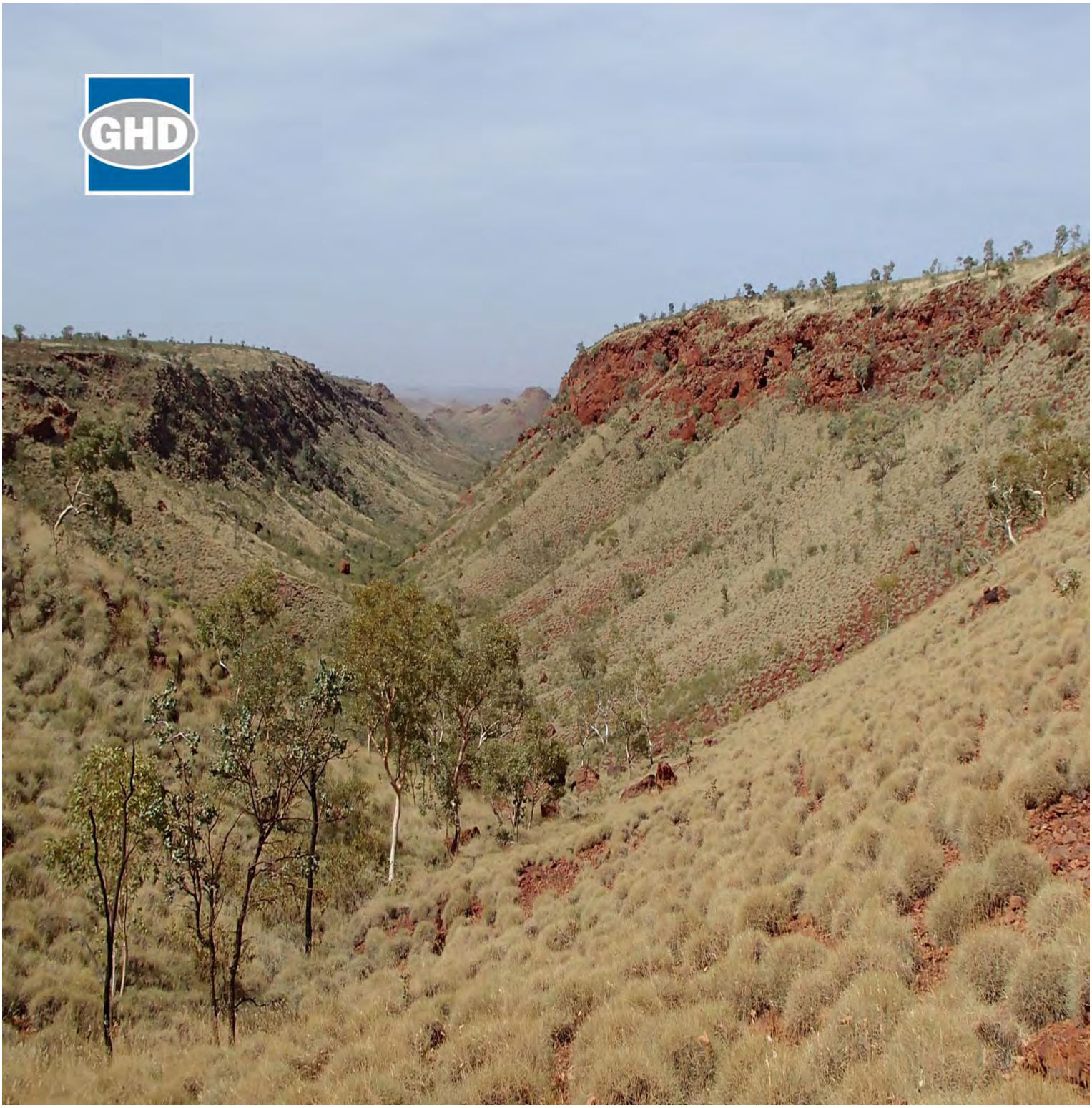

Fortescue Metals Group Iron Bridge

North Star Mine

Pilbara Leaf-nosed Bat roost habitat survey

November 2015

Executive Summary

Introduction

Fortescue Metals Group Iron Bridge (FMGIB) have been granted approval pursuant to the Conditions outlined in the Environmental Protection Authority (EPA) Ministerial Statement 993 to develop the North Star Magnetite open cut iron ore mine and associated infrastructure. The mine is located 110 kilometres (km) south-east of Port Hedland.

Condition 10 of the Ministerial Statement details the specific measures that FMGIB must implement to mitigate the impacts of the development to the Pilbara Leaf-nosed Bat (PLNB) colony located in Cave 13 due to mining activities. The intent of Conditions 10-3 to 10-11 is to ensure the viability of the PLNB population is maintained through the relocation and establishment of a 'viable portion' of the colony at Cave 13 to an alternative (either natural or artificial) site.

GHD was engaged by FMGIB to undertake surveys to locate and describe diurnal and maternity roost sites within two pre-determined search areas: the Blue Square and Zane's Gorge for the PLNB within a 30 km radius of Cave 13. These surveys were completed in January and February of 2015.

This report also includes the findings of opportunistic habitat assessments completed by GHD and FMGIB during November 2014 and habitat assessments and ultrasonic surveys completed by FMGIB during March and April of 2015.

Methods

GHD completed a desktop review of topographical information and aerial photography to further delineate areas which may contain a maternity roost within the two pre-determined search areas. The aim of the desktop review was to further refine the survey area and consider safety management for the field survey.

Following the desktop review a field survey for the diurnal and maternity roost within the two pre-determined search areas was completed. The aim of the survey was to locate the maternity roost and undertake targeted surveys using a combination of methods to confirm the presence of the maternity roost. Field surveys were completed over two periods: January 7th – 13th 2015, Blue Square; and February 20th – 24th 2015, Zane's Gorge, and three additional sites using the following methods:

- Cave habitat assessments
- Ultrasonic detection surveys
- Infrared video camera surveillance

Results

A total of 27 sites were assessed across the two survey periods by GHD within the study area. Some sites consisted of a single cave, and others consisted of multiple caves, thus in excess of 52 caves with the majority being classified as potential nocturnal roosts, were surveyed.

The habitat assessment did not confirm the absence of a maternity roost within the study area however one site within the colloquially named Zane's Gorge area (Joe's Cave) was classified as a diurnal roost, based on the habitat characteristics of the cave and the analysis of ultrasonic detection survey data and infrared camera data.

It was also determined that the likelihood of a maternity or diurnal roost occurring within the Blue Square would be limited to the south-west portion and southern boundary of the Blue Square, including the colloquially named Nicko's Gorge and possibly a small area of the north-east portion of the Blue Square associated with the tributaries of Black Boy Creek. The Blue Square also contains at least three large pools which in turn support riparian vegetation which provides an important resource for the PLNB.

Nicko's Gorge is a large gorge system located at the bottom of a valley in the south-west corner of the Blue Square. The gorge contains a pool and ephemeral waterfall, which in turn supports aquatic, semi-aquatic and riparian vegetation including a large stand of Melaleuca. The gorge is formed from very steep, sometimes sheer walls / cliffs which provides more than 30 sites (overhangs, small caves, large caves) of which at least half could not be investigated due to their location and safety constraints. The valleys and ephemeral creeks leading into and extending away from the gorge are generally well vegetated and would provide good foraging opportunities for the PLNB.

Although not located during the field survey, the analysis of the ultrasonic survey data revealed that there may be a diurnal roost located within or immediately adjacent Nicko's Gorge.

No PLNB were observed in any of the caves surveyed during the survey period, however two other species were regularly recorded roosting within different cave habitats (*Taphozous georgianus* and *Vespadelus finlaysoni*). The conservation significant Ghost Bat (*Macroderma gigas*) was recorded at two sites during the survey.

Key outcomes

Given the results of the survey including the habitat assessments and ultrasonic survey data it is possible that a diurnal or maternity roost does occur within the Blue Square, possibly within the Nicko's Gorge area. Considering the data collected during the habitat assessment, ultrasonic survey data and temperature and humidity data, it is unlikely that a maternity roost is located at any of the sites surveyed with the Zane's Gorge area, including Joe's Cave. It is possible that a small number of individual PLNB occupied Joe's Cave at the time of the survey (e.g. some individuals may have hidden with small cracks/crevices that could not be accessed or were overlooked during the survey), however it is unlikely that Joe's Cave contained a colony (e.g. > 50 individuals) of PLNB at the time of the surveys.

This report has been prepared by GHD for FMGIB based on the assumptions and limitations outlined in section 1.4 and 2.5 and may only be used and relied on by FMGIB for the purpose agreed between GHD and FMGIB as set out in section 1.2 of this report. GHD otherwise disclaims responsibility to any person other than FMGIB arising in connection with this report.

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Appendices

1. Introduction

1.1 Project background

FMG Iron Bridge Pty Ltd (FMGIB) have been granted approval to develop the North Star Magnetite open cut iron ore mine and associated infrastructure, 110 kilometres (km) south-east of Port Hedland (Figure 1). The approval has been granted pursuant to the Conditions outlined in the Environmental Protection Authority (EPA) Ministerial Statement 993.

Condition 10 of the Ministerial Statement details the specific measures that FMGIB must implement to mitigate the impacts of the development to the Pilbara Leaf-nosed Bat (PLNB) colony located in Cave 13 due to mining activities. The intent of Conditions 10-3 to 10-11 is to ensure the viability of the PLNB population is maintained through the relocation and establishment of a 'viable portion' of the colony at Cave 13 to an alternative (either natural or artificial) site.

GHD was engaged by FMGIB to undertake surveys to locate and describe diurnal and maternity roost sites for the PLNB within a 30 km radius of Cave 13.

To assist with the surveys GHD engaged Bat Call WA in November 2014 to collect observational and ultrasonic call data to assist with characterising the roosting habitat of the PLNB within a 30 km radius of Cave 13 at the North Star mine. A key outcome of the ultrasonic surveys was the discovery of a 5 km square area located to the north-west of Cave 13 (here in referred to as the Blue Square) which may support a maternity or diurnal roost habitat. Following a review of the survey results and a reconnaissance survey by FMGIB, GHD with the assistance of FMGIB completed observational and ultrasonic surveys of sites within the Blue Square in January 2015.

In late January FMGIB completed a reconnaissance survey including ultrasonic surveys within an area known as Zane's Gorge located west of Cave 13 and south of the Blue Square. Following a review of the results by Bat Call WA and FMGIB, GHD was engaged to undertake additional observational and ultrasonic surveys in February 2015 within the Zane's Gorge area to locate and describe potential diurnal and maternity roost sites.

Bat Call WA was then engaged by GHD to undertake the call analysis to aid in the characterisation of the potential roosting habitat for the PLNB from the data collected from the Blue Square and Zane's Gorge survey areas.

This report provides a consolidated summary of the methods and results for the surveys undertaken during January and February 2015 by GHD and FMGIB as per the scope of works.

This report also includes the findings of opportunistic habitat assessments completed by GHD and FMGIB during November 2014 and habitat assessments and ultrasonic surveys completed by FMGIB during March and April of 2015 which were not part of the original scope of works.

1.2 Purpose and scope

1.2.1 Purpose

The purpose of this study was to undertake a desktop assessment and field survey to locate and describe diurnal and maternity roost sites within two pre-determined search areas: the Blue Square and Zane's Gorge (Figure 2).

1.2.2 Scope of works

The scope of this work was to:

- Undertake a desktop review of topographical information and aerial photography to further delineate areas which may contain a maternity roost within the two pre-determined search areas. The aim of the desktop review was to further refine the survey area and consider safety management for the field survey.
- Undertake a field survey for the diurnal and maternity roost within the two pre-determined search areas. The survey would aim to locate the maternity roost and undertake targeted surveys using a combination of methods to confirm the presence of the maternity roost.
- Provide a summary report and map of the methods and results including key findings and classification of sites into different roosts (e.g. nocturnal, diurnal and maternity).

At the request of FMGIB the scope of the study was expanded to include an assessment of the suitability of roost habitats located within the North Star development area based on information provided by FMGIB.

1.3 Study area

For the purpose of this report the GHD study area includes the Blue Square (21 sites) and Zane's Gorge (six sites) and nine additional sites located west (seven), north-east (one site) and south (one site) of Cave 13 (Figure 2).

Appendix C provides further details regarding the location of each site within the study area.

1.4 Assumptions and limitations

This report has been prepared by GHD for FMGIB and may only be used and relied on by FMGIB for the purpose agreed between GHD and FMGIB as set out in section 1.2 of this report. GHD otherwise disclaims responsibility to any person other than FMGIB 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. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by and others who provided information to GHD (including Bat Call WA and FMGIB), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of infrastructure, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

This assessment is based upon the GHD study area shown in Figure 2.

640,000 670,000 700,000 730,000

7,740,000 7,710,000 7,680,000 7,650,000

PORT HEDLAND
SOUTH HEDLAND
Finucane Island
Downes Island
Weerdee Is
Cooke Pt
REDBANK
WEDGEFIELD
ABORIGINAL RESERVE
Boodarie Hill
Boodarie
Bing
Sandy Hill
Pippingarra
Table Hill
Mt St George
NORTHERN
GREAT
32
10
14
16
STRELLEY
MARBLE
BAR
Ord
Ridley
River
Ranges
E GREY
DE GRE
Shaw
Hedland
BULLANGANA
BOODARIE
PIPPINGARRA
Bullen Hill
Red Hill
Trig Hill
Beebingarra Ck
Petermarer Ck
Tabba
Strelley
River
Carlindie
138
101
25
1
HWY
Port Hedland RD
42
WALLAREENYA
WALLAREENYA RD
Wallareenya
Cookes Hill
Wallaringa Peak
Turner River
INDEE RD
Mt Berghaus
Indee
Yule
INDEE
Tabba
Mt Dove
Newman
39
Magpie Range
East
West
LALLA ROOKH RD
Fey Hill
Lalla Rookh
McPhee Hill
Chinnamon
Mt York
124
95
KANGAN
RD
YANDEYARRA
Mt Tinstone
Pincunah Hill
Cleland Rock
Railway
Turner
Creek
NORTH STAR MAGNETITE / HEMATITE MINE
CAVE 13
Mt Francisco
Obstinate Ck
ABYDOS ABORIGINAL COMMUNITY
Abydos
Pyramid Hill
64

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0 2.5 5 10 15

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

FMG

powered by SLIP ENABLER

Fortescue Metals Group Ltd
Pilbara Leaf-nosed Bat North Star Management Plan

Job Number	61-31473
Revision	0
Date	05 Mar 2015

Locality Map

Figure 1

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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

Data source: FMG: Bat Cave 13 - 20141007, Mine footprint - 20141121; Landgate: Travellers Atlas 2004. Created by: AF

660,000 680,000 700,000 720,000 740,000 760,000

7,680,000 7,660,000 7,640,000 7,620,000

1 2 3 4

Paper Size A3

0 2.5 5 10 15

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

LEGEND

- Cave - GHD
- SM2 - GHD
- Other - GHD
- Cave 13
- Sourced Tracks (Landgate)
- Sourced Tracks (FMG)
- Proposed Hematite Project Outlines
- North Star Magnetite Proposed Infrastructure
- North Star GV Proposed Infrastructure
- Blue Square Study Area
- 30km from Cave 13
- FMG Tenements

Tracklogs

- 8 Jan 2015
- 9 Jan 2015
- 10 Jan 2015
- 11 Jan 2015
- 12 Jan 2015

GHD FMG SLIP ENABLER

Fortescue Metals Group Ltd
Pilbara Leaf-nosed Bat North Star Management Plan

Job Number	61-31473
Revision	0
Date	06 Nov 2015

Survey methods and Cave locations

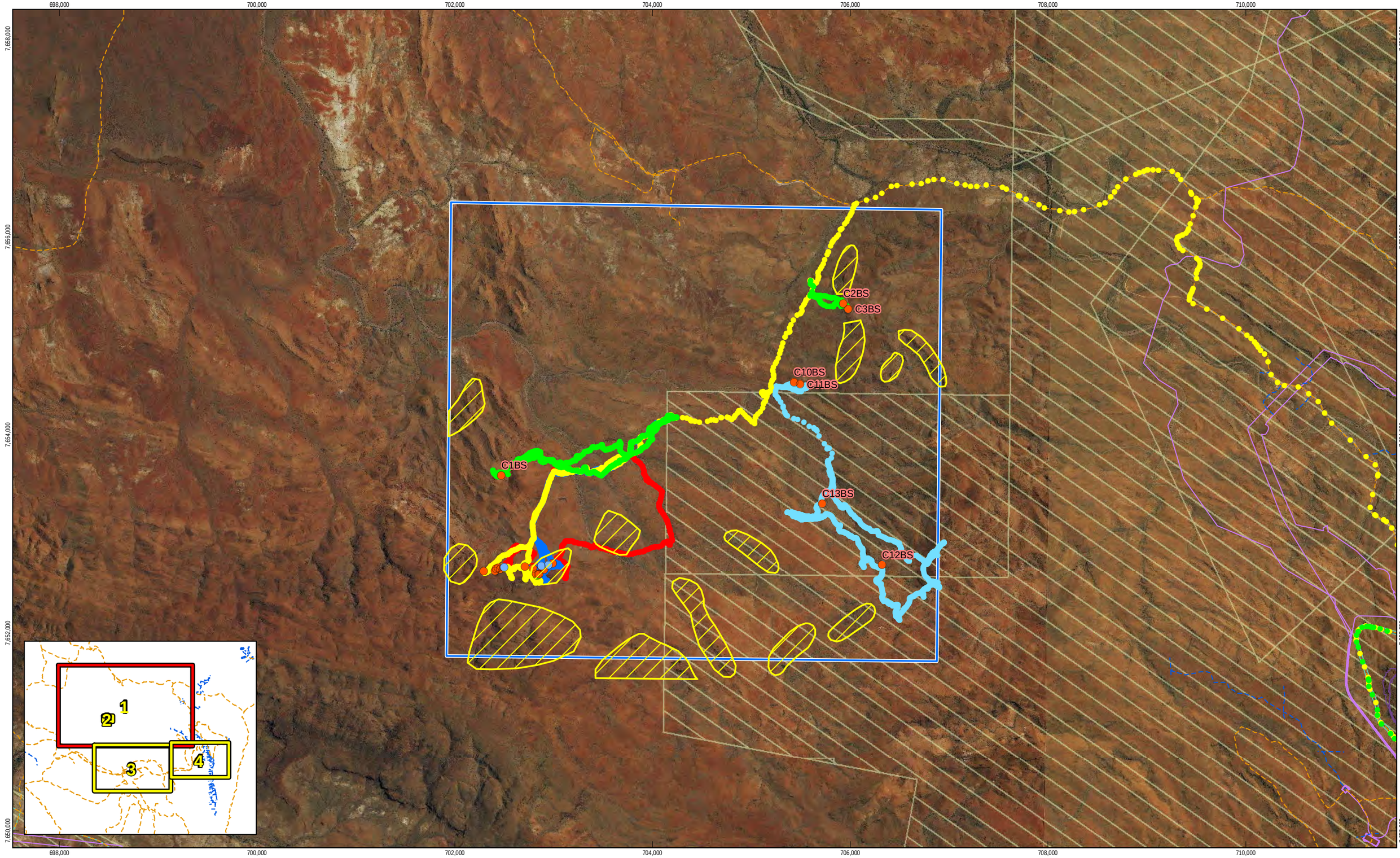
Overview

Figure 2

G:\61\31473\GIS\Maps\MXD\Survey Effort\6131473_G001_Rev0_SurveyEffortOverview.mxd

Data source: FMG: Cave 13 Location, Sourced Tracks, Blue Square Study Area, Proposed Hematite Project Outlines, North Star Magnetite Proposed Infrastructure, North Star GV Project Proposed Infrastructure, FMG tenements; GHD: 30km from Cave 13 - 20141008, GHD Survey Effort, Tracklog; Landgate: Imagery (Virtual Mosaic) - 20151106. Created by:afeeney

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



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Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

LEGEND

- Cave - GHD
- SM2 - GHD
- Other - GHD
- Cave 13
- Sourced Tracks (Landgate)
- Sourced Tracks (FMG)
- Proposed Hematite Project Outlines
- North Star Magnetite Proposed Infrastructure
- Possible cave area
- North Star GV Proposed Infrastructure
- Blue Square Study Area
- FMG Tenements

Tracklogs

- 8 Jan 2015
- 9 Jan 2015
- 10 Jan 2015
- 11 Jan 2015
- 12 Jan 2015

GHD

FMG SLIP ENABLER

Fortescue Metals Group Ltd
Pilbara Leaf-nosed Bat North Star Management Plan

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Survey methods and Cave locations

Figure 2

G:\61\31473\GIS\Maps\MXD\Survey Effort\6131473_G001_Rev0_SurveyEffortMapBook_Page1of4.mxd

