Main Roads Western Australia

Neerabup Road Extension

Fauna Movement Study

February 2014

Executive Summary

The Mitchell Freeway provides the primary road access route from the Perth north-west corridor towards the City of Perth. Neerabup Road is an important east-west link connecting the industrial and residential areas east of Wanneroo Road with the Mitchell Freeway and areas west of the freeway. Neerabup Road will be a significant freight route for efficient traffic movement in and out of the Neerabup industrial area.

Main Roads Western Australia (Main Roads) commissioned GHD Pty Ltd (GHD) to undertake an assessment on the movement of fauna (this study) in the site of the proposed Neerabup Road Extension (the Study Area). The purpose of this study was to identify areas within the Study Area where there may be greater levels of fauna activity, and therefore identify locations where fauna underpasses, overpasses or bridging are recommended as a means of reducing impacts to fauna and the impacts to the safety of road users.

The key sampling method for this fauna movement study was recording animal prints along sandy tracks each day for several days. A combination of tracks within Neerabup National Park were selected as the Study Area for the movement study, totalling approximately 2 km in length. Sampling was undertaken by walking the Study Area in the morning and the afternoon, identifying and GPS recording all fauna prints. Print identification was undertaken to the most accurate level possible, that is where possible, prints were identified to a genus or species level. The results were graphed and tabulated using the species (or fauna group) diversity, rate of occurrence, direction and locality of occurrence, in order to provide a basic assessment of the fauna movement in the Study Area.

All print observation data was collated and geographical locations imported into ArcGIS 10.1 for geo-processing. This data was used to undertake a Hot Spot Analysis. The Hot Spot Analysis outputs were used to identify if the local patterns of fauna movement were significantly different to what was generally observed across the whole Study Area.

In total, 1059 fauna prints from at least 18 fauna species were observed during the movement study, this includes birds (terrestrial records) and introduced fauna species. Of all species identified, Western Grey Kangaroos were the most common species recorded in the Study Area with 480 occurrences, or 45% of all records. This was approximately five times greater than the next most recorded species, the Fox (92 occurrences or 9%).

The Hot Spot Analysis identified that fauna species used the entire Study Area to move throughout the environment. The analysis identified three distinct areas where fauna tracks were more prevalent. Two of these areas are within Tuart woodland at 646 m and 903 m from the start of the Study Area at the Wanneroo road end. The third area is within Jarrah/Banksia woodland and is 425 m from the start of the Study Area.

A key implication from this study is the records of large terrestrial fauna species occurring within the Neerabup Road Extension alignment area. These large species may venture onto the road resulting in an increased frequency of road strikes. These strikes could be serious, causing accidents and/or vehicle damage, in particular due to the size of the Emus and Western Grey Kangaroos observed during the study.

During the road design phase of the Neerabup Road Extension serious consideration should be given to construction of fauna underpasses (or wildlife crossing alternatives) in order to reduce the potential impacts to fauna from the road. The three areas of high fauna movement identified during this study are strongly recommended as locations where fauna underpasses or wildlife crossing alternatives should be established to allow future fauna movement.

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1. Introduction

1.1 Background

The Mitchell Freeway provides the primary road access route from the Perth north-west corridor towards the City of Perth. The freeway currently terminates at Burns Beach Road. The freeway has been constructed in several stages since the 1960s, with further extensions and widening works are planned. The Mitchell Freeway Extension beyond Burns Beach Road has been the subject of a planning process undertaken by Main Roads Western Australia (Main Roads).

The business case prepared for the project divides the project into three stages to be completed over a period of time. These stages are:

- Stage 1 – Freeway extension from Burns Beach Road to Hester Avenue and the connecting roads (Neerabup Road and Hester Avenue) 2015–2017
- Stage 2 – Freeway extension from Hester Avenue to Romeo Road and connecting road (Romeo Road) 2017–2021
- Stage 3 – Wanneroo Road duplication from Joondalup Drive to Hall Road 2027–2029

The study presented in this report focuses on the Neerabup Road extension which bisects 2.0 km of natural vegetation within the Neerabup National Park.

Neerabup Road is an important east-west link connecting the industrial and residential areas east of Wanneroo Road with the Mitchell Freeway and areas west of the freeway. The link is considered necessary as the existing Burns Beach Road / Joondalup Drive link will reach capacity as urban development proceeds. Neerabup Road will be a significant freight route for efficient traffic movement in and out of the Neerabup industrial area.

Neerabup Road is planned as a four lane dual carriageway (two lanes each way with a central median). The width of the road is dictated by geometric factors based on the type and frequency of traffic likely to be carried on the new road. The cross section would typically comprise:

- Number of lanes: 4
- Cross section: 2.0 m shoulder + 2 x 3.5 m lanes + median + 2 x 3.5 m lanes + 2.0 m shoulder
- Shared path: 3.0 m on north side.

Main Roads commissioned GHD Pty Ltd (GHD) to undertake an assessment on the movement of fauna (this study) in the site of the proposed Neerabup Road Extension (the Study Area).

1.2 Study Area

The Neerabup Road Extension alignment (the Study Area) is located approximately 30 km north of Perth, Western Australia within the City of Wanneroo.

The Study Area for this fauna movement study extends from the eastern end of the existing Neerabup Road, east to Wanneroo Road, and comprises numerous dirt tracks, walking trails, native vegetation and parts of Neerabup National Park.

The Study Area is shown on Figure 1, Appendix A.

1.3 Purpose of this report

The purpose of this study was to identify areas within the Study Area where there may be greater levels of fauna activity, and therefore identify locations where fauna underpasses,

overpasses or bridging are recommended as a means of reducing impacts to fauna and the impacts to the safety of road users. The results of this study can be used to inform the road design team in establishing fauna underpasses or other methods to facilitate future fauna movement after the construction of the Neerabup Road Extension.

1.4 Scope and limitations

This report: has been prepared by GHD for Main Roads Western Australia and may only be used and relied on by Main Roads Western Australia for the purpose agreed between GHD and the Main Roads Western Australia as set out in section 1.3 of this report.

GHD otherwise disclaims responsibility to any person other than Main Roads Western Australia arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer to section 2.6.5 and 2.7 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

2. Methodology

2.1 Overview

The key sampling method for this fauna movement study was recording animal prints along sandy tracks each day for several days. This method can be used to determine the presence of fauna species in an area and the frequency of occurrence (Triggs 1998; Moseby *et al.* 2011). This method has been applied to similar studies such as the Project Eden predator control and reintroduction program in Shark Bay (pers comm. C. Simms) and the Mount Gibson Predator study (pers comm. J. Kuiper).

2.2 Site selection and preparation

The methodology applied in this study required tracks with sandy substrates. The proposed Neerabup Road Extension alignment transects an area of native vegetation where there are very limited sandy tracks. As such it was necessary to use tracks (in very close proximity to the proposed alignment) as a substitute sampling location. On the 24th November 2014, GHD and Department of Parks and Wildlife (DPaW) Regional staff visited the Neerabup Road Extension alignment area to select appropriate substitute sampling locations and define the Study Area. Dirt tracks were selected for the Study Area based on the following features:

- The tracks were as close to the proposed impact area (MRS boundary of Neerabup Road Extension) as possible, to be accurately representative of species using the area.
- The tracks span the width of Neerabup National Park, capturing all movements of fauna over the alignment.
- The tracks must be of suitable substrate to identify fauna prints, sand being preferred.
- There must be the ability to clean the track prior to, and between, each sampling period.
- There must ability to restrict access to the tracks over the study period, so fauna are not disturbed during their daily activities and/or prints are not covered by human activity.

A combination of tracks within Neerabup National Park were selected as the Study Area for the movement study, totalling approximately 2 km in length. The Study Area is situated just north of the proposed Neerabup Road Extension alignment, and a portion of the Study Area bisects the alignment at around 1 km from Wanneroo Road. The fauna movement Study Area and the proposed Neerabup Road Extension alignment are shown in Figure 1, Appendix A.

The track was cleaned and surface levelled on the 30th October 2013 by DPaW with a brush clearing dozer and hand cleaned by GHD staff with rakes. The dozer removed any young vegetation on the tracks and disturbed the surface layer leaving a cleaner sandy surface.

2.2.1 Supplementary survey method

Two areas along the Study Area track had scattered limestone rocks and pebbles and were not a consistent sandy surface (unlike the majority of the Study Area). In these two sections reading prints was likely to be more difficult due to the uneven surface texture. These areas were located approximately 300 m and 1400 m from the start of the Study Area (eastern end near Wanneroo Road). Each area was approximately 50–100 m long. At one of these sections (Wanneroo Road end) four infrared motion sensor cameras were placed along the track to capture records of fauna species that may have been missed through the print assessment. These cameras were in situ for four nights.

