal Plain. These sites are often found on sandy crests near water sources and are moderate to large in size (Amergin, 2014).

At the time of European colonisation the land in the southwest of Western Australia was occupied by the Nyungar people. The Nyungar people lived a hunter-gatherer lifestyle. The area around Perth was part of the territory of the Whadjuk or Whadjug (Amergin, 2014). Within the Whadjug, there were a number of bands, which in turn comprised of a number of families.

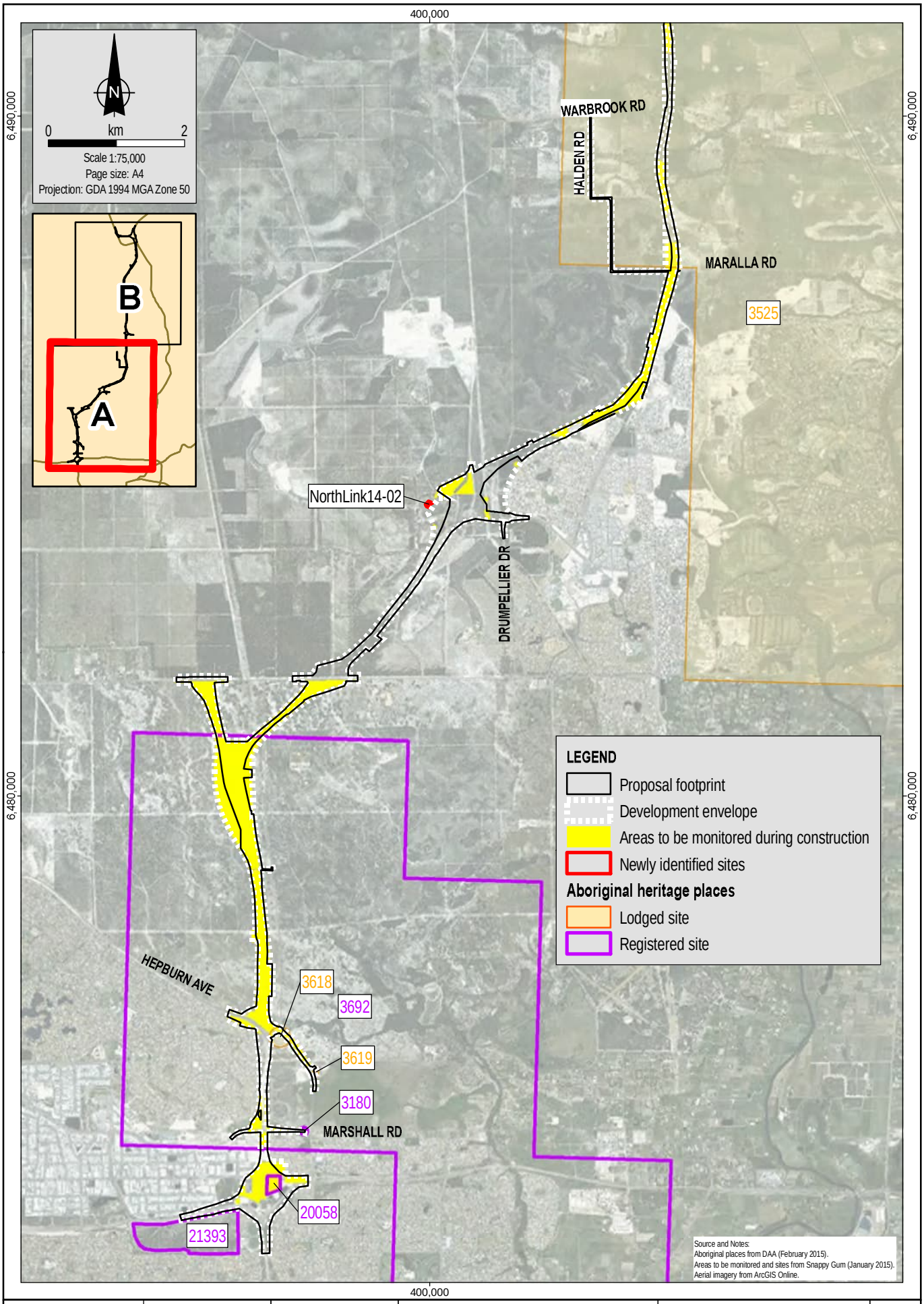
Archaeological evidence of the use of the country by Aboriginal people in historic times is manifested in historical artefacts such as stone artefact scatters, flaked glass, clay pipes or matchbox and tobacco tins. Other connections include the continuing use of bush resources such as medicinal plants and the transmission of cultural knowledge.

Other historical sites such as farm camps, burials, fringe camps, missions and other institutions now since closed also have contemporary importance to local Aboriginal communities (Snappy Gum, 2015a).

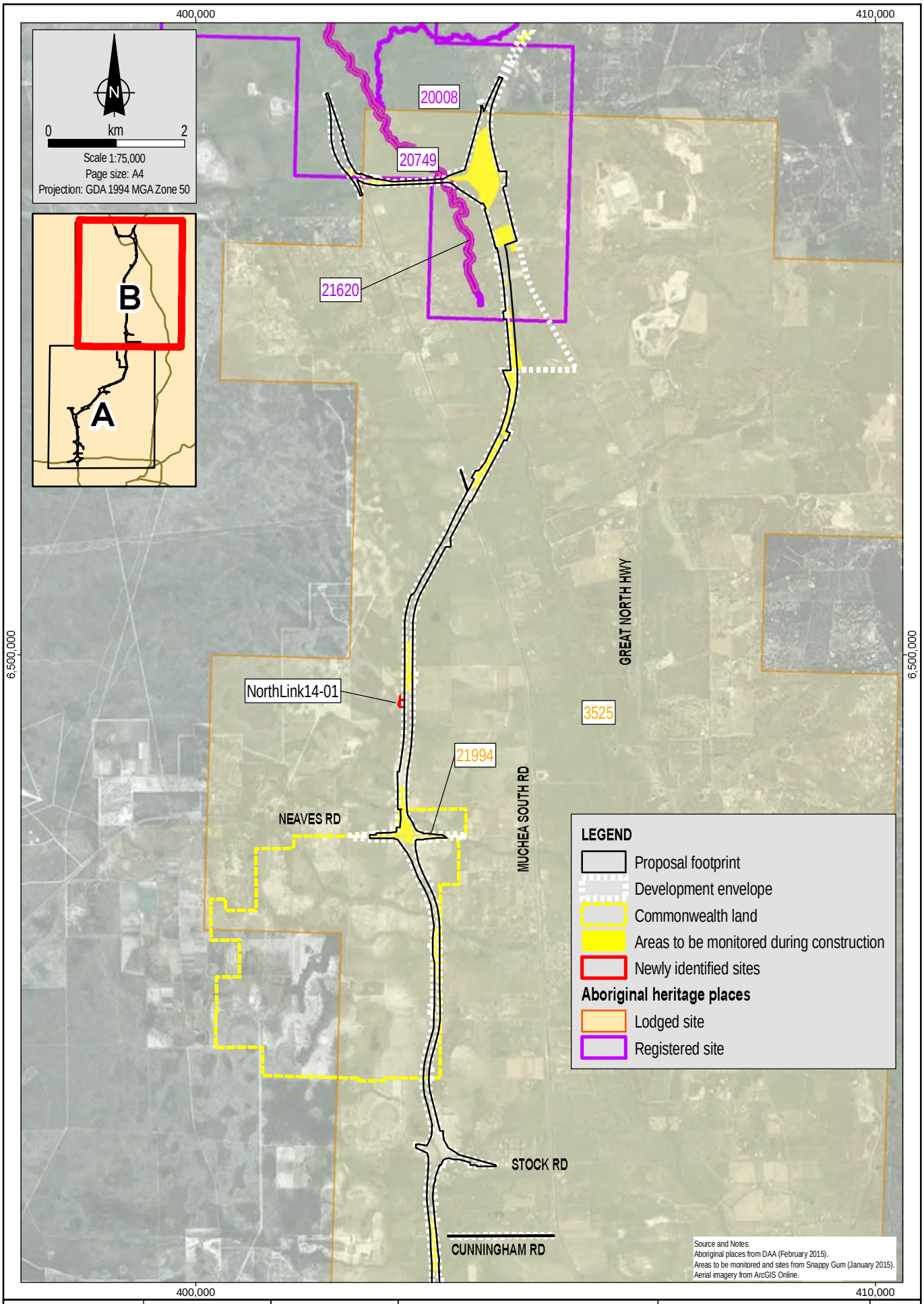
There are currently no determined Native Title Holders over the development envelope. However, it is encompassed by one registered Native Title Claim, namely the 'Whadjuk People' Native Title Claim (WC2011/09) which is represented by the South West Aboriginal Land and Sea Council (SWALSC).

13.2.1 Registered Aboriginal Sites

The field survey identified four sites that could potentially be impacted by the proposal footprint (Table 13.1 and Figure 13.1) (Amergin, 2015) (Appendix Q).



NorthLinkWA	coffey	Date: 18.06.2015 MXD: 4483AA_03_GIS091_2 File Name: 4483AA_03_F13.1A_GIS	Main Roads WA Public Environmental Review Perth–Darwin National Highway	Registered and lodged Aboriginal heritage sites Map 1 of 2	Figure No: 13.1A



NorthLinkWA | coffey

Date: 05.06.2015
MXD: 4483AA_03_GIS092_2
File Name: 4483AA_03_F13.1B_GIS

Main Roads WA
Public Environmental Review
Perth–Darwin National Highway

Registered and lodged Aboriginal heritage sites
Map 2 of 2

Figure No: 13.1B

Table 13.1 Registered Aboriginal sites overlapping the proposal footprint

Site ID	Site name	Site type	Additional information
3692	Bennett Brook in Toto	Mythological	Restricted site
20058	Temporary Camp	Camp	Destroyed in the 1990s
21393	NOR/02 Lightning Swamp	Ceremonial, Mythological	Archaeological deposit, meeting place, plant resource, camp, Hunting place, natural feature, water source
21620	Chandala Brook	Mythological	Part of DAA Complex 42

13.2.1.1 Site 3692: Bennett Brook in Toto

This ethnographic site is a restricted[1] site. The site is recorded to include the brook and the banks on either side (see Figure 13.1). The entire brook is of significance because it was formed by the Waugal, whose spiritual essence is believed to exist there. The site extends approximately 7 km from Bennett Brook/Swan River converging at Mussel Pool in Whiteman Park, and also includes the tributary of Bennett Brook (O'Connor cited in Amergin, 2014). A review of the site file confirmed that two tributaries of Bennett Brook have previously been mapped as part of the registered site and are intersected by the proposal footprint to the west of Beechboro Road, north of Hepburn Avenue.

13.2.1.2 Site 20058: Temporary Camp

This site was recorded in 1994 as a former camping area and is in the vicinity of Tonkin/Reid interchange (see Figure 13.1). This site is considered to be an important former camping site (Amergin, 2014).

13.2.1.3 Site 21393: NOR/02 Lightning Swamp

The site was reported as a "place of high cultural significance" following a survey in 2009 (Amergin, 2015). The wetland was reported to be part of the Bennett Brook system and the bushland surrounding it a place of camping and hunting. The site was also previously reported as a meeting place for cultural activities. The development envelope marginally intersects the site's boundary.

13.2.1.4 Site 21620: Chandala Brook

This is an ethnographic site, and forms part of DAA site Complex 42, which comprises all of the wetlands and watercourses between Bullsbrook and Moore River (Amergin, 2014).

13.2.2 Lodged Aboriginal Sites

The desktop study identified six sites that were considered as part of the field survey; however, of those that were investigated, only one site occurs in the proposal footprint (Table 13.2 and Figure 13.1) (Amergin, 2015).

[1] Restricted sites are those sites that have been afforded protection from disclosure of information in the public arena. Information about sites is often restricted by being held by the Traditional Owners and possibly even restricted to only some key people within the group of Traditional Owners.

Table 13.2 Lodged Aboriginal sites overlapping the proposal footprint

Site ID	Site name	Site type	Additional information
3525	Ellen Brook, Upper Swan	Mythological	Waterways and wetlands between Bullsbrook and Moore River (restricted site)

13.2.3 Newly Identified Sites

Two previously unrecorded artefact scatters (NorthLink 14-01 and NorthLink 14-02) were identified during a field survey (Snappy Gum, 2015a) (Appendix R). These sites were identified as being potential 'Aboriginal sites' owing to the presence of a range of artefact sizes and types, the close proximity of lithologically-similar artefacts and areas that suggest some site integrity.

Both NorthLink 14-01 and NorthLink 14-02 were identified as occurring in close proximity to but still outside the proposal footprint and are unlikely to be impacted (Amergin, 2015) (Appendix Q).

- NorthLink 14-01 had an estimate of 60 visible artefacts, comprising both quartz and silcrete assemblages. It is considered to have archaeological significance for its ability to address the pattern and nature of Aboriginal occupation of this portion of the SCP, particularly addressing archaeological concerns related to post-colonial contact.
- NorthLink 14-02 had an estimate of 100 visible artefacts comprising mostly quartz, a single piece of fossiliferous debris and a silcrete flake. This site is considered to have archaeological significance for its ability to address the pattern and nature of Aboriginal occupation of this portion of the SCP including research questions about the spatial distribution and technological change in fossiliferous chert assemblages.

13.3 Potential Impacts

The sites that fall within the proposal footprint are likely to be disturbed by construction activities and no physical evidence will remain. Views expressed by Aboriginal participants in the survey are detailed in Appendix Q.

13.4 Management and Mitigation

To reduce the proposal's impacts to Aboriginal heritage, 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.

To ensure that impacts to Aboriginal heritage present within and in the proposal footprint are minimised and that the relevant EPA objectives can be met, MRWA commits to the following outcomes:

- No disturbance to any Aboriginal heritage site outside of that approved under Section 18 of the AH Act.
- Minimise impacts to unknown Aboriginal heritage sites.

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).

Mitigation and management strategies summarised below that can be applied to achieve the above environmental commitments:

The following management measures will be incorporated into an Aboriginal Heritage Management Plan and apply to Aboriginal sites in the proposal footprint:

- An application under Section 18 of the AH Act will be submitted to the DAA to obtain approval from the Minister of Aboriginal Affairs to disturb these sites within the proposal footprint.
- All relevant staff/contractors will be informed about the presence and location of Aboriginal archaeological sites NorthLink 14-01 and NorthLink 14-02, which may be considered Aboriginal sites under Section 5(a) of the AH Act.
- Other stakeholders such as landowners will be informed about any sites on their property.
- Prior to nearby ground disturbance, sites NorthLink 14-01 and NorthLink 14-02 will be clearly delineated using physical markers and/or fencing and existing induction programmes/materials altered to alert staff in the area about the restrictions in entering or working near these heritage areas. Physical barriers may require periodic maintenance to ensure effectiveness.
- SWALSC and other relevant Aboriginal people will be consulted before commencing work within the boundaries of Stored (archaeological) place 3552. Otherwise, there are no legal impediments for proposed work at this place.
- Should any ground disturbance be proposed for Registered (archaeological) Sites/Lodged Places DAA Place ID 3692, DAA Place ID 20058, DAA Place ID 21393, DAA Place ID 21620, NorthLink 14-01 and NorthLink 14-02:
  - MRWA will seek formal, written advice from the DAA as to whether Ministerial consent is required under Section 18 of the AH Act for the proposed works.
  - Consultation with SWALSC and other relevant Aboriginal people will take place.
  - An application will be made under Section 18 of the AH Act to use the ground on which the sites are located, where necessary.
- Monitoring by archaeologists and/or appropriately trained members of the Noongar community will take place in areas that have high potential for sites with some archaeological integrity.