Data source: FMG: Sourced Tracks, Blue Square Study Area, Proposed Hematite Project Outlines, North Star Magnetite Proposed Infrastructure, North Star GV Project Proposed Infrastructure, FMG tenements; GHD: GHD Survey Effort, Tracklog; Landgate: Imagery (Virtual Mosaic) - 20151106. Created by:afeeney

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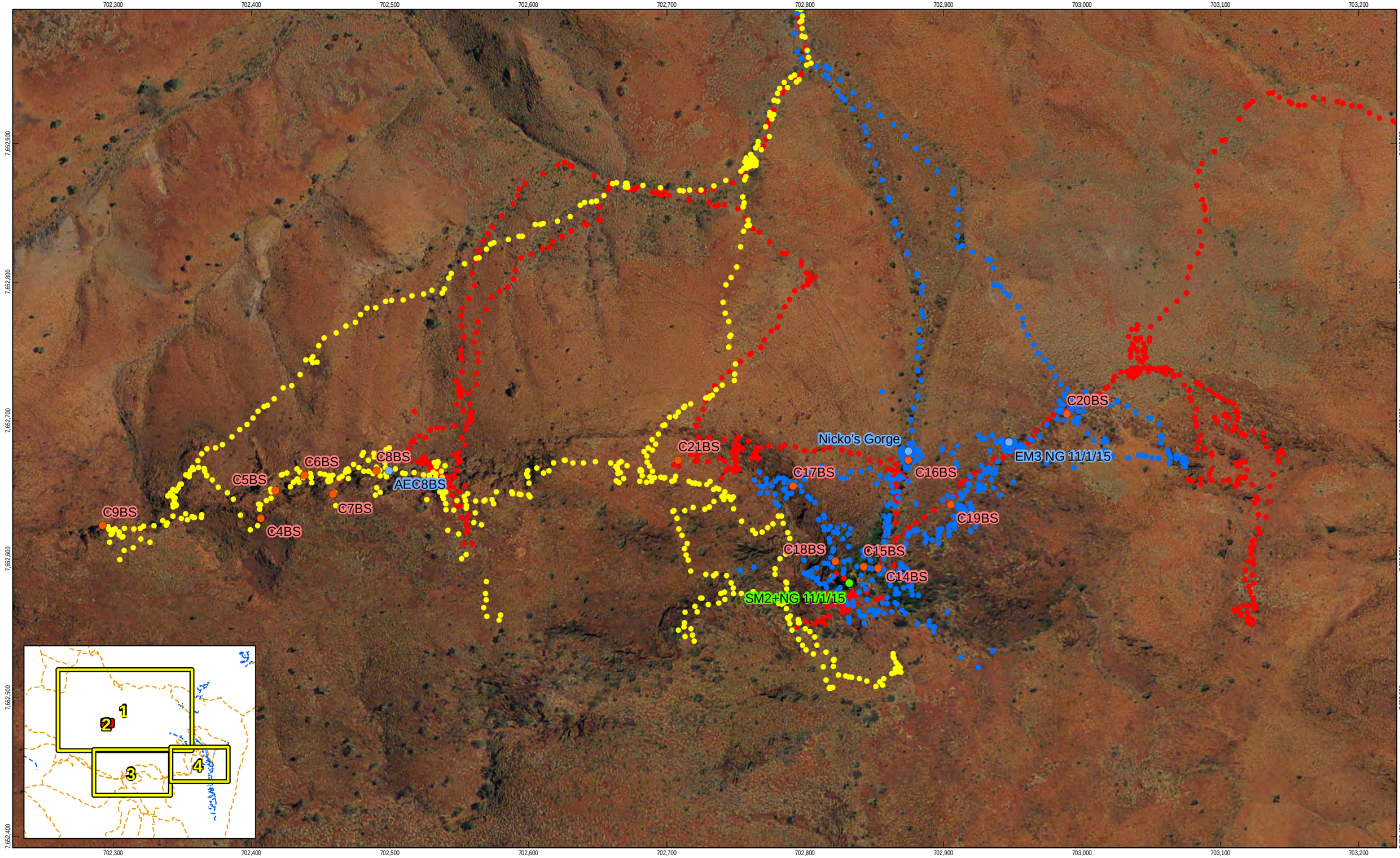

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Kilometres

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Grid: GDA 1994 MGA Zone 50

N

LEGEND

Cave - GHD
SM2 - GHD
Other - GHD

Tracklogs

8 Jan 2015
9 Jan 2015
10 Jan 2015
11 Jan 2015
12 Jan 2015

Fortescue Metals Group Ltd
Pilbara Leaf-nosed Bat North Star Management Plan

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Survey methods and Cave locations

Figure 2

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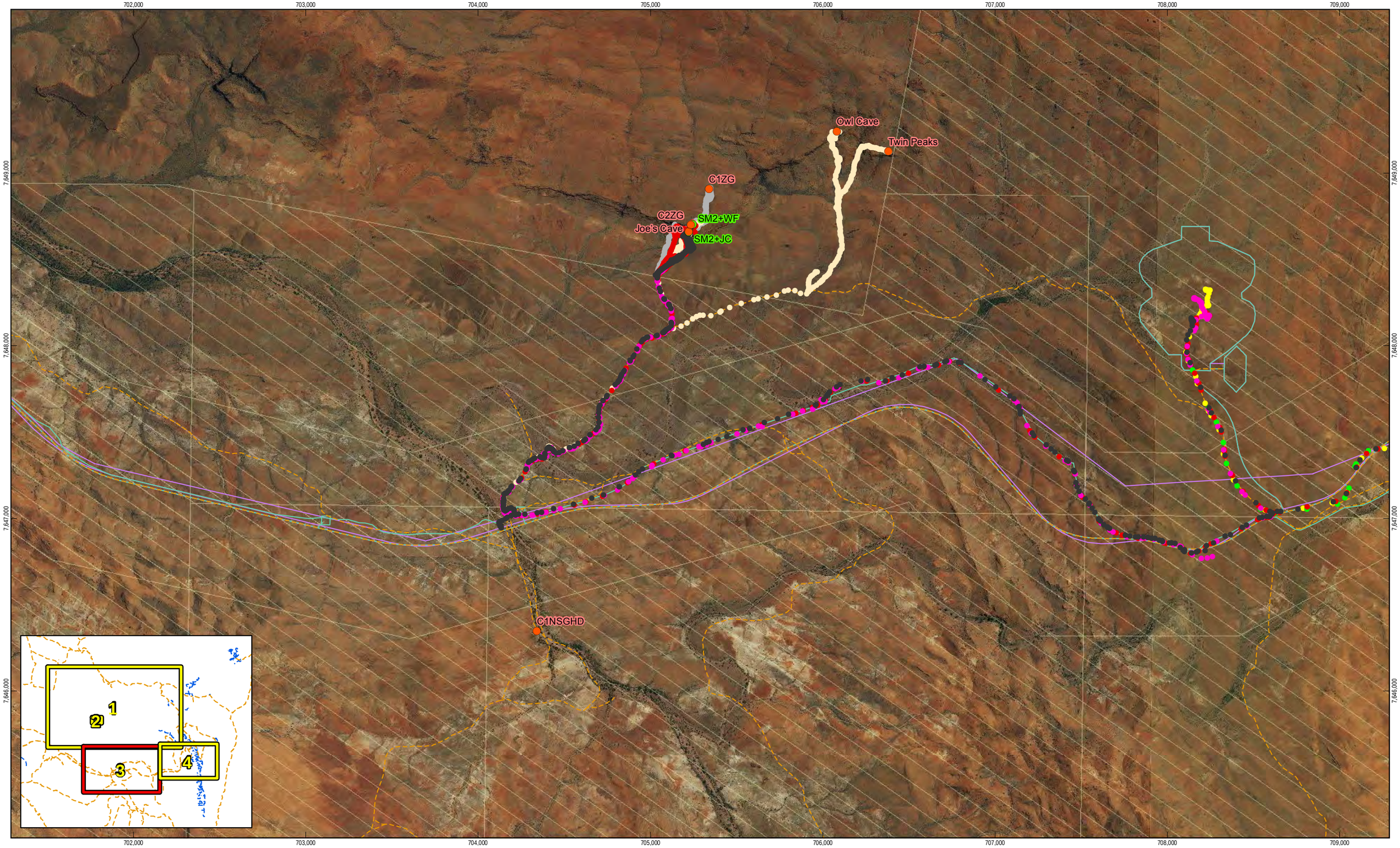

Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

LEGEND

- Cave - GHD
- SM2 - GHD
- Other - GHD
- Sourced Tracks (Landgate)
- Sourced Tracks (FMG)
- Proposed Hematite Project Outlines
- North Star Magnetite Proposed Infrastructure
- FMG Tenements
- North Star GV Proposed Infrastructure

Tracklogs

- 8 Jan 2015
- 9 Jan 2015
- 10 Jan 2015
- 11 Jan 2015
- 12 Jan 2015
- 20 Feb 2015
- 21 Feb 2015
- 22 Feb 2015
- 23 Feb 2015
- 24 Feb 2015

Fortescue Metals Group Ltd
Pilbara Leaf-nosed Bat North Star Management Plan

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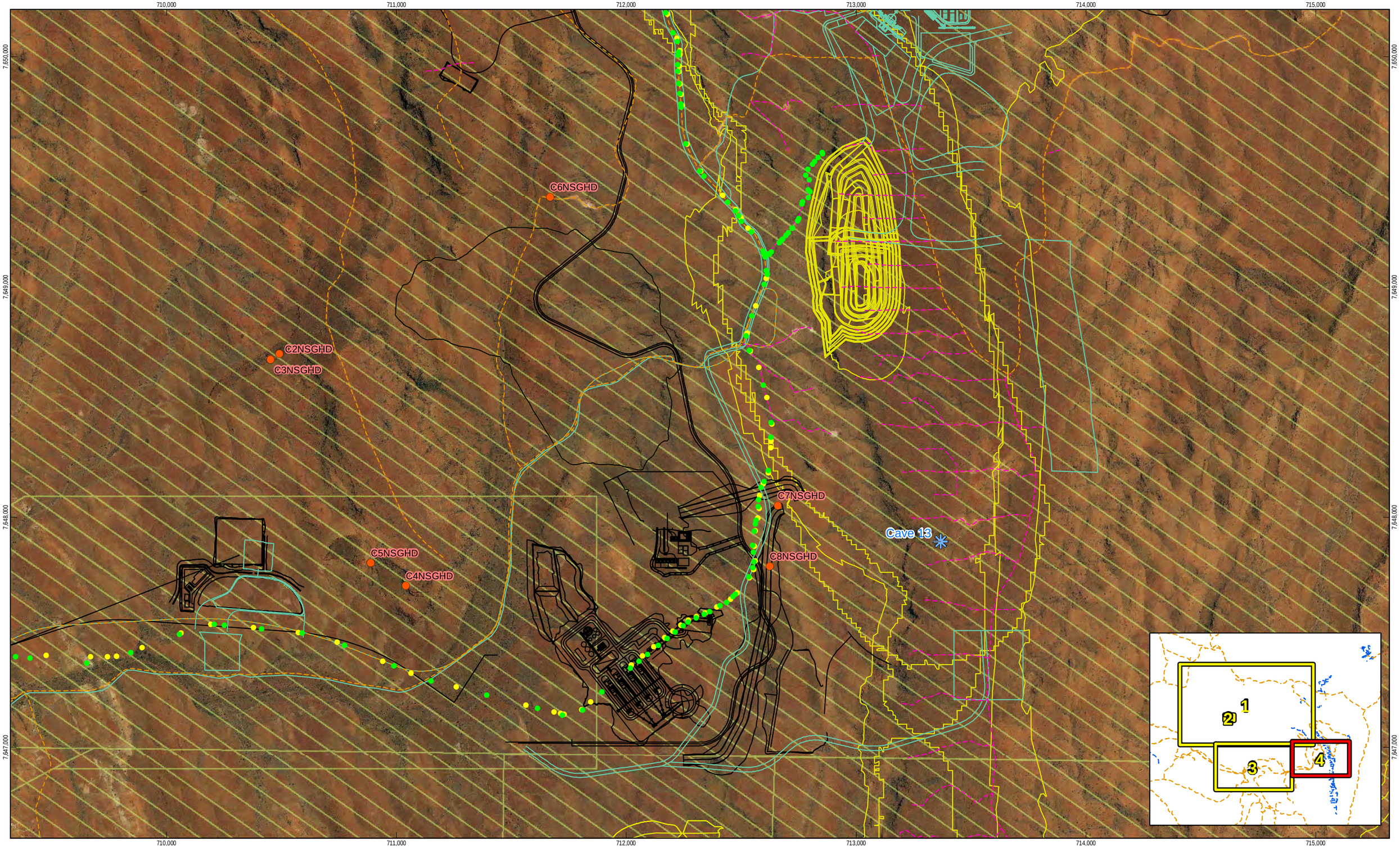
Survey methods and Cave locations

Figure 2

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



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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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- 10 Jan 2015
- 11 Jan 2015
- 12 Jan 2015

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Survey methods and Cave locations

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Figure 2

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Data source: FMG: Cave 13 Location, Sourced Tracks, Proposed Hematite Project Outlines, North Star Magnetite Proposed Infrastructure, North Star GV Project Proposed Infrastructure, FMG tenements; GHD: GHD Survey Effort, Tracklog; Landgate: Imagery (Virtual Mosaic) - 20151106. Created by:afeeney

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

2. Methods

2.1 Desktop review

The aim of the desktop review was to further refine the survey area and consider safety management for the field survey.

2.1.1 Map interpretation and survey site reconnaissance

The review included an assessment of topographical information and aerial photography including the Fortescue Earth mapping system which contains recent 3D /elevation imagery to further delineate areas which may contain a maternity roost within the two search areas.

The desktop review was further informed by information provided from the FMGIB Environmental Advisor who had completed reconnaissance surveys to determine opportunities for access to survey areas and the refinement of potential cave locations (e.g. Nicko's Gorge within the Blue Square).

A field survey investigation map was produced as a result of the desktop review and was used to support the job safety and environmental assessment and field surveys.

2.1.2 Roost description

To assist with a standardised approach to classifying the different types of roost habitats for the PLNB, a review of current terms and descriptions was undertaken (DPaW 2014; Cramer et al. 2015; Armstrong 2001). Following the review it was decided that a variation of the Draft Conservation Advice for the PLNB released by DPaW (2014) for this report be adopted.

The Draft Conservation Advice for the PLNB released by DPaW (2014) discusses three types of roosts that are important for the survival of the PLNB: nocturnal, diurnal (day) and maternity roosts.

Maternity roosts tend to be located in deep, humid caves associated with hard iron rich rock strata and are highly likely to be habitat critical to the survival of the PLNB. Nocturnal and diurnal roosts are likely to represent habitat critical to the survival of the species if they are occupied by >100 PLNB or are a naturally occurring cave roost that is unlikely to collapse and provides optimal roosting conditions (i.e. depth, > 30 degrees and >90 % humidity) (DPaW 2014).

Roosts can be natural structures or disused mine shafts and can be complex and involve off shoots from the main chamber. Disused mine shafts occupied by ≤100 PLNB that are unstable, have or are likely to be subject to collapses and are not currently subject to restoration and management works, are unlikely to be habitat critical to the survival of the PLNB (DPaW 2014).

Roosts that contribute to a new understanding of distribution or are previously unknown habitat types are likely to be habitat critical to the survival of the PLNB. For example an artificially constructed roost found to be occupied by PLNB could contribute significantly to a better understanding of roosting preferences and creation of artificial roost sites that could help recover the species (DPaW 2014).

For the purpose of this report the following terms have been used to classify different types of roosting habitat:

Maternity roost - a natural cave roost or artificial cave roost occupied by breeding PLNB and/or PLNB young during the breeding season[1]. The roost provides optimal roosting conditions (i.e. depth, > 30 degrees and > 90% humidity).

Diurnal roost - a natural cave roost or artificial cave roost utilised by PLNB which provides potentially optimal roosting conditions (i.e. depth, > 30 degrees and > 90% humidity). A diurnal roost may be a potential maternity roost for the PLNB, however evidence of the roost being utilised for breeding by PLNB at the time of the survey could not be confirmed.

Nocturnal roost - a cave likely to represent foraging and/or temporary refuge habitat for the PLNB. A nocturnal roost is a natural occurring cave roost that is unlikely to provide optimal roosting conditions (i.e. depth, > 30 degrees and > 90% humidity).

2.2 Field survey

The field survey team comprised GHD Senior Ecologist Craig Grabham and FMGIB North Star Environment Advisor, Nicholas Barr. The survey was conducted under "Licence to Take Fauna for Scientific Purposes" (Regulation 17) Permit No. SF010137.

Field surveys were completed over two periods: January 7th – 13th 2015 at Blue Square; and February 20th – 24th 2015 at Zane's Gorge and three additional sites.

The following methods were utilised:

- Cave habitat assessments
- Ultrasonic detection surveys
- Infrared video camera surveillance

Appendix A provides a detailed description of each method. The results of these surveys are presented in Section 3.

2.3 Other surveys

This report also includes the findings of the following surveys:

- Opportunistic habitat surveys were also undertaken by GHD on the 14th November 2014 of an area located west of Cave 13 (Figure 2), as part of a separate field investigation with FMGIB (see Section 3). Cave habitat assessments as described in Appendix A were not undertaken, however general notes regarding the suitability of caves and other structures to support habitat for bats were recorded.
- The November 2014 survey by Bat Call WA and FMGIB to assist with characterising the roosting habitat of the PLNB within a 30 km radius of Cave 13 at the North Star mine (Appendix B).
- Ultrasonic detector surveys of Zane's Gorge and a cave (Wayne Manor) located north-east of Cave 13 during January 2015 by FMGIB. The calls analysis for these surveys was completed by Bat Call WA and is presented in Appendix B.
- Habitat observations, ultrasonic detector surveys and calls analysis completed by FMGIB during March and April of 2015 (Appendix C).

The additional data gathered by GHD (November 2014) and FMGIB is included in this report to ensure that all survey effort and data is consolidated and provided in one report and to avoid unnecessary repetition of survey effort.

[1] PLNB young are generally born in December, with lactation from December through late February, primarily during the productive (wet) season. Young are generally weaned late February-early March (DotE 2015 and McKenzie and Bullen 2014)

2.4 Survey conditions and weather

The Bureau of Meteorology (BoM) Marble Bar Station (Station number 004106) is the nearest weather station to the study area (approximately 120 km south-west of the study area), with continuous long-term data. Climatic data from this site indicates the mean maximum temperature of the region ranges from 40.4°C in November to 39.4°C in February and the mean minimum temperature ranges from 23.8°C in November to 25.9°C in February.

The weather during the January and February survey periods was hot to very hot during the day followed by warm to hot evenings, typical of early wet season weather. Daytime temperatures were between 32°C and 50°C and minimum night time temperatures were around 24°C. Thunderstorms in the district occurred throughout the period but no cyclonic rain events occurred.

Table 1. Temperature and rainfall (BOM) and observational weather data for survey period

Date	Maximum Temperature (Degrees Celsius °C)*	Minimum Temperature (Degrees Celsius °C)*	Rainfall (mm) *	Survey conditions /observational weather data recorded during field surveys from site by GHD
Blue Square				
7/01/2015	44.7	31.1	0	Hot, humid. Cloud cover increased as day progressed. No winds.
8/01/2015	44	30	0	Hot, humid. Cloud cover increased as day progressed. No winds.
9/01/2015	43.2	29.9	0	Hot, humid during day. Cloud cover increased as day progressed. Light to moderate rainfall overnight.
10/01/2015	36.8	23.3	5.6	Hot, humid. Cloud cover increased as day progressed. Light winds.
11/01/2015	32.2	20.8	33.8	Warm-hot. Cloud cover increased as day progressed. Light winds
12/01/2015	36.9	23.8	0.2	Hot, moderately humid. Light winds.
13/01/2015	37.5	24.7	4.2	Hot, moderately humid.
Zane's Gorge				
20/02/2015	47.6	28.2	0.8	Very overcast, hot humid morning, with hot winds developing in the afternoon.
21/02/2015	47.3	30.4	0	Very hot morning 50 °C (car temperature gauge reading) at 11:45 am. Overcast afternoon, lightning early evening and light – moderate rain for approx. 2 - 3 hours late evening.
22/02/2015	43.3	29.6	0	Hot, clear morning. Overcast afternoon, with strong – gale force hot winds late afternoon developing to thunderstorms and heavy lightning with showers from 18:30. Heavy showers from 20:30 for approx. 2 hrs followed by moderate showers to midnight with scattered light-moderate rain through morning.
23/02/2015	39.8	23.3	6.2	Hot, moderately humid
24/02/2015	34.1	26.7	1	Hot, moderately humid

*data from BOM 2015 for Marble Bar weather station

2.5 Survey limitations

Experience

The GHD survey team for the January and February 2015 surveys was led by Craig Grabham who has 15 years' experience undertaking microchiropteran bat surveys across Australia. Craig has undertaken surveys across three separate periods (November 2014, January 2015 and February 2015) for the PLNB within the study area.