2.3 Sampling effort

The movement study was undertaken by GHD zoologists Glen Gaikhorst, Laura Zimmerman, Jo Kuiper and Craig Grabham from the 31st October 2013 to the 7th November 2013 with two additional days sampled on the 11th and 12th of November 2013. In total, sampling occurred over a 14 day period and 17 sampling sessions were undertaken.

Two sampling sessions were undertaken to capture diurnal and nocturnal use. Morning sampling commenced around 6.00 am and afternoon sampling was undertaken around 4.00 pm. Each sampling session took approximately 1.5 hours to complete.

After each sampling session the track was swept with a wooden drag to create a clean sampling surface (i.e. remove fauna prints from the previous sampling session). Plate 1 shows this cleaning process and Plate 2 shows the cleaned sampling surface.

This study was subject to numerous assumptions and limitations. These are described in Section 2.6.5 and 2.7, respectively.

Plate 1 Wooden drag structure (without branches attached)

Plate 2 Swept track for sampling

2.4 Sampling data

Sampling was undertaken by walking the Study Area in the morning and the afternoon, identifying and GPS recording all fauna prints. GPS units used were Garmin 62S with an accuracy of +/- 2 m – 8 m.

Print identification was undertaken to the most accurate level possible, that is where possible, prints were identified to a genus or species level (such as Western Grey Kangaroo or Bobtail/Western Bluetongue). Where it was not possible to identify the species then print records were grouped (such as large snake or small reptile). Prints that could not be identified or those that were of invertebrates were not recorded. All remaining groups or species were recorded, including birds and introduced fauna species. Bird recordings were only those that were terrestrial in nature (i.e. had prints over the track).

Where possible directional data was collected for each print observation. This directional data identified whether the animal (as shown by the print) was moving in a north, south, east or west direction. This data was collected to assess any variation in movement within the Study Area, as local disturbance or seasonal variation in species activity may have influenced the activity levels within the area. The direction the species was moving in could not always be determined. Prints where direction could not be determined included:

- Groups of birds (Ravens/Magpies) and some mobs of Western Grey Kangaroos tended to randomly move within the Study Area foraging and did not traverse in any one direction.
- The direction of the print was sometimes indistinguishable, such as some snake and skink prints.

2.5 Ecological data analysis

The location, fauna group (or species, where possible) and direction of movement was recorded on 17 separate occasions for the Study Area. The results were graphed and tabulated using the species (or fauna group) diversity, rate of occurrence, direction and locality of occurrence, in order to provide a basic assessment of the fauna movement in the Study Area.

The frequencies of fauna movements were also graphed for the Study Area, in order to determine any areas where movement was greatest. These graphs excluded birds (except Emu due to their terrestrial nature) and feral species such as foxes, cats and dogs, in order to remove bias.

2.6 Statistical analysis of data – hot spot analysis

2.6.1 Data treatment

All print observation data was collated and geographical locations imported into ArcGIS 10.1 for geo-processing. This data was used to undertake a Hot Spot Analysis.

For the analysis, all fauna movement data was used, excluding feral species and flight able bird species. Feral species, such as foxes, cats and dogs, and all birds (except Emus due to their terrestrial nature) were excluded in order to remove bias. The analysis therefore included the use of 842 observations over the Study Area.

2.6.2 Hot Spot Analysis

Hot Spot Analysis identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots) (ArcGIS 2013). This tool works by looking at each feature within the context of neighbouring features. A feature with a high value is interesting but may not be a statistically significant hot spot. To be a statistically significant hotspot, a feature will have a high value and be surrounded by other features with high values as well. Plate 3 provides an illustration of Hot Spot Analysis.

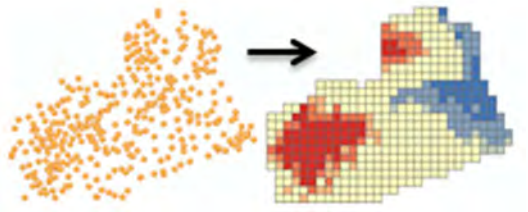


Plate 3 Illustration of Hot Spot Analysis

2.6.3 Data analysis

The point locations of each print observation were buffered by 2.5 m for the analysis. For areas where buffers overlapped, the total counts of occurrences were summarized. The full count was then used as the weight field for the Hot Spot Analysis, and spatial-relationship among features was conceptualized using “Inverse distance” method - where closer features are weighed more heavily than features that are further away (the impact of one feature on another feature decreases with distance).

2.6.4 Interpretation

The Hot Spot Analysis outputs were used to identify if the local patterns of fauna movement were significantly different to what was generally observed across the whole Study Area.

2.6.5 Assumptions

The following assumptions were made for the movement study:

- Two areas along the Study Area had limestone rocks and pebbles throughout the substrate, making visual inspection for tracks more difficult than in sandy areas. We have assumed in this assessment that all crossings were recorded.
- To perform the Hot Spot Analysis, a buffer had to be assigned to each data point. In this study, 2.5 m was assigned inferring that within a 5 m diameter each crossing could have occurred, creating enough overlap for the analysis to be effective.
- This study only looked at the absolute movement of fauna over the Study Area sampled. Each track observation was treated as an individual observation, and does not give an indication of the number of individuals using the area. Bias may have been created where fauna species made multiple tracks in the same area over a short period of time

2.7 Limitations

2.7.1 Access by public

The Study Area near Wanneroo Road lies adjacent to the 10th Light Horse Trail walk which is regularly used by the public. Members of the public and their pets were observed in the area and within the Study Area on numerous occasions prior to the fauna movement study commencing. To reduce access by the public, the access tracks were blocked off with warning tape and signs prohibiting access were erected at all entrance points. This approach appeared to be relatively effective, however several observations of members of the public walking dogs were recorded in the Study Area. This may have impacted on species using the area over the study period.

2.7.2 Off road vehicles

Neerabup National Park is frequently used by members of the public in off road vehicles, including both 4x4 cars and dirt bikes. Blockading and signage on tracks stopped all 4x4 use, however on three occasions evidence that motor bikes had been ridden along the Study Area track was observed. This may have impacted on species use and interfered with print observations.

2.7.3 Camera traps

Four infrared cameras (Reconyx Hyperfire HC500) were set up in one of the sections with limestone rock and pebbles on the track. These cameras were set up to capture fauna movements that may have otherwise been missed through prints assessments. Cameras also allowed comparison of camera results to print records to test if the if the limestone areas reduced the detection of fauna prints. Unfortunately two members of the public discovered the cameras and due to the risk of theft or vandalism the cameras were removed after four days of sampling.

2.7.4 Unsuitable substrate - limestone

Two areas along the alignment had some limestone rocks and pebbles and therefore did not provide a consistent sandy substrate to detect fauna prints. These areas were approximately

300 m and 1400 m from the start of the Study Area (eastern end near Wanneroo Road). Each area was approximately 50–100 m long. Although these areas were not solid limestone and sandy patches were present, observations in these areas were more difficult and consequently some prints may have been missed. However the extent to which the limestone reduced print detectability was potential limited as prints records were consistent in these areas with observations each side of the limestone sections (suggesting no impact on data recorded).

2.7.5 Weather

The study was undertaken in late October and early November 2013, a typically dry period of the year. However, on 4th November 2013 a small rain event (> 2 mls) over the Study Area occurred in the afternoon making observations of prints difficult. Data from this sampling session was therefore excluded from the analysis. The track was reswept in the afternoon in preparation for the following day's sampling session. An additional sampling session was added to the end of the study to account for this.

2.7.6 GPS Error

The Garmin 62S unit used during the study has an accuracy of +/- 2 m – 8 m. The GPS data identified numerous outliers (GPS error) and these were corrected (under the direction of the Senior Zoologist) to the closest point within the track boundary which was clearly visible in the Metro Central 2013 imagery (Landgate). This was done to enable the Hot Spot Analysis to be more accurate and reflective of the actual data collected.

2.7.7 One-off sampling period

This study was conducted over a 14 day period, during one season of one year. The data collected during this study therefore only presents a snapshot of the fauna present through the Study Area during this time.

3. Results

3.1 Diversity

In total, 1059 fauna prints from at least 18 fauna species were observed during the movement study, this includes birds (terrestrial records) and introduced fauna species. The number of observations of each species is shown in Graph 1, and a complete list of observations is provided in Table 1, Appendix B. All of the observations, excluding introduced fauna species, are also presented in Figure 2.

Of all species identified, Western Grey Kangaroos were the most common species recorded in the Study Area with 480 occurrences, or 45% of all records. This was approximately five times greater than the next most recorded species, the Fox (92 occurrences or 9%). Bobtails/ Western Bluetongue, skink, snake and Raven/Magpie prints were also high with 84 (8%), 68 (6%), 64 (6%) and 65 (6%) occurrences, respectively.