13.5 Residual Impact

It is expected that, even following the implementation of the management and mitigation measures discussed above in Section 13.4, the sites located in the proposal footprint will be disturbed or cleared.

The wetlands and watercourses in the vicinity of the proposal footprint were identified by Aboriginal representatives as being “sacred”, primarily through their association with the Waugal (a spirit ancestor), and of special significance. The proposal makes allowance for sufficient water crossings and culverts to ensure the flow in these watercourses are not permanently impacted through the construction of the proposal. Although Ellen Brook and other watercourses may reasonably be considered as Aboriginal Sites by the DAA, the temporary disturbance of these watercourses is not regarded to have a significant effect on Aboriginal heritage values. As such, the proposal is likely to meet the EPA’s objectives in this regard.

Approximately 1.2 ha of Lightning Swamp (DAA Place ID 21393) adjacent to Reid Highway will be impacted through construction of the proposal. However, the impact was not described by Aboriginal representatives as significant and it is considered that the proposal is likely to meet the EPA's objective with implementation of appropriate management measures.

The registered Aboriginal Site DAA Place ID 20058 is not extant as it was destroyed in the 1990s and construction will have no additional impact and is therefore considered to meet the EPA's objective in regards to heritage.

A summary of the proposal's residual impacts on Aboriginal heritage following the implementation of mitigation and management measures is provided in Table 13.3.

Table 13.3 Summary of residual impacts to Aboriginal heritage following implementation of management and mitigation measures

Aspect	Predicted impacts	Management and mitigation	Residual impacts
Ground disturbance associated with excavation of road cuttings and other construction activities.	Disturbance to Aboriginal heritage sites. • Registered sites: – Bennett Brook in Toto (ID 3692). – Temporary camp (ID 20058). – NOR/02 Lightning Swamp (ID 21393). – Chandala Brook (ID 21620).	• Should any ground disturbance be proposed for Registered (archaeological) sites: – MRWA will seek formal, written advice from the DAA as to whether Ministerial consent is required under Section 18 of the AH Act for the proposed works. – Consultation with the SWALSC and other relevant Aboriginal people will take place. – An application will be made under Section 18 of the AH Act to use the ground on which the sites are located, where necessary. • Prior to nearby ground disturbance, sites NorthLink 14-01 and NorthLink 14-02 will be clearly delineated using physical markers and/or fencing and existing induction programmes/materials altered to alert staff in the area about the restrictions in entering or working near these heritage areas. • Monitoring by archaeologists and/or appropriately trained members of the Noongar community will take place in areas that have high potential for sites with some archaeological integrity. • MRWA will continue to consult with SWALSC and other relevant Aboriginal people on the documentation and management of Aboriginal sites.	Disturbance and clearance of Aboriginal heritage values in proposal footprint.

14 EUROPEAN HERITAGE

14.1 EPA Objectives

The EPA's objective for heritage is to ensure that historical and cultural associations, and natural heritage, are not adversely affected (EPA, 2015a).

European heritage was not identified in the ESD by the EPA as a preliminary key environmental factor and no specific objectives were set for this. However, heritage was identified as one of two other environmental factors that require consideration in the PER. In addition, MRWA recognises the significance of European heritage and a survey was undertaken for the proposal footprint. No listed heritage places that have been afforded statutory protection were identified within the proposal footprint (Appendix S).

14.2 Existing Environment

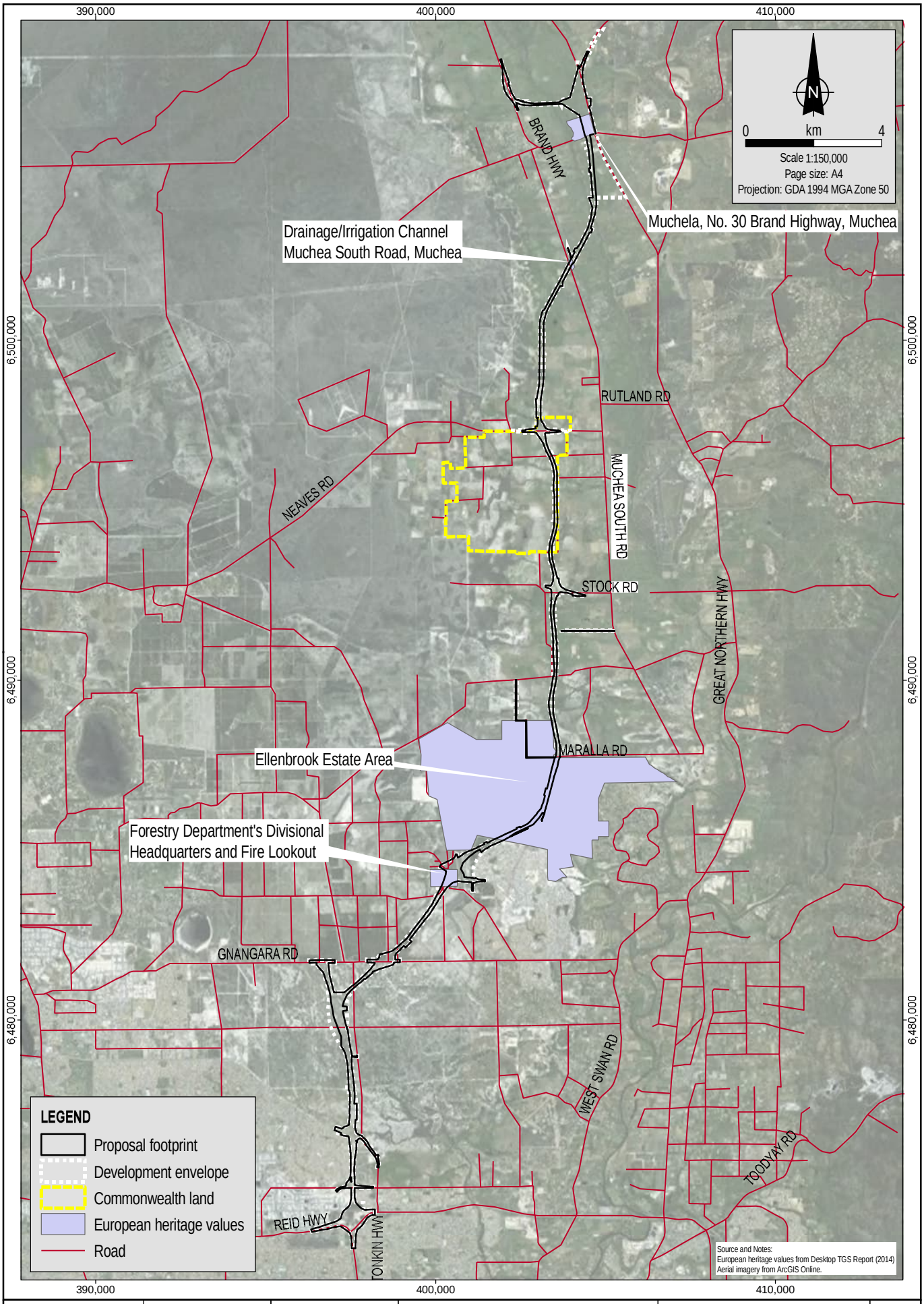
Various heritage database searches were undertaken to identify if any European heritage values listed on the statutory national, state or local heritage lists exist within the study area (TPG, 2015a). No places on any of the statutory national or state heritage lists were identified within the proposal footprint.

Two places on the Shire of Chittering's Heritage List (Figure 14.1) were identified:

- Muchela – No. 30 Brand Highway, Muchea. The site has significance as it was first selected by George Fletcher Moore, who named it Muchela, after which the town of Muchea was named.
- Drainage/Irrigation Channel – The various sites are significant for their association with early drainage practices in the Muchea district.

These places were assigned a Management Category No. 5, which means they are 'of some cultural significance to the Shire of Chittering'. However, little or no tangible evidence of their cultural significance remains (TPG, 2015a).

The Ellenbrook Estate Area is included on both the National Trust List of Classified Places and the Register of the National Estate (both are non-statutory) (TPG, 2015a). Although this property is not on any of the statutory lists, the portion of the place within the proposal boundary will be subject to the Government Heritage Property Disposal Process (GHPDP) as it meets the criteria whereby it is 'already on an existing heritage list'. The Ellenbrook Estate Area was included on the above lists as a result of the area being considered significant due to the presence of large continuous remnant native vegetation, Threatened and Priority plant species, Priority Fauna species and a good representation of ecosystems on leached sands and seasonally inundated alluvial plains (TPG, 2015a).



NorthLinkWA	coffey	Date: 05.06.2015 MXD: 4483AA_03_GIS063_2 File Name: 4483AA_03_F014.1_GIS	Main Roads WA Public Environmental Review Perth–Darwin National Highway	European heritage values	Figure No: 14.1

In addition, the desktop assessment identified the Forestry Department's Divisional Headquarters and Fire Lookout located west of Ellenbrook (TPG, 2015a). The place was initially thought to have potential significance in terms of historic and scientific value, even though it was largely demolished sometime between 1980 and 1995. An archaeological survey was also undertaken (Snappy Gum, 2015b; see Appendix T) to provide a more complete understanding of the archaeological potential and scientific value of the subject place. Using aerial imagery and field investigations it was ascertained that the Forestry Department Lookout has little archaeological significance and that it is no longer considered a place of archaeological potential. In addition, TPG (2015b) (Appendix U) found that all former buildings at the location have been removed and the social value of the site is limited and not of State-wide significance. The site does have some historic value associated with its use by the Forestry Department, however, its condition and authenticity have been eroded to the point where its former use is no longer apparent. It was concluded that the place is not likely to have sufficient value to be included on the State Register of Heritage Places; however, this decision is one to be made by the Heritage Council of Western Australia and must go through due process under the GHPDP.

14.3 Potential Impacts

There are a number of European heritage values located in the proposal footprint that will require demolishing as a result of the proposal (see Figure 14.1). These heritage values are described in Table 14.1.

Table 14.1 European heritage values impacted by the proposal

Places	Heritage list	Requirement
Muchela – No. 30 Brand Highway, Muchea	Shire of Chittering-Municipal Heritage Inventory	• Planning approval potentially required under the Shire of Chittering's Local Planning Scheme No. 6. • May trigger GHPDP as meets the criteria whereby it is "already listed on an existing heritage list".
Drainage/Irrigation Channel, Muchea South Road, Muchea	Shire of Chittering-Municipal Heritage Inventory	• Planning approval potentially required under the Shire of Chittering's Local Planning Scheme No. 6. • May trigger GHPDP as meets the criteria whereby it is 'already listed on an existing heritage list'.
Ellenbrook Estate Area	Register of the National Estate List of Classified Places (the National Trust)	• May trigger GHPDP as it meets the criteria whereby it is 'already listed on an existing heritage list".
Forestry Department's Divisional Headquarters and Fire Lookout	Not heritage listed	• May trigger GHPDP as the place has potential significance in terms of historic value; however, it was largely demolished sometime between 1980 and 1995.

There were a number of locations adjacent to the study area that were identified as having some protection through the Local Planning Scheme Heritage list (statutory) and on Local Government Inventory list (non-statutory). Care should be taken throughout the proposal to ensure that the works do not adversely impact on these places, most importantly those with statutory protection. Should the study area boundaries change, steps should be taken to ensure that these places are not adversely impacted or altered without undertaking proper consultation with the relevant local government authority.

14.4 Management and Mitigation

To reduce the proposal's impacts to existing European heritage sites, the mitigation hierarchy (i.e. avoid, minimise, rehabilitate/restore and offset) discussed in Chapter 7 has been applied during proposal design and in the development of appropriate mitigation and management strategies and offsets.

To ensure that impacts to European heritage 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:

- No disturbance to any European heritage site outside of the proposal footprint.

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).

Mitigation and management strategies summarised below that can be applied to achieve the above environmental commitments:

- Comply with the GHPDP through preparing a letter to the State Heritage Office advising of further clearance of the Ellenbrook Estate Area, Muchela, the Drainage/Irrigation Channel and the Forestry Department's Divisional Headquarters' and Fire Lookout site.
- Inform the Shire of Chittering and advise that the proposal is occurring and will directly impact on two locally listed heritage places: Muchela and the Drainage/Irrigation Channel. Clarification is required on the status of these places on the Shire's Heritage List and what process is required to enable the further clearance of this site.
- Clearly mark the European heritage values identified adjacent to the study area on future mapping for the proposal in order to ensure that all construction personnel are aware of their location and the need for care during construction or with any future boundary changes.
- Inform the City of Swan, Shire of Chittering and City of Bayswater that the proposal is occurring and that it is occurring in close proximity to locally listed heritage places.

14.5 Residual Impacts

European heritage places within the proposal footprint will not be retained and will be demolished (or cleared) as a result of construction and no evidence will remain. The European heritage in the proposal footprint is of limited archaeological or cultural value and is not included on any Commonwealth or State statutory heritage lists. The demolition/clearing of these places is not likely to adversely affect any historical or cultural associations. As such, the proposal is expected to meet the EPA's objectives.

A summary of the proposal's residual impacts on European Heritage following the implementation of mitigation and management measures is provided in Table 14.2.

Table 14.2 Summary of residual impacts to European heritage following implementation of management and mitigation measures

Aspect	Predicted impacts	Management and mitigation	Residual impacts
Ground disturbance associated with excavation of road cuttings and other construction activities.	Disturbance to European heritage sites: • Muchela – No. 30 Brand Highway, Muchea. • Drainage/Irrigation Channel, Muchea South Road, Muchea. • Ellenbrook Estate Area. • Forestry Department's Divisional Headquarters and Fire Lookout.	• A site visit will be undertaken to enable external photographs to be taken of the Ellenbrook Estate Area, Muchela and the Drainage/Irrigation Channel that may be subject to the GHPDP. The site visit should enable an understanding of the nature and extent of original/historic fabric remaining on-site. • The GHPDP will be complied with by preparing a letter to the State Heritage Office advising of further clearance of the Ellenbrook Estate Area, Muchela, the Drainage/Irrigation Channel and the Forestry Department's Divisional Headquarters' and Fire Lookout site. • The Shire of Chittering will be advised that the proposal is occurring and that it will directly impact on two locally listed heritage places, Muchela and the Drainage/Irrigation Channel. Clarification is required on the status of these places on the Shire's Heritage List and what process is required to enable the further clearance of this site. • The European Heritage values identified adjacent to the study area will be clearly marked on future mapping for the proposal to ensure that all construction personnel are aware of their location and the need for care during construction or with any future boundary changes. • The City of Swan, Shire of Chittering and City of Bayswater will be informed that the proposal is occurring and that it is occurring in close proximity to locally listed heritage places.	Disturbance and clearance of European heritage values in proposal footprint.

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15 AMENITY (RESERVES)

15.1 EPA Objective

The EPA's objective for amenity is to ensure that impacts to amenity are reduced to as low as practicable (EPA, 2015a).