Survey timing

The timing of the surveys was suitable to determine the presence of breeding PLNB within the study area. PLNB young are generally born in December, with lactation from December through late February, primarily during the productive (wet) season. Young are generally weaned late February-early March (Dote 2015 and McKenzie and Bullen 2014).

Survey and site conditions

Surveys conducted within the Blue Square were constrained by access, terrain and work safety requirements. Consequently the majority of the area within the southern portion of the Blue Square remains to be thoroughly searched. Vehicle access to the centre of the Blue Square was achievable during dry conditions; however rain hindered vehicle access to the southern portion of the Blue Square for one day. The restricted vehicle access in combination with the distances required to travel on foot to parts of the Blue Square severely hindered survey efforts, particularly to Nicko's Gorge, preventing the survey team from completing a thorough survey of this location.

The team was restricted to working between the hours of 5 am and 1 pm during the January survey period when temperatures were above 40 ^{o}C. The restricted working hours and remote location of the potential cave sites (i.e. Nicko's Gorge) prevented the survey team from undertaking emergence surveys and night work (e.g. surveying the interior of potential caves after the emergence period) within the Blue Square.

In a few locations the terrain consisted of very steep and in some places almost vertical cliffs with potential cave sites (e.g. Nicko's Gorge). The survey team was not equipped to undertake surveys in this terrain, nor did the safety plan allow for these survey conditions. Some caves contained narrow passages and small sub-chambers (e.g. Caves 8 and 9 within the Blue Square, and Wayne Manor) which did not allow for safe egress.

Severe weather including a 50 ^{o}C day and two evenings of thunderstorms and localised lighting strikes hindered survey efforts in the Zane's Gorge area during the February surveys (Plate 1). The survey team were forced to reduce the day time survey effort for roost habitat searches for one day (21st February 2015) due to the high temperatures. Evening thunderstorms with heavy winds then rain and localised lightning strikes prevented the survey team from undertaking successful emergence surveys of Joes Cave (21st and 22nd February 2015).

Large portions of the study area were subject to fire during December 2014. At least 40-50% of the Blue Square was burnt during December 2014. Many areas burnt contained roost habitats, however few of the burnt areas that were surveyed contained potential diurnal/maternity roost sites with the exception of some small pockets located immediately north of Nicko's Gorge within the Blue Square (see Section 3.1.1 – 3.1.2). Much of the area west of the camp into the Zane's Gorge area was also burnt during the December 2014 fires.

Plate 1 Lighting strike at Zane's Gorge as viewed from North Star camp – February 2015

3. Results

3.1 Cave habitat assessment and observations GHD January and February 2015

A total of 27 sites were assessed across the two survey periods (Table 2 and Figure 2). Some sites consisted of a single cave, and others consisted of multiple caves, thus in excess of 52 caves with the majority being classified as potential nocturnal roosts were surveyed. The habitat assessment did not confirm the absence of a maternity roost within the survey area, however one site (Site 24 - Joes Cave) was classified as a potential maternity and/or diurnal roost based on the habitat characteristics of the cave. Nicko's Gorge, which contains many nocturnal cave sites and additional caves which could not be investigated during the current survey may also provide suitable diurnal and maternity roosting habitat.

No PLNB were observed in any of the caves surveyed during the survey period, however two other species were regularly recorded roosting within different cave habitats (*Taphozous georgianus* and *Vespadelus finlaysoni*). The conservation significant Ghost Bat (*Macroderma gigas*) was recorded at two sites during the survey.

It is important to note that it was unlikely that all bats present during the cave habitat surveys were visually observed. Some individuals may have hidden within small cracks/crevices or along narrow passages and small sub-chambers that could not be accessed during the survey. Therefore it is possible that some of the roost habitats classified as potential diurnal roosts contained one or a few individuals at the time of the surveys, however it is unlikely that the sites classified as potential diurnal roosts contained a colony (e.g. > 50 individuals) of PLNB at the time of the surveys.

3.1.1 Blue Square

The survey team was able to view large areas of the Blue Square on foot and from elevated positions with the aid of binoculars, particularly the central, eastern and south-eastern portions of the Blue Square. This method in combination with the recent fires allowed for largely unimpeded views.

Nicko's Gorge, as the name suggests, is a large gorge system located at the bottom of a valley in the south-west corner of the Blue Square (Figure 2; Plates 3, 4 and 5). At the time of the survey, the gorge contained a pool (see Plate 2) and ephemeral waterfall (approximately 40 – 50 m), which in turn supports aquatic, semi-aquatic and riparian vegetation including a large stand of Melaleuca. The waterfall was not flowing during the survey. The gorge is formed from very steep, sometimes sheer walls / cliffs (approximately 60 – 70 m high) which provides a myriad of cave habitats. The valleys and ephemeral creeks leading into and extending away from the gorge are generally well vegetated and would provide good foraging opportunities for the PLNB.

The gorge contains more than 30 sites (overhangs, small caves, large caves) of which at least half could not be investigated thoroughly due to their location and safety constraints. The sites assessed during the survey are presented in Table 2. The majority of caves sites within the surveyed area of the Blue Square were classified as nocturnal roosts.

Following the field surveys a desktop assessment of the areas not traversed on foot within the Blue Square was undertaken using the information collected from the field surveys (e.g. location data of roost sites) and a review of the Fortescue Earth mapping system in combination with topographical and geological information. This desktop assessment allowed for a further

reduction of the areas within the Blue Square that may support potential diurnal and maternity roost sites (see Figure 2).

It was determined that the likelihood of a maternity or diurnal roost occurring within the Blue Square would be limited to the south-west portion and southern boundary of the Blue Square including Nicko's Gorge and possibly a small area of the north-east portion of the Blue Square associated with the tributaries of Black Boy Creek. The Blue Square also contains at least three large pools, which in turn support riparian vegetation which provides an important resource for the PLNB.

It is important to note that large portions of the Blue Square were burnt during December 2014 (see Plate 2). Some of the areas burnt contained nocturnal roost habitat, however none of the burnt areas that were surveyed contained potential diurnal/maternity roost sites, with the exception of some small pockets located immediately north of Nicko's Gorge within the Blue Square. It is possible that the recent fires may have prohibited the local occurrence of PLNB in the survey area and it is possible that PLNB may have temporarily abandoned potential cave habitats and foraging areas due to the fires and moved to other nearby unaffected habitats.

Plate 2. Blue Square displaying recent evidence of fire looking north from the centre of the study area.

Plate 3 Ephemeral drainage line and riparian vegetation looking east to entrance of Nicko's Gorge

Plate 4 . Nicko's Gorge (top photo) looking east toward waterfall and Plate 5.pool (bottom photo).

3.1.2 Zane's Gorge

The Zane's Gorge area consists of a large elevated gorge and valley system located through a significant banded ironstone formation (BIF) west of Cave 13 (Plate 6). The majority of caves sites within the surveyed area were classified as potential nocturnal roosting habitat. The gorge and valley supported two pools and a number of caves along the length of the valley (Plate 7).

The survey team were able to access the entire area of Zane's Gorge and a number of other cave sites which occurred in smaller gorges and valleys east and north-east of Zane's Gorge. Only a small portion of Zane's Gorge was burnt during the recent fires, however the majority of the surrounding area was burnt including the smaller gorges and valleys with cave sites. As a result of the habitat assessment Joe's Cave was located approximately 200 m east of the entrance to Zane's Gorge and was classified as a potential diurnal roost (see Table 2). No surveys were undertaken west of Zane's Gorge by GHD during the February 2015 surveys.

Plate 6 Zane's Gorge looking north from the gorge entrance

Plate 7 Pool at Zane's Gorge

Table 2 Summary of cave habitat assessment surveys and observations – GHD January and February 2015

Location / site name/ date	Figure (symbol) / label	Elevation (m) / aspect	Cave location / morphology	Bat evidence	Microclimate	Photo /Sketch (Appendix E)	Notes and preliminary cave classification[2]
Blue square							
Site 1 8/1/15	C1BS	282 / north	Near top of slope Small closed cave. Entrance approximately (~) 4-5 meters (m) wide (w) x 2 m height (h) Depth (d) ~ 3 m Small sub-chamber at rear	Few old scattered guano	Relatively dry with minor humidity. Breeze	Plate 1	Potential nocturnal roost
Site 2 8/1/15	C2BS	295 / west, south-west	Near top of slope Large open cave with multiple entrances. Entrance ~ > 4 m (w) x 1.5 m (h) d ~ 5 m Small sub-chamber at rear	No	Dry open cave with short ceiling	Plate 2	Largest cave of a small grouping of caves all considered to be potential nocturnal roost habitat Recent fire near entrance of cave
Site 3 8/1/15	C3BS	291/ south	Near top of slope to side of small gully Large open cave with multiple entrances. Entrance ~ > 5 m (w) x 5 m (h) d ~ 3 m Small sub-chamber at top of ceiling near entrance	No	Dry cave with high ceiling and not much depth	No	Potential nocturnal roost
Site 4 9/1/15	C4BS	320/ north	Near top of slope Small, shallow closed cave	No	Dry shallow cave with short ceiling	No	Potential nocturnal roost
Site 5 9/1/15	C5BS	319 / north	Near top of slope Small, shallow closed cave	No	Dry shallow cave with short ceiling	No	Potential nocturnal roost
Site 6 9/1/15	C6BS	326 / north	Near top of slope Small, shallow closed cave	No	Dry shallow cave with short ceiling	No	Potential nocturnal roost
Site 7 9/1/15	C7BS	326 / north	Near top of slope Small, shallow closed cave	No	Dry shallow cave with short	No	Potential nocturnal roost

[2] Preliminary classification of cave based on habitat survey and habitat characteristics prior to a review of ultrasonic analysis data and other data (e.g. temperature and humidity infrared camera data) where available.

Location / site name/ date	Figure (symbol) / label	Elevation (m) / aspect	Cave location / morphology	Bat evidence	Microclimate	Photo /Sketch (Appendix E)	Notes and preliminary cave classification[2]
					ceiling		
Site 8 9/1/15	C8BS	331/ north, north-west	Near top of slope Large open cave with two entrances (1 large, 1 small). Large entrance ~ > 8 m (w) x 3 m (h). Large main chamber ~ 6-8 m (d), 8 – 10 m (w), 3-4 m (h). 1 small sub-chamber off main chamber with entrance at floor level (left side of cave). Entrance ~ 0.5 (h) 1 m (w) 6-8 m (d), chamber ~ 1-1.5 m (h), 4 m (w), 6-8 m (d).	~ 7 x *T. georgianus* roosting with young at back of main chamber on ceiling behind larger fallen boulder. 1 x *Macroderma gigas* flushed from cave upon entry. At least 5 x unknown small micro bat species were disturbed when inspecting small chamber. Parts of floor damp with scattered guano.	Main chamber relatively dry with minor humidity. Smaller sub-chamber very high humidity with water dripping from ceiling.	Plate 3	Potential diurnal roost The larger main chamber provides nocturnal roost and foraging habitat. The smaller sub-chamber provides potential diurnal and nocturnal roost habitat. No PLNB were recorded within the smaller sub-chamber using EM3 detector, however there are limitations with this method. Note: type (Anabat) and position of detector may have not accurately assessed the presence/absence of PLNB.
Site 9 9/1/15	C9BS	317 / north, north-west	Large open cave with small cavity in ceiling near entrance.	~ 2 x *T. georgianus*	Dry open cave with high ceiling	No	Potential nocturnal
Site 10 10/1/15	C10BS	265 / north, north-east	Small cave. One of few similar caves in close proximity Entrance ~ 1 (h) 1 – 2 m (w) 1- 3 m (d)	No	Small open, dry cave	Plate 4	Potential nocturnal roost Recent fire
Site 11 10/1/15	C11BS	281 / -	Small cave. One of a few similar caves in close proximity adjacent to and along small gully	No	Small open, dry cave	Plate 5	Potential nocturnal roost Recent fire
Site 12 10/1/15	C12BS	307 / -	Small cave. One of a few similar caves in close proximity adjacent to and along small gully Entrance ~ 1 (h) 1 – 2 m (w) 1- 2 m (d)	old scattered guano	Small open, dry cave	Plate 6	Potential nocturnal roost
Site 13 10/1/15	C13BS	308 / -	Small cave. One of a few similar caves in close proximity adjacent to and along small gully	old scattered guano	Small open, dry cave	Plate 7	Potential nocturnal roost

Location / site name/ date	Figure (symbol) / label	Elevation (m) / aspect	Cave location / morphology	Bat evidence	Microclimate	Photo /Sketch (Appendix E)	Notes and preliminary cave classification[2]
			Entrance ~ 1 (h) 1 – 2 m (w) 1- 2 m (d)				
Blue Square / Nicko's Gorge							
Site 14 11/1/15	C14BS	261 / north, north-west	Midway up wall of gorge Small cave / overhang amongst many similar smaller caves and overhangs Entrance ~ 2 (h) 2 – 3 m (w) 1- 3 m (d) Large boulder fallen from ceiling provides roosting diurnal roosting habitat	*T. georgianus* and small bat (assumed) *V. finlaysoni* old scattered guano	Dry	Plate 8	Potential nocturnal roost
Site 15 11/1/15	C15BS	276 / north, north-west	Near bottom of wall of gorge above pool Large open overhang amongst many smaller caves and overhangs	No	Dry and open	Plate 9	Potential nocturnal roost/
Site 16 11/1/15	C16BS	284 / north, north-west	Small cave / overhang amongst many similar smaller caves and overhangs	No	Dry	Plate 10	Potential nocturnal roost
Site 17 11/1/15	C17BS	305 / north, north-west	Small cave near top of slope along small gully. Unstable fractured rock. Small triangle shaped entrance ~ 0.5 - 1 (h) 1 m (w) 1- 3 m (d) leading into small narrow passage with small chamber at end.	*V. finlaysoni*	Dry	Plate 11	Potential nocturnal roost
Site 18 11/1/15	C18BS	260 / north	Small cave immediately above pool Not accessed – viewed from opposite side of pool.	-	-	Plate 12	Potential nocturnal roost. Cave appears small. No additional passages / chambers observed when viewed with binoculars
Site 19 11/1/15	C19BS	292 / south	Midway up slope Small cave with entrance ~ 0.5 - 1 m (w) 0.5 - 1 m (h) with chamber and small passage off back of chamber where bats were seeking refuge when disturbed. Chamber ~ 3 - 5 m (d), 3 - 4 m (w), 1 m (h). Chamber appears stable however entrance may be unstable and part of fractured rock formation. Large fallen boulder at entrance.	7 – 8 *T. georgianus* with young and up to 2 smaller bats (assumed) *V. finlaysoni* Guano was recorded however difficult to age because of moist conditions. No piles of guano.	Very humid chamber, with water dripping from ceiling. Chamber floor, smooth and damp.	Plate 13	Potential diurnal roost EM3 detector site Could not access cave at time of survey to assess full extent of chamber and rear passage.

Location / site name/ date	Figure (symbol) / label	Elevation (m) / aspect	Cave location / morphology	Bat evidence	Microclimate	Photo /Sketch (Appendix E)	Notes and preliminary cave classification[2]
Site 20 12/1/15	C20BS	301	Located near top of BIF – north of Nicko's Gorge One of many small caves and overhangs in this area location along mid slope and near top of slope and along small gully's	No	Dry, open	Plate 14	Potential nocturnal roost
Site 21 12/1/15	C21BS	308 / south	Located near top of BIF – north of Nicko's Gorge One of many small caves and overhangs in this area location along mid slope and near top of slope and along small gully's	No	Dry, open	Plate 15	Potential nocturnal roost
Zane's Gorge							
Site 22 21/2/15	C1ZG	323 / south	Located at the head of the valley from the start of the gorge above a pool adjacent small ephemeral waterfall. Overhang that leads into a small cave - entrance ~ 1 – 2 m (w) 0.5 - 1 m (h) leading into dome shaped chamber 5 - 6 m (d), 3 - 4 m (w), 2.5 m (h). With small sub-chamber off back of main chamber at floor level.	*3 x T. georgianus* and up to 4 x *V. finlaysoni* Scattered old and recent guano recorded. No piles of guano.	Relatively dry, low humidity toward back of cave	Plate 16	Potential nocturnal roost
Site 23 21/2/15	C2ZG	322 / east	Two small adjoining caves located along the western side of the gorge midway up the slope, near a pool. Cave 1 smaller, shallow ~ 0.5 – 1 m (w) 0.5 - 1 m (h) 2 -3 m (d) Cave 2 ~ larger with dome shaped chamber 3 - 4 m (w) 1 – 1.5 m (h) 4 -5 m (d)	*3 x T. georgianus* and up to 4 x *V. finlaysoni* flushed during survey Scattered old guano recorded. No piles of guano.	Dry	Plate 17	Potential nocturnal roost
Study area surrounding Zane's Gorge							
Site 24 21/2/15	C3ZG (Joe's Cave)	314 / south-west	Very large cave located near top of an extensive BIF east of Zane's Gorge. Cave consists of a large entrance with a passage leading to a very large chamber with a short ceiling. Maximum depth of cave from entrance > 32 m.	Small population of breeding/non-breeding *T. georgianus* and *V. finlaysoni* occupy this cave. Guano was recorded	Hot, very humid main chamber with moisture on ceiling and floor Note : ibutton data (max temp	Plate 18	Potential diurnal roost. Recent fire to mouth of cave. It is possible that a few individual PLNB could have been present during

Location / site name/ date	Figure (symbol) / label	Elevation (m) / aspect	Cave location / morphology	Bat evidence	Microclimate	Photo /Sketch (Appendix E)	Notes and preliminary cave classification[2]
			Entrance, 4- 5 m (w) 1.5 – 2.5 m (h) leading into a passage (5 - 6 m (w) 1.5 – 2.5 m (h) 7 m (d) with flat floor). Main chamber – wide oval shaped with a short ceiling and two small shallow sub-chambers/cavities off rear of main chamber Main chamber, 8 - 9 m (w) 1 – 1.5 m (h) 9 - 15 m (d) with flat floor. It was estimated the ceiling was probably between 2 -4 metres thick as the cave was locate near the top of the BIF and roots, presumably from trees/vegetation were protruding through the ceiling near the back of the cave.	throughout the cave with larger piles/deposits recorded along the walls of the main chamber, just in from the passage. Cave is also regularly used by kangaroos and other fauna (see Appendix E).	- 32^{0}C /max humidity 71%) – sample period 3 days and 3 nights 22/2 – 25/2/15 See ibutton data – Figure 3. Note there were significant humidity fluctuations across the survey period, probably corresponding with fluctuating weather events.		the surveys (e.g. seek refuge with small cracks/crevices in ceiling), however it is unlikely that a noticeable population of PLNB occupied the cave during the habitat assessment. See Section 3.2.2 for SM2 results. Appendix E for camera surveillance summary
Site 25 21/2/15	C4ZG (Owl Cave)	304	Consists of two small cavities (< 1 x 2 m) located in the ceiling of a fractured overhang near the head of a small gully Other small caves and overhangs were investigated in this area.	Few old guano, however owl flushed from cavity and old quoll scat located at rear of cavity	Dry	Plate 17	Owl cave - Potential nocturnal Other caves/overhangs – classified as potential nocturnal roost
Site 26 21/2/15	C5ZG (Twin Peaks)	330	A small-medium cave consisting of two chambers located near the top of a degraded BIF cap. Entrance, 1 – 2 m (w) 0.5 - 1 m (h) leading into two chambers Chamber 1, 0.5 – 1 m (w) 1 – 1.5 m (h) 5 - 6 m (d) with flat floor Chamber 2, 1.5 – 2.5 m (w) 1 – 2 m (h) 6 - 7 m (d) floor inclining at 40^{O} slope toward back of chamber.	Ghost bat feeding midden and guano pile with fresh and old guano (see photos). *3 x T. georgianus* and 1 x *V. finlaysoni* flushed during survey	Hot, humid cave with moisture on ceiling and second chamber floor ibutton data (max temp - 39.6 ^{0}C max /humidity 40.8% – sample period 30 mins)	Plate 18	Potential nocturnal roost