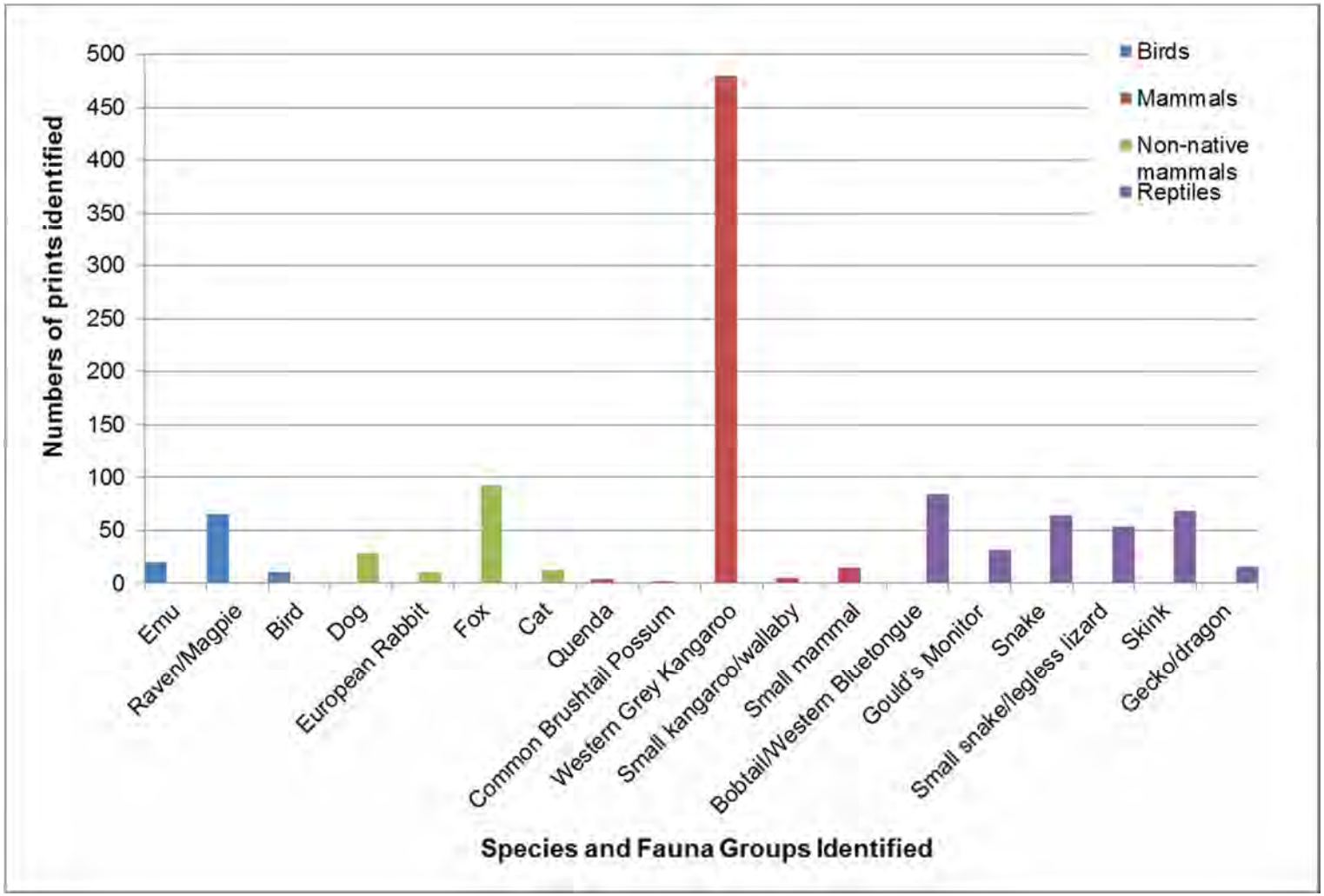
In addition to the 480 Western Grey Kangaroo prints, 11 other native mammal prints were also recorded including Quenda, Common Brushtail Possum and small kangaroo/wallaby. In total 54% of the prints recorded were from native mammals. Small mammal prints were excluded from this result due to the possibility of recording of Black Rat and House Mice prints which are readily mistaken for native rodent prints.

Reptiles, (including all species and groups of reptiles), comprised 316 (35%) observations and birds comprised 95 (10%) observations over the Study Area.

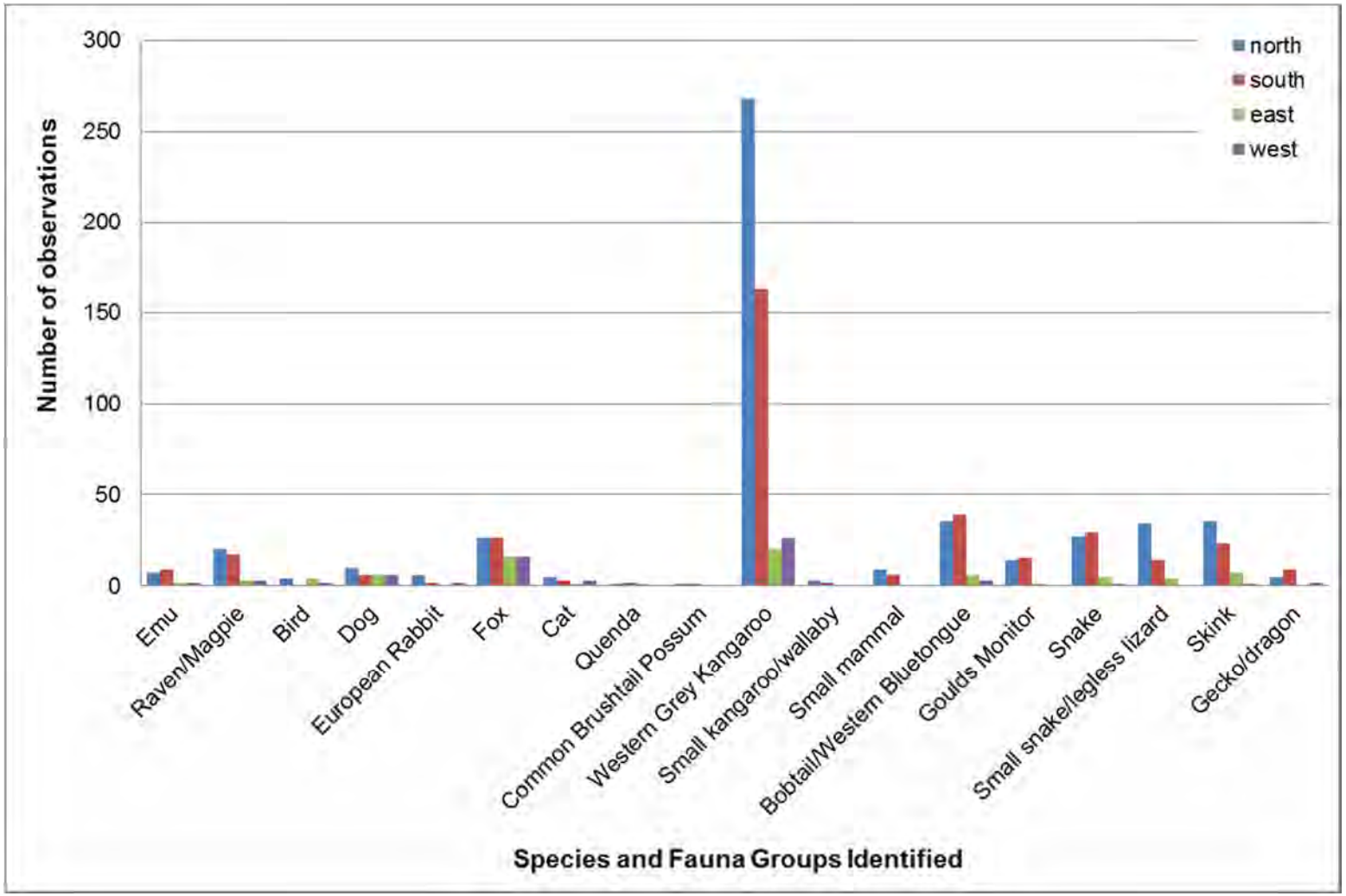
3.2 Direction of fauna movement

The direction of movement from 1023 prints was determined during the movement study. This included all birds (terrestrial records) and introduced fauna species. The complete list of observations is presented in Graph 2 below and in Table 2 in Appendix B.

Of the directional data records, most species showed about an even amount of north and south movements within the Study Area. The exceptions to this are the Western Grey Kangaroo, Small snakes/legless lizards and Skinks which showed a trend to move north within the Study Area. Additionally, the data shows a lack of movement in an east-west direction, compared to north-west movements. Foxes, Dogs and Western Grey Kangaroos tended to move more frequently east and west which is along the track, rather than across the track.