15.2 Existing Environment

15.2.1 Dick Perry Reserve

Dick Perry Reserve is located within Gnangara Park, west of Ellenbrook, and managed by DPAW (Figure 15.1). A recreational node directly east of Centre Way and north of Gnangara Road was identified as part of the Concept Plan for Gnangara Park (CALM et al., undated). The initial Concept Plan for the primary recreational node of Dick Perry Reserve was developed in 1999, after the Gnangara Park concept was approved by Cabinet in 1996 as part of the WA Government's strategy to address increasing salinisation and eutrophication of water resources.

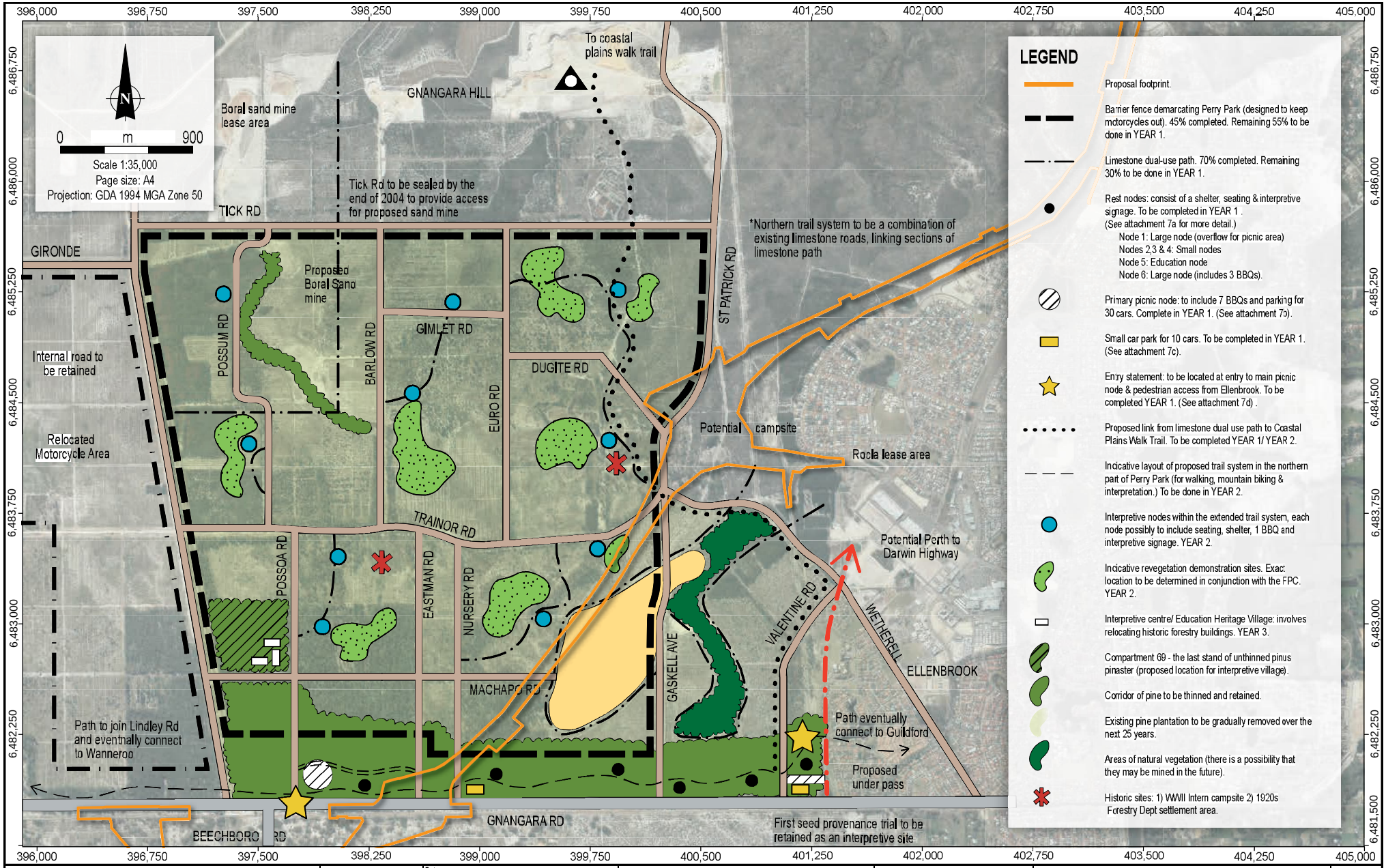
A Recreation Master Plan for Dick Perry Reserve was developed in 2004 with a range of strategies for recreation development and activities (CALM, 2004). This included:

- Rest nodes consisting of a shelter, seating and interpretive signage.
- A primary picnic node with BBQs and parking area.
- Smaller car parks.
- Walking trails.
- Interpretive nodes within the trail system.
- Indicative revegetation demonstration sites.
- An interpretive centre and Education Heritage Village, which involves relocating historic forestry buildings.

A number of existing and historic mining leases issued by Department of Mines and Petroleum (DMP) exist within the Gnangara Park area and the Concept Plan recognises these leases. A revegetated sand mining area is located in the southeastern corner of the reserve, while a Native Vegetation Clearing Permit was issued to Rocla Quarries on 31 December 2014 (CPS 6362/1) for a portion of land in the northwest of the reserve.

The area is currently used for pine plantations and these are managed by the FPC. The plantations are currently being harvested and will not be replanted. Harvesting of a portion of pines in the area earmarked for the development of Dick Perry Reserve has occurred since the proposal development commenced in 2014 and no revegetation has occurred.

Since the development of the Recreation Master Plan, a barrier fence has been erected around the reserve, a limestone walk trail (unpaved) developed, and a picnic node established to the west of Ellenbrook (outside of the reserve).



Source: Imagery from Google Earth.
Note: Recreated from CALM, 2004 (indicative only)

coffey

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File Name: 4483_P03_F15.01_GL_4

Main Roads WA

Public Environmental Review
Perth–Darwin National Highway

NorthLinkWA

Gnangara Park recreational master plan

Figure No: 15.1

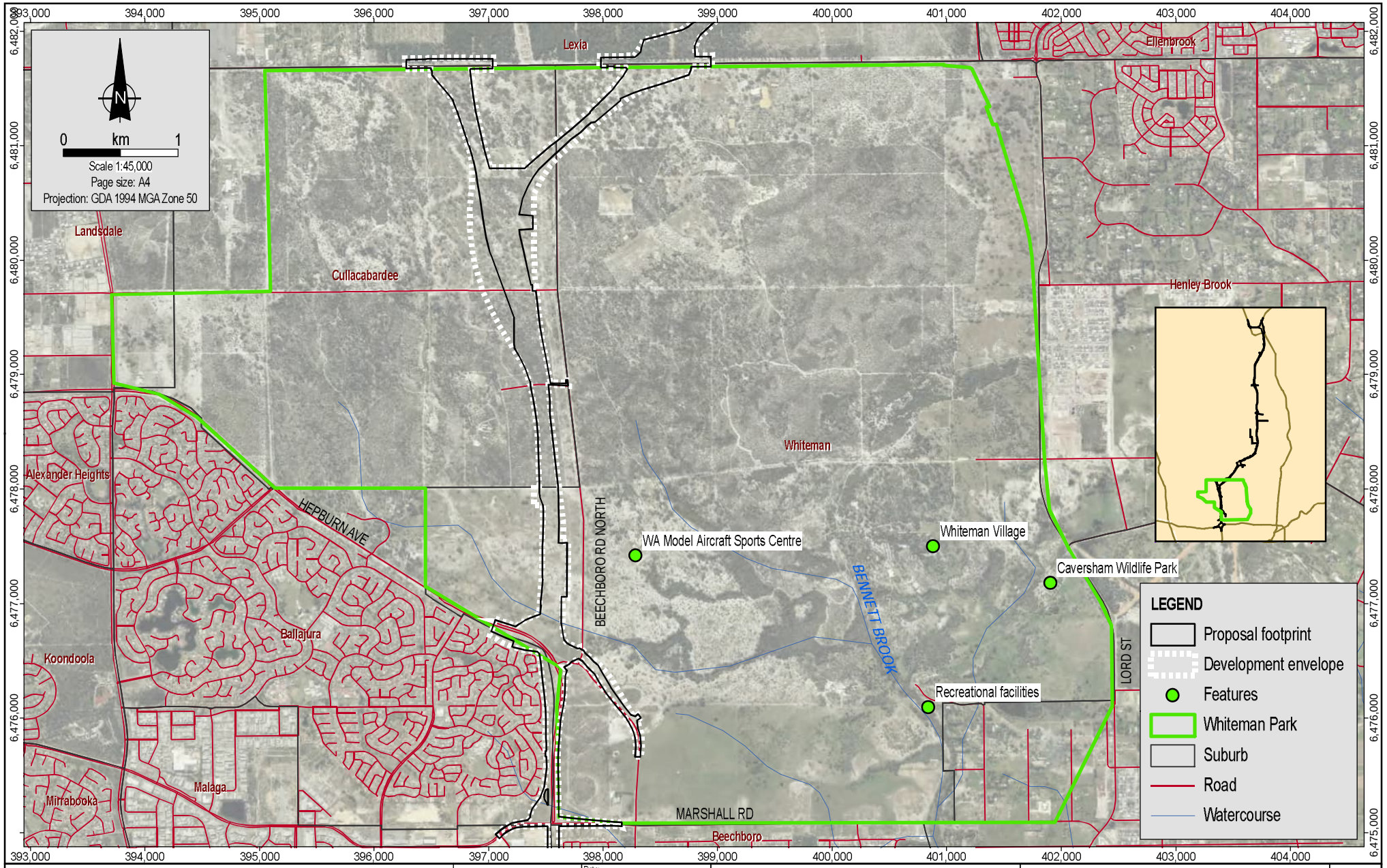
15.2.2 Whiteman Park

Whiteman Park, an area of approximately 4,000 ha, is bordered by Gnangara Road in the north, Lord Street in the east, Marshall Road in the south, and Hepburn Avenue in the southwest. Beechboro Road North runs in a north-south direction through the park and the proposal would be located parallel and to the west of this road (Figure 15.2) (Whiteman Park, 2015).

Whiteman Park was established in 1978 when the State government purchased land from a variety of private owners. The DOP is currently tasked with the operational management of the park on behalf of the WAPC. Whiteman Park is reserved for parks and recreation in the MRS, creating a space for the community whilst also providing protection to the Gnangara Mound, which supplies a large proportion of Perth's drinking water.

Facilities in the park include:

- Three bush walking trails, including Werillyiup, Goo Loorto and Wununga.
- Walking and cycling paths.
- Sports facilities, including a cricket oval, basketball and tennis courts.
- Dog park.
- Water playground.
- Orienteering courses.
- Picnic and BBQ areas.
- Playgrounds.
- Caversham Wildlife Park.
- Children's Forest.
- Woodland Reserve.
- Motor Museum of WA.
- Tractor Museum of WA.
- Revolutions Transport Museum.
- Train and tram rides.
- Speciality shops.



Source & Notes:
Whiteman Park boundaries and facilities digitised from Whiteman Park, 2015 (indicative only).
Suburbs from ABS (2011).
Aerial imagery from Landgate (August 2014).

NorthLinkWA

coffey

Date: 18.06.2015
MXD: 4483AA_03_GIS097_2
File Name: 4483AA_03_F15.2_GIS

Main Roads WA
Public Environmental Review
Perth–Darwin National Highway

Whiteman Park

Figure No: 15.2

15.2.3 Conservation Areas

The proposal intersects the following conservation areas (Figure 15.3):

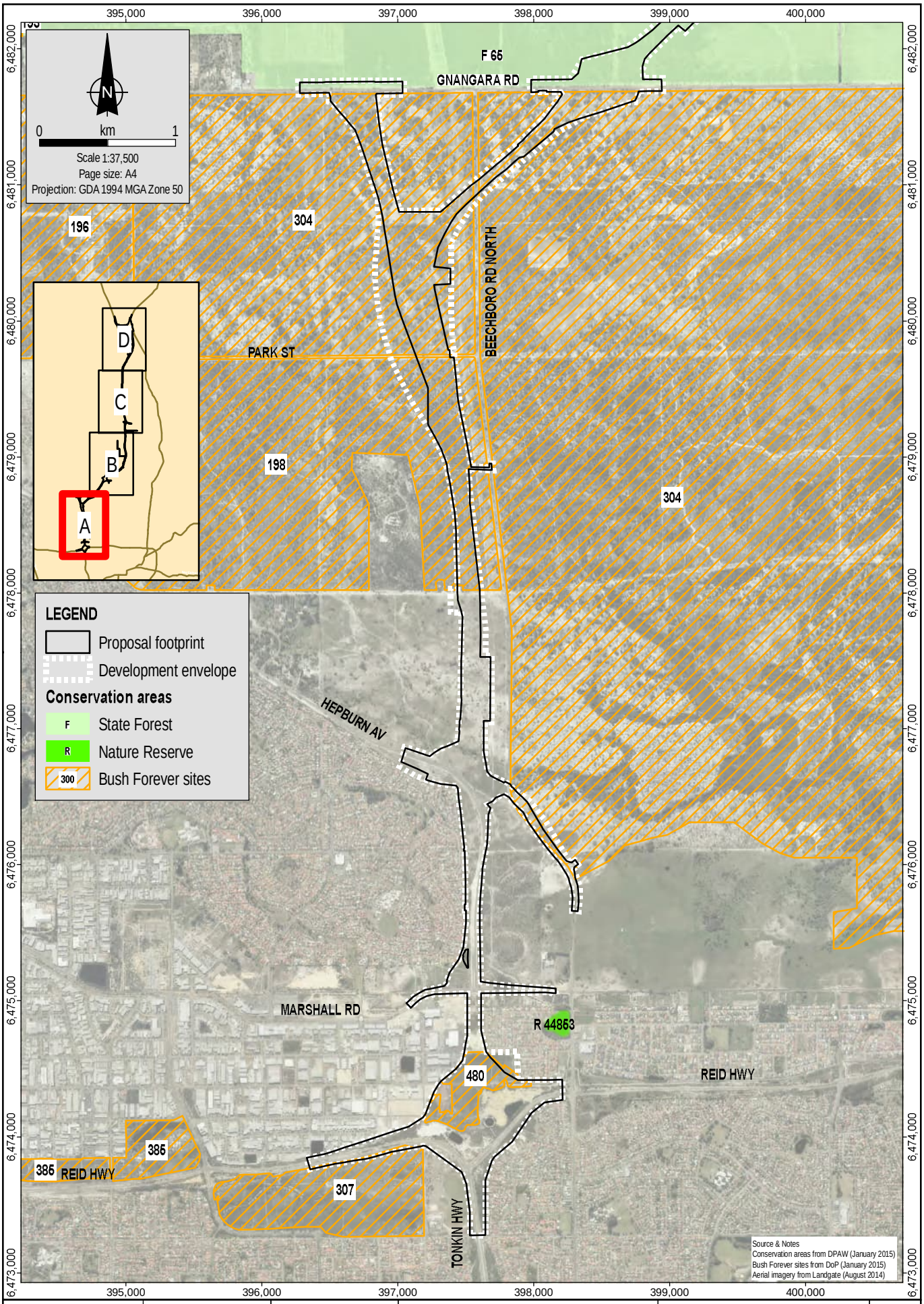
- Class A Nature Reserve 46919 (unnamed).
- Class A Nature Reserve 46920 (unnamed).
- Gnangara–Moore River State Forest No. 65.
- Nine Bush Forever sites, including sites 97, 100, 192, 198, 300, 304, 307, 399 and 480.