Location / site name/ date	Figure (symbol) / label	Elevation (m) / aspect	Cave location / morphology	Bat evidence	Microclimate	Photo /Sketch (Appendix E)	Notes and preliminary cave classification[2]
Study area north-east of North Star operations							
Site 27 21/2/15	C1NE (Wayne Manor)	313 / north	A large complex cave structure located midway up slope consisting of multiple chambers and refuge areas created from fallen rock. . Cave consists of a large entrance leading immediately into the main chamber with a passage leading to a rear chamber. Two other chambers are located to the right and left of the main chamber. Right chamber could be considered an extension of the main chamber. Ceiling height varies up to 3 m and maximum depth of cave from entrance > 29 m. The floor elevation varies considerably and is covered with fallen rock/boulders and in some areas is elevated / inclined. Entrance, 2- 3 m (w) 2 – 2.5 m (h) leading into the main chamber. Main chamber- right side chamber, 4 - 5 m (w) 1.5 – 2.5 m (h) 9 - 10 m (d). It was estimated the ceiling was probably between 2 -4 metres thick. Rear chamber, 3 - 5 m (w) 1.5 – 2.5 m (h) 6 - 6.5 m (d) with floor inclining at 10 -20^{O} slope toward back of chamber with smaller sub-chambers at floor level from rear wall. Left chamber – small dry at floor height.	Small population of breeding/non-breeding *V. finlaysoni* recorded in rear chamber and right side chamber. 4 x *T. georgianus*. Guano was recorded throughout the cave with larger piles/deposits recorded at right side chamber and rear chamber. Cave is also regularly used by kangaroos and other fauna.	The rear chamber was hot with moisture on ceiling. The main chamber was dry – humid however the local winds created a breeze near the entrance. ibutton data from rear chamber (max temp - 39.6 ^{0}C /max humidity 65% – sample period 1 day)	Plate 19	Large complex cave Rear chamber - potential diurnal roost. Lots of fallen rock/fractured structure suggests cave may be unstable. See Appendix E for camera surveillance summary

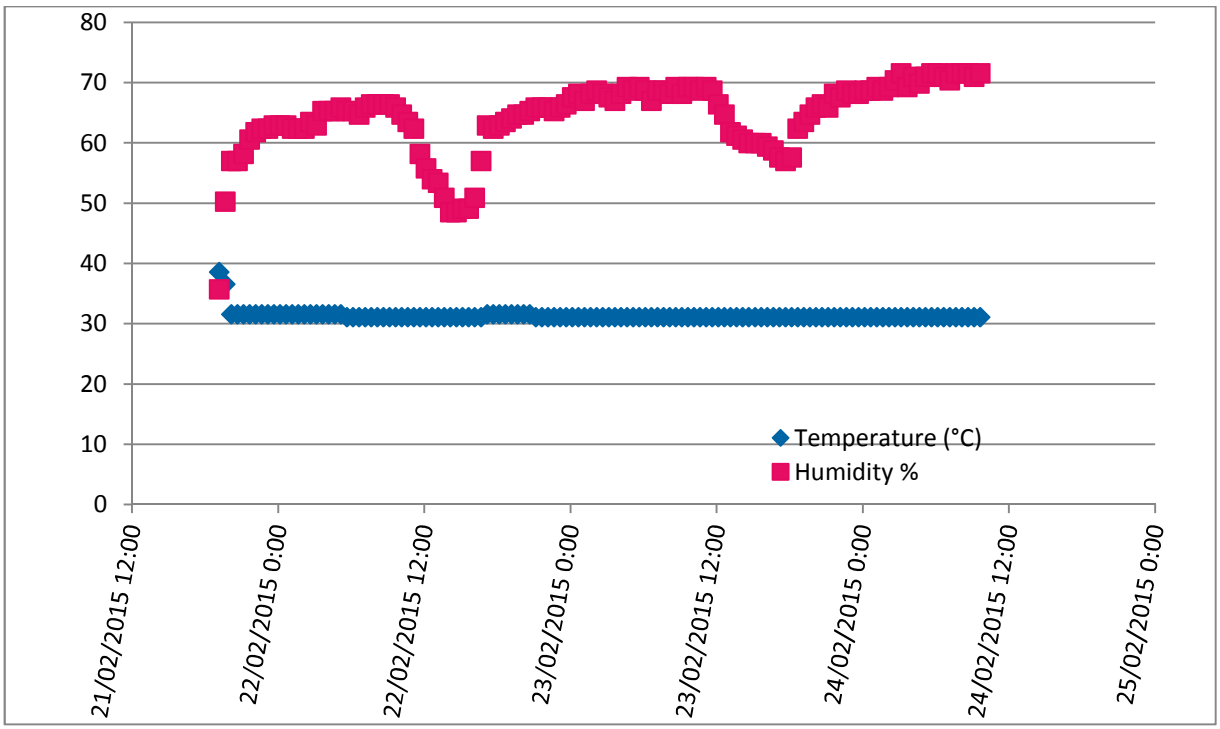

Figure 3 Temperature and relative humidity – Joes Cave 21 – 24/2/15

3.1.3 Habitat observations – GHD November 2014

As part of a separate field investigation with FMGIB, opportunistic habitat surveys were undertaken by GHD on the 14th November 2014 of the flat top BIF with the telecommunications tower located east of camp and west of Cave 13 and three rocky outcrop locations between the main access road and west of Cave 13 (Figure 2). General notes regarding the suitability of caves and other structures to support habitat for bats were recorded.

The majority of the flat top BIF was traversed with the exception of culturally sensitive areas located along the eastern and western flanks of the BIF. The areas searched revealed approximately five potential nocturnal roost sites; however no diurnal or maternity roost habitats were recorded.

No maternity or diurnal roost habitats were recorded for the three locations along the main access road; however potential nocturnal roost habitat was recorded at each site.

3.2 Ultrasonic detection surveys – January and February 2015

A summary of the Bat Call WA call analysis for the January and February 2015 surveys is provided below. Detailed survey methods and results for the Bat Call WA November 2014 survey and GHD and FMGIB ultrasonic surveys conducted during 2015 are provided in Appendix B. For convenience the naming convention adopted by both GHD and Bat Call WA has been provided for the summary. GHD site names are provided in the first instance, followed by Bat Call WA sites names in brackets.

According to the analysis completed by Bat Call WA, PLNB were detected across a broad area but some sites had higher activity than others. PLNB were detected at nine of twelve sites surveyed using SM2 and EM3 detectors. Detections with high and very high activity levels were made within the Blue Square in Nicko's Gorge and in an area around Zane's Gorge. Low activity levels were detected at Wayne Manor, a cave to the north east of North Star near where limited foraging detections have been made in the past (Bat Call WA 2013).

3.2.1 Blue Square – January 2015

Within the Blue Square, two sites in Nicko's Gorge produced detections: an EM3 placed at Site 19 (NSjan01) and an SM2 placed at an overhang (NSjan02) – see summary of survey methods and effort table, Appendix A. The SM2 placed at the overhang produced very high activity with 822 calls being detected on 11th January. The first calls at this site were recorded five minutes after dusk and the last calls were recorded five minutes before dawn civil twilight. The temporal pattern shows continuous activity all night with peaks immediately after evening and before morning twilight. This indicates that this overhang may be in close proximity to a potential diurnal roosting site. Low activity levels beginning five minutes after civil twilight were detected at Site 19 (NSjan01). These detections were in small groups that were approximately one hour apart for the period up to 21:45 hours that the detector was operating, indicating that this cave is a potential foraging location, however this data only provides for a limited survey sample (e.g. approximately 4 hours for one night).

3.2.2 Zane's Gorge – January and February 2015

Within the Zane's Gorge area, five of seven sites produced detections. At Site 24 – Joe's Cave (NSjan05) variable activity was recorded in late January, and early and late February. Call counts ranged from a low of 69 to a high of 1369. Between 23rd and 26th January the highest activity was recorded after sunset and on all nights except for the 23rd there was a second peak before sunrise. On the 23rd there were high activity levels all night following the initial peak. The initial calls were detected between 5 and 15 minutes after twilight at dusk and the last calls were between 10 minutes prior to and at twilight at dawn. Between 7th and 10th February there was a strong bimodal activity pattern with virtually no activity between 10 PM and 3 AM. The initial calls were detected between civil twilight and 15 minutes afterward and the last calls were between 15 minutes prior to and at civil twilight. From the 20th to 28th February there was consistent activity with between 200 and 1200 calls per night beginning and ending at civil twilight. The combined results of the temporal patterns indicate that this cave was probably being used as a diurnal roost, between January and March.

PLNB were detected at three other caves in the Zane's Gorge area: Site 22 (NSjan03), Site 23(NSjan04) and Camp view cave[3] (NSfeb01), a pool near Site 23 (NSfeb05) and a cliff site east of Joes Cave, near Camp view cave (NSfeb06). There were less than 250 calls per night at each. At Site 22 the calls began a minimum of 25 minutes after and the latest were 5 minutes before twilight. At Site 23 the calls began a minimum of 25 minutes after and the latest were 10 minutes before twilight. The pool close to Site 23 gave similar results with approximately 200 calls beginning at 5 minutes after twilight. At Camp view cave the calls began a minimum of 15 minutes after and the latest were 10 minutes before twilight. On each night the earliest and latest calls were between 5 and 25 minutes after/before those at Joe's Cave. The single exception was the latest call on the 7th February where the latest call was timed three minutes after that at Joe's Cave. The nearby cliff site gave similar results to Camp view cave. These patterns indicate that all three caves are probably foraging caves and probably not permanent diurnal roosts.

Site 27 - Wayne Manor Cave (NSfeb04) produced activity with a nightly activity maximum and minimum of 89 and 1 calls respectively. The first and last calls at this cave were at least forty minutes after and thirty five minutes before civil twilight in the evening and morning respectively. The temporal pattern at this cave entrance indicates that this cave may be a foraging cave distant from a diurnal roost.

[3] Camp view cave was not assessed as part of the GHD surveys

3.3 Infrared camera surveys GHD February 2015

Low glow LED infrared cameras (LTL Acorn - model 5310s) were used to record bats at two locations (Joe's Cave and Wayne Manor) during the February 2015 survey. The purpose of using the cameras was to assist with understanding the temporal activity patterns of the bat population at each of the cave sites (see Appendix A for method description).

A camera was placed at the entrance of Joe's Cave for a period of four nights (21st - 25th February 2015), however due to technical issues (i.e. the camera software defaulting to the sensor mode) and strong winds (e.g. camera was moved by the wind from its original position) limited data capture was achieved. One camera was placed inside the entrance of Wayne Manor (24th February 2015), however due to unknown technical issues the camera recorded for the first four of the possible 12 hours.

Given the field limitations experienced during the survey and inherent limitations of this technique (e.g. video quality) the interpretation of the data was limited to the analysis of bat activity for one night (the 23rd – 24th February) at Joe's Cave and observations regarding species identification from viewing the video footage.

Figure 4 presents the analysis of the count data for each 30 minute period for the night of the 23rd to 24th February 2015 for Joe's Cave. The first count (either a bat on a wall, or flying in or flying out of the cave) for the night was at 6:25 pm and last count at 6:50 am.

Bat activity was recorded for each 30 minute period, however the number of 30 second video clips varied between each period (e.g. more than seven clips were recorded for the majority of 30 minute periods, however some periods recorded less than seven clips). Two peaks in activity were observed: the first hour during the emergence period (starting at approximately 6:25 pm) and the two hours prior to sunrise as the majority of bats were probably returning to the roost (between 4:55 and 6:55 am). A spike in activity was also recorded around 8:55 pm.

As stated in the methods, it is near impossible to identify the bats to species when in flight using this technique, however observations of bat species hanging on the walls of the cave revealed at least two species belong to the *Taphozous* genus (probably *T. georgianus*) and at least one other smaller bat (possibly *Vespadelus finlaysoni* and/or PLNB). It was also obvious by comparing the size and shape of bats flying from a review of paused video footage that at least two species of bat were recorded flying in and out of the cave.

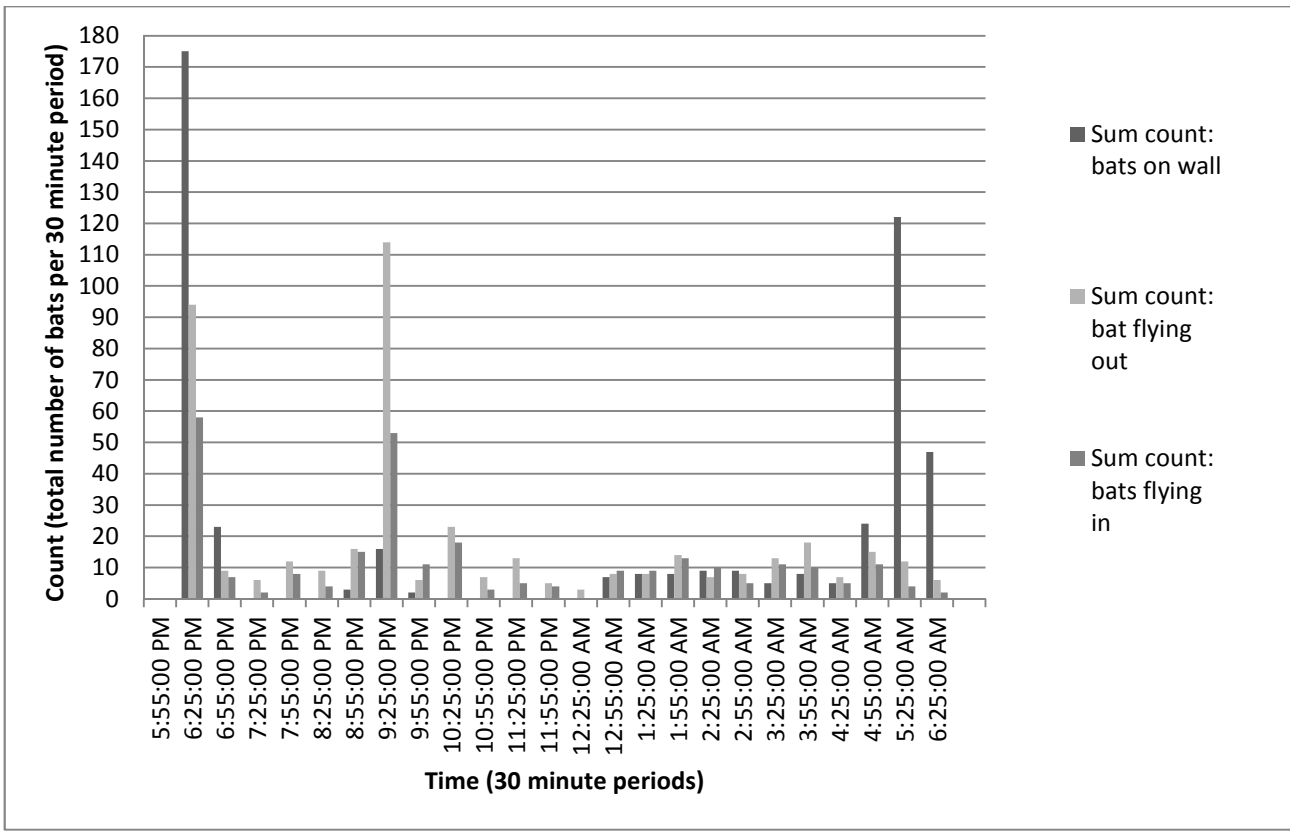

Figure 4. Bat activity from Joe's Cave – infrared camera analysis (23-24/02/2015)

4. Key outcomes

4.1 GHD surveys January and February 2015

GHD completed surveys of 27 sites (52 caves consisting of single and multiple caves) within the study area. Following a review of all available data presented in Section 3 the classification of the majority of cave sites has not changed – that being the majority are classified as nocturnal roost sites. This finding is supported by the habitat assessment and ultrasonic survey data. Therefore the assessment did not confirm the absence of a maternity roost within the study area.

One site (Site 24 - Joe's Cave) within the Zane's Gorge area was classified as a possible diurnal roost, based on the habitat characteristics of the cave recorded during the cave habitat assessment survey. An analysis of the temperature and humidity data from Joe's Cave suggests that whilst consistently providing optimal temperatures (e.g. > 30 degrees) the humidity was less than optimal (e.g. less than 70% humidity for the survey period). The fluctuating humidity levels suggest that the cave is subject to outside environmental conditions (e.g. the fluctuating storm conditions during the survey period), thus may not provide a stable humid climate needed during the breeding period for the PLNB as suggested by the literature. However, it is not clear in the literature that PLNB can cope with short term fluctuations in humidity or temperature during the breeding period. Furthermore the temperature and humidity data was recorded over a four day period thus should not be considered a comprehensive data set.

Following a review of the temperature and humidity data and ultrasonic survey data, Joe's Cave remains classified as a diurnal roost.

The infrared camera data provided limited information, and it was difficult to compare the activity patterns captured by the camera to the ultrasonic survey data and interpret correlations. Therefore no clear results or discussion could be drawn from this method other than a variety of microchirpteran bat species regularly utilise the cave for roosting.

It was determined that the likelihood of a maternity or diurnal roost occurring within the Blue Square would be limited to the south-west portion and southern boundary of the Blue Square including Nicko's Gorge and possibly a small area of the north-east portion of the Blue Square associated with the tributaries of Black Boy Creek. The analysis of the ultrasonic survey data from an overhang within Nicko's Gorge revealed that there may be a diurnal roost located within or immediately adjacent to Nicko's Gorge, which is supported the findings of the habitat assessment.

Given the results of the survey it is possible that a diurnal or maternity roost does occur within the Blue Square, possibly within the Nicko's Gorge area. Considering the data collected during the habitat assessment, ultrasonic survey data and temperature and humidity data it is unlikely that a maternity roost is located at any of the sites surveyed with the Zane's Gorge area including Joe's Cave. It is possible that a small number of individual PLNB occupied Joe's Cave at the time of the survey (e.g. some individuals may have hidden with small cracks/crevices that could not be accessed or were overlooked during the survey), however it is unlikely that Joe's Cave contained a colony (e.g. > 50 individuals) of PLNB at the time of the surveys.

Further assessment is required within the Blue Square area to determine the presence or absence of a diurnal and/or maternity roost, particularly within or in close proximity to Nicko's Gorge.

4.2 FMG surveys March and April 2015

The FMGIB surveys conducted during March and April of 2015 within the mining footprint at North Star has identified one cave that may be a potential diurnal roost cave (Chateau – see Appendix C).

Further assessment is required of the site to determine the presence or absence of a diurnal and/or maternity roost associated with the cave identified within the North Star footprint.

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Appendices

Appendix A – Field survey methods

Cave habitat assessment

Cave habitat assessments to determine the presence/absence of bats and suitable habitat was undertaken by two observers using the following procedure:

- Surveys would commence using binoculars at a suitable distance away from the cave entrance so as to avoid disturbing bats. The observers would then cautiously approach the cave so as to avoid 'flushing' bats from the cave.
- At the entrance of the cave two observers completed a visual inspection of the cave stability to determine if the cave was safe to enter. If deemed safe then observer one entered the cave to undertake the cave assessment and observer two remained at the entrance of the cave to watch for any bats emerging from the cave during the assessment.
- Upon entering the cave observer one would undertake a visual assessment assisted by the use of a low-glow LED infrared camera (LTL Acorn - model 5310s) and /or torch light (dim beam) so as to record the presence of roosting bats (e.g. location in cave) and reduce the level of disturbance to roosting bats. Where the target species or other bat species of conservation significance was recorded the observer would retreat from the cave to minimise disturbance and return either early that evening (at least 30 minutes after bats were recorded departing the roost) or early the following morning (at least 30 minutes before sunrise) to conduct the cave assessment. The cave assessment involved recording the following parameters using a field check sheet:
    - Cave unique identification number, location (GPS), date and time of assessment, and assessors
    - Photographs including cave entrance and internal cavity
    - Cave morphology: external cave position (upper, lower slope), entrance orientation, approximate entrance width and height, cave depth and number and approximate dimensions for chambers. A Leica DistoX2 laser distance range finder was used to measure cave dimensions during the February 2015 survey.
    - Habitat type and condition outside cave including signs of disturbance and presence of water nearby and inside cave
    - Presence of bats: number of individuals, time of use, type of use (e.g. feeding roost, day roost, maternity roost), presence of gravid females or juveniles
    - Level of bat use (based on guano/ scat pile accumulations)

This information was then be used to assist with categorising the cave type. Appendix D provides the coordinate location details of each site within the study area. The table below provides a summary of the sites visited during the GHD survey completed during January and February 2015.

Environmental data

Temperature and humidity was recorded for caves categorized as potential maternity sites. This information was collected using temperature/humidity logger iButtons (model DS1923, Maxim Integrated Products, Inc.). One iButton was placed at/near a potential maternity roost site within the cave if present. iButtons were set to record air temperature and relative humidity at pre-determined times (to save power and increase the length of the monitoring) and were deployed for at least four days at each location.

Ultrasonic detection surveys

The primary method of recording ultrasonic bat calls was the SM2BAT+ SongMeter recorder (Wildlife Acoustics Inc, USA). The SM2 was deployed at the majority of sites for at least one night to detect and record ultrasonic echolocation calls emitted by microchiropteran bats. The settings used for each SM2 detector are provided in Appendix A.

Anabat Express (Titley Electronics Pty Ltd) detector and EM3 recorder (Wildlife Acoustics Inc, USA) were also used at a few sites. Detector locations are displayed in Figure 2. A summary of the detector survey effort for each location is provided in the table below.