Graph 1 Number of fauna print observations in the Study Area

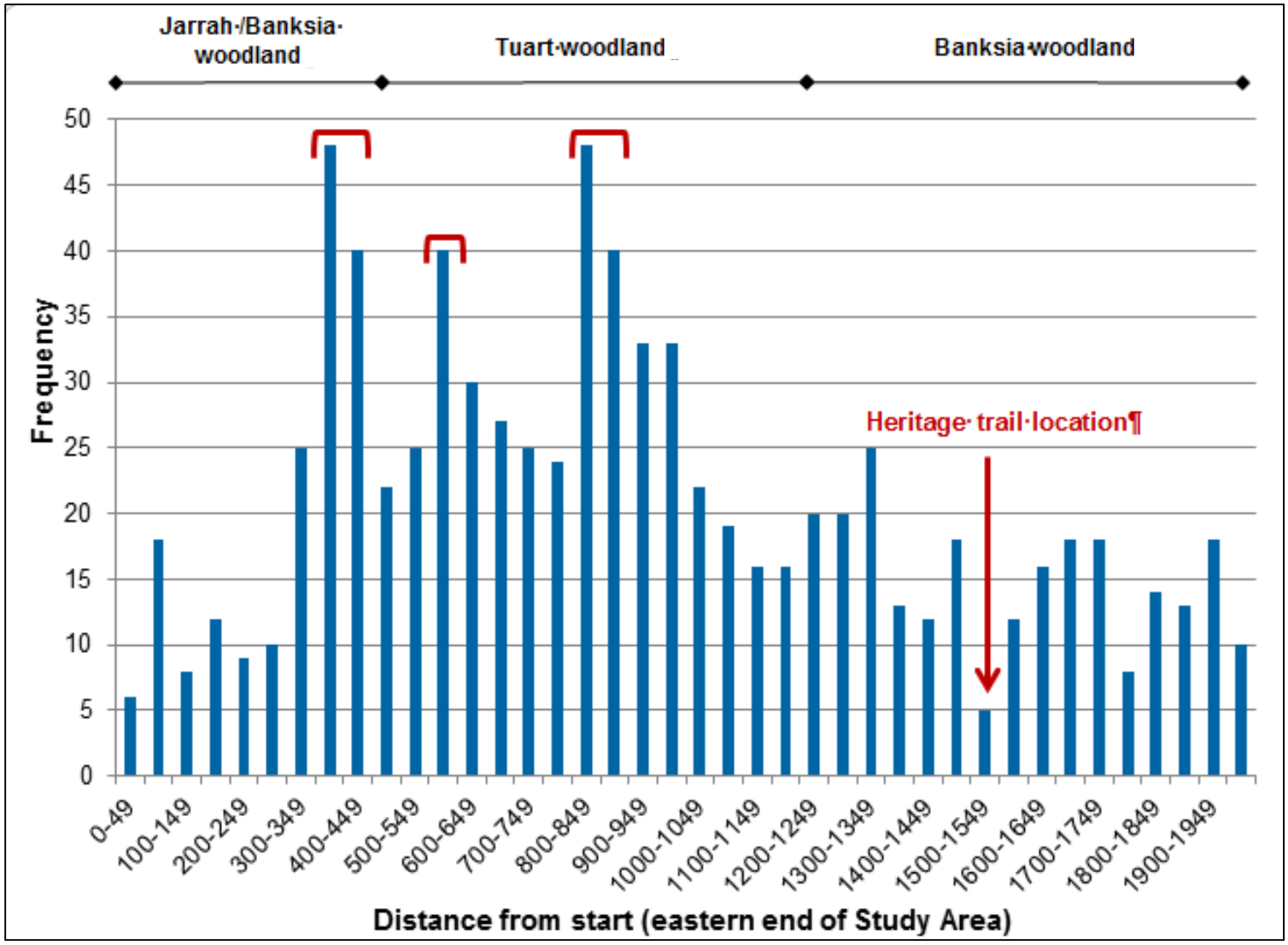


Graph 2 Directional data of fauna movements

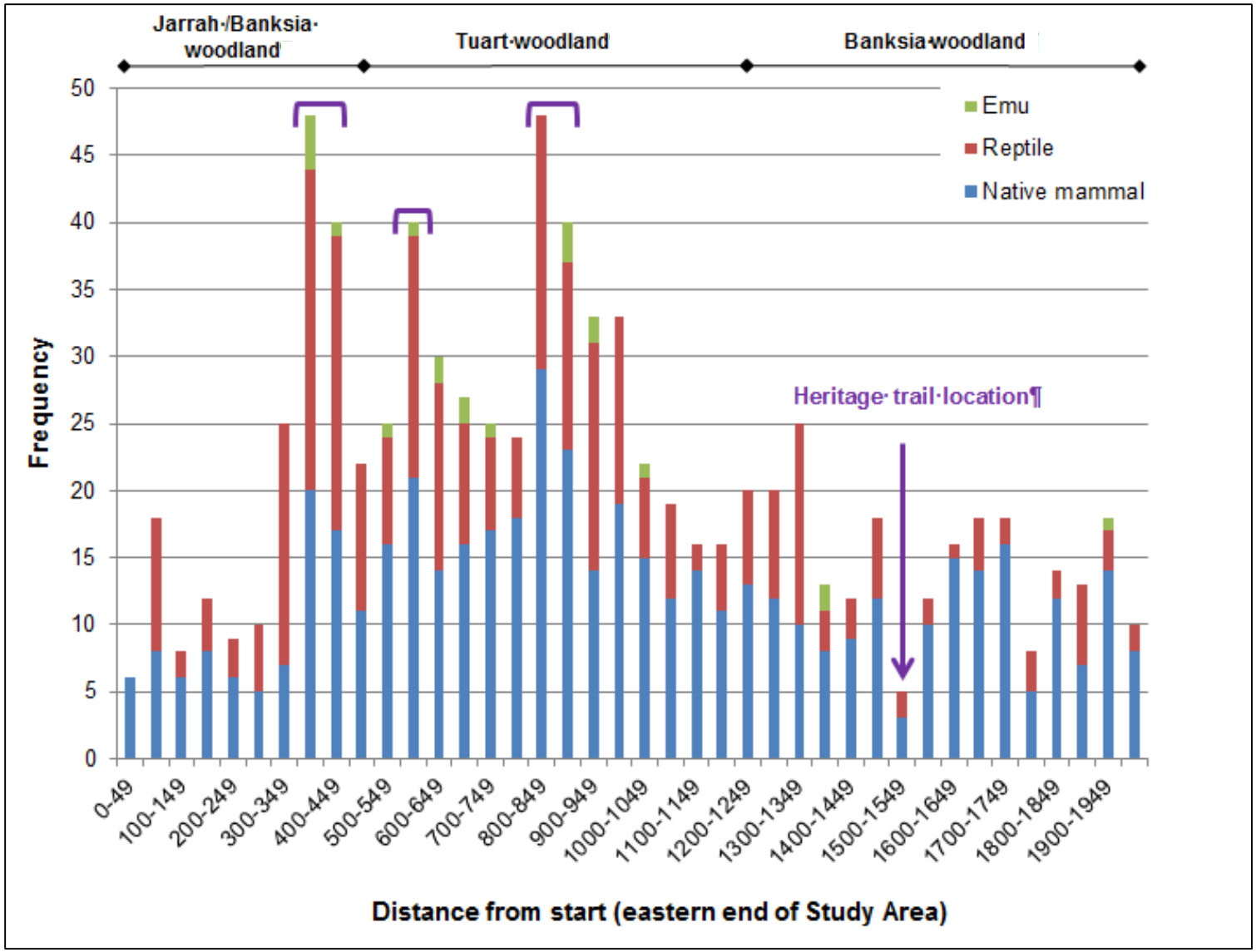
3.3 Frequency

During this movement study fauna prints were recorded throughout the entire Study Area, with greater frequency the eastern half of the Study Area. As shown in Graph 3, there were three areas where fauna movement frequency was greatest, generally between 350 – 450 m, 550 – 600 m and 800 – 900 m from the start of the Study Area (shown by the red brackets). The first area is located within Jarrah/Banksia woodland, and the second two are located within Tuart woodland. The lowest frequency of movement occurred around the Heritage Trail area, at 1500 – 1550 m from the start of the Study Area (Graph 3).

Native mammals made up the greatest proportion of fauna movement throughout the Study Area, in particular in the western portion in the Jarrah/Banksia woodland (Graph 4). Reptiles made up then next greatest proportion of movements, followed by a low frequency of Emu movements.