Class A Nature Reserves are areas of Crown land in WA that have been afforded the highest classification of protection and are usually created for a specific purpose. Both Class A Nature Reserves 46919 and 46920 are reserved for the purpose of conservation of flora and fauna.

State Forest is an area of Crown land set aside for uses including timber production, conservation and recreation. This includes Crown land reserved as State Forest and used to grow non-native plantation species, as is the case for the Gnangara–Moore River State Forest, which is largely managed by the FPC as a non-native pine plantation for the purpose of timber production.

Bush Forever is a strategic plan for the conservation of bushland on the SCP portion of the PMR, designed to identify, protect and manage regionally significant bushland in order to achieve a sustainable balance between conservation and development in the PMR (Government of Western Australia, 2000b). Bush Forever identifies 51,200 ha of regionally significant bushland for protection within the SCP of the PMR, nearly two thirds of which is already protected. Bush Forever sites were selected based on their conservation value and to ensure representation of regional ecosystems and habitats, and play a central role in the conservation of Perth's biodiversity (Government of Western Australia, 2000b).

Bush Forever sites are not formally protected unless they have been vested as some form of conservation estate (e.g. Nature Reserve).



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File Name: 4483AA_03_F015.3A_GIS

Main Roads WA
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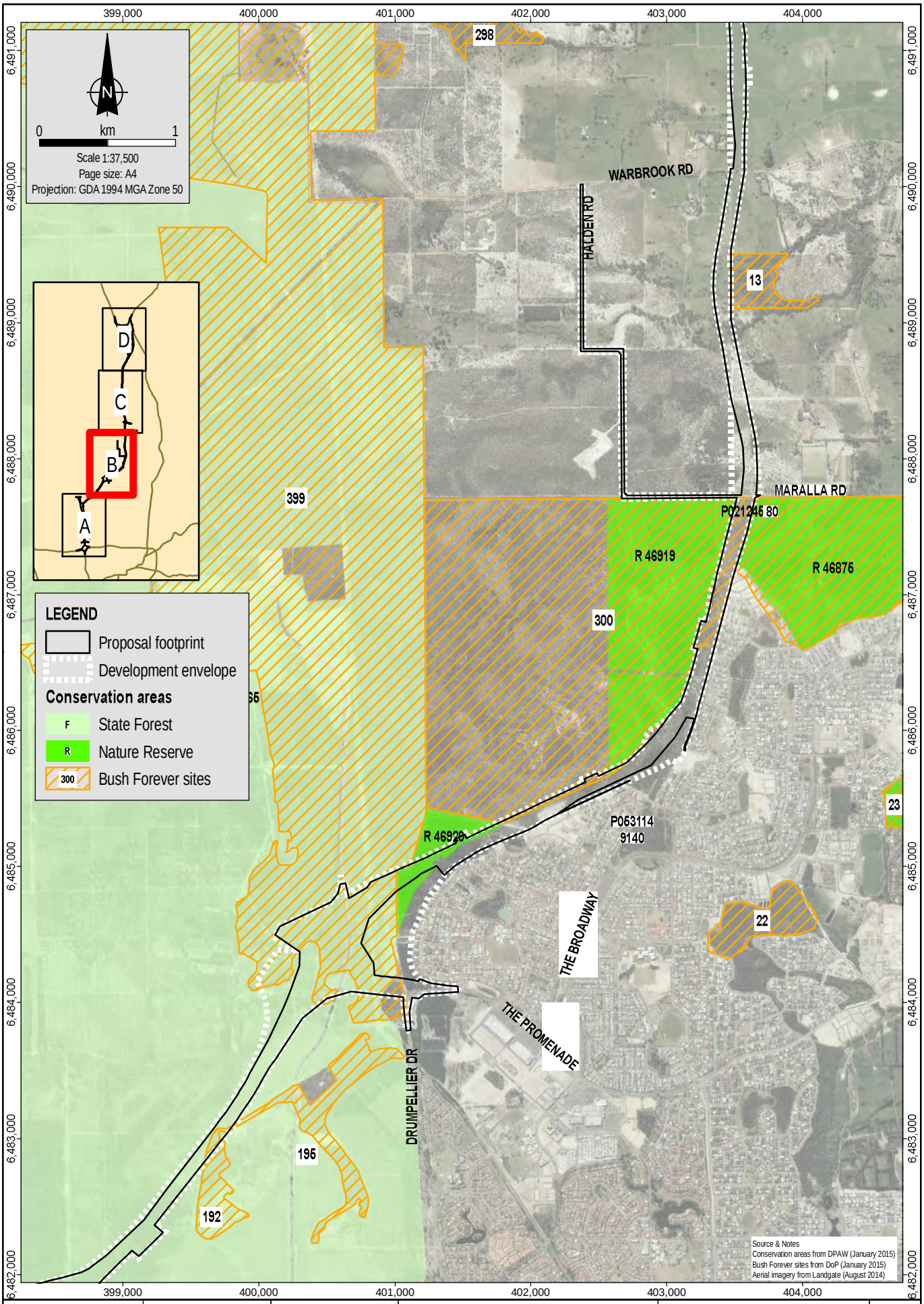
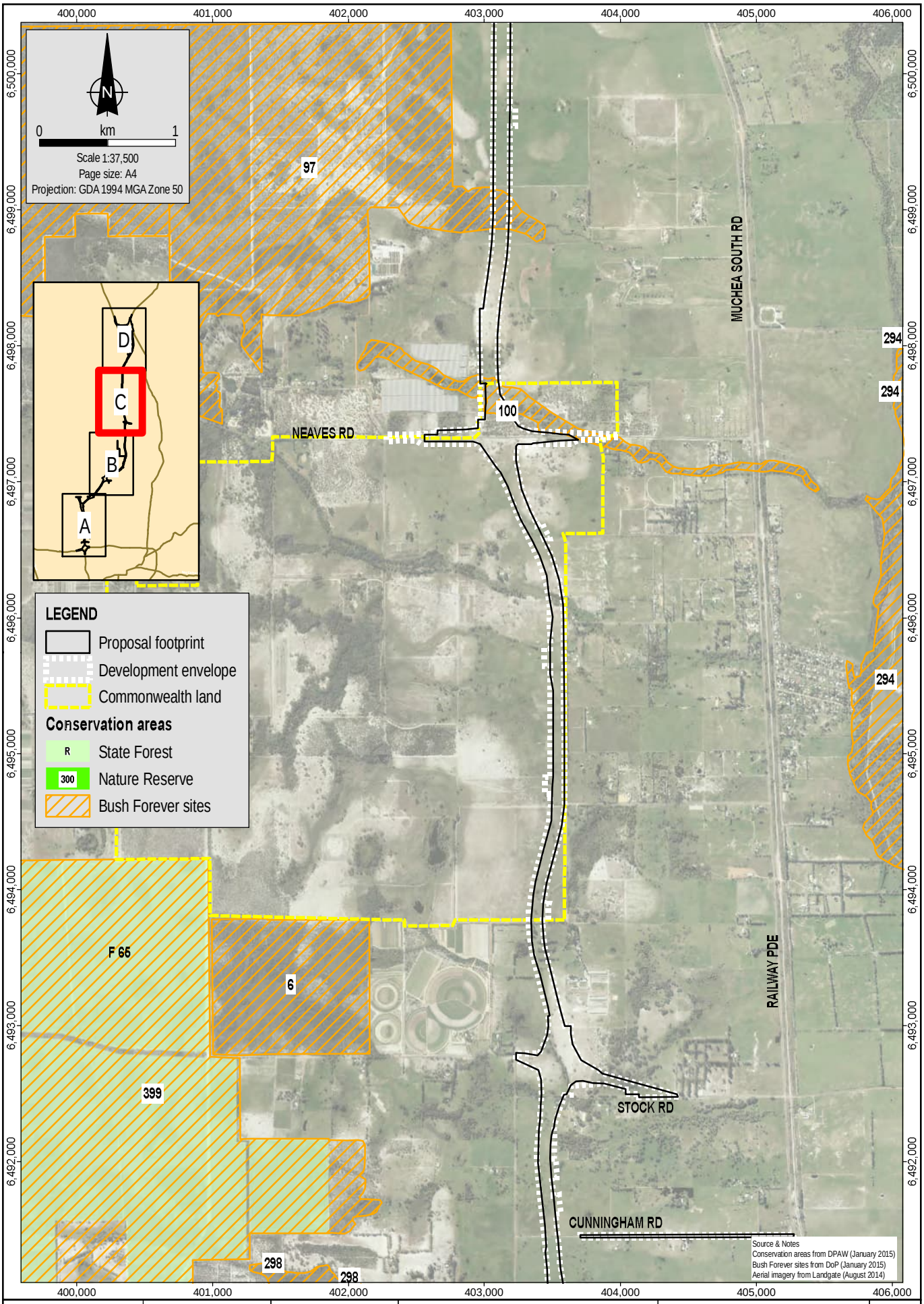
Conservation areas
Map 1 of 4

Figure No:
15.3A



NorthLinkWA	coffey	Date: 18.06.2015 MXD: 4483AA_03_GIS075_2 File Name: 4483AA_03_F015.3B_GIS	Main Roads WA Public Environmental Review Perth–Darwin National Highway	Conservation areas Map 2 of 4	Figure No: 15.3B



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File Name: 4483AA_03_F015.3C_GIS

Main Roads WA
Public Environmental Review
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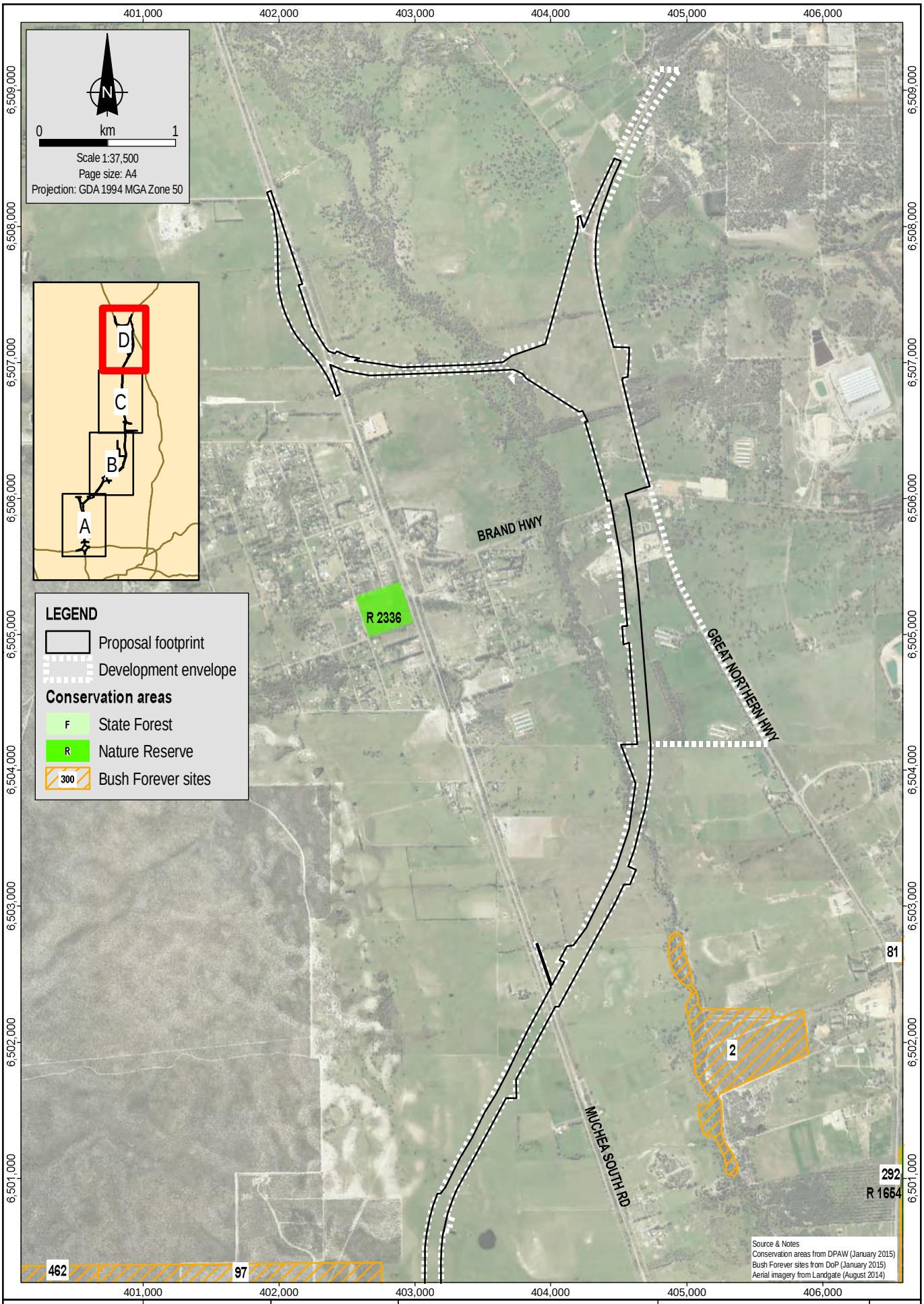
Conservation areas
Map 3 of 4

Figure No:
15.3C



NorthLinkWA	coffey	Date: 18.06.2015 MXD: 4483AA_03_GIS075_2 File Name: 4483AA_03_F015.3D_GIS	Main Roads WA Public Environmental Review Perth–Darwin National Highway	Conservation areas Map 4 of 4	Figure No: 15.3D

15.3 Potential Impacts

15.3.1 Dick Perry Reserve

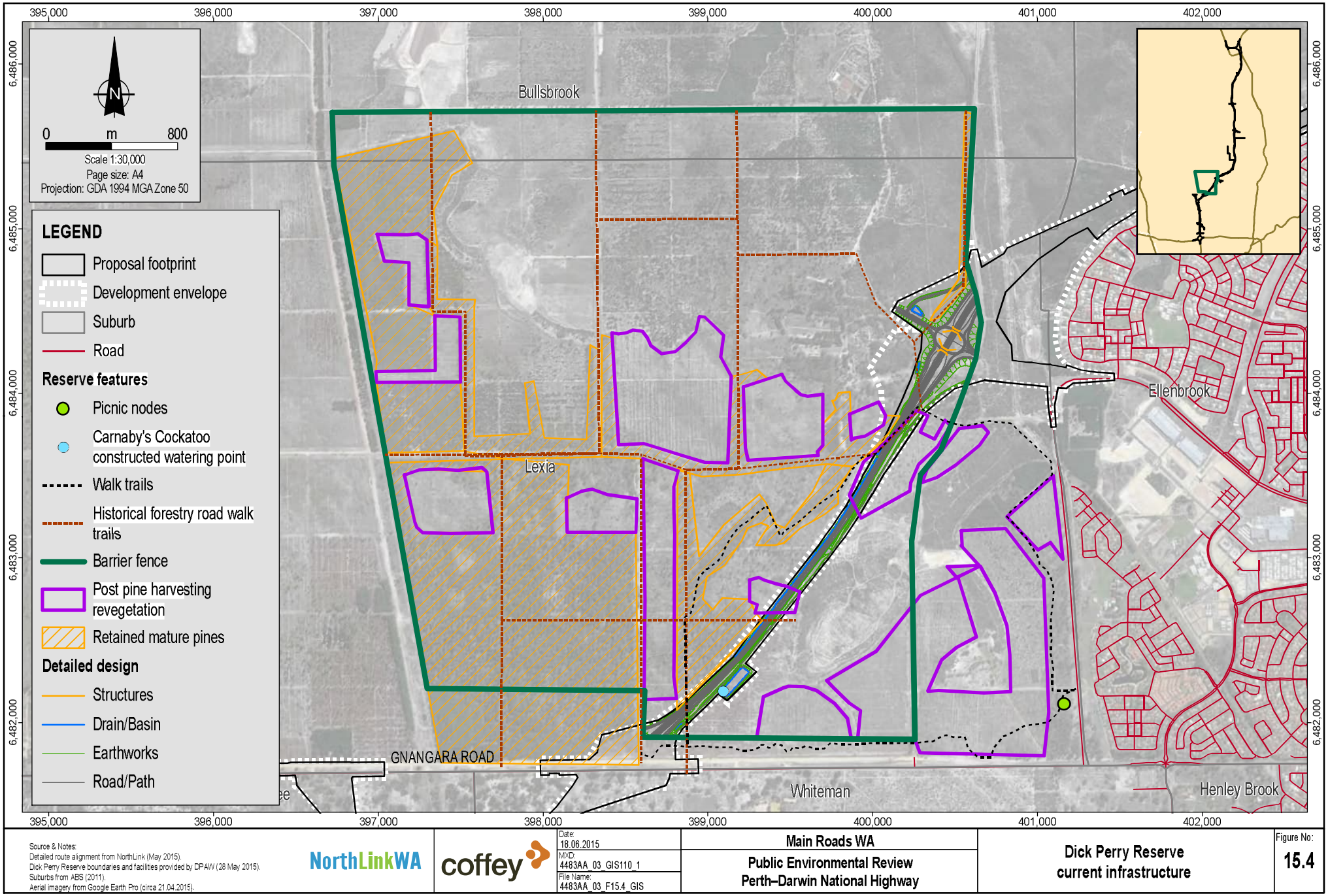
The proposal footprint crosses the southeastern part of the proposed reserve, with an interchange located at Gnangara Road (southern boundary of the proposed reserve) and another interchange located along the eastern boundary of the proposed reserve (see Figure 15.1 and Figure 15.4).