Detectors were usually deployed at the entrance of a cave deemed to be potential maternity or diurnal roosting habitat. Other detectors were placed at locations other than caves (e.g. gorges with water holes and overhangs) to assist with characterising PLNB activity within the 30 km radius of Cave 13.

Call analysis

Call analysis of files from SM2 and EM3 detectors was undertaken by Bat Call WA. Files from the SM2 and EM3 detectors were reformatted as .wav files and reviewed using COOL EDIT 2000 software. PLNB calls were confirmed by recognition of the species diagnostic call characteristics. Detailed methods for call analysis are presented in Appendix C

Call analysis from files recorded from Anabat Express detector was undertaken by Craig Grabham of GHD. Files from the Anabat Express were processed using AnalookW software (version 4.1s, Chris Corben 2015). Calls were the analysed using zero-crossing analysis and AnalookW software (version 4.1s) by visually comparing the time-frequency graph and call characteristics (e.g. characteristic frequency and call shape) with species call descriptions from published guidelines (e.g. Armstrong and Cole 2007; McKenzie and Bullen 2009 and 2012).

The PLNB has a distinct call from all other microchripteran bat species in the region. Unlike other species the pulse structure is constant frequency (CF) with a characteristic frequency (Fc) of 118–128 kHz (DEWHA 2010). Identification was confirmed from a minimum of two or more consecutive pulses (each > 4 ms duration) in a sequence within the characteristic range of the species (Armstrong and Coles 2007).

Thermal video camera surveillance survey

Infrared video was deployed at two sites for one night each (Joes Cave, Zane's Gorge and at SM2+ BS, Blue Square) as a technique for determining occupancy, activity and where possible colony size when coupled with the Song Meter SM2BAT+. The camera was set to start recording at the cave entrance/location at least 15 minutes prior to the bats nightly emergence. Recordings were then to be analysed and bats counted using missile tracking software, as is described by Sabol (1995)[4]. This system has not been used extensively in Western Australia, but has found application in South Australia at a large colony of the Critically Endangered Southern Bent-winged Bat, and on Ghost Bats in the Northern Territory and other species in New South Wales (http://www.abc.net.au/news/2013-12-28/thermal-missile-technology-tracks-microbat/5176936), as well as species overseas.

Unfortunately due to animal interference and equipment failure no viable data was recorded using this technique.

[4] Sabol, B.M. and Hudson, M.K. (1995). Technique using thermal infrared-imaging for estimating populations of gray bats. Journal of mammalogy 76: 1242-1248

Infrared video camera surveillance survey

Low glow LED infrared camera (LTL Acorn - model 5310s) were used to record bats at two locations (Joes Cave and Wayne Manor) during the February 2015 survey. The purpose of using the cameras was to assist with understanding the temporal activity patterns of the bat population at each of the cave sites. The data captured by the video cameras when combined with the ultrasonic call analysis of echolocation calls may provide visual information (e.g. bat departure and entry into a cave) which cannot be provided by ultrasonic analysis alone (e.g. ultrasonic call analysis may reveal high activity levels which may be created by a few bats, or may be created by bats flying around the entrance to a cave).

The cameras were pre-programmed to record 30 second video clips every minute from 15 minutes before sunset to 15 minutes after sunrise or until the battery life expired or memory card reached capacity. Given the speed that bats are known to exit caves it was thought best to set the cameras to record for set periods of time rather than rely upon the sensors of the camera to detect movement. Cameras were placed at the entrance in order to view the entire entrance area or 3-4 meters inside of the entrance of the cave depending on the size of the cave entrance.

One camera was placed at the entrance of Joes Cave for a period of four nights (21 - 25 February 2015). Due to technical issues (i.e. the camera software defaulting to the sensor mode) and strong winds (e.g. the camera was moved by the wind from its original position) only one night of complete data was recorded (i.e. 30 second video clips were recorded throughout the night). One camera was placed at inside the entrance of Wayne Manor (24 February 2015) however due to unknown technical issues the camera recorded for the first four of the possible 12 hours.

The following counts were undertaken for each 30 second video clip:

- number of bats observed on the wall of the cave
- number of bats observed flying into the cave
- number of bats observed flying out of the cave.

For analysis purposes and to compare the data with the ultrasonic detection surveys for the same period, data was presented for each 30 minute period of time, commencing from the first count. The sum of all counts taken for each 30 second video clip was combined within each 30 minute period to provide an overall activity count for the three count types (e.g. the total number of bats observed on the wall for each 30 minute period).

The poor quality of the video footage in combination with the speed at which the bats were flying in and out of the cave prohibited the identification of bats flying in and out of the cave to species. Identification of some individuals to genus level was possible where bats were observed clinging to the wall of the cave, yet quality and type (i.e. black and white footage) prevented identification to species level.

This is a cheap novel method which has not been used extensively in Western Australia and provides a number of benefits, including:

- An alternative and complementary method of gathering unassisted observational information to bat detectors (ultrasonic detection). For example the daytime occupancy of PLNB in a roost is often difficult to determine because of their tendency to use some features as ‘night roosts’. The species has often been recorded flying into caves soon after dusk, rather than out of them (DEWHA 2010). The use of infrared surveillance cameras (e.g. the LTL Acorn - model 5310s) provides an alternative non-invasive method to assist with confirming roost occupancy. However the quality of the video footage of

some cameras may be prohibitive (e.g. species cannot be identified), therefore it is important to couple this data with other survey techniques (e.g. ultrasonic detection).

- Improved opportunities for observation as compared to unassisted observation. Benefits include a record of bats flying in and out of the roost for a designated period (e.g. periodic 30 second clips for the 2 hours during the emergence period or an entire night for as long as the equipment battery life and memory capacity will last) and possibly identification of specific access points from roosts, bat behaviour and bat numbers.
- It is also not always possible to obtain accurate counts for the PLNB and other species using bat detectors placed at roost entrances because of their tendency to fly about at entrances, or enter structures after sunset (DEWHA 2010). An index of activity (e.g. based on ultrasonic recordings over the course of the emergence period) is a practical way to assess usage and relative importance of a roost (DEWHA 2010), and the use of infrared surveillance cameras can assist with this process.
- An additional back up method of recording information and evidence (additional to sound recording and thermal camera).

The video files raw analysis data for each site has been provided as excel files on usb.

Summary of detector and camera survey effort at each location/site during the January and February 2015 surveys

Location/site	latitude/ longitude	Ultrasonic detection - date (deployed/ recovered) and effort (Figure 2 map label in bold)	Thermal and infrared camera surveys - date (deployed/ recovered) and effort
Blue square			
Site 8 Cave 8	-21.21728702/ 118.9518	Anabat Express detector at Cave 8 from 9/1/15 – 12/1/15 (3 nights) **C8BS**	-
Overhang above water hole	-21.21700899/ 118.9542	SM2 placed under over hang (not cave) – multiple potential caves within very close proximity - 11/1/15 – 12/1/15 (1 night) **SM2 BS**	Thermal camera deployed for one night (11-12/1/15) – no data captured
Site 19 Cave 19	-21.21607801/ 118.9553	EM3 placed for one night 11/1/15 for approximately 3 hrs from 18:30 – 21:42 located at Cave 19 (C19BS) - 11/1/15 – 12/1/15 **EM3 BS**	-
Zane's Gorge			
Site 24 - Joes Cave	-21.25217099/ 118.9777	SM2 placed at entrance of Joe's Cave - 20/2/15-24/2/15 (4 nights) **SM2 JC** Anabat Express placed at entrance of Joe's Cave (Note: data not analysed as SM2 data used instead) - 20/2/15-23/2/15 (3 nights) **AE JC**	Thermal camera deployed for one night (20/2/15) – no data captured LTL Acorn infrared video camera 4 nights
East of Joes Cave		SM2 placed approximately 200 m east/north-east from entrance of Joe's Cave at similar elevation along front of same BIF (not in front of a cave) - 21/2/15-22/2/15 (2 nights) **SM2 E**	-
Waterhole	-21.25176497/ 118.9779	SM2 placed above freshwater pool (top of waterfall) approx. 50 m from Cave 1 - 21/2/15-23/2/15	-

		SM2 WF	
North east of Cave 13			
Wayne Manor	-21.21665996/ 119.0769	SM2 placed at entrance of Wayne Manor Cave - 21/2/15-22/2/15 (2 nights) **SM2 WM**	LTL Acorn infrared video camera 2 nights
South of Cave 13			
South Star	-21.30579103/ 119.0633	SM2 placed at the gap off new exploration track past glacier valley - 21/2/15-22/2/15 (2 nights) **SM2 SS**	-

Appendix B – WA Bat Call report

Fortescue Metals Group
North Star Project,
Pilbara Leaf-nosed Bat Regional Survey,
November 2014 to March 2015

Prepared for GHD Pty Ltd

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Issue 1
12 May 2015

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Document Revision History

Date	Issue	Revision History
27 Dec 2014	Issue A	Initial draft covering Phase 1 prepared for GHD review
6 March 2015	B	Updated draft with Phase 2 (Jan and Feb 2015) data included
28 March 2015	C	Updated draft with additional Phase 2 data included
12 May 2015	1	Issue 1 following client review.

Executive Summary

Orange Leaf-nosed Bats, Pilbara form (*Rhinonicteris aurantia*), herein referred as Pilbara Leaf-nosed Bats (PLNb), have been detected at the Fortescue Metals Group (Fortescue) Project, at the North Star resource in the Iron Bridge project, Western Australia (Bat Call 2013). A diurnal roost cave has been identified within the project's boundary, named Cave 13. A diurnal roost is one that the PLNb roost in during daylight hours for part or all of the year and is differentiated from a foraging location which is used only nocturnally. Permanent diurnal roosts are thought to be maternity sites. Continuous monitoring of the activity of PLNb at Cave 13 and at the nearby permanent waterhole at Fig Pool is ongoing. This monitoring has shown that PLNb are not continuously resident at Cave 13 throughout the year and has indicated that there is at least one permanent diurnal (probably maternal) roost within approximately 15 km of the site (Bat Call 2015). There is no known PLNb roost within this radius, the nearest known permanent roosts being at the historical Lalla Rookh underground mine; 32 km to the north east and near Mt Webber mine, 40 km to the south east.

A regional survey of PLNb activity followed by a targeted roost search has been undertaken between November 2014 and March 2015. Bat Call WA (Bat Call) acting as subcontractor to GHD Australia (GHD) carried out a short dry season survey in early November 2014 utilising current industry standard systems to determine the presence of any PLNb diurnal roosts close to North Star.

The aims of the survey were to:

- Collect observational and ultrasonic call recording data to characterise the roosting and foraging habitat of the PLNb within a 30 km survey area centred on cave 13 (refer figure 6 of Ministerial Approval Statement 993).
- To provide a focussed search area within which the permanent diurnal roost is indicated;
- If possible to locate the permanent roost cave and to confirm its status as a maternity roost.

During November, PLNb activity was detected generally to the north and west of the North Star project that includes the majority of Fortescue's tenements in the district. Timing of the calls detected, together with the monitoring data from Cave 13 and Fig

Pool, confirmed that there is at least one unidentified diurnal roost in the 30 km search area that is probably permanent. The exact location of the roost was not found but the activity levels and temporal pattern of detections suggest that it lies in one of the ridges approximately 10 km to the north west of North Star possibly within Fortescue's extended tenements, within or adjacent to a 5 km square area nominated as the "Blue Square". To date, no evidence of a diurnal roost has been found within 20 km to the south of North Star.

Guided by the results of the November survey, during January and February 2015 staff from GHD and Fortescue have placed ultrasonic bat detectors at a series of locations to the west and north of North Star in an attempt to locate the permanent diurnal/maternity roost. Observational and ultrasonic surveys were also undertaken of additional sites in February 2015 within an area known as Zane's Gorge located to the west of Cave 13 by FMG and GHD.

Timing of the calls detected and the temporal patterns of calls suggest that there are at least two diurnal roosts within or to the south of the "Blue Square". Sites NSjan02 (Nickos Cave 1 complex) has been shown to be immediately adjacent to an active diurnal roost. Site NSjan05 (Joes Cave) approximately 5 km south east of the square, has been shown to be a diurnal roost with a small number of PLNb present. Neither has been confirmed as the permanent diurnal/maternity roost at this point.

Confirming the sites of the two possible permanent roosts will require additional survey work.

Introduction

Project Background

Fortescue Metals Group has begun to develop the North Star resource, a part of the broader Iron Bridge Project, as a part of its current Pilbara operations, Figure 1.

Recent surveys at the project have detected Orange Leaf-nosed Bat, Pilbara form (*Rhinonicteris aurantia* referred herein as Pilbara Leaf-nosed Bat or PLNb, see Armstrong 2006; previously J.E. Gray, 1845), (Bat Call 2013). PLNb presence characterised as roosting and foraging activity has been recorded at Cave 13 within the project's footprint. Continuous monitoring of the activity of PLNb at this cave and at the nearby permanent waterhole at Fig Pool began in March 2014 (Bat Call 2015). This monitoring has shown that PLNb are not continuously resident at Cave 13 throughout the year and has indicated that there is a permanent diurnal (probably maternal) roost within approximately 15 km of the site. There is no known PLNb roost within this radius, the nearest known permanent roosts being at the historical Lalla Rookh underground mine, 32 km to the north east, and near the Mt Webber mine, 40 km to the south east.

The PLNb is listed as Vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation* (*EPBC) Act 1999*. Within the state of Western Australia it is listed as a Schedule 1 species under the *Wildlife Conservation Act 1950*.

Bat Call has been engaged by GHD to assist with undertaking surveys for the PLNb within a 30 km radius of Cave 13 after Ministerial Approval Statement #993 (Min Stat #993). In November 2014, Bat Call was engaged to collect observational and ultrasonic call data to assist with characterising the roosting and foraging habitat of the PLNb within a 30 km radius of Cave 13 at the North Star mine.

Following the review of the November 2014 survey results by Bat Call, observational and ultrasonic surveys were undertaken of additional sites in January 2015 with a 5 km square area (here in referred to as the Blue Square) located to the north-west of Cave 13 by FMG and GHD.

Observational and ultrasonic surveys were also undertaken of additional sites in February 2015 within an area known as Zane's Gorge located to the west of Cave 13 by FMG and GHD.

Bat Call WA was then engaged by GHD to undertake the call analysis of the data collected from the Blue Square and Zane's Gorge survey areas to assist with further characterising the roosting habitat of the PLNb within a 30 km radius of Cave 13.

This report provides a consolidated document of the methods and results for the survey undertaken during November 2014 and the call analysis completed for ultrasonic surveys undertaken during January and February 2015.

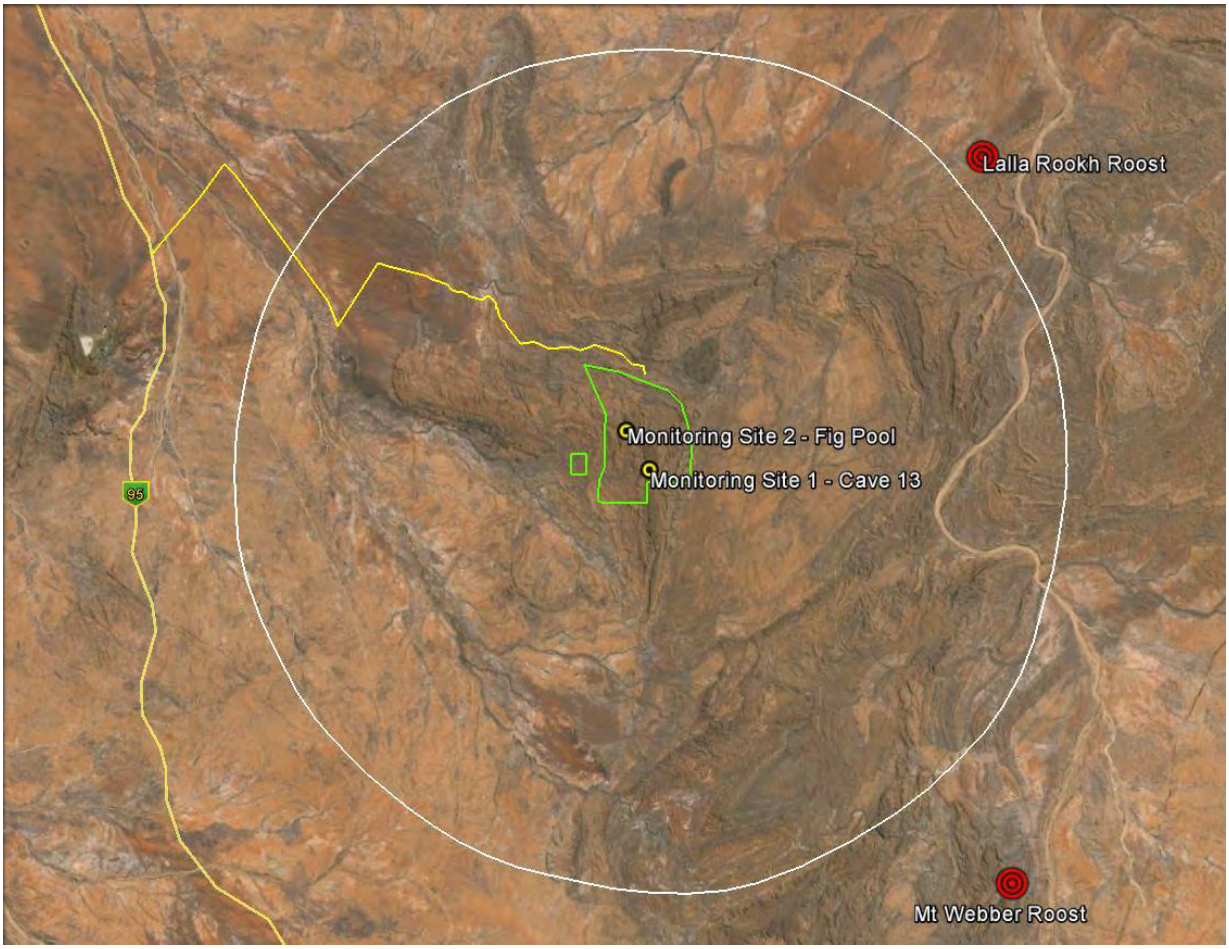


Figure 1: General Arrangement of the location of the North Star mine development envelope (in green) highlighting the location of the PLNb monitoring sites at Cave 13 and Fig Pool. The white 30 km circle indicates the study area centred on Cave 13 containing the previously unknown PLNb diurnal roost identified by ongoing monitoring at Cave 13 and Fig Pool. The location of the closest known diurnal/maternity roost is at Lalla Rookh mine, 32 km to the north east while the Mt Webber diurnal roost lies 40 km to the south east.

Climate

The climate of the Pilbara region of Western Australia is classified as arid tropical with two distinct seasons: a hot wet summer (October to April) and a mild dry winter (May to September). During the summer, heat-generated low pressure systems dominate the inland Pilbara region generating intermittent thunder storms. Tropical cyclones develop over warm tropical waters of the Indian Ocean to the north and west between December and April. These often track southwest along the Pilbara coast, or turn inland across the Pilbara bringing destructive winds, widespread rain and flooding (Payne and Tille, 1992). During winter the passage of high pressure systems to the south often produce easterly winds and some precipitation over the inland Pilbara (Van Vreeswyk *et al*., 2004).

Based on data from the nearest weather station at Marble Bar the mean annual rainfall is 360 mm, with very high seasonal and annual variability (Bureau of Meteorology [BOM], 2015). The mean maximum temperatures at Marble Bar are above 30˚C for nine months of the year and exceed 35˚C during the months of October to April. Mean maximum temperatures drop below 30˚C during the months of June to August. Minimum overnight temperatures exceed 15˚C for all but these cool months.

Topography and Geology

The study area occurs within the Interim Biogeographic Regionalisation for Australia (IBRA) PIL1 Chichester subregion of the Pilbara bioregion. It is located in the northern section of the Pilbara Craton and characterised by Archean basaltic and sedimentary mountainous areas, dissected by gullies and gorges, with plains and low hills of Granitic origin to the east and south west. The ranges are dominated by *Eucalyptus* spp over *Triodia* spp (spinifex) hummock grasses (Kendrick and McKenzie, 2001). Plains support a shrub steppe characterised by thin woodland over *Triodia* spp. Cave density is low with few deep natural caves apparent.

Surface Water

The study area contains numerous ephemeral water courses with the largest containing a small number of permanent and semi-permanent pools. The Shaw River to the east, Lost Boys Creek to the north and the Turner River to the west and their tributaries drain the area. Numerous ephemeral creek lines cross the ridges and plains.

Historical Mining Operations

Historic open-cut and underground mining operations have been underway for many years in the district. The underground operations are typically small scale with access by shallow shafts.

Approximately 32 km north east is the known PLNb diurnal/maternal roost at the abandoned deep Lalla Rookh mine. This colony has been estimated to contain over 1500 PLNb (author's unpublished data).