Graph 3 Frequency of fauna movement throughout the Study Area (beginning at the eastern end near Wanneroo road)



Graph 4 Frequency of fauna movement throughout the Study Area, by species group

3.4 Hot Spot Analysis

The Hot Spot Analysis identified that fauna species used the entire Study Area to move throughout the environment. No areas were distinctly avoided, however, the area around the Heritage Trail that crosses the Study Area did have slightly reduced use. The analysis identified three distinct areas where fauna tracks were more prevalent. Two of these areas are within Tuart woodland at 646 m and 903 m from the start of the Study Area at the Wanneroo road end. The third area is within Jarrah/Banksia woodland and is 425 m from the start of the Study Area. The Hot Spot Analysis which identifies these three locations is presented in Figure 3.

3.5 Camera traps

Four infrared camera traps were deployed for four days and four nights in the limestone incursion areas. No species or any fauna movements were recorded on these cameras and therefore these were not included in the dataset.

4. Discussion

4.1 Key outcomes

4.1.1 Diversity

The movement study identified regular activity and diverse fauna groups over the 2 km long Study Area. In total, 1059 fauna prints were recorded over the sampling period. A large proportion of these (505) were from large terrestrial fauna species, such as Western Grey Kangaroos, Wallabies and Emus.

In additional to the suite of species recorded during this movement study there are other fauna taxa known to occur in the Study Area. A trapping program undertaken at the same time as the movement study identified 96 species including 13 mammals (six of these introduced species), 58 birds, 24 reptiles and one amphibian (GHD 2014). Given these species are known to occur in the Study Area they are likely to move through the Study Area to some extent.

4.1.2 Fauna movement hot spots

The frequency data (raw data) and the Hot Spot Analysis identified the same three areas where fauna movement was concentrated. These areas are generally around 350 – 450 m, 550 – 600 m and 800 – 900 m from the start of the Study Area. All three of these areas are within the Tuart and Jarrah/Banksia Woodland in the central and eastern parts of the Study Area.

4.1.3 Direction of fauna movement

The directional data results showed that species tended to travel north-south rather than east-west; this study aimed to assess the species and frequency of fauna movement in the Study Area rather than broader fauna movement patterns in the Neerabup National park. However, (in providing comment on the broader context of the directional results) the north-south movement patterns may be attributed to a funnelling effect created by linear shape of the Neerabup National park and the proximity of the Study Area to the train line (to the east) and Wanneroo road (to the west).

Observations of fox and cat prints moving along the Study Area track were also common, and this is typical behaviour of these predators as they use open linear corridors for movement.

4.2 Key implication

A key implication from this study is the records of large terrestrial fauna species occurring within the Neerabup Road Extension alignment area. These large species may venture onto the road resulting in an increased frequency of road strikes (Jones 2000; Taylor and Goldingay 2004). These strikes could be serious, causing accidents and/or vehicle damage, in particular due to the size of the Emus and Western Grey Kangaroos observed during the study. The larger taxa may cause appreciable threats to the safety of road users and furthermore, the local Western Grey Kangaroo, Emu and Wallaby populations could be affected and decline accordingly.

In addition to implications arising from the large taxa, the smaller species in the area may also be adversely impacted by direct (being injured or killed by cars) and indirect (fragmentation of habitat and reduction of resources) impacts from the project (impacts are being addressed in an environmental impact assessment document, and construction environmental management plan).

4.3 Recommendations

4.3.1 Road design

During the road design phase of the Neerabup Road Extension serious consideration should be given to construction of fauna underpasses (or wildlife crossing alternatives) in order to reduce the potential impacts to fauna from the road. The three areas of high fauna movement identified during this study are strongly recommended as locations where fauna underpasses or wildlife crossing alternatives should be established to allow future fauna movement. The fauna underpasses or wildlife crossing alternatives are recommended to be placed in the general areas of 350 – 450 m, 550 – 600 m and 800 – 900 m from the start of the Study Area.

This recommendation leaves no underpasses in the western portion of the Study Area. As part of the road design process, an underpass has been planned for the existing Heritage Trail in the Banksia woodland in the western end of the Study Area. A low frequency of fauna movement was recorded in the area around the Heritage Trail during this study. This is likely to be due to the fact that this trail is heavily used by the public, which may have reduced the frequency of fauna movement. Fauna movements were recorded throughout the Banksia woodland in other areas of the Study Area, and therefore it is recommended that the planned Heritage Trail underpass be installed in this habitat, in addition to those identified in the fauna movement analysis.

Therefore, in total, it is recommended that four fauna underpasses or wildlife crossings should be established along the Neerabup Road Extension.

4.3.2 Underpass design

The effectiveness of the recommended underpasses is imperative to reduce the impacts to fauna and safety of road users. GHD recommends that underpasses should be 9 m across and 3 metres high (see Plate 4 for a conceptual design). Research in Western Australia has shown that smaller culverts are not adequate and are exploited by feral predators that predate on native species passing through (Harris *et al* 2010). Within established culverts, substrate and fauna habitat should be also be added to provide cover from predators.

If underpasses are established for this project, Main Roads proposes to construct fencing between the underpasses in order to reduce the movement of ground-dwelling fauna across the Neerabup Road Extension.

4.3.3 Alternatives to underpasses

There are several options for wildlife crossings that could be incorporated or combined into the design of the Neerabup Road Extension including land bridges and raised road design.

The three areas of concentrated fauna movement within the eastern portion of the Study Area are relatively close together, being 120 – 150 m apart. It may be viable option to bridge this section of road creating one continuous underpass over this area. An example of a similar bridging option is shown in Plate 5, which is part of the Bemboka bridge project in NSW (modifications to bridge design over significant Platypus feeding grounds) (Ngh Environmental 2012).

In places where the elevation of slope is not suited to an underpass or bridge, an overpass or land bridge may be used to achieve the same goal. A recent example of this in Australia is outlined by Bond and Jones (2008), where a land bridge was developed for kangaroo, wallaby, koala and possums use (as shown below in Plate 6 and Plate 7). This land bridge was constructed with a rope bridge through the middle of it with the aim of assisting with possum crossings (seen in Plate 6). However, it should be noted that rope bridges are generally

constructed in areas with large arboreal mammal populations (such as possums or gliders). To date, no land bridges are known to have been constructed in Western Australia.

Plate 4 Conceptual design of a fauna underpass without the fauna habitat

Plate 5 Bemboka bridge in NSW

Plate 6 Image of the land bridge from Bond and Jones (2008).

Plate 7 Areal view of a vegetated land Bridge (Bond and Jones 2008)

5. References

ArcGIS (2013). Esri ArcGIS 10.1 citation for Hot Spot Analysis

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Appendices

Appendix A - Figures

1:8,000 (at A3)

0 40 80 160 240 320 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

N

LEGEND

- Study location
- Study area
- Broader project area

Main Roads Western Australia
Mitchell Freeway - Fauna movement study

Job Number	61-294350802
Revision	0
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Locality

Figure 1

G:\61\29435\GIS\Maps\MXD\61294350802_G004_Fig1_Rev0.mxd

Data source: GHD: Location - 20140130, Study area - 20140130; Landgate : Metro Central Mosaic - Feb 2013; MRWA: Roads - 2013. Created by: vdinh

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380,500 380,600 380,700 380,800

6,493,200

6,493,100

6,493,000

Mitchell Fwy

1:1,000 (at A3)

0 5 10 20 30 40 50

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

N

LEGEND

Native Fauna Sightings

Mammals
- Small hopping mammal
- Small Rodent
- Small mammal
- mammal

Marpsupials
- Small kangaroo / wallaby
- Brushtail possum
- Quenda
- Kangaroo

Birds
- Emu
- Raven / Magpie
- Large Bird
- Bird

Reptiles
- Bobtail / Western Bluetongue
- Skink
- Monitor
- Snake
- Small snake / legless lizard
- Dragon

Stage
- Stage 1
- Stage 3

Main Roads Western Australia
Mitchell Fwy Fauna Movement Study

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Revision	0
Date	28 Feb 2014

Map Sheet 1 of 5

Fauna Movement

Figure 2

G:\61\29435\GIS\Maps\MXD\61294350802_G001_Fig2_Rev0.mxd

Data source: GA: NatMap 250k Topo Series 3 - 2006; Landgate: Metro Central Jan 2013 Mosaic - 2013; GHD: Stage - 20130905, Native Fauna Sightings - 20131129. Created by: erice, bflorczak

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1:1,000 (at A3)

0 5 10 20 30 40 50

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

N

LEGEND

Native Fauna Sightings

Mammals
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- Small mammal
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- Large Bird
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- Skink
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- Snake
- Small snake / legless lizard
- Dragon