The proposal will result in the following impacts on Dick Perry Reserve:

- Severing the northern and southern section of the limestone trail.
- Removal of a dam constructed near the southern boundary of the reserve, which serves as a watering source for cockatoos.
- Clearing of revegetated mining lease area.
- Severing a proposed north-south limestone dual use path planned to link the area to the Coastal Plains Walking Trail.
- Impact on the former site of the Gnangara Forestry Headquarters (European heritage site – see Chapter 14). A review of Landgate historic aerial imagery suggested that the structures at this site were demolished between 1985 and 1995.

The corridor of pine trees that was earmarked to be retained along Gnangara Road in the Recreation Master Plan has since been removed as part of the harvesting of the pine trees by FPC and as such has already impacted on the proposed future use of this area.

Construction of the proposal, as well as mining activities in the northwestern part of the reserve, will result in a significant reduction in the size of the proposed reserve and its potential to be utilised as recreational open space by the community.



Source & Notes:
Detailed route alignment from NorthLink (May 2015).
Dick Perry Reserve boundaries and facilities provided by DPAW (28 May 2015).
Suburbs from ABS (2011).
Aerial imagery from Google Earth Pro (circa 21.04.2015).

NorthLinkWA

coffey

Date: 18.06.2015
MXD: 4483AA_03_GIS110_1
File Name: 4483AA_03_F15.4_GIS

Main Roads WA
Public Environmental Review
Perth–Darwin National Highway

Dick Perry Reserve
current infrastructure

Figure No:
15.4

15.3.2 Whiteman Park

15.3.2.1 Construction Phase Impacts

Impacts on Whiteman Park during the construction phase of the proposal largely relate to native vegetation clearing, habitat fragmentation and potential fauna mortalities. These are discussed in detail in Chapters 8 and 9.

15.3.2.2 Operation Phase Impacts

The main impacts during the operation phase of the proposal relate to habitat fragmentation and fauna mortalities from fauna/vehicle interactions. These are discussed in detail in Sections 9.4.1 and 9.4.2.

Where the alignment intersects Beechboro Road North (south of Gnangara Road), traffic access to Whiteman Park will be severed through a cul-de-sac on Beechboro Road North. As the alignment is located to the west of Beechboro Road North, none of the facilities currently accessed by the community will be impacted by the proposal.

15.3.3 Conservation Areas

As discussed in Section 15.2.3 the proposal intersects Gnangara–Moore River State Forest No. 65, two Class A Nature Reserves (46919 and 46920). As the proposal is not consistent with the current purpose of the reserved land, a proposal to excise areas from each reserve is being submitted to Parliament under Section 45(4) of the *Land Administration Act 1997*. The area proposed to be excised is based on the proposal's development envelope and includes approximately (see Figure 15.3):

- 0.3 ha of Class A Nature Reserve 46919.
- 7.4 ha of Class A Nature Reserve 46920.
- 106 ha of Gnangara–Moore River State Forest No. 65.

However, as indicated on Figure 15.3, not all land proposed to be excised will be impacted by the proposal footprint. Table 15.1 distinguishes the loss of conservation estate and the actual impact of the proposal footprint on conservation values (i.e. intact native vegetation, Black Cockatoo habitat and Priority listed flora or ecological communities) within areas of conservation estate.

Table 15.1 Impacts to Conservation estate

Conservation estate	Area of conservation estate[1]	Area of native vegetation	Area of Black Cockatoo habitat	Priority listed flora or area of PEC
Class A Nature Reserve 46919	0.3 ha	0.25 ha	0.2 ha Moderate value habitat	• 0.2 ha of SCP21c (P3)
Class A Nature Reserve 46920	7.4 ha	0.14 ha	0.2 ha Moderate value habitat	• 1 individual of *Hypolaena robusta* (P4) • 0.1 ha of SCP22 (P3) • 0.6 ha of SCP21c (P3)
Gnangara–Moore River State Forest No. 65	106.0 ha	30.8 ha	2.5 ha of High value habitat and 28.0 ha of Moderate value habitat	• 9.2 ha of Banksia dominated woodlands on the SCP (P3) • 20.7 ha of SCP21c (P3) • 2.6 ha of SCP24 (P3)

1. Based on the State Forest and Nature Reserve excision areas.

In addition, as discussed in Section 8.4.3, the proposal will result in the loss of 128.5 ha of intact native vegetation across nine Bush Forever sites (97, 100, 192, 198, 300, 304, 307, 399 and 480). However, 31.5 ha of this also occurs within and is formally protected by Gnangara–Moore River State Forest and Class A Nature Reserve 46919. Table 15.2 summarises the loss of conservation values (i.e. intact native vegetation, Black Cockatoo habitat and Priority listed flora or ecological communities) within Bush Forever sites.

Table 15.2 Impacts to Bush Forever sites

Bush Forever Site	Area of intact native vegetation	Area of Black Cockatoo habitat	Number of Priority listed flora	Area of Priority Ecological Community
97	3.3 ha	1.5 ha of High value habitat	–	–
100	0.2 ha	1.9 ha of High value habitat	–	–
192	1.3 ha	–	–	• 1.3 ha of SCP24 (P3)
198	30.7 ha	15.8 ha of High value habitat and 15.3 ha of Moderate value habitat	• 3 individuals of *Millotia tenuifolia* var. *laevis* (P2) • 1 individual of *Hypolaena robusta* (P4) • 1 individual of *Anigozanthos humilis* subsp. *chrysanthus* (P4)	• 3.8 ha of SCP20a (En) • 10.6 ha of Banksia dominated woodlands on the SCP (P3) • 9.0 ha of SCP21c (P3) • 7.5 ha of SCP23b (P3)
300	16.9 ha	1.3 ha of High value habitat and 15.4 ha of Moderate value habitat	–	• 4.3 ha of Banksia dominated woodlands on the SCP (P3) • 10.5 ha of SCP21c (P3) • 1.9 ha of SCP23b (P3)
304	29.7 ha	71.1 ha of High value habitat	–	• 12.0 ha of Banksia dominated woodlands on the SCP (P3) • 1.0 ha of SCP23b (P3)
307	1.0 ha	1.0 ha of Moderate value habitat	–	–
399	29.6 ha	2.5 ha of High value habitat and 27.9 ha of Moderate value habitat	–	• 10.6 ha of Banksia dominated woodlands on the SCP (P3) • 19.5 ha of SCP21c (P3) • 0.7 ha of SCP24 (P3)
480	15.9 ha	1.6 ha of High value habitat	• 1 individual *Meeboldina decipiens* subsp. *decipiens ms* (P3)	• 0.9 ha of Banksia dominated woodlands on the SCP (P3) • 4.5 ha of SCP24 (P3)

Impacts to the specific environmental values (i.e. flora and vegetation, fauna and habitats, and wetlands) within each of these conservation areas are addressed separately in Sections 8.5, 9.5, 10.5 and 16.1.

15.4 Mitigation and Management

15.4.1 Dick Perry Reserve

Management measures to address the continued use and viability of the reserve have been addressed through the design of the proposal and include:

- Re-establishment of a barrier fence along the western side of the proposal to ensure access to the reserve is controlled. Gates for access for fire management activities will be established at regular intervals as agreed with DPAW.
- Linking of walk trails with PSP at the interchanges on Gnangara Road and at Ellenbrook to ensure continuity of the trails.

Planning for facilities in the Dick Perry Reserve is at an early stage although funds have been invested into this area over recent years. Construction of the proposal is likely to require DPAW to amend the Master Plan for Dick Perry Reserve and Gnangara Park. Amendment of this Master Plan falls outside of the scope of the proposal.

15.4.2 Whiteman Park

Management measures to address habitat fragmentation have been incorporated in the UPDC of the proposal. These are discussed in more detail in Section 9.5.1.

To ensure safe exit in the event of fire, a vehicle underpass will be provided further south at the crossing of Baal Street. Additionally, an access road parallel to the alignment will be constructed in this vicinity to provide access for the Cullacabardee community.

15.4.3 Conservation Areas

Mitigation measures relevant to the specific environmental values (i.e. flora and vegetation, fauna and habitats, and wetlands) impacted within each of these conservation areas are provided in Sections 8.5, 9.5, 10.5 and 16.1. The loss of conservation estate and Bush Forever sites cannot be avoided; however, the area to be excised through the State excision process has been minimised as far as practicable, whilst ensuring a suitably sized development envelope to accommodate a safe and efficient highway in these areas.

15.5 Residual Impacts

15.5.1 Dick Perry Reserve

It is expected that the proposal will result in impacts to the southeastern and eastern parts of Dick Perry Reserve. The implementation of the management and mitigation measures discussed in Section 15.4.1 will reduce impacts to Dick Perry Reserve amenity to the maximum extent practicable and so it is anticipated that this proposal will meet the EPA's objective.

A summary of the proposal's residual impacts on the amenity of Dick Perry Reserve following implementation of mitigation and management measures is provided in Table 15.3.

15.5.2 Whiteman Park

It is expected that the proposal will result in minimal residual impacts to the amenity of Whiteman Park following the implementation of the management and mitigation measured. Measures to mitigate habitat

fragmentation and access issues will reduce amenity impacts to Whiteman Park to the extent practicable and so it is anticipated that this proposal will meet the EPA's objective.

A summary of the proposals residual impacts on the amenity of Whiteman Park following the implementation of mitigation and management measures is provided in Table 15.3.

15.5.3 Conservation Areas

The impact to specific environmental values in each of these conservation areas (i.e. flora and vegetation, fauna and habitats, and wetlands) is provided separately in Chapters 8, 9, 10 and 16.

The loss of 114 ha of conservation estate (including approximately 8 ha of Class A Nature Reserve and 106 ha of State Forest) and 128.5 ha of Bush Forever cannot be avoided; however, the area to be excised through the State excision process has been minimised as much as practical, and so is likely to meet the EPA's objective, even before consideration of proposed offsets (see Chapter 17).

A summary of the proposal's residual impacts on the amenity of Dick Perry Reserve following implementation of mitigation and management measures is provided in Table 15.3.

Table 15.3 Summary of residual impacts on amenity to Dick Perry Reserve and Whiteman Park

Aspect	Predicted impacts	Management and mitigation	Residual impacts
Construction and clearing activities required for the proposal	Reduction in the size of Dick Perry Reserve and the potential to be utilised as recreational open space by the community.	• Construction of the proposal is likely to require changes to the Master Plan to accommodate the relocation or redesign of planned infrastructure. • Re-establishment of a barrier fence along the western side of the proposal to ensure access to the reserve is controlled. Gates for access for fire management activities will be established at regular intervals as agreed with DPAW. • Linking of walk trails with PSP at the interchanges on Gnangara Road and at Ellenbrook to ensure continuity of the trails.	Reduced amenity of the proposed Dick Perry Reserve and its utilisation as open space.
	Native vegetation clearance, habitat fragmentation and potential fauna mortalities along Whiteman Park.	• Management measures to address habitat fragmentation have been incorporated in the UPDC of the proposal. These are discussed in more detail in Section 9.5.1. • The use of fauna spotters and a translocation program to reduce risk of fauna mortalities.	Minor and localised impacts on fauna populations.
	Loss of conservation areas.	• Minimise the State Forest and Nature Reserve excision area, and area of Bush Forever as much as practical. • Implementation of mitigation measures relevant to the specific environmental values (i.e. flora and vegetation, fauna and habitats, and wetlands) detailed in Sections 8.5, 9.5, 10.5 and 16.1.	Loss of 114 ha of conservation estate.
Road traffic using proposal	Habitat fragmentation and fauna mortalities from fauna/vehicle interactions in the vicinity of Whiteman Park.	• Implementation of a vehicle underpass south at crossing of Baal Street. Additionally, an access road parallel to the alignment will be constructed in this vicinity to provide access to the Cullacabardee community. • Implementation of fauna underpasses on or adjacent to Whiteman Park to facilitate fauna movement and maintain ecological connectivity.	Fragmentation of fauna habitats will increase due to the proposal. However, the inclusion of fauna underpasses allows the maintenance of ecological connectivity to the greatest practicable extent.

16 MATTERS PROTECTED UNDER THE EPBC ACT

16.1 Matters of National Environmental Significance

The Commonwealth EPBC Act provides a legal framework to protect and manage MNES, including:

- World heritage properties.
- National heritage places.
- Wetlands of international importance (often called 'Ramsar' wetlands after the international treaty under which such wetlands are listed).
- Listed threatened species and ecological communities.
- Migratory species protected under international agreements.
- Commonwealth marine areas.
- The Great Barrier Reef Marine Park.
- Nuclear actions (including uranium mining).
- A water resource, in relation to coal seam gas development and large coal mining development.

In addition, the Act allows for the following matters to be protected:

- The environment, where actions proposed are on, or will affect, Commonwealth land.
- The environment, where Commonwealth agencies are proposing to take an action.

The proposal has the potential to have a significant impact on the following matters (see Appendix B):

- Listed threatened species and communities (sections 18 and 18A of the Act).
- Migratory species (sections 20 and 20A of the Act).
- Commonwealth land (sections 26 and 27A of the Act).