Bats of the Pilbara

The Pilbara region contains 17 species of Microchiropteran bat (microbat). Of these, 13 have the potential to be found in the Chichester subregion (Van Dyck and Strahan, 2008; McKenzie and Bullen, 2009). The PLNb (a small 10 g insectivore) is of National environmental significance and as such, is listed in the EPBC Act. The PLNb is endemic to northern Australia. The Pilbara population is isolated from the main tropical population by the uninhabitable arid zone to the north and east. The Pilbara population is semi-desert adapted and has specific roosting requirements of temperature and humidity.

The Pilbara Leaf-nosed Bat

The PLNb is listed as Vulnerable by the Commonwealth *EPBC Act*. It is also listed as Schedule 1 (fauna that is rare or likely to become extinct) under *Wildlife Conservation Act 1950*. This species listing is on the basis of the impact to habitats providing suitable roosts with the correct microclimate. It is a geographically isolated form of the tropical populations of Orange Leaf-nosed Bat, being separated by approximately 400 km of the Great Sandy Desert. The PLNb is known solely from the Pilbara and Ashburton bioregions of Western Australia. Approximately 30 identified diurnal roosts (Bullen 2013) are concentrated in caves in gorge systems and disused mines in the eastern Pilbara, in the Hamersley Ranges and in the Barlee Nature Reserve (DoE, 2014). Sites where PLNb are detected can be classified as one of three types. Foraging sites are used nocturnally and include caves that PLNb forage within and may rest in for short periods at night. Diurnal roosts are caves or manmade structures such as mine adits where the PLNb roost during daylight hours for part or all of the year. Permanent diurnal roosts are those that are occupied all year and are assumed to be maternity sites.

The PLNb is an acrobatic, high-energy flyer that forages for its prey along the gorges and ridgelines around its roost. It is most often observed in flight over water holes or flying along road easements approximately 1-2 m from the ground (Churchill, 2008). McKenzie and Bullen (2009) characterise its "mode" flight speed (*i.e.* the speed most often measured during free flight) as 6.1 $m.s^{-1}$ (22 kph).

Bat Call's unpublished data shows that speeds up to 20kph are commonly used while dispersing from the diurnal roosts. Bat Call's unpublished data also shows the species to be capable of level flight speeds in excess of 8.6 $m.s^{-1}$ (31 kph) while commuting to and from distant sites.

Foraging habitat for the PLNb is diverse. The species generally hunts with a manoeuvrable flight through riparian vegetation in gorges, and over hummock grassland and sparse tree and shrub savannah (Duncan *et al*., 1999). In the Pilbara, it has been observed in *Triodia* hummock grasslands covering low rolling hills and shallow gullies, with scattered *Eucalyptus camaldulensis* along the creeks (Armstrong, 2001; Churchill *et al*., 1988). It has also been recorded over small watercourses amongst granite boulder terrain; over pools and low shrubs in ironstone gorges; and above low shrubs and around pools in gravely watercourses with *Melaleuca leucodendron*, such as in Barlee Range Nature Reserve (Armstrong, 2001). It is often detected foraging in the entrances of caves and shelters (author's unpublished data).

In contrast to the tropical Orange Leaf-nosed Bat roosts located in a more mesic climate, documented PLNb roosts contain relatively small numbers ranging from a few individuals to a few hundred, with 30 appearing to be a typical Pilbara roost size based on published data (DoE, 2014). Recent census work at several roosts in natural caves suggests that several hundred to 1,500 is a more typical figure (Bat Call WA, unpublished data). One roost in the Western Hamersley ranges contains many thousands.

Across northern Australia, the Orange Leaf-nosed Bat is reliant on roost sites in caves or mine adits with stable, very hot (28–32°C) and very humid (96–100%) microclimates (Churchill 2008). This is a result of their limited ability to conserve heat and water (Churchill, 1991; Armstrong, 2001). Caves and abandoned mines deep enough to create this environment are relatively uncommon in the Pilbara (Van Dyck and Strahan, 2008), which limits the availability of diurnal roosts for this species. The PLNb is subject to rapid dehydration and death within a day if removed from a roosting location with this type of microclimate (Churchill 2008). The closest known roost to the project is at Lalla Rookh Mine with the Mt Webber roost cave being approximately 40 km to the south east. The closest roosts to the east and west are over 70 km distant. There appears to be a close correlation between PLNb roosts located to date and permanent water pools within a flying distance of approximately 5 km. (Bat Call WA, unpublished data).

PLNb are now known to depart and return to diurnal roosts at specific times of the night following a seasonal pattern (Bat Call unpublished data). Long term monitoring data from several known PLNb

colonies supported by data from other roost caves shows that during the dry season the bats begin to depart their roost within a few minutes of civil twilight on the majority of nights (Bullen 2013). This occurs unless there are overcast conditions lowering evening light levels when the bats begin to depart earlier, during summer electrical storms or during the very cold conditions of mid-winter when the bats begin to depart later. They then disperse over their foraging range typically using flight speeds up to their mode cruise speed of approximately 20 kph, returning before civil twilight in the morning.

The species is known to have a typical dry season foraging range of 15-20 km from its primary roost caves (Bullen 2013). It does forage at greater distances if suitable water sources are available (Bat Call WA, unpublished data). It also appears to range nomadically from these roosts when wet season conditions allow it to use satellite roosts and to consolidate back during the dry (Bullen and McKenzie 2011). It is not known if these ranges apply to males and females equally.

Methodology

Survey Team

The survey team for phase 1 consisted of Mr Robert Bullen of Bat Call and Mr Nick Barr of Fortescue. The team for phase 2 was Mr Craig Grabham of GHD and Mr Barr. Mr Bullen completed the identification of bat calls for both phases.

Survey Timing and Weather

Phase 1 was undertaken from 14th to 18th November 2014. For the survey, the weather was very hot and dry during the day followed by hot evenings typical of late dry season weather. Daytime temperatures were between 35 and 40°C and minimum night time temperatures were around 25°C. Sunset/rise times at North Star during the survey were within two minutes of 18:22 and 05:15. Similarly civil twilight times were within two minutes of 18:46 and 04:51. Civil twilight occurs when the Sun is 6 degrees below the horizon, both evening (civil dusk) and morning (civil dawn). There is enough natural sunlight during the period between sunset/rise and civil twilight that may deter some animals including bats from undertaking nocturnal activities. Therefore the active period of such animals is generally influenced by the civil twilight period. The moon was at last quarter during this period.

Phase 2 was undertaken during January and February 2015. The weather was very hot during the day followed by hot evenings typical of early wet season weather. Daytime temperatures were between 35 and 50°C and minimum night time temperatures were around 25°C. Thunderstorms in the district occurred throughout the period but no cyclonic rain events occurred. Reference meteorological data were taken from the Bureau of Meteorological site at Marble Bar (BoM 2015).

Phase 1 Site selection and foraging habitat assessment

Sites for echolocation recording (Figure 2) were selected to address the objectives of the study (see Introduction) and included Cave 13 and Fig Pool. All were within a 25 km radius of North Star. Sites were selected based on the likelihood that the PLNb would be roosting at or close by a cave, foraging at, or commuting past, the location, should they be present. Detectors were not deployed at sites to the northeast or southeast, close to the Lalla Rookh and Mt Webber roosts as PLNb from those roosts were most likely to be detected. Initially sites to the north of the mine were selected followed by sites to the west and south. The distant site to the south, NSnov10, was at the Mercury Hill mine location. Four sites were then selected within the mine envelope to characterise the level of PLNb activity close by the mine operations. Finally the most distant sites to the west were

selected to ensure that no additional roost was located in that area and to provide data to localize the diurnal roost. Access into all areas and therefore the number of sites that could be sampled was limited to the available 4WD tracks into the ranges and the proximity of Atlas Iron's Abydos mine to the north.

Typically during this type of survey, a subset of sites return detections that are close to the time of dusk or dawn civil twilight. Sites with time differentials less than 60 minutes, along with the usual commuting flight speed, can be used to indicate the maximum flying range of the bat from its source diurnal roost. When enough of these detections are made at scattered detection sites the approximate location of the diurnal roost can be inferred by triangulating the flying ranges.

An assessment of PLNb foraging habitat was undertaken at each site after Min. Stat. #993. The assessment was based on Bat Call's unpublished observations on the species collected over fifteen years. Each site was characterised as high, moderate or low following the definitions in Table 1.

Phase 2 Site selection

Sites for echolocation recording were selected by the survey team and are listed in Appendix A. All were within a 15 km radius of North Star. Sites were selected based on the likelihood that the PLNb would be roosting within a cave. Some sites were selected to provide information regarding activity levels to assist with the characterisation of roosting habitat within the survey area.

Table 1: Criteria for characterising foraging habitat rating.

Habitat Rating	Suitability for foraging
Low	PLNb are unlikely to forage in these areas but may traverse while crossing to more productive areas.
Moderate	PLNb may occasionally forage in these areas due to the presence of suitable vegetation, seasonal water and may also use areas regularly as a flyway
High	PLNb are likely to roost at or to forage in these areas if in flying range of a roost. They may be detected exiting a cave, passing along creek lines, vegetation lines or rock faces or foraging in the most productive areas e.g. cave entrances with insect swarms.

Bat Echolocation Recordings

Phase 1 Echolocation call data were collected at twenty two sites within the study area (Figure 2, Appendix B). At one site, NSnov03, detectors were placed on a cliff line nearby a deep cave entrance and at the cave entrance, sites '3A and '3B respectively. Phase 2 data were collected at a further twelve sites (Figure 3, Appendix C) with Joes Cave being surveyed on three separate occasions.

Full spectrum ultrasonic bat detectors (Songmeter SM2BAT+ and Echometer EM3+ models (phase 2 only), Wildlife Acoustics, USA) were used to record bat activity. The settings used on each SM2 detector are shown in Appendix A. During Phase 1 the detectors were deployed for a single night at each location and the data obtained were reviewed daily. During Phase 2, detectors were placed for multiple nights at sites and the recordings reviewed following recovery. PLNb presence was confirmed by recording of distinctive diagnostic ultrasonic calls at the sites. A PLNb call (pass) is usually a sequence of multiple consecutive pulses of similar frequency and shape (Figure 4). As the PLNb individual pulses are unique, calls with one or two pulses are easily identified.

The SM2BAT recordings, once reformatted as .wav files, were reviewed using COOL EDIT 2000 (Now available as AUDITION from Adobe Systems Inc.). This displayed each call sequence with information on the number and timing of calls. PLNb activity levels were then assessed from the identified calls (Table 2).

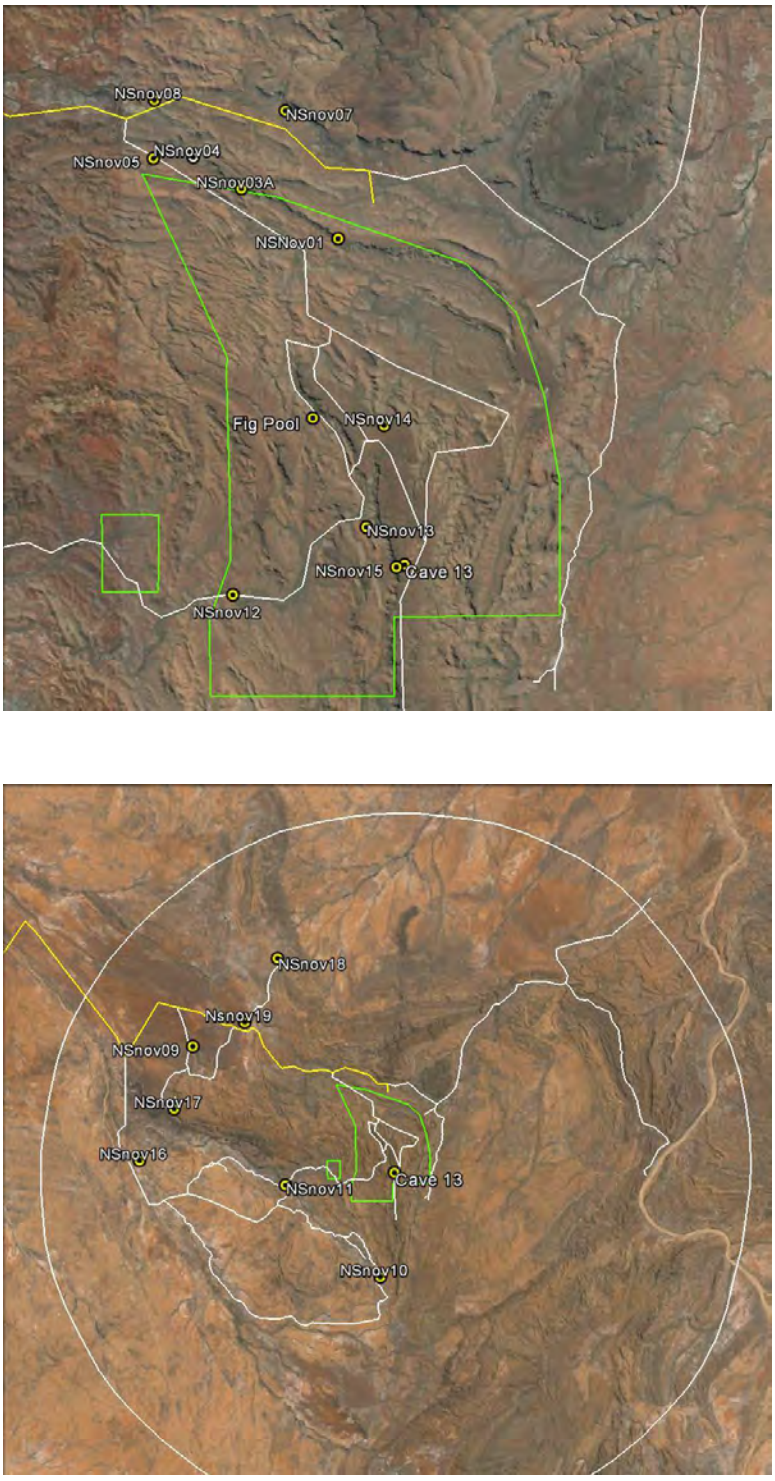


Figure 2: Phase 1 bat detector locations within the study area. The sites selected for assessment are numbered NSnov01 to NSnov19 (note that NSnov03 has site A and site B nearby) and include Cave 13 and Fig Pool. Figure 2A shows the sites within and nearby the mine while figure 2B shows the more distant sites selected. The green outline indicates North Star's mine development envelope. The white circle is the 30 km radius study area. The 4WD tracks providing access to the study area are indicated by the white lines. No echolocation sites were placed to the northeast, east and southeast due to the proximity of the Lalla Rookh and Mt Webber roosts and the high probability of detection of bats from those roosts. No data was collected from the adjoining Abydos mine operational area immediately to the north of North Star. Sites not shown are NSnov02, 03B and '06 which are nearby sites NSnov01, '03A and '04 respectively.

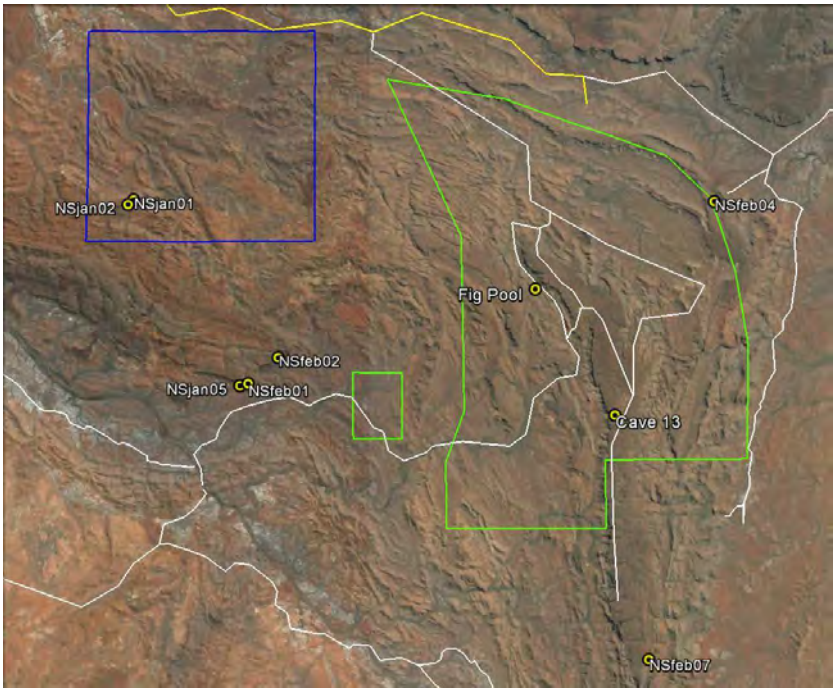


Figure 3: Phase 2 bat detector locations. Sites not shown are NSjan03, '04, '06, NSfeb03, '05 and '06 which are nearby site NSjan05. The blue square is the area identified during Phase 1 that is likely to contain the permanent diurnal roost (see Results section below).

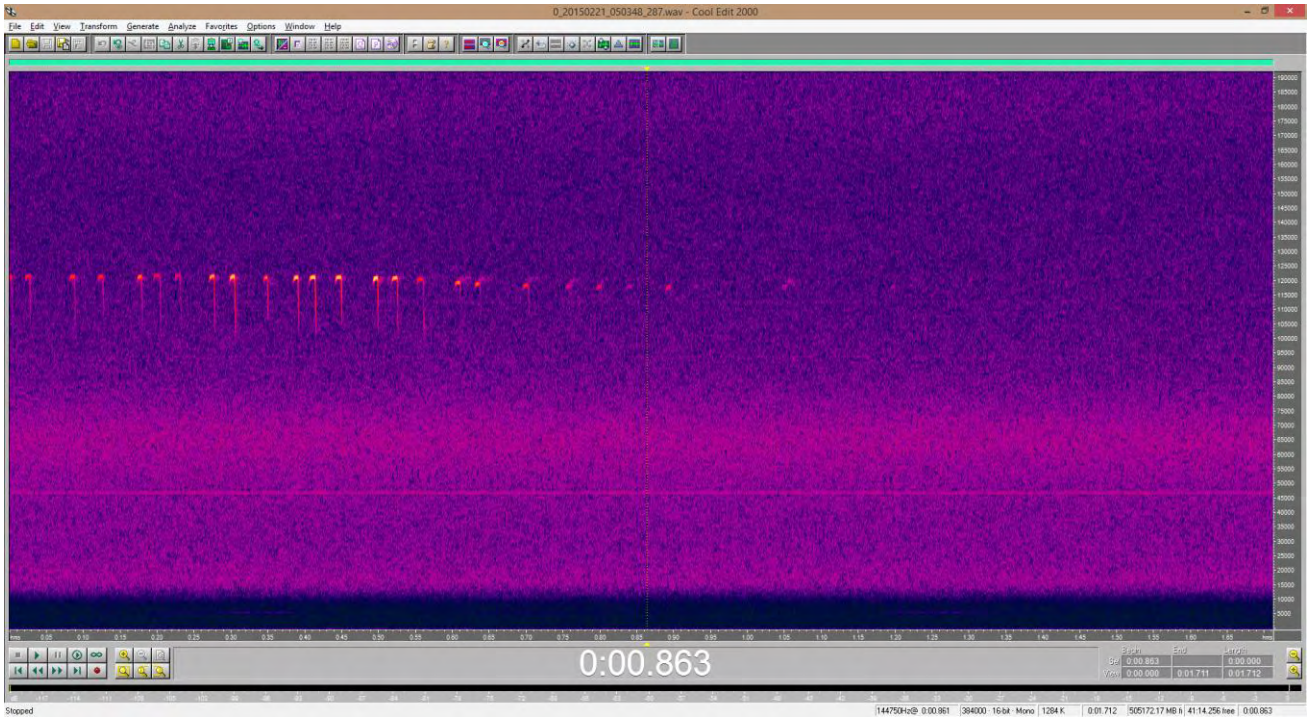


Figure 4: Example PLNb call detected at Cave 13.

Table 2: Criteria for characterising bat activity levels.

Bat Activity Rating	Criteria
Low	Species is recorded with call spacing greater than ten minutes.
Medium	Species is recorded with call spacing of less than 10 minutes but greater than 2 minutes. This pattern is observed for at least an hour followed by sporadic records for the remainder of the session.
High	Species is recorded with call spacing less than 2 minutes apart for at least two hours followed by regular records for the remainder of the session.
Very High	Species is recorded in very large numbers with call spacing less than 2 minutes apart for over four hours followed by regular records for the remainder of the session.

Note: activity levels show a measure of the number of bat passes. They do not directly provide a guide to the usage of the site as a roost, forage location, commute site, etc. or accurate abundance data. However, data may be used to assist in inferring such results.