Stage
- Stage 1
- Stage 3

Main Roads Western Australia
Mitchell Fwy Fauna Movement Study

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Revision	0
Date	28 Feb 2014

Map Sheet 2 of 5

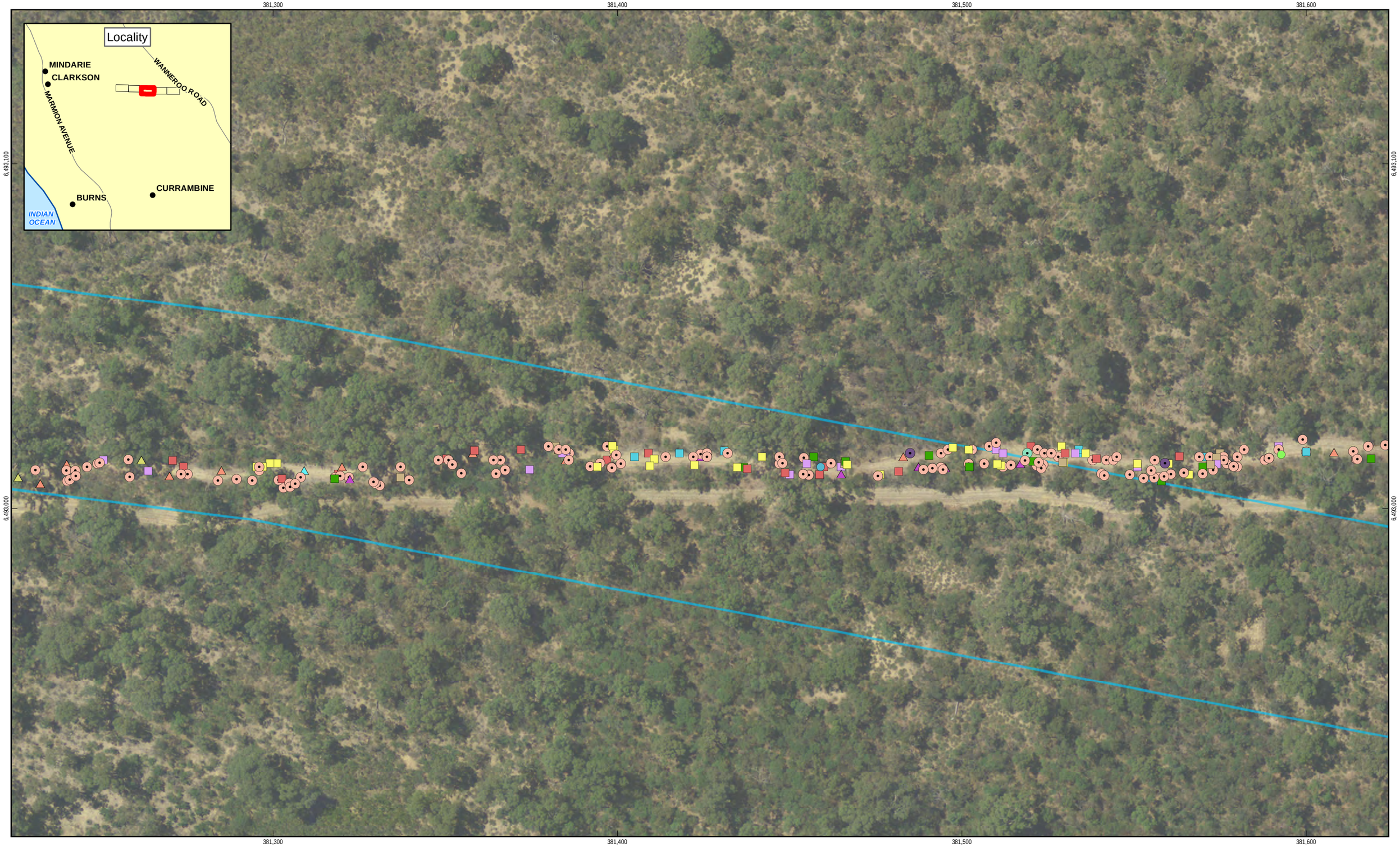
Fauna Movement

Figure 2

G:\61\29435\GIS\Maps\MXD\61294350802_G001_Fig2_Rev0.mxd

Data source: GA: NatMap 250k Topo Series 3 - 2006; Landgate: Metro Central Jan 2013 Mosaic - 2013; GHD: Stage - 20130905, Native Fauna Sightings - 20131129. Created by: erice, bflorczak

239 Adelaide Terrace Perth WA 6004 Australia **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au



1:1,000 (at A3)

0 5 10 20 30 40 50

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

N

LEGEND

Native Fauna Sightings

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Stage
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- Stage 3

Main Roads Western Australia
Mitchell Fwy Fauna Movement Study

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Date	28 Feb 2014

Map Sheet 3 of 5

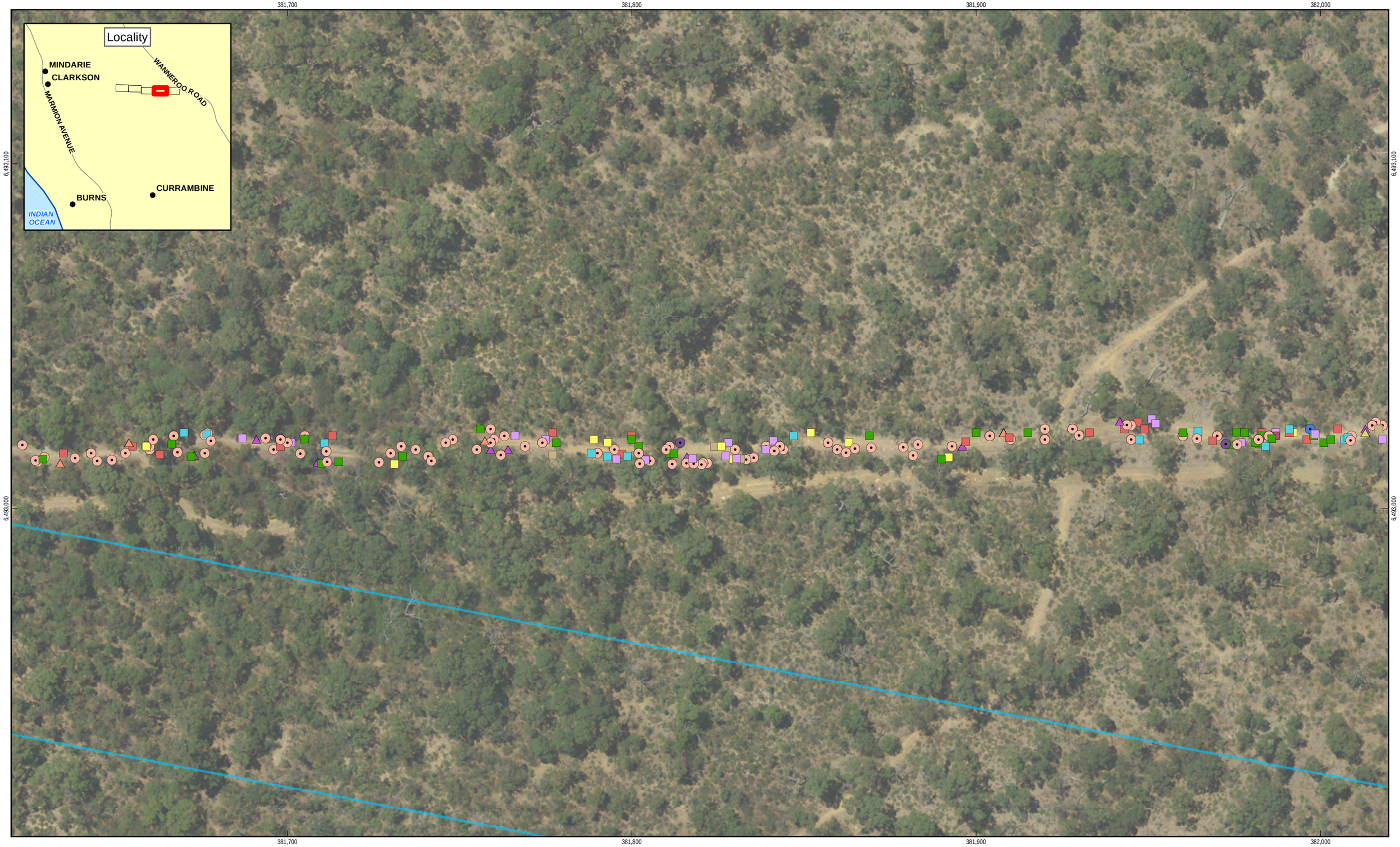
Fauna Movement

Figure 2

G:\61\29435\GIS\Maps\MXD\61294350802_G001_Fig2_Rev0.mxd

Data source: GA: NatMap 250k Topo Series 3 - 2006; Landgate: Metro Central Jan 2013 Mosaic - 2013; GHD: Stage - 20130905, Native Fauna Sightings - 20131129. Created by: erice, bflorczak