16.2 Listed Threatened Flora Species and Communities

A search of the Protected Matters Search Tool (PMST) and review of the flora and vegetation survey conducted by Coffey (2015a) (Appendix C), indicated that 26 conservation significant flora species protected under the EPBC Act may be present within a 10 km radius of the proposed proposal footprint. This includes the Grand Spider Orchid (*Caladenia huegelii*), Curved-leaf Grevillea (*Grevillea curviloba* subsp. *curviloba*), Narrow curved-leaf Grevillea (*Grevillea curviloba* subsp. *incurva*), Muchea Bell (*Darwinia foetida*) and Grass Wattle (*Acacia anomala*), which were listed in the ESD (EPA, 2014a).

EPBC listed threatened flora species potentially occurring in the proposal footprint according to DPAW databases are listed in Table 16.1. The likelihood of EPBC Act listed flora occurring in the proposal footprint has been assessed based on habitat preference and the nearest known localities to the proposal footprint.

Table 16.1 EPBC Act listed flora potentially occurring in the proposal footprint

Species	Common name	EPBC Status	Likelihood of occurrence	Nearest known location (km)	Comment
Acacia anomala	Grass Wattle, Chittering Grass Wattle	Vulnerable	Unlikely	0.04[1]	Known to occur on lateritic soils which do not occur within the proposal footprint.
Andersonia gracilis	Slender Andersonia	Endangered	Unlikely	16	Known to occur north of Perth in the Northern Sandplains with outlier populations south of Perth. Preferred habitat of Heath of *Banksia telmatiaea*, which does not occur within the Proposal footprint.
Anigozanthos viridis subsp. *terraspectans*	Dwarf Green Kangaroo Paw	Vulnerable	Unlikely	>50	Known to occur in the Northern Sandplains. Vegetation association is Heath of *Banksia telmatiaea*, which does not occur within the Proposal footprint.
Caladenia huegelii	King Spider-orchid, Grand Spider-orchid, Rusty Spider-orchid	Endangered	Likely	0.1	Known to occur within 100 m of the proposal footprint. Preferred habitat available. Recorded in the flora study area during flora and vegetation survey (Appendix C).
Calytrix breviseta subsp. *breviseta*	Swamp Starflower	Endangered	Unlikely	7.3	Only known from several restricted sites south of Perth in swampy flats.
Centrolepis caespitosa	_	Endangered	Unlikely	3.9	Nearest known localities are south of Perth. Preferred habitat not present within the proposal footprint.
Chamelaucium sp. Gingin (N.G. Marchant 6)	Gingin Wax	Endangered	Unlikely	9.2	Known to occur north of Muchea with restricted distribution. Preferred habitat not present within the proposal footprint.
Conospermum densiflorum subsp. *unicephalatum*	One-headed Smokebush	Endangered	Unlikely	>50	Known to occur in the northern extent of the Jarrah Forest, north of Bindoon.

Species	Common name	EPBC Status	Likelihood of occurrence	Nearest known location (km)	Comment
Darwinia foetida	Muchea Bell	Critically Endangered	Likely	0.3	Known to occur within 250 m of the proposal footprint, in the Bullsbrook and Muchea area, with preferred habitat present. Recorded in the flora study area during flora and vegetation survey (Appendix C).
Diuris micrantha	Dwarf Bee-orchid	Vulnerable	Unlikely	38	Known to occur to the south of Perth. Preferred habitat not present within the proposal footprint.
Diuris purdiei	Purdie's Donkey-orchid	Endangered	Unlikely	14.5	Known to occur in winter-wet swamps south of Perth. Preferred habitat not present within the proposal footprint.
Drakaea elastica	Glossy-leaved Hammer-orchid, Praying Virgin	Endangered	Unlikely	7	Known to occur south of Perth, with one outlier near Dandaragan. Preferred habitat not present within the proposal footprint.
Drakaea micrantha	Dwarf Hammer-orchid	Vulnerable	Unlikely	25.3	Known to occur in the southern suburbs of Perth and along the southwest coast.
Eleocharis keigheryi	Keighery's Eleocharis	Vulnerable	Possible	1.9	Preferred habitat not present within the proposal footprint but in land adjacent to the proposal footprint.
Eucalyptus balanites	Cadda Road Mallee, Cadda Mallee	Endangered	Unlikely	4.7	Known to occur in the Armadale area and north of Perth near Badgingarra.
Eucalyptus leprophloia	Scaly Butt Mallee, Scaly-butt Mallee	Endangered	Unlikely	>135	Known to occur well north of Perth in the Northern Sandplains. Preferred habitat not present within the proposal footprint.
Grevillea althoferorum subsp. *fragilis*	_	Endangered	Possible	4.2	Known to occur in close proximity to the proposal footprint. The preferred habitat is present within the proposal footprint.
Grevillea corrugata	_	Endangered	Unlikely	12.3	Preferred habitat (gravelly loam) and associated vegetation is not present within the proposal footprint.

Species	Common name	EPBC Status	Likelihood of occurrence	Nearest known location (km)	Comment
Grevillea curviloba subsp. *curviloba*	Curved-leaf Grevillea	Endangered	Likely	0.04	Known to occur within 100 m of the proposal footprint with preferred habitat present.
Grevillea curviloba subsp. *incurva*	Narrow Curved-leaf Grevillea	Endangered	Likely	0.02	Known to occur within 100 m of the proposal footprint with preferred habitat present. Recorded in the flora study area during flora and vegetation survey (Appendix C).
Lepidosperma rostratum	Beaked Lepidosperma	Endangered	Unlikely	16.6	Known to occur south of Perth. Preferred habitat not present within the proposal footprint.
Macarthuria keigheryi	Keighery's Macarthuria	Endangered	Unlikely	6.7	Known to occur north of the proposal footprint, and a population south of Perth, preferred habitat present.
Thelymitra dedmaniarum	_	Endangered	Unlikely	10.3	Preferred habitat (granite) not present within the proposal footprint.
Thelymitra stellata	Star Sun-orchid	Endangered	Possible	2.8	Preferred habitat (lateritic loam) is not present within the proposal footprint.
Trithuria occidentalis	Swan Hydatella	Endangered	Possible	1.9	Preferred habitat (winter-wet brown- grey claypans) not present within the proposal footprint

The desktop assessment did not identify any Threatened flora listed by the Commonwealth as occurring within the proposal footprint. Upon review of the known locations and habitat preferences for each Threatened flora:

- Four are considered 'Likely' to occur (*Caladenia huegelii, Darwinia foetida, Grevillea curviloba* subsp. *curviloba* and *Grevillea curviloba* subsp. *incurva*).
- Four are considered 'Possible' to occur (*Eleocharis keigheryi, Grevillea althoferorum* subsp. *fragilis, Thelymitra stellata* and *Trithuria occidentalis*).
- Seventeen are considered 'Unlikely' to occur (see Table 16.1).

As detailed in Section 8.2.3, three Commonwealth listed Threatened flora, *Caladenia huegelii, Darwinia foetida* and *Grevillea curviloba* subsp. *incurva,* were recorded within the flora study area. Of the remaining species considered likely (*Grevillea curviloba* subsp. *curviloba*) and possible (*Eleocharis keigheryi, Grevillea althoferorum* subsp. *fragilis, Thelymitra stellata* and *Trithuria occidentalis*) to occur within the proposal footprint, no individuals or populations were recorded during flora and vegetation surveys undertaken in 2012 (GHD, 2013a), 2013 (360 Environmental, 2014c) and 2014 (Coffey, 2015a).

The surveys were undertaken in spring, the optimal time to record the majority of the Commonwealth listed Threatened flora species. Additional targeted surveys within the proposal footprint were undertaken in November 2014 to identify the presence of late flowering Threatened flora species (for example *Calytrix breviseta* subsp. *breviseta*).

Caladenia huegelii, or Grand Spider Orchid, was recorded from one location in the Ellenbrook region. It is located in- between the Ellenbrook Estate and the proposal footprint and occurs within 20 m of a proposed noise wall. The habitat surrounding this known location is considered to be critical habitat (DEC, 2009).

The critical habitat for the Grand Spider Orchid has been mapped across the flora study area and the proposal footprint. In total, 228.3 ha of potential critical habitat occur within the flora study area, while 39.2 ha of this occur within the proposal footprint (see Figure 8.1). This equates to 17.2% of the total mapped area of potential critical habitat for the Grand Spider Orchid located within the flora study area.

Grevillea curviloba subsp. *incurva* was recorded from one location in association with previously known locations (DPAW, 2014a). No new or previously known populations of *Grevillea curviloba* subsp. *incurva* were recorded in the proposal footprint. The closest record was located 10 m from the proposal footprint boundary. The vegetation surrounding this location along the verge of Brand Highway and within the rail reserve is considered to be critical habitat (Phillimore and English, 2000), although it is in a degraded condition. The extent of critical habitat for *Grevillea curviloba* subsp. *incurva* within the proposal footprint is 2.0 ha (see Figure 8.1).

Darwinia foetida was located in association with previously known locations (DPAW, 2014a). No new population or individuals were recorded from the proposal footprint. The population was located 250 m from the proposal footprint North of Neaves Road. There is no continuous vegetation between the population of *Darwinia foetida* and the proposal footprint (Figure 8.1).

16.2.1 Potential Impacts and Management Measures

As discussed in Section 8.4.5, there are no direct impacts to the Grand Spider Orchid. Indirect impacts will be managed through the retention of a vegetated buffer no less than 50 m wide, where appropriate and available. The individual recorded from the flora study area is located approximately 20 m west of Ellenbrook and so the area of buffer will be reduced to the east of the individual due to the existing disturbed areas and the housing development. The distance between the plant and the Ellenbrook suburb to the east is not considered to be an issue because the impacts associated with the suburb are present and

ongoing while the plant has been present. The project will increase the protection of the plant to the east with the construction of a noise wall along the boundaries of the properties abutting the project.

Surveys of the buffer area will be completed prior and during the construction phase to monitor the known location and the health of the surrounding vegetation within the buffer. The buffer to the east is reduced due to existing urban development. A management and monitoring program will be included within the EMP to ensure that the condition and structural integrity of the vegetated buffer is maintained.

Vegetation surveys undertaken in spring 2015 will assist in defining the extent of critical habitat for the Grand Spider Orchid. In addition, the description of critical habitat for the Grand Spider Orchid detailed in the recovery plan (DEC, 2009) will assist in defining the extent of critical habitat with regards to important populations and habitat. This will be based on known populations/individuals and surrounding similar habitat.

Darwinia foetida (Muchea Bell) is known to occur greater than 250 m to the west of the Neaves Road separation and will not have direct impacts from the proposal footprint. The known location was searched, with the population located and considered to be in good condition. The vegetation surrounding the population was in good to degraded condition with introduced grasses prevalent. Critical habitat has not been identified for *Darwinia foetida*. However, as no populations or intact native vegetation within 200 m of the populations will be impacted, the project is not considered to impact on critical habitat for *Darwinia foetida*. This population occurs on the edge of a Multiple Use Wetland and is surrounded by agriculture and industry; it is unlikely that there will be any indirect impacts to *Darwinia foetida.* The direction of ground water flow near the population of *Darwinia foetida* is from west to east (Golder, 2015), with the proposal located to the east of this population. It is unlikely that there will be any impact to *Darwinia foetida* from alteration in hydrology.

The proposal is not considered to have any direct impacts on Muchea Bell, while indirect impacts are considered to be negligible and will be managed through the development and implementation of the EMP. Indirect impacts to which the proposal may contribute include groundwater abstraction resulting in a lowering of the groundwater and the introduction or spread of dieback and significant environmental weeds. Muchea Bell occurs on swampy, seasonally wet habitats, so the lowering of the groundwater may impact on the habitat supporting the population.

The design of the proposal will ensure that there are no direct impacts and the indirect impacts, if present and measurable, will be managed through the implementation of the EMP. The groundwater abstraction required for the project will be undertaken in such a manner that there is no measurable reduction in groundwater associated with the population of Muchea Bell. The population is located upstream of the project, with all flows moving in a south-easterly direction. Therefore, impacts associated with pooling and contamination of surface water as a result of the project will not influence the population. In addition, the construction of retention basins will assist in separating pollutants from the surface water of the proposed highway.

Grevillea curviloba subsp. *incurva* (or Narrow Curved-leaf Grevillea) was recorded from three locations within the Brand Highway road reserve at Muchea. The locations are consistent with previously known records (Coffey, 2015a). No new additional individuals or populations were recorded during flora and vegetation surveys of the proposal footprint.

The three locations, and other known locations of the Narrow Curved-leaf Grevillea, do not occur within the proposal footprint. The locations along the Brand Highway road reserve are within 10 m of the proposal footprint; however, the proposal will cross over Brand Highway at this point and includes a bridge structure system to ensure adequate clearance over the railway line. The design will ensure that a separation distance of at least 10 m to individual plants is maintained where possible. The bridge structure will also allow continuity of the remnant vegetation located along the Brand Highway road reserve.

Critical habitat for the Narrow Curved-leaf Grevillea includes areas of known occupancy and corridors of vegetation that link populations (Phillimore and English, 2000). The remnant vegetation on the road and rail reserve along Brand Highway is considered critical habitat as it links the Muchea population to populations located to the south on Muchea Road South. The connectivity of the populations needs to be maintained to ensure sufficient movement of genetic material as per the requirements in the Narrow Curved-leaf Grevillea (*Grevillea curviloba* subsp. *incurva*) Interim Recovery Plan (Phillimore and English, 2000).

The construction of the proposal has potential for indirect impacts to *Grevillea curviloba* subsp. *incurva* due to the proximity of the road; however, impacts due to shadowing, smothering, hydrology or introduction/spread of dieback are unlikely from this proposal.

The Narrow Curved-leaf Grevillea occurs in association with winter-wet heaths and is reliant on high soil moisture during the winter and early spring months. The bridge structure located in association with Brand Highway and the known locations of the Narrow Curved-leaf Grevillea will ensure the current altered hydrology (which is constrained by the presence of the highway and the railway) will be maintained.

The significance of any potential direct and indirect impacts to the three Threatened flora has been assessed based on the significant impact criteria (DOTE, 2013) and is detailed in Table 16.2.