Survey Limitations

The objectives of Phase 1 of the survey were the characterisation of the PLNb activity within, adjacent to and up to 30 km distant from the North Star mine envelopes and adjacent tenements (figure 1). All aspects of the regional survey except for remote country access, i.e. team make-up and experience levels, equipment used including bat detectors (provided by Bat Call) and 4WD vehicles, logistics and safety support (provided by Fortescue) were suitable for the task. Access to the majority of the area to the west of the mine development was not possible using 4WD vehicles. Limited access was able to be gained to the periphery of this area using the only available tracks. Access by foot into this tenement was impossible due to the distances and extreme heat encountered during the survey. No interior searches of caves were carried out. No activities were undertaken that could cause harm to the bats present.

The primary objective of Phase 2 of the survey was the characterisation of the PLNb activity primarily within the Blue Square and Zanes Gorge survey areas (Figure 3). Access to the majority of the area to the northwest of the mine development was difficult using 4WD vehicles. Limited access was able to be gained to Zanes Gorge and the "Blue Square" using the only available tracks. Further access by foot was limited due to the distances and extreme heat encountered during the survey. Therefore the majority of the area to the south of the "Blue Square" remains to be thoroughly searched.

Abundance estimates of the PLNb at the sites are impossible to calculate from ultrasonic recordings due to the possibility of multiple passes by individual bats. Instead, activity levels were documented based on the criteria above (Table 2). It is important to note that the number of bat passes recorded gives a measure of activity level. They do not directly provide a measure of the usage of the site as a roost, forage location, commute site, etc. or accurate abundance data. However, data may be used to assist in inferring such results.

Placement of detectors at the two probable diurnal roost sites (NSjan02 in the blue square and NSjan05 (Joes Cave), see results section below) were not made simultaneously. Therefore the conclusion that the two sites are independent diurnal roosts, while made with a high level of confidence, will need to be confirmed at a later date by a simultaneous detector placement.

Results

Phase 1

PLNb were detected at fourteen of twenty two sites (Figure 5). A broad pattern of calls is evident in the data with detections being made within, to the north and to the west of the mine area. Three sites produced High activity levels with greater than 50 calls per night recorded. These were the Cave 13 entrance, and the permanent pools at Tank Pool (site '09) and Kunagunarrina Pool (site '16) on the Turner River. The highest number of calls was at Cave 13 with 277. Ninety two and 72 calls were detected at sites '09 and '16 respectively. Medium level activity was recorded at four sites (25, 21, 32 and 38 calls at Fig Pool and sites '02, '03A and '03B respectively). Low activity was recorded at another seven sites with nightly call totals between one and thirteen. No detections were made at eight sites including the Mercury Hill mine to the south (site '10).

The temporal pattern of detections at each site (Figure 6) begins at least 50 minutes after sunset (the earliest call detected being at 1910 hours at site '02) and the latest call detected was approximately one hour before sunrise (04:18 hours at site '11). These patterns are all consistent with nightly foraging. This includes the result from Cave 13 where there is no evidence of PLNb roosting diurnally during this period despite a continuing high level of late night activity.

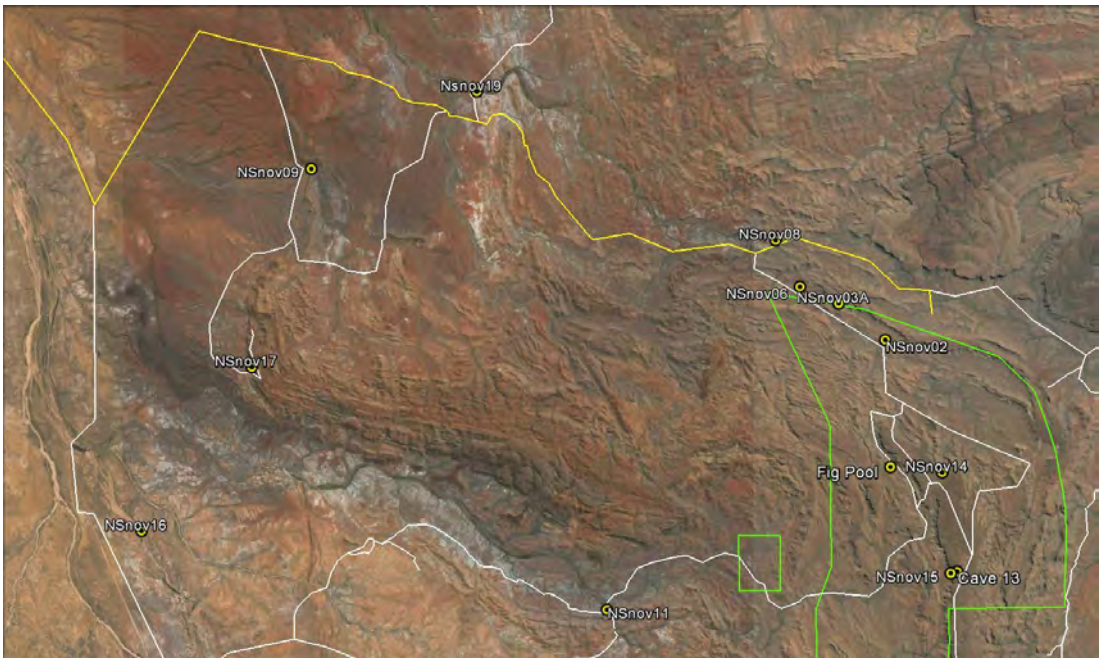
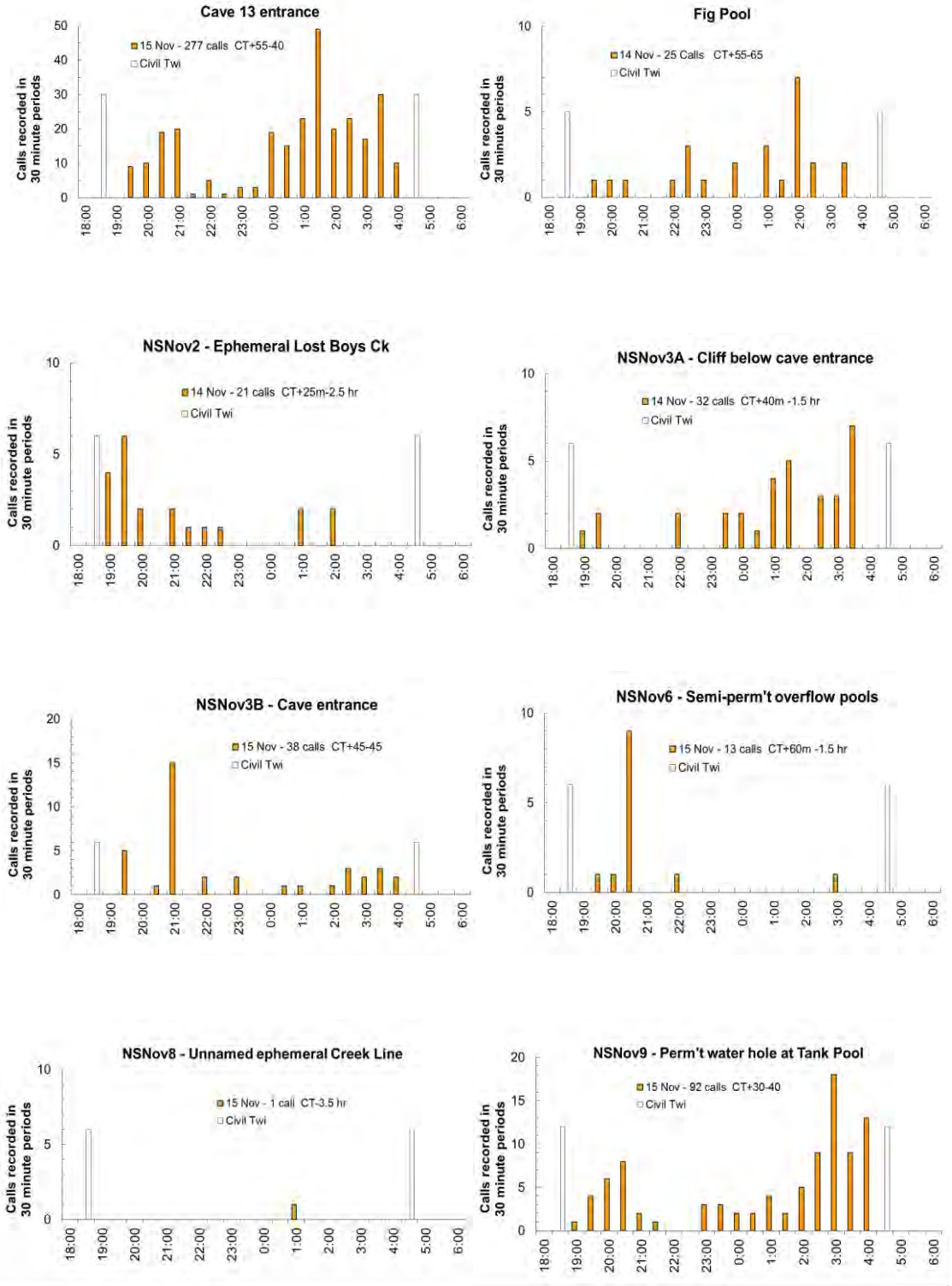
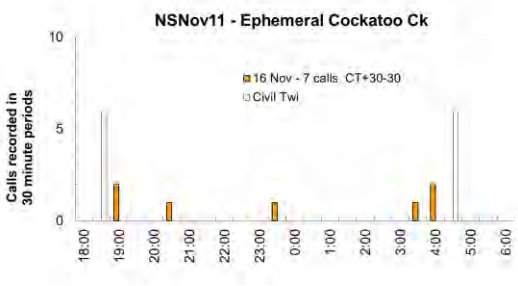
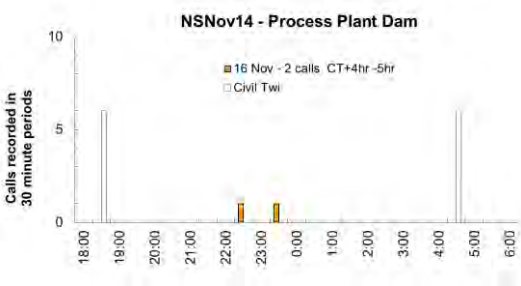


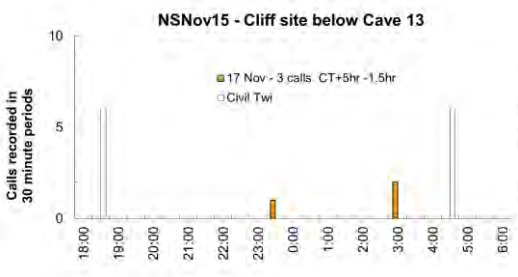
Figure 5. Location of Pilbara Leaf-nosed Bat detections during phase 1.

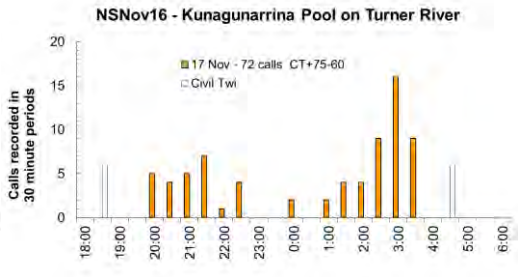
Figure 6. Series of graphs depicting the temporal patterns of phase 1 Pilbara Leaf-nosed bat call detections. The number of calls and the times of the first and last calls compared to civil twilight (in minutes unless otherwise noted) are shown. The civil twilight bars are shown for illustrative purposes of temporal pattern only.

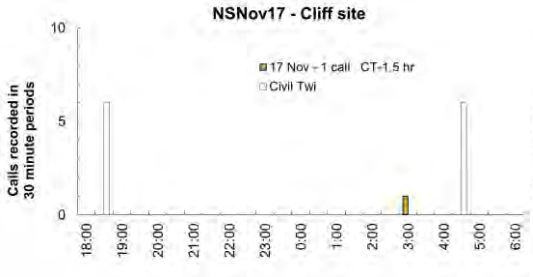


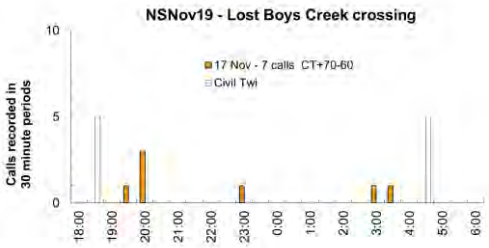

NSNov11 - Ephemeral Cockatoo Ck
16 Nov - 7 calls CT+30-30
Civil Twi
Calls recorded in 30 minute periods
0
5
10
18:00
19:00
20:00
21:00
22:00
23:00
0:00
1:00
2:00
3:00
4:00
5:00
6:00


NSNov14 - Process Plant Dam
16 Nov - 2 calls CT+4hr -5hr
Civil Twi
Calls recorded in 30 minute periods
0
5
10
18:00
19:00
20:00
21:00
22:00
23:00
0:00
1:00
2:00
3:00
4:00
5:00
6:00


NSNov15 - Cliff site below Cave 13
17 Nov - 3 calls CT+5hr -1.5hr
Civil Twi
Calls recorded in 30 minute periods
0
5
10
18:00
19:00
20:00
21:00
22:00
23:00
0:00
1:00
2:00
3:00
4:00
5:00
6:00


NSNov16 - Kunagunarrina Pool on Turner River
17 Nov - 72 calls CT+75-60
Civil Twi
Calls recorded in 30 minute periods
0
5
10
15
20
18:00
19:00
20:00
21:00
22:00
23:00
0:00
1:00
2:00
3:00
4:00
5:00
6:00


NSNov17 - Cliff site
17 Nov - 1 call CT-1.5 hr
Civil Twi
Calls recorded in 30 minute periods
0
5
10
18:00
19:00
20:00
21:00
22:00
23:00
0:00
1:00
2:00
3:00
4:00
5:00
6:00


NSNov19 - Lost Boys Creek crossing
17 Nov - 7 calls CT+70-60
Civil Twi
Calls recorded in 30 minute periods
0
5
10
18:00
19:00
20:00
21:00
22:00
23:00
0:00
1:00
2:00
3:00
4:00
5:00
6:00

Assessing the location of possible PLNb diurnal roosting sites.

The theoretical flying range from four of 14 sites (figure 7) with calls within 60 minutes of twilight (see Methods) is consistent with a roost that lies within approximately 4 km of a location 11 km northwest of Cave 13, Figure 7. This area is northwest of the impact area but overlaps Fortescue's tenement. This is primarily an upland area where Lost Boys Creek and its southern tributaries have cut gorges and gullies into the ranges.

The dispersal pattern of the earliest and latest calls at all sites where PLNb were detected, figure 8, also supports this location as the most likely one for the roost. This pattern shows that all of the calls lie within the area that can be reached when flying cross country at or below 20 kph. Further, this pattern shows that all sites where PLNb were detected are closer than 15km to the theoretical roost location.

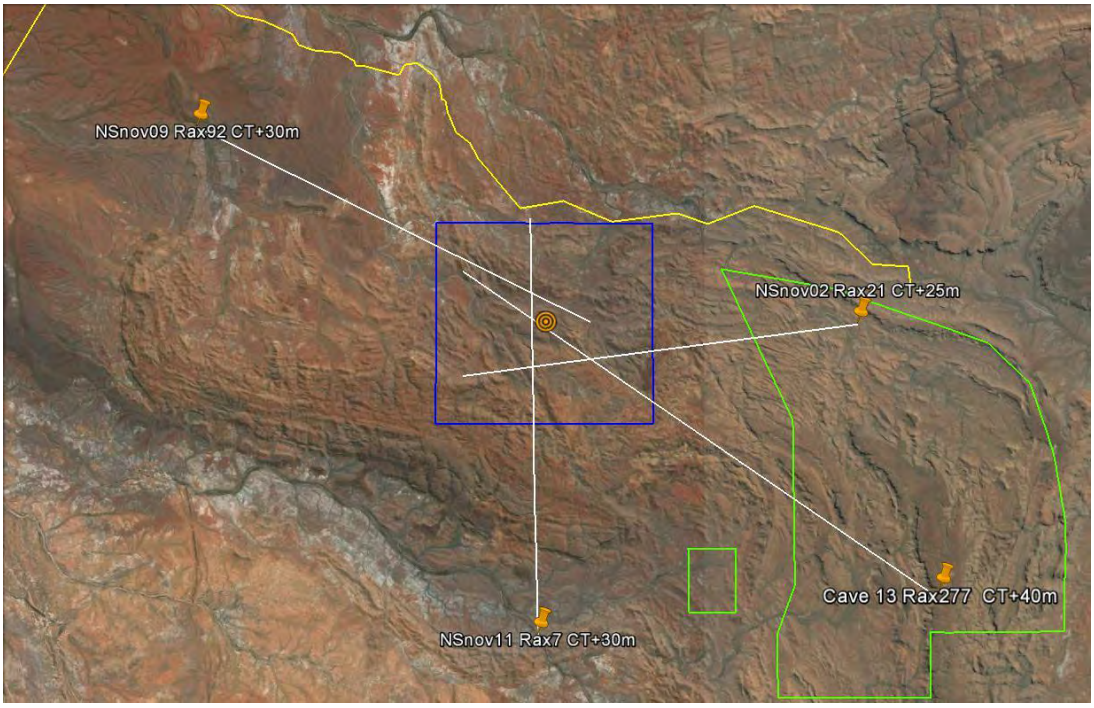


Figure 7. Results at four sites with calls within 60 minutes of twilight. Nightly PLNb call count and the time of the first call after civil twilight (CT) are shown. Triangulating the theoretical flying range from each (white rays) indicates that the roost lies within approximately 4 km of the location marked with the orange dot to the northwest of Cave 13, i.e. within or adjacent to the blue square.

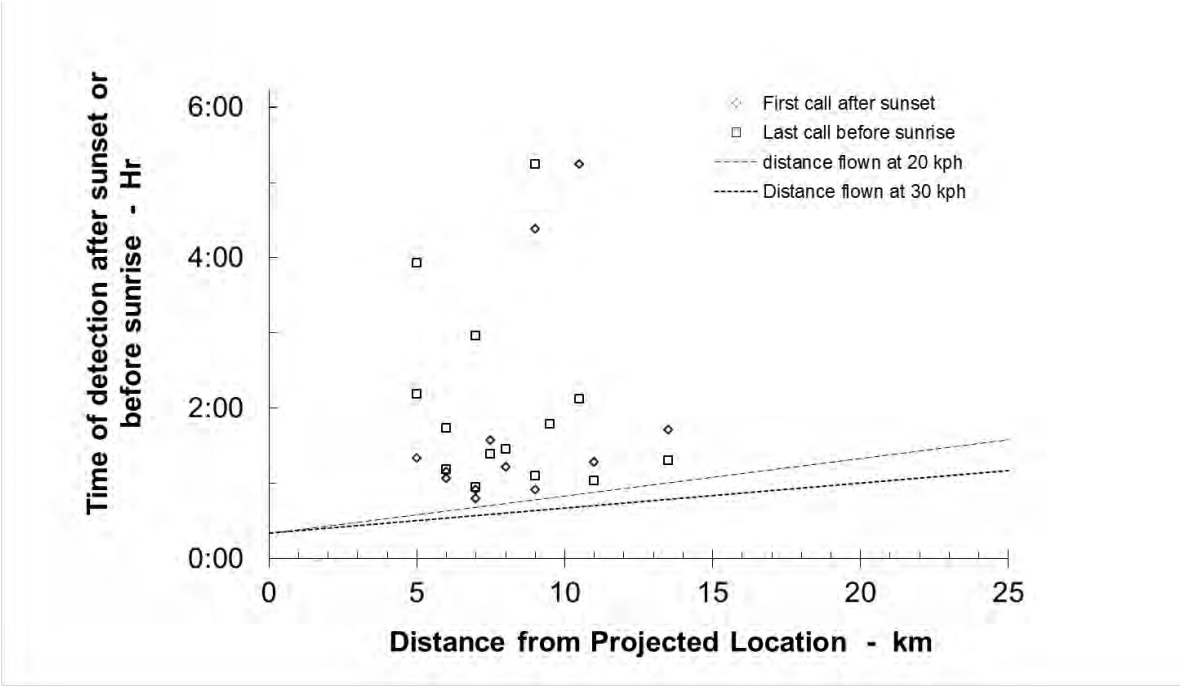


Figure 8. Dispersal pattern of the earliest and latest PLNb calls at all sites where PLNb were detected. Note that all fall above the 20 kph distance line which is well within the species theoretical flying range.

Phase 2 Results

PLNb were detected across a broad area but some sites had higher activity than others. Bats were detected at nine of twelve sites during the study (Figures 9, 10, 11 and Appendix C). Detections with high and very high activity levels were made within the targeted blue square in Nicko's Gorge (sites NSjan01 and '02), in an area around Zane's Gorge 5 km to the south east (sites NSjan03, '04, '05, NSfeb01, '05 and '06). Low activity levels were detected at a cave (site NSfeb04, Wayne Manor cave) to the north east of North Star near where limited foraging detections have been made in the past (Bat Call 2013).