239 Adelaide Terrace Perth WA 6004 Australia **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au



1:1,000 (at A3)

0 5 10 20 30 40 50

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

N

LEGEND

Native Fauna Sightings

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Stage
- Stage 1
- Stage 3

Main Roads Western Australia
Mitchell Fwy Fauna Movement Study

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Map Sheet 4 of 5

Fauna Movement

Figure 2

G:\61\29435\GIS\Maps\MXD\61294350802_G001_Fig2_Rev0.mxd

Data source: GA: NatMap 250k Topo Series 3 - 2006; Landgate: Metro Central Jan 2013 Mosaic - 2013; GHD: Stage - 20130905, Native Fauna Sightings - 20131129. Created by: erice, bflorczak

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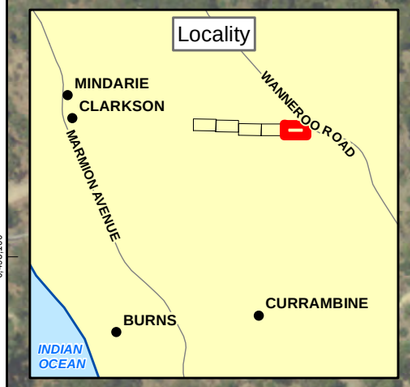
382,100 382,200 382,300 382,400

6,493,100

6,493,000



1:1,000 (at A3)

0 5 10 20 30 40 50

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

N

LEGEND

Native Fauna Sightings

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- Small Rodent
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- Small kangaroo / wallaby
- Brushtail possum
- Quenda
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- Emu
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- Bobtail / Western Bluetongue
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- Monitor
- Snake
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- Dragon

Stage
- Stage 1
- Stage 3

Main Roads Western Australia
Mitchell Fwy Fauna Movement Study

Job Number	61-294350802
Revision	0
Date	28 Feb 2014

Map Sheet 5 of 5

Fauna Movement

Figure 2

G:\61\29435\GIS\Maps\MXD\61294350802_G001_Fig2_Rev0.mxd

Data source: GA: NatMap 250k Topo Series 3 - 2006; Landgate: Metro Central Jan 2013 Mosaic - 2013; GHD: Stage - 20130905, Native Fauna Sightings - 20131129. Created by: erice, bflorczak

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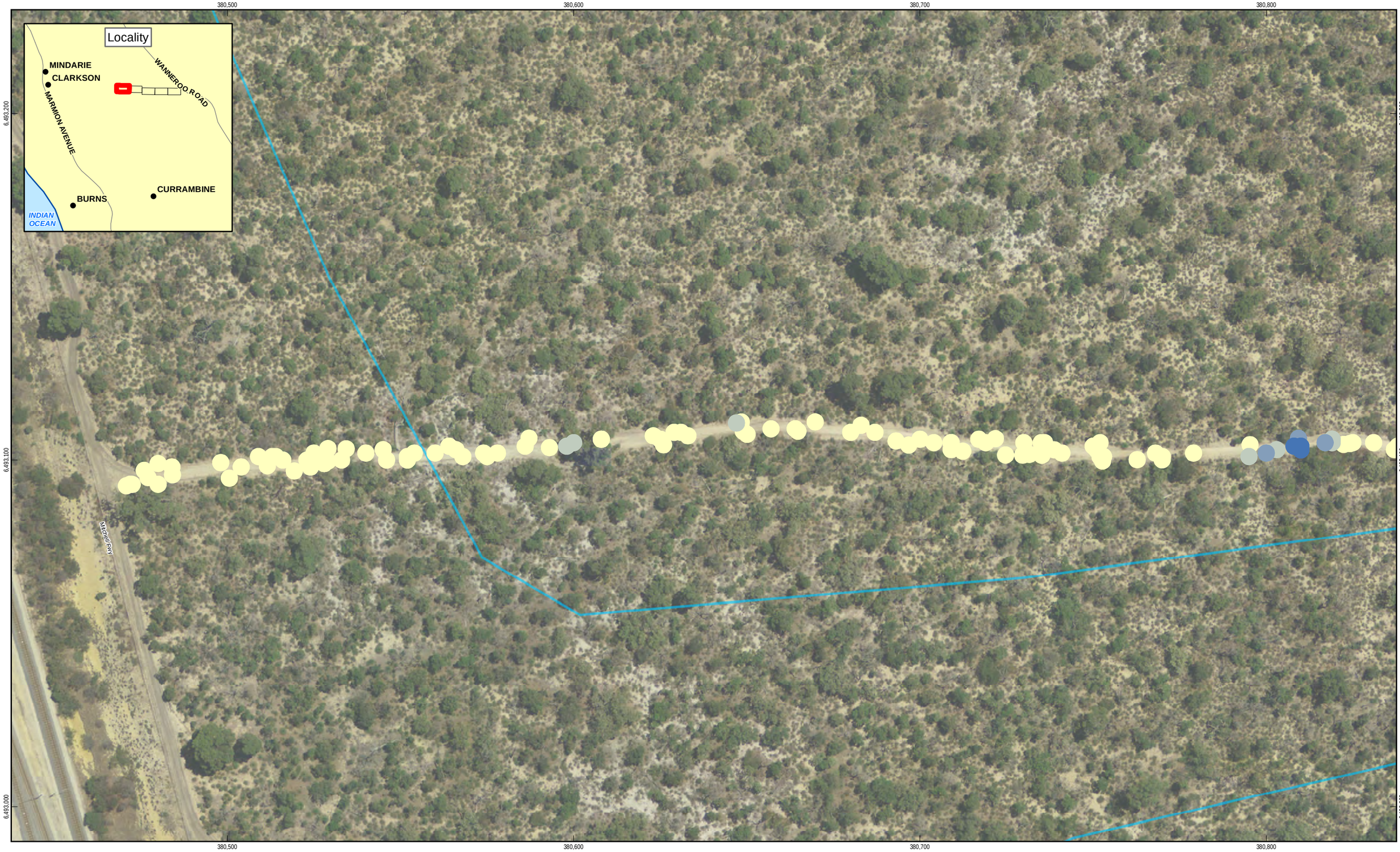

1:1,000 (at A3)

0 5 10 20 30 40 50

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

N

LEGEND

Cold-Neutral-Hot Spots				Stage
< -2.58 Std. Dev.	-1.96 - -1.65 Std. Dev.	-1.65 - 1.65 Std. Dev.	1.96 - 2.58 Std. Dev.	Stage 1
-2.58 - -1.96 Std. Dev.	1.65 - 1.96 Std. Dev.		> 2.58 Std. Dev.	Stage 3

Main Roads Western Australia
Mitchell Fwy Fauna Movement Study

Fauna Movement (no Birds, emus retained) Hot Spot Analysis

Job Number	61-294350802
Revision	0
Date	28 Feb 2014

Map Sheet 1 of 5

Figure 3

G:\61\29435\GIS\Maps\MXD\61294350802_G003_Fig3_Rev0.mxd

Data source: GA: NatMap 250k Topo Series 3 - 2006; Landgate: Metro Central Jan 2013 Mosaic - 2013; GHD: Stage - 20130905, Native Fauna Sightings - 20131129. Created by: erice, bflorczak

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1:1,000 (at A3)

0 5 10 20 30 40 50

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

N

LEGEND

Cold-Neutral-Hot Spots

- < -2.58 Std. Dev.
- -2.58 - -1.96 Std. Dev.
- -1.96 - -1.65 Std. Dev.
- -1.65 - 1.65 Std. Dev.
- 1.65 - 1.96 Std. Dev.
- 1.96 - 2.58 Std. Dev.
- > 2.58 Std. Dev.