Table 16.2 Significant impact criteria for flora

Species	Significant impact criteria	Proposal relevance	Significant impact?
Caladenia huegelii	Lead to a long-term decrease in the size of a population.	The proposal will not directly impact on any known populations	No
	Reduce the area of occupancy of the species.	The proposal is unlikely to reduce the area of occupancy for *Caladenia huegelii*.	No
	Fragment an existing population into two or more populations.	The proposal will not fragment a population into two.	No
	Adversely affect habitat critical to the survival of a species.	The proposal will impact on 39.2 ha of native vegetation that is potential critical habitat. The extent of critical habitat will be redefined following vegetation surveys in spring 2015. It is anticipated that the extent of critical habitat will reduce due to the habitat specificity of the species.	Potential
	Disrupt the breeding cycle of a population.	A vegetated buffer will be maintained around known populations, ensuring the native pollinators are able to persist in the area.	No
	Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.	The proposal is unlikely to modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that *Caladenia huegelii* is likely to decline. Although 39.2 ha of intact critical habitat are present within the proposal footprint, this is considered to be an over-estimation. Refinement of the vegetation as habitat in spring 2015 will further refine the extent of critical habitat within the proposal footprint.	No

Species	Significant impact criteria	Proposal relevance	Significant impact?
	Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat.	The proposal has the potential to introduce invasive weeds which may potentially degrade critical habitat supporting the known populations. The EMP will manage the introduction and/or spread of invasive weeds.	No
	Introduce disease that may cause the species to decline.	The EMP for the proposal will manage the risk of introduction or spread of diseases (i.e. *Phytophthora* Dieback).	No
	Interfere with the recovery of the species.	The proposal will not interfere with the recovery of *Caladenia huegelii*.	No
Darwinia foetida	Lead to a long-term decrease in the size of a population.	The proposal will not directly impact on any known populations	No
	Reduce the area of occupancy of the species.	The proposal is unlikely to reduce the area of occupancy for *Darwinia foetida*.	No
	Fragment an existing population into two or more populations.	The proposal will not fragment a population into two.	No
	Adversely affect habitat critical to the survival of a species.	Critical habitat has not been identified for *Darwinia foetida*. However, as no populations or intact native vegetation within 200 m of the populations will be impacted, the project is not considered to impact on critical habitat for *Darwinia foetida*.	No
	Disrupt the breeding cycle of a population.	Areas of known occupancy will not be directly impacts, and therefore the breeding cycle of a population will not be disrupted. The nearest known population is greater than 250 m from the proposal.	No
	Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.	The proposal is unlikely to modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that *Darwinia foetida* is likely to decline.	No
	Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat.	The proposal will not introduce new invasive species to the area of known occupancy due to the distance between the proposal footprint and the known population. The known population is already impacted by the presence of introduced species.	No
	Introduce disease that may cause the species to decline.	The EMP for the proposal will manage the risk of introduction or spread of diseases (i.e. *Phytophthora* Dieback).	No
	Interfere with the recovery of the species.	The proposal will not interfere with the recovery of *Darwinia foetida*.	No

Species	Significant impact criteria	Proposal relevance	Significant impact?
Grevillea curviloba subsp. *incurva*	Lead to a long-term decrease in the size of a population.	The proposal is not expected to impact directly on a known population. A population is located within 10 m of the proposal footprint; however, the EMP and design of the proposal will ensure the population is not directly impacted. A separation distance of 10 m will be maintained, where possible. A bridge structure will ensure there is minimal direct impact to native vegetation near the known populations.	No
	Reduce the area of occupancy of the species.	The proposal is unlikely to reduce the area of occupancy for *Grevillea curviloba* subsp. *incurva*.	No
	Fragment an existing population into two or more populations.	The design will ensure a connection between subpopulations is maintained across the proposal footprint. A bridge structure will maintain continuity in a north-south direction.	No
	Adversely affect habitat critical to the survival of a species.	The proposal will impact on 2.0 ha of degraded native vegetation that is considered to be critical habitat. This is only considered to be minor and the proposal will ensure a connection is maintained across the proposal footprint with the construction of bridge structures.	No
	Disrupt the breeding cycle of a population.	A vegetated buffer will be maintained around known populations, while a separation distance of 10 m will be maintained, where possible, between the known population and the proposal.	No
	Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.	The proposal is unlikely to modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that *Grevillea curviloba* subsp. *incurva* is likely to decline.	No
	Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat.	The proposal has the potential to introduce invasive weeds that may potentially degrade critical habitat supporting the known populations. It was noted that the habitat supporting the population is highly degraded with a high density and diversity of introduced species. The EMP will manage the introduction and/or spread of invasive weeds.	Potential
	Introduce disease that may cause the species to decline.	The EMP for the proposal will manage the risk of introduction or spread of diseases (i.e. *Phytophthora* Dieback).	No
	Interfere with the recovery of the species.	The proposal will not interfere with the recovery of *Grevillea curviloba* subsp. *incurva*.	No

16.2.2 Residual Impacts

A summary of the management measures and residual impacts detailed for the Grand Spider Orchid and Narrow Curved-leaf Grevillea are provided in Table 16.3. Based on the significant impact criteria (Table 16.2), the proposal may have a significant impact on the Grand Spider Orchid by the clearing of 39 ha of potential critical habitat. The proposal is not likely to have a significant impact on the Muchea Bell or the Narrow Curved-leaf Grevillea.

Management measures within the EMP will ensure that there is no direct impact on individuals within 10 m of the road and that no sub-populations of Narrow Curved-leaf Grevillea are fragmented.

The management measures are consistent with MRWA policies and procedures and are aligned with current industry practice. The effectiveness of the management measures in mitigating the residual impact on the Grand Spider Orchid and the Narrow Curved-leaf Grevillea will be dependent on the successful implementation of the EMP during the construction phase of the project by the relevant contractor appointed by MRWA.

The predicted success of these management measures are expected to substantially reduce impacts of the proposal on MNES.

Table 16.3 Summary of residual impacts to Threatened flora following implementation of management and mitigation measures

Species and EPBC Act conservation status	Existing environment	Management measures	Residual impacts
Grand Spider Orchid (*Caladenia huegelii*) Endangered	One individual was recorded within approximately 20 m of the proposal footprint. Previous records of this species are known to occur within 100 m of the proposal footprint (Coffey, 2015a). Approximately 228 ha of critical habitat occur within the flora study area. The extent of critical habitat is considered to be an over-estimation.	• A vegetated buffer will be maintained around the known locations of threatened flora. The buffer will be a minimum of 50 m where possible. • Vegetation to be retained as a buffer for the Threatened flora will be clearly demarcated. • Preparation and implementation of an EMP and monitoring program prior to construction to ensure impacts to Threatened flora and their vegetated buffers are being appropriately managed. • If clearing occurs within the buffer, the impacted vegetation will be immediately rehabilitated and revegetated. • Additional targeted surveys will be undertaken prior to vegetation clearing to clearly define population boundaries and to identify any additional populations within and adjacent to the proposal footprint, to inform the final design and construction. • If populations of Grand Spider Orchid are identified as occurring within the proposal footprint, the merits of translocation will be researched. If feasible, the plants will be translocated to adjacent populations. • Habitat surveys will occur in spring 2015 to further define the extent of critical habitat within the proposal footprint.	Approximately 39 ha of potential critical habitat will be impacted within the proposal footprint.

Species and EPBC Act conservation status	Existing environment	Management measures	Residual impacts
Narrow Curved-leaf Grevillea (*Grevillea curviloba* subsp. *incurva*) Endangered	*Grevillea curviloba* subsp. *incurva* was recorded at previously known locations. No new populations or individuals were recorded from the proposal footprint. The known locations are within 10 m of the proposal footprint (Coffey, 2015a). The vegetation located along the Brand Highway verge and the rail reserve is considered to be critical habitat for *Grevillea curviloba* subsp. *incurva* (Phillimore and English, 2000).	• A vegetated buffer will be maintained around the known locations of threatened flora. The buffer will be a minimum of 10 m. • Vegetation to be retained as a buffer for the Threatened flora will be clearly demarcated. • Vegetation located along the Brand Highway road reserve will be maintained during final design of the proposal with the aid of a bridge structure. The construction of a bridge will ensure continuity in the habitat along Brand Highway • Preparation and implementation of an EMP and monitoring program prior to construction to ensure impacts to Threatened flora and their vegetated buffers are being appropriately managed. • If clearing occurs within the buffer, the impacted vegetation will be immediately rehabilitated and revegetated. • Additional targeted surveys will be undertaken prior to vegetation clearing to clearly define population boundaries and to identify any additional populations within and adjacent to the proposal footprint, to inform the final design and construction.	Connectivity between known populations may be interrupted depending on the design of the Brand Highway cross over.

16.3 Listed Threatened Ecological Communities

A search of the PMST and review of the flora and vegetation survey conducted (Coffey, 2015a) indicated that seven TECs listed under the EPBC Act may be located within five kilometres of the proposal in both the Muchea and Ellenbrook sections:

- Assemblages of plants and invertebrate animals of tumulus (organic mound) springs of the Swan Coastal Plain (Mound Springs SCP) – Endangered.
- Claypans of the Swan Coastal Plain – Critically Endangered.
- *Corymbia calophylla – Kingia australis* woodlands on heavy soils of the Swan Coastal Plain – Endangered.
- *Corymbia calophylla – Xanthorrhoea preissii* woodlands and shrublands of the Swan Coastal Plain – Endangered.
- Shrublands and woodlands of the eastern Swan Coastal Plain – Endangered.
- Shrublands and Woodlands on Muchea Limestone of the Swan Coastal Plain – Endangered.
- Subtropical and Temperate Coastal Saltmarsh – Vulnerable.

A series of tumulus springs were known to occur adjacent to the proposal footprint (Attachment 4 in GHD, 2008a). During the alignment definition (2003–2005) the alignment was designed to avoid direct impact on the springs (GHD, 2013b). The former Department of Environment and Conservation (now DPAW) required that detailed assessments be undertaken to justify the location of the proposal within the catchment of the TEC and determine how the potential impacts would be managed. To ensure that there would be no impacts to the hydrology of the TEC (given that the proposal is located within the catchment of the TEC), the proposal was re-aligned to the east of the TEC.

A detailed Level 2 flora and vegetation survey of the study area (Section 8.1), conducted in 2014 (Coffey, 2015a), included a statistical multivariate analysis of floristic data collected from the proposal footprint. The survey also reviewed previous studies to identify if any TECs have previously been recorded within the proposal footprint. The results of the statistical analysis and review of available information indicated that one TEC, Claypans of the SCP, occurs within the flora study area. The TEC was mapped in association with remnant native vegetation on clay based soils north of Muchea, adjacent to the Great Northern Highway.

The TEC Mound Springs SCP occurs within the flora study area near Gaston Road. In addition to the Claypans SCP and the Mound Springs SCP, the buffers of additional Mound Springs SCP sites and Shrublands and Woodlands on Muchea Limestone of the Swan Coastal Plain (Muchea Limestone SCP) sites occur across the proposal footprint in several locations. Although the proposal footprint occurs within portions of the TEC buffers, the impact on the TECs as a result of the construction and operation of the proposal is considered to be negligible. The minimum distance between the Muchea Limestone SCP and the proposal footprint is 1.5 km, and generally incorporates residential housing and cleared paddocks (Figure 8.4).

The proposal footprint is located down gradient of the known Mound Springs SCP TEC locations, except for one location in Ellenbrook. The buffer surrounding the Mound Spring SCP TEC in Ellenbrook incorporates the residential housing; as such, the construction and operation of the proposal will not impact on the location of the TEC in Ellenbrook.

The proposal will not impact on the Mound Springs SCP and the Muchea Limestone SCP as a result of the buffers occurring in association with the proposal footprint.

16.3.1 Potential Impacts and Management Measures

No TECs listed by the Commonwealth under the EPBC Act are known to occur within the proposal footprint. The impacts are considered to be negligible due to the distance between the TEC and the proposal footprint and the current land uses (i.e. residential housing, cleared paddocks) between the TECs and the proposal footprint.

The Mound Springs SCP TEC will not be directly impacted, and the potential indirect impacts associated with hydrological changes can be readily managed during the construction and operation phases of the proposal. The management measures associated with indirect impacts to the Mound Springs SCP TEC is discussed in Sections 8.5 and 10.5.

As discussed in Section 8.4.4, the proposal footprint will not directly impact on the TEC Claypans of the SCP. Existing earthworks of man-made dams located within the mapped TEC and the current Great Northern Highway may potentially be indirectly impacting the hydrology of the TEC.

The Claypans of the SCP TEC is dependent on the wetlands filling and drying at appropriate times of the year. Groundwater abstraction for construction purposes may lower the groundwater table, which may reduce the amount of wetland 'filling', reducing the biodiversity of the wetlands. Alterations to groundwater levels are expected to be localised, minimal and on a short-term basis (see Section 10.4.9).

To mitigate the potential impact of groundwater alteration on the Claypans of the SCP TEC, an investigation into dewatering and water abstraction requirements will be undertaken to understand the extent and scale of impacts on the groundwater and the TEC. The groundwater abstraction is not anticipated to adversely impact the groundwater levels that influence the TEC. In addition, surface water flows will be maintained during the construction and operation phase of the proposal.

16.3.2 Residual Impacts

A summary of the management measures and residual impacts detailed for Commonwealth TECs Claypans of the SCP and Mound Springs SCP are provided in Table 16.4, and are addressed in Section 10.4.9. Based on the significant impact criteria for critically endangered and endangered TECs (DOTE, 2013), the proposal will not have a significant impact on either the Mound Springs SCP TEC or the Claypans of the SCP TEC.

The management measures are consistent with MRWA policies and procedures and are aligned with current industry practice. The effectiveness of the management measures in mitigating the residual impact on the two TECs will be dependent on the successful implementation of the EMP during the construction phase of the project by the relevant contractor appointed by MRWA.

It is predicted that the impacts to these TECs will be fully mitigated.

Table 16.4 Summary of residual impacts to Threatened Ecological Communities following implementation of management and mitigation measures

TEC and conservation rating	Existing environment	Management measures	Residual impacts
Claypans of the SCP Critically Endangered (Commonwealth TEC)	9.8 ha in size and ranged in condition from very good to degraded. Dependent on the wetlands filling and drying at appropriate times of the year.	• Disturbance will be restricted to the proposal footprint. • The Commonwealth TEC Claypans of the SCP will be avoided. • Groundwater abstraction will not adversely impact the groundwater levels that influence the TEC. • An investigation into dewatering and water abstraction requirements will be undertaken to understand the extent and scale of impacts on the groundwater and the TEC. • Preparation and implementation of an EMP and monitoring program prior to construction to ensure there are no indirect impacts to the functionality of the TEC.	Nil.
Mound Springs SCP Endangered (Commonwealth TEC) and Critically Endangered (State TEC)	1.5 ha occurs in the flora study area. The habitat of this community is characterised by the continuous discharge of groundwater in raised areas of peat. The peat and immediate surrounds provide a stable, permanently moist series of microhabitats. The design of the proposal ensured the proposal footprint was located down gradient from the local catchment for the Mound Springs SCP TEC.	• Project disturbance will be restricted to the proposal footprint. • The Commonwealth TEC Mound Springs SCP will be avoided. • Groundwater abstraction will not adversely impact the groundwater levels that influence the TEC. • Preparation and implementation of an EMP and monitoring program prior to construction to ensure there are no indirect impacts to the functionality of the TEC.	Nil.

TEC and conservation rating	Existing environment	Management measures	Residual impacts
Shrublands and Woodlands on Muchea Limestone of the SCP Endangered (Commonwealth TEC)	The buffers of two locations occur across the proposal footprint. Although the proposal footprint occurs in association with portions of the TEC buffers, the impact on the TECs as a result of the construction and operation of the proposal is considered to be negligible. The Muchea Limestone SCP and the proposal footprint is 1.5 km, and is predominately residential housing and cleared paddocks. The proposal will not impact on the Muchea Limestone SCP as a result of the buffers occurring in association with the proposal footprint.	• Project disturbance will be restricted to the proposal footprint. • The Commonwealth TEC Muchea Limestone on the SCP will be avoided. • Groundwater abstraction will not adversely impact the groundwater levels that influence the TEC. • Preparation and implementation of an EMP and monitoring program prior to construction to ensure there are no indirect impacts to the functionality of the TEC.	Nil.

16.4 Threatened and Migratory Fauna Species

Threatened fauna under the EPBC Act are classified according to the following categories: Extinct, Extinct in the Wild, Critically Endangered, Endangered or Vulnerable. Species can also be classified as migratory under the EPBC Act if they are listed under international conventions and/or agreements to which Australia is party to e.g., Bonn Convention, CAMBA or JAMBA.