Stage

- Stage 1
- Stage 3

Main Roads Western Australia
Mitchell Fwy Fauna Movement Study

Fauna Movement (no Birds, emus retained) Hot Spot Analysis

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Revision	0
Date	28 Feb 2014

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Figure 3

G:\61\29435\GIS\Maps\MXD\61294350802_G003_Fig3_Rev0.mxd

Data source: GA: NatMap 250k Topo Series 3 - 2006; Landgate: Metro Central Jan 2013 Mosaic - 2013; GHD: Stage - 20130905, Native Fauna Sightings - 20131129. Created by: erice, bflorczak

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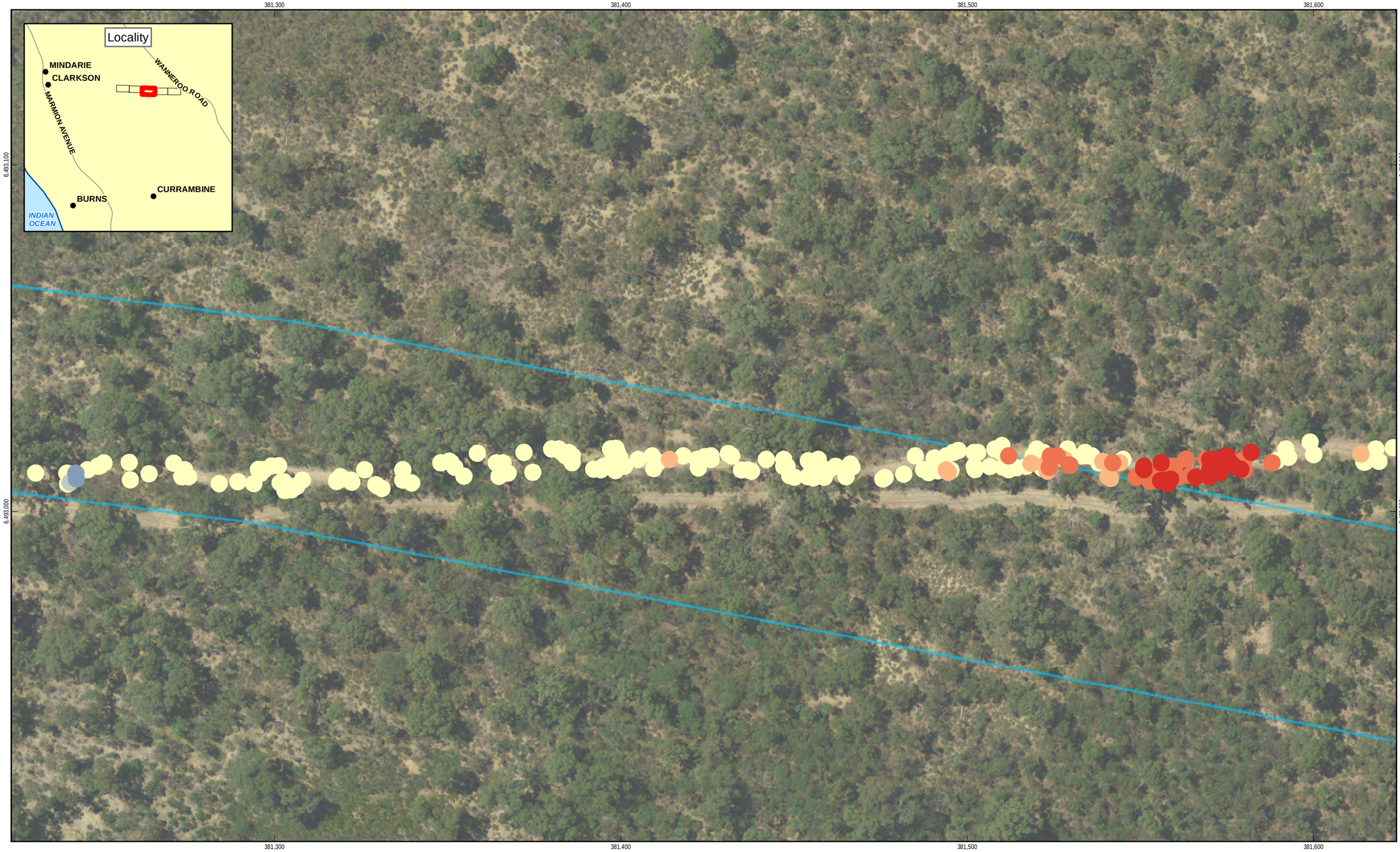

1:1,000 (at A3)

0 5 10 20 30 40 50

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

N

LEGEND

Cold-Neutral-Hot Spots

- < -2.58 Std. Dev.
- -2.58 - -1.96 Std. Dev.
- -1.96 - -1.65 Std. Dev.
- -1.65 - 1.65 Std. Dev.
- 1.65 - 1.96 Std. Dev.
- 1.96 - 2.58 Std. Dev.
- > 2.58 Std. Dev.

Stage

- Stage 1
- Stage 3

Main Roads Western Australia
Mitchell Fwy Fauna Movement Study

Fauna Movement (no Birds, emus retained) Hot Spot Analysis

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Date	28 Feb 2014

Map Sheet 3 of 5

Figure 3

G:\61\29435\GIS\Maps\MXD\61294350802_G003_Fig3_Rev0.mxd

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381,700 381,800 381,900 382,000

6,493,100

6,493,000

1:1,000 (at A3)

0 5 10 20 30 40 50

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

N

LEGEND

Cold-Neutral-Hot Spots				Stage
< -2.58 Std. Dev.	-1.96 - -1.65 Std. Dev.	1.96 - 2.58 Std. Dev.		Stage 1
-2.58 - -1.96 Std. Dev.	-1.65 - 1.65 Std. Dev.	> 2.58 Std. Dev.		Stage 3
	1.65 - 1.96 Std. Dev.			

Main Roads Western Australia
Mitchell Fwy Fauna Movement Study

Fauna Movement (no Birds, emus retained) Hot Spot Analysis

Job Number	61-294350802
Revision	0
Date	28 Feb 2014

Map Sheet 4 of 5

Figure 3

G:\61\29435\GIS\Maps\MXD\61294350802_G003_Fig3_Rev0.mxd

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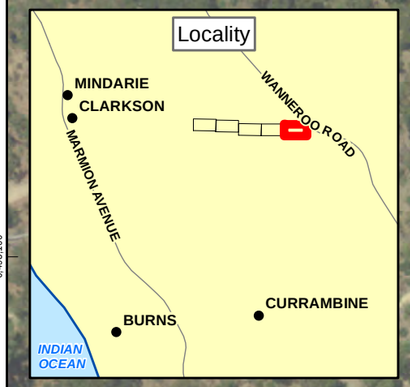
382,100 382,200 382,300 382,400

6,493,100

6,493,000



1:1,000 (at A3)

0 5 10 20 30 40 50

Metres

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Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

N

LEGEND

Cold-Neutral-Hot Spots				Stage
< -2.58 Std. Dev.	-1.96 - -1.65 Std. Dev.	-1.65 - 1.65 Std. Dev.	1.96 - 2.58 Std. Dev.	Stage 1
-2.58 - -1.96 Std. Dev.	1.65 - 1.96 Std. Dev.		> 2.58 Std. Dev.	Stage 3

Main Roads Western Australia
Mitchell Fwy Fauna Movement Study

Fauna Movement (no Birds, emus retained) Hot Spot Analysis

Job Number	61-294350802
Revision	0
Date	28 Feb 2014

Map Sheet 5 of 5

Figure 3

G:\61\29435\GIS\Maps\MXD\61294350802_G003_Fig3_Rev0.mxd

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Appendix B - Tables

Complete list of Fauna Movement Records

Table 1 Complete list of fauna movement records

Species	Introduced	Crossings
Birds		
Species		
Magpie		11
Raven		10
Emu		20
Group		
Raven/Magpie		44
Bird		10
Mammals		
Species		
Dog	yes	28
European Rabbit	yes	10
Western Grey Kangaroo		480
Fox	yes	92
Quenda		4
Cat	yes	12
Common Brushtail Possum		2
Group		
Small kangaroo/wallaby		5
Small mammal		15
Reptiles		
Species		
Western Bluetongue		9
Bobtail		75
Gould's Monitor		31
Group		
Snake		64
Small snake/legless lizard		53
Skink		68
Gecko/dragon		16

Table 2 Complete data set of directional data

Species or Grouping	North	South	East	West	Total
Birds					
Species					
Magpie	1			2	**3**
Raven	2	3	2	2	**9**
Emu	7	9	2	2	**20**
Group					
Raven/Magpie	17	14	2	2	**35**
Bird	4		4	2	**10**
Mammals					
Species					
Dog	10	6	6	6	**28**
European Rabbit	6	2		2	**10**
Western Grey Kangaroo	268	163	20	26	**477**
Fox	26	26	16	16	**84**
Quenda	1	2	1		**4**
Cat	5	3	1	3	**12**
Common Brushtail Possum	1	1			**2**
Group					
Small kangaroo/wallaby	3	2			**5**
Small mammal	9	6			**15**
Reptiles					
Species					
Western Bluetongue	1	3	4	1	**9**
Bobtail	34	36	2	2	**74**
Goulds Monitor	14	15	1		**30**
Group					
Snake	27	29	5	1	**62**
Small snake/legless lizard	34	14	4		**52**
Skink	35	23	7	1	**66**
Gecko/dragon	5	9		2	**16**
totals	**510**	**366**	**57**	**42**	**976**

GHD

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A	G Gaikhorst	Jo Kuiper		T Moulds		29/1/2014
1	L.Zimmermann	G Gaikhorst		T Moulds		28/02/2014

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