A review of database searches (DOTE, 2014f; DPAW, 2014c, d) indicated that 41 conservation significant fauna species protected under the EPBC Act potentially occur within a 10 km radius of the proposal footprint. Of the 41 species identified as potentially occurring in the proposal footprint, two species were recorded during the fauna survey: Carnaby's Cockatoo (*Calyptorhynchus latirostris*) and Forest Red-tailed Black Cockatoo (*Calyptorhynchus banksii naso*). Three species were classified as likely to occur: Great Egret (*Ardea alba*), Cattle Egret (*Ardea ibis*) and Rainbow Bee-eater (*Merops ornatus*) (Coffey, 2015b) (Appendix G). As the proposal footprint does not contain suitable habitat, is not in the current distribution or does not contain recent records for the other 36 species, they were not assessed (aside from the Western Swamp Tortoise in Section 16.4.2). Further information on the species not considered likely to occur in the proposal footprint is contained in Appendix G.

16.4.1 Potential Impacts to Black Cockatoos and Migratory Fauna

The proposal is not expected to result in a significant impact on the majority of threatened or migratory fauna except for the Carnaby's Cockatoo and the Forest Red-tailed Black Cockatoo. The significant impact criteria for each of these species are summarised in Table 16.5.

16.4.2 Potential Impacts to the Western Swamp Tortoise

The Western Swamp Tortoise is classified as highly unlikely to occur in the proposal footprint as it currently occurs in only four known locations outside the proposal footprint. In addition, the proposal footprint lacks the ephemeral swamps over clay-based soils this species requires (Coffey, 2015b) (see Appendix G). However, due to the close proximity of the proposal footprint to sensitive habitat (Twin Swamps Nature Reserve and Ellen Brook Nature Reserve) and the conservation significance of this species, an analysis on the potential impact to these habitats from road runoff and pollutants was undertaken.

The Western Swamp Tortoise is listed as Critically Endangered under the EPBC Act and Schedule 1 under the WC Act. Its current distribution occurs at four locations, namely Ellen Brook Nature Reserve, Twin Swamps Nature Reserve, Moore River Nature Reserve and Mogumber Nature Reserve. The populations at the two latter locations are maintained by translocated individuals (DOTE, 2014g). Current populations at each reserve include 30 individuals at Ellen Brook Nature Reserve, six individuals at Twin Swamps Nature Reserve and approximately 26 individuals at Mogumber Nature Reserve (based upon 2004 data). The release of captive bred individuals to Moore River Nature Reserve commenced in 2007 (DOTE, 2014g; Burbidge et al., 2010). The significant impact criteria for the Western Swamp Tortoise are summarised in Table 16.6.

The wetlands within Twin Swamps Nature Reserve fill with water in response to the first winter rains from direct rainfall and surface runoff. The wetlands are also fed by groundwater, part of which is thought to be due to groundwater flow from the Darling Scarp in the east (EPA, 2006c). Surface water flows from the proposal towards the east and before the reserve split to the south and north of Twin Swamps Nature Reserve, therefore, there is no direct flow path from the proposal area into the swamps (Appendix J). Furthermore, given the expected sandy nature of the surrounding soils and the separation distance between the swamps and the proposal, groundwater levels at the swamps will not be impacted by the construction of the road embankment (see Appendix J).

Table 16.5 Significant impact criteria for fauna

Species and conservation status	Significant impact criteria	Proposal relevance	Significant impact
Carnaby's Cockatoo (Endangered) Forest Red-tailed Black Cockatoo (Vulnerable)	Will the proposal lead to a long-term decrease in the size of a population/important population of a species?	The proposal is unlikely to result in a long-term decrease in the size of the population for either species. The loss of habitat from the proposal represents approximately 0.04% of the bioregional habitat available for the Carnaby's Cockatoo and approximately 0.03% of the bioregional habitat available for the Forest Red-tailed Black Cockatoo (474,000 ha of Black Cockatoo habitat on the SCP) (Johnston, 2013).	No
	Will the proposal reduce the area of occupancy of this species/an important population?	The proposal is not expected to reduce the area of occupancy for each species (Carnaby's Cockatoo 10,000 km^2 and Forest Red-tailed Black Cockatoo 20,000 km^2) (Garnett et al., 2011).	No
	Will the proposal fragment an existing population/ important population into two or more populations?	Both species are nomadic within their range and have strong dispersal capabilities. The proposal will not fragment the population of either species.	No
	Will the proposal adversely affect habitat critical to the survival of a species?	The proposal will clear vegetation that provides food resources and roosting sites in the non-breeding season for the Carnaby's Cockatoo. The proposal will clear Marri and Jarrah Woodland in an area of the southwest of WA that receives more than 600 mm of annual average rainfall. Under the critical habitat criteria in the recovery plan for each species both of these actions constitute a significant impact (DPAW, 2013a; Chapman, 2007).	Yes
	Will the proposal disrupt the breeding cycle of a population/important population?	The proposal footprint does not occur within the current breeding range of either species.	No
	Will the proposal modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?	Although the proposal will clear quality habitat for both species, the extent of loss in a bioregional context is small (between 0.03% and 0.04%). As such, neither species is expected to decline due to the proposal.	No
	Will the proposal result in invasive species that are harmful to an endangered/vulnerable species becoming established in the endangered/vulnerable species' habitat?	The proposal footprint will not introduce an invasive species that may be harmful to either species.	No

Species and conservation status	Significant impact criteria	Proposal relevance	Significant impact
	Will the proposal introduce disease that may cause the species to decline?	The residual impacts of *Phytophthora* Dieback from the proposal are considered to be low with the implementation of an EMP. Any residual impacts are not likely to cause a decline to either species.	No
	Will the proposal interfere substantially with the recovery of the species?	Although the proposal will clear critical habitat for both species the extent of loss in a bioregional context is small (between 0.03% and 0.04%). As such, the recovery of either is not expected to be interfered with.	No
Great Egret, Cattle Egret and Rainbow Bee-eater (all Migratory)	Will the proposal substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat for a migratory species?	The proposal footprint does not contain habitat classified as important for this relatively common and widespread species, as it does not: • Support an ecologically significant proportion of this species. • Contain habitat critical to a lifecycle stage. • Occur at the limit of this species range. • Occur within an area where this species is declining.	No
	Will the proposal result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species?	The proposal footprint will not introduce an invasive species that may be harmful to migratory species.	No
	Will the proposal seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species?	The Great Egret occurs throughout Australia with Western Australian populations occurring across the greater part of the state, except the arid eastern interior (Johnstone and Storr, 1998). The Cattle Egret occurs in the wetter parts of WA, and also in Northern and Eastern Australia, New Zealand and Southeast Asia (Johnstone and Storr, 1998). The Rainbow Bee-eater is one of the most widespread bird species in Australia (Barrett et al., 2003). As such, the proposal footprint does not support a significant proportion of the population of these species.	No

Table 16.6 Significant impact criteria for the Western Swamp Tortoise

Species and conservation status	Significant impact criteria	Proposal relevance	Significant impact
Western Swamp Tortoise (Critically Endangered)	Will the proposal lead to a long-term decrease in the size of a population of the species?	Impacts to the Twin Swamps and Ellen Brook Nature Reserves will not create a long-term decrease in the size of the population of this species.	No
	Will the proposal reduce the area of occupancy of this species?	The proposal, at its closest point, comes within 2.6 km of Twin Swamps Nature Reserve and 4.8 km of Ellen Brook Nature Reserve. The proposal will not reduce the area of occupancy for this species.	No
	Will the proposal fragment an existing population into two or more populations?	The proposal, at its closest point, comes within 2.6 km of Twin Swamps Nature Reserve and 4.8 km of Ellen Brook Nature Reserve. The proposal will not fragment these already isolated populations.	No
	Will the proposal adversely affect habitat critical to the survival this species?	Surface water and groundwater drainage into Twin Swamps or Ellen Brook Nature Reserve will not be disrupted by the proposal.	No
	Will the proposal disrupt the breeding cycle of a population?	The proposal, at its closest point, comes within 2.6 km of Twin Swamps Nature Reserve and 4.8 km of Ellen Brook Nature Reserve. The proposal will not disrupt the breeding cycle of those populations.	No
	Will the proposal modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?	Impacts from the proposal are upon habitats unsuitable for this species to inhabit. As such, the species is not expected to decline due to the proposal.	No
	Will the proposal result in invasive species that are harmful to a critically endangered species becoming established in the critically endangered species' habitat?	The proposal footprint will not introduce an invasive species that may be harmful to this species.	No
	Will the proposal introduce disease that may cause the species to decline?	The residual impacts of *Phytophthora* Dieback from the proposal are considered to be low with the implementation of an EMP. Due to the distance from the proposal any residual impacts are not likely to impact into Twin Swamps or Ellen Brook Nature Reserve.	No
	Will the proposal interfere substantially with the recovery of the species?	The proposal at its closest point comes within 2.6 km of Twin Swamps Nature Reserve and 4.8 km of Ellen Brook Nature Reserve. The proposal will not interfere with the recovery of this species.	No

The swamps within Ellen Brook Nature Reserve are fed by rainfall and surface water runoff from immediately adjoining properties. The proposal crosses Ellen Brook approximately 10 km upstream from Ellen Brook Nature Reserve. 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 (EPA, 2006c). Ellen Brook swamp is not expected to be impacted by changes to groundwater levels or flows as it is perched on a less permeable clay base and is not fed by groundwater (EPA, 2006c).

Based on the information in this section, the proposal is not expected to impact the Western Swamp Tortoise or its critical habitat at Twin Swamps Nature Reserve or Ellen Brook Nature Reserve. Impacts are considered to be fully mitigated and no effects are predicted.

16.4.3 Residual Impacts

A summary of management measures and residual impacts for the threatened/migratory fauna recorded or likely to occur in the proposal footprint is provided in Table 16.7. For more details on the impacts and mitigation/management measures refer to Section 9.5. All mitigation measures listed were considered through the application of the management hierarchy (Government of Western Australia, 2014) and based on current best practice methods. The EMP will be finalised prior to construction and implemented by the relevant contactor appointed by MRWA. Offset commitments will meet the requirements of the WA Environmental Offset Guidelines (Government of Western Australia, 2014).

Based on the significant impact criteria for Migratory species and the Western Swamp Tortoise, the proposal will not have a significant impact these species. Impacts from the proposal on both Black Cockatoo species are considered a significant impact based upon the Significant Impact Guidelines 1.1 (DOTE, 2013).

Table 16.7 Summary of residual impacts to Threatened and Migratory fauna following implementation of management and mitigation measures

Species and EPBC Act conservation status	Existing environment	Management measures	Residual impacts	Percentage of habitat loss at a local[1] and regional[2] scale
Carnaby's Black Cockatoo (*Calyptorhynchus latirostris*) Endangered	There have been numerous records of this species occurring in the vicinity of the proposal footprint. This species was recorded foraging along Reid Highway and Cullacabardee Bushland during the survey (Coffey, 2015b).	• Avoidance of vegetated areas in design (49.6 ha) and keep clearing to a minimum during construction. • Reduce design footprint to minimise impact on suitable breeding trees (68 trees avoided) and foraging habitat. • Offsetting of lost habitat. • Landscaping design to avoid foraging species planted on road verge. • Implementation of management measures in the EMP.	• Loss of suitable habitat: – 201.8 ha foraging habitat. – 58.6 ha roosting habitat. – 120.1 ha breeding habitat. – 763 potential breeding trees. • Increased occurrence of vehicle collision. • Habitat degradation.	• Foraging habitat: – 2.6% at a local scale. – 1% at a regional scale. – 0.04% at a bioregional scale[3].

Species and EPBC Act conservation status	Existing environment	Management measures	Residual impacts	Percentage of habitat loss at a local[1] and regional[2] scale
Forest Red-tailed Black Cockatoo (*Calyptorhynchus Banksia naso*) Vulnerable	This species has previously been recorded in the vicinity of the proposal footprint. The Forest Red-tailed Black Cockatoo was recorded foraging in the Banksia Woodland in the Maralla Road Bushland during the survey (Coffey, 2015b).	• Avoidance of vegetated areas in design (49.6 ha) and keeping clearing to a minimum during construction. • Reduction of design footprint to lessen impact on suitable breeding trees (68 trees avoided) and foraging habitat. • Offsetting of habitat loss. • Landscaping design to avoid foraging species planted on road verge. • Implementation of management measures in the EMP.	• Loss of suitable habitat: – 120.1 ha foraging habitat. – 58.6 ha roosting habitat. – 120.1 ha breeding habitat. – 763 potential breeding trees. • Increased occurrence of vehicle collision. • Habitat degradation.	• Foraging habitat: – 1.6% at a local scale. – 0.6% at a regional scale. – 0.03% at a bioregional scale[3].
Great Egret (*Ardea alba*) Migratory	The Great Egret has been previously recorded at Lightning Swamp, Whiteman Park, Bennett Brook, Waltham Reserve and Malaga Regional Open Space, which are all directly adjacent to the proposal footprint. The Wetlands of the proposal footprint provide suitable habitat for this species (Coffey, 2015b). No important habitat for this species occurs within the proposal footprint.. An ecologically significant proportion of the population of this species will not occur within the proposal footprint.	• Implementation of management measures contained in the EMP.	• No significant impact • Habitat degradation and habitat loss (15.5 ha). • Due to the widespread occurrence of this species and extent of its preferred habitats, impacts are expected to be negligible.	Cannot be calculated[4].

Species and EPBC Act conservation status	Existing environment	Management measures	Residual impacts	Percentage of habitat loss at a local[1] and regional[2] scale
Cattle Egret (*Ardea ibis*) Migratory	Records of this species exist from the Lake Joondalup area, which is approximately 10 km west of the proposal footprint. The Wetland and Paddock habitat types provide suitable habitat for this species. A Cattle Egret was recorded foraging in pastures adjacent to the proposal footprint during the survey (Coffey, 2015b). No important habitat for this species occurs within the proposal footprint. An ecologically significant proportion of the population of this species will not occur within the proposal footprint.	• Implementation of management measures contained in the EMP.	• No significant impact • Habitat degradation and habitat loss (271.3 ha). • Due to the widespread occurrence of this species and extent of its preferred habitats, impacts are expected to be negligible.	Cannot be calculated[4].
Rainbow Bee-eater (*Merops ornatus*) Migratory	This species has been previously recorded in the vicinity of the proposal footprint. All natural fauna habitats and the Modified Vegetation secondary habitat provide suitable habitat for this species (Coffey, 2015b). No important habitat for this species occurs within the proposal footprint.. An ecologically significant proportion of the population of this species will not occur within the proposal footprint.	• Avoidance of vegetated areas in design and keeping clearing to a minimum during construction. • Implementation of management measures contained in the EMP.	• No significant impact • Habitat degradation and habitat loss (367.5 ha). • Due to the widespread and common occurrence of this species and extent of its preferred habitats, impacts are expected to be negligible.	• 4.8% at a local scale. • 1.8% at a regional scale.

1. Local scale represents the extent of all Bush Forever sites within 1 km of the proposal footprint.
2. Regional scale represents the extent of all Bush Forever sites within 10 km of the proposal footprint.
3. Bioregional scale represents the amount of Black Cockatoo habitat on the SCP.
4. Cannot be calculated due to the lack of information pertaining to the local or regional scale of the specific habitat requirements of that species.