Blue Square: Within the "blue square", two sites in Nicko's Gorge produced detections (sites NSjan01 and '02). An overhang close to a complex of caves, site '02, produced very high activity with 822 calls being detected on 11 January. The first and last calls at this site were five minutes after and at dusk and dawn civil twilight respectively. The temporal pattern shows continuous activity all night with peaks immediately after and before evening and morning twilight, Figure 11. This indicates that this overhang is in close proximity to a potential diurnal roosting site. Low activity levels beginning five minutes after civil twilight were detected at NSjan01. These detections were in small

groups that were approximately 1 hour apart for the period up to 21:45 hours that the detector was operating, indicating that this cave is a foraging location.

Zane's Gorge: Within the Zane's Gorge area, five of seven sites produced detections. At site NSjan05 (Joes Cave) variable activity was recorded in late January, early and late February. Call counts ranged from a low of 69 to a high of 1369. Between 23rd and 26th January the highest activity was recorded after sunset and on nights except the 23rd there was a second peak before sunrise. On the 23rd there were high activity levels all night following the initial peak. The initial calls were detected between 5 and 15 minutes after twilight and the last calls were between 10 minutes prior to and at twilight. Between 7th and 10th February there was a strong bimodal activity pattern with virtually no activity between 10 PM and 3 AM. The initial calls were detected between civil twilight and 15 minutes afterward and the last calls were between 15 minutes prior to and at civil twilight. From the 20th to 28th February there was consistent activity with between 200 and 1200 calls per night beginning and ending at civil twilight. The combined results of the temporal patterns, Figure 11, indicate that this cave was being used as a diurnal roost, between January and March. PLNb activity data are presented for Cave 13 in Figure 11 for comparison. These confirm that cave 13 was not used as a diurnal roost during this period.

PLNb were detected at three other caves in the Zane's Gorge area (NSjan03, '04 and NSfeb01), a gully site (NSfeb05) and a cliff site (NSfeb06). As demonstrated in figure 11, there were less than 250 calls per night at each. At NSjan03 the calls began a minimum of 25 minutes after and the latest were 5 minutes before twilight. At NSjan04 the calls began a minimum of 25 minutes after and the latest were 10 minutes before twilight. NSfeb05 close by NSjan04 gave similar results with approximately 200 calls beginning at 5 minutes after twilight. At NSfeb01 (Campview Cave) the calls began a minimum of 15 minutes after and the latest were 10 minutes before twilight. On each night the earliest and latest calls were between 5 and 25 minutes after/before those at NSjan05 (Joes Cave). The single exception was the latest call on the 7th February where the latest call was timed three minutes after that at Joes Cave. The nearby NSfeb06 gave similar results to cave NSfeb01. These patterns indicate that all three caves are foraging caves and not permanent diurnal roosts.

No PLNb calls were detected at caves NSfeb02 (Owl Cave) or '03 (Twin Peaks Cave).

Within the area to the north of North Star, Cave NSfeb04 (Wayne Manor) produced activity with a nightly activity maximum and minimum of 89 and 1 calls respectively. The first and last calls at this cave were at least forty minutes after and thirty five minutes before civil twilight in the evening and morning respectively. The temporal pattern at this cave entrance, Figure 11, indicates that this cave is a foraging cave distant from a diurnal roost.

No PLNb calls were detected at the South Star hill side site NSfeb07. Note that this site was not in front of a cave entrance.

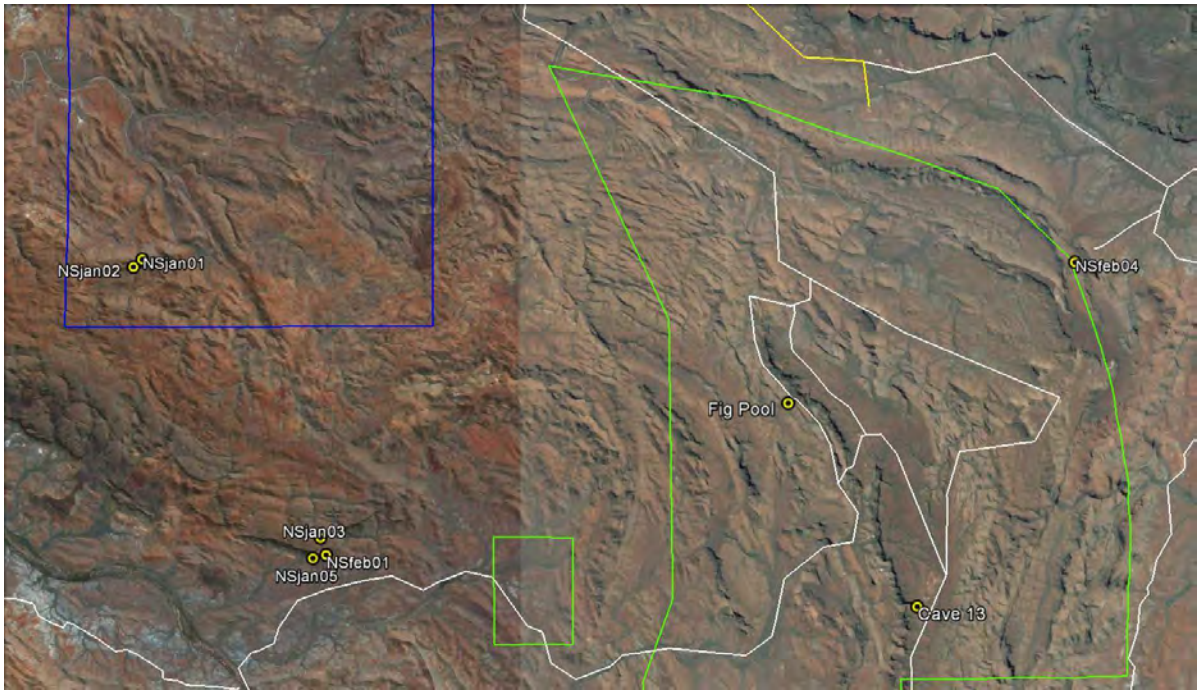


Figure 9. Location of Phase 2 sites where Pilbara Leaf-nosed Bats were detected. Cave 13 and Fig Pool are shown for context as are the green envelopes of the mine development area and the "Blue Square" from Phase 1. Sites not shown are NSjan04, NSfeb05 and '06 which are nearby site NSjan05.

A comparison of activity at the diurnal roost NSjan05 with Cave 13 where no PLNb were roosting (Bat Call 2015) can be made between 24 and 28 February, Figure 11. Activity levels at NSjan05 were higher with nightly call counts of 300 to 400 compared with 50 to 300 at Cave 13. Timing of the initial and final calls also differs with the timing differentials from civil twilight at NSjan05 being within 10 minutes compared with 30 to 90 minutes at Cave 13

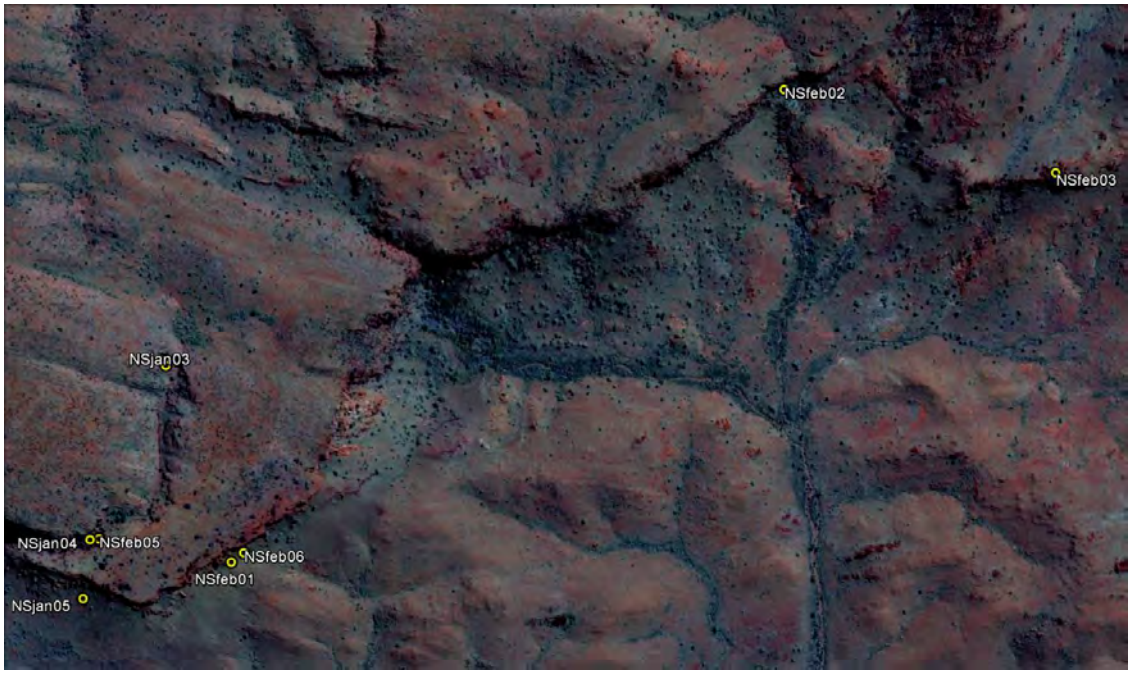
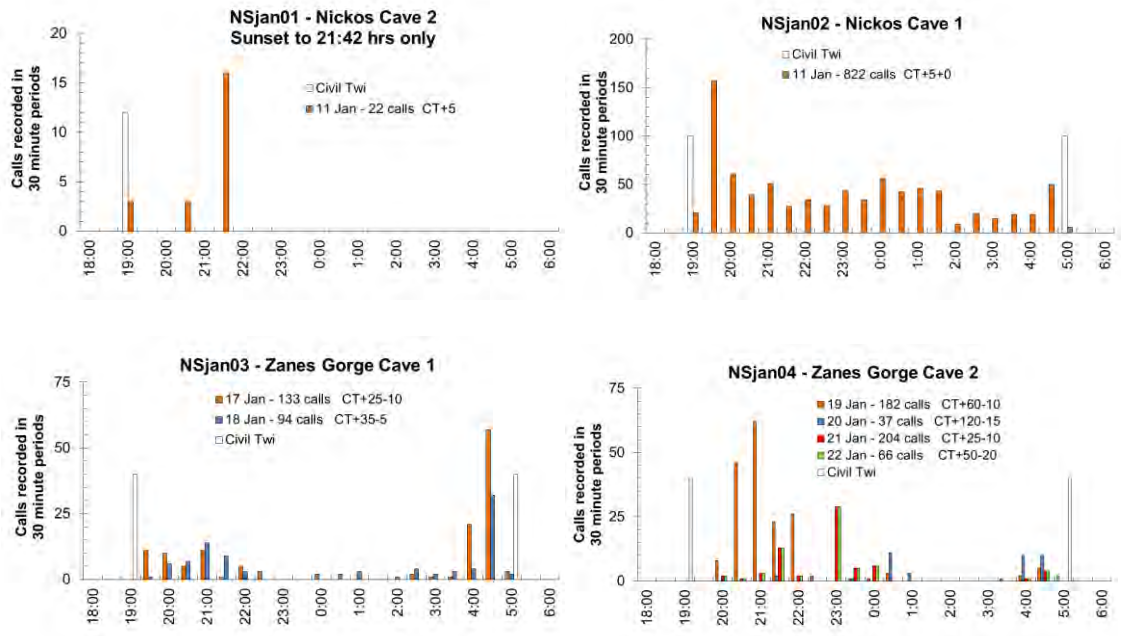
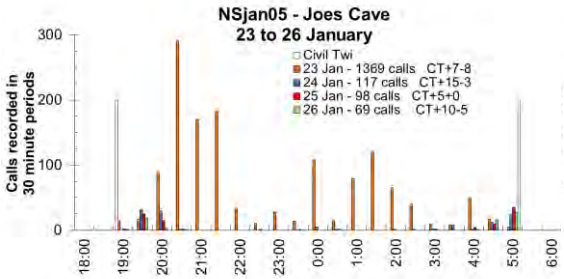
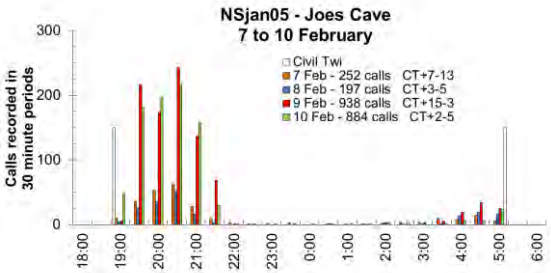


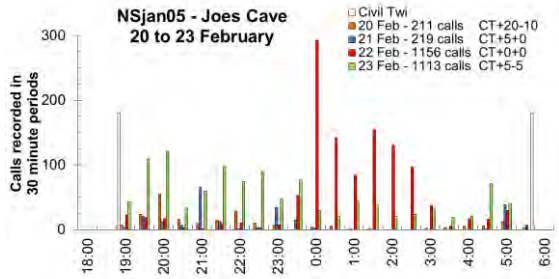
Figure 10. Location of detector sites in the immediate vicinity of site NSjan05 (Joe's Cave). PLNb were detected at all sites except NSfeb02 and NSfeb03.

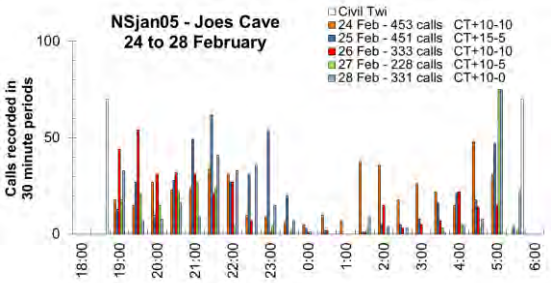
Figure 11. Series of graphs depicting the temporal pattern of Pilbara Leaf-nosed Bats calls recorded. For each site the number of calls detected is shown as is the timing of the earliest and latest calls (in minutes) after and before civil twilight. Cave 13 data for the period 24 to 28 Feb are shown for comparison.

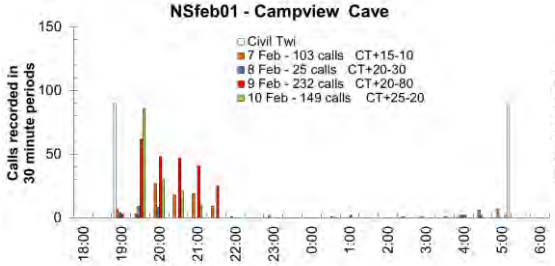


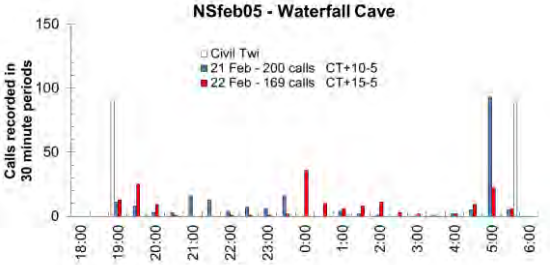

NSjan05 - Joes Cave
23 to 26 January
Civil Twi
23 Jan - 1369 calls CT+7-8
24 Jan - 117 calls CT+15-3
25 Jan - 98 calls CT+5+0
26 Jan - 69 calls CT+10-5
Calls recorded in 30 minute periods

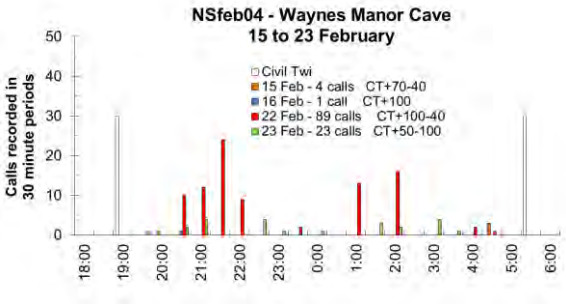

NSjan05 - Joes Cave
7 to 10 February
Civil Twi
7 Feb - 252 calls CT+7-13
8 Feb - 197 calls CT+3-5
9 Feb - 938 calls CT+15-3
10 Feb - 884 calls CT+2-5
Calls recorded in 30 minute periods

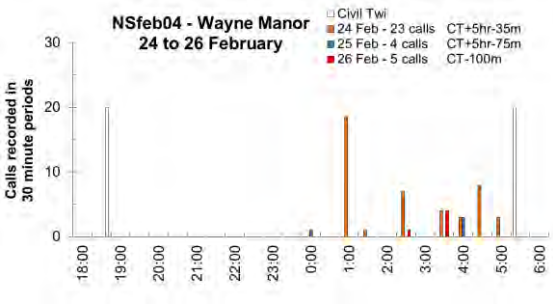

NSjan05 - Joes Cave
20 to 23 February
Civil Twi
20 Feb - 211 calls CT+20-10
21 Feb - 219 calls CT+5+0
22 Feb - 1156 calls CT+0+0
23 Feb - 1113 calls CT+5-5
Calls recorded in 30 minute periods

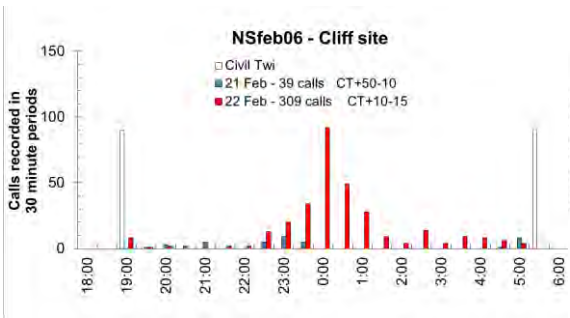

NSjan05 - Joes Cave
24 to 28 February
Civil Twi
24 Feb - 453 calls CT+10-10
25 Feb - 451 calls CT+15-5
26 Feb - 333 calls CT+10-10
27 Feb - 228 calls CT+10-5
28 Feb - 331 calls CT+10-0
Calls recorded in 30 minute periods

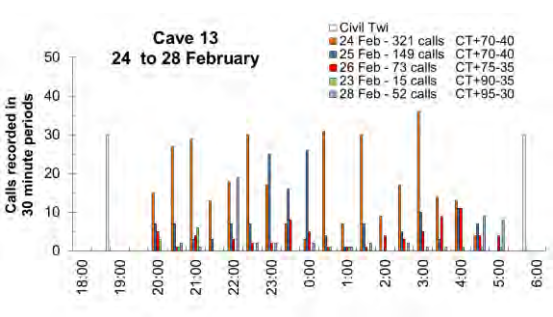

NSfeb01 - Campview Cave
Civil Twi
7 Feb - 103 calls CT+15-10
8 Feb - 25 calls CT+20-30
9 Feb - 232 calls CT+20-80
10 Feb - 149 calls CT+25-20
Calls recorded in 30 minute periods


NSfeb05 - Waterfall Cave
Civil Twi
21 Feb - 200 calls CT+10-5
22 Feb - 169 calls CT+15-5
Calls recorded in 30 minute periods


NSfeb04 - Waynes Manor Cave
15 to 23 February
Civil Twi
15 Feb - 4 calls CT+70-40
16 Feb - 1 call CT+100
22 Feb - 89 calls CT+100-40
23 Feb - 23 calls CT+50-100
Calls recorded in 30 minute periods


NSfeb04 - Wayne Manor
24 to 26 February
Civil Twi
24 Feb - 23 calls CT+5hr-35m
25 Feb - 4 calls CT+5hr-75m
26 Feb - 5 calls CT-100m
Calls recorded in 30 minute periods


NSfeb06 - Cliff site
Civil Twi
21 Feb - 39 calls CT+50-10
22 Feb - 309 calls CT+10-15
Calls recorded in 30 minute periods


Cave 13
24 to 28 February
Civil Twi
24 Feb - 321 calls CT+70-40
25 Feb - 149 calls CT+70-40
26 Feb - 73 calls CT+75-35
23 Feb - 15 calls CT+90-35
28 Feb - 52 calls CT+95-30
Calls recorded in 30 minute periods

Discussion

The results of the survey show that the ridges and creek lines in the vicinity of Iron Bridge provide foraging habitat for the PLNb with a medium to high activity rating. The majority of the high quality foraging habitat is in the ridges to the west and north of the project that contain ephemeral creeks and pools that remain through the dry season and also that contain caves and shelters that are likely to have nightly insect aggregations within their entrances. It is expected that a significant percentage of the bats from the colony(s) at Iron Bridge will use these pools, caves and gullies on a nightly basis. The area to the east includes the plain crossed by Honeyeater and Six Mile Creeks with the Shaw River more distant. To the south is a plain crossed by several unnamed tributaries of the Turner River. Both plains provide only low quality foraging habitat.

Call counts considerably higher than those recorded further east were recorded at two sites to the west of the project with 92 and 72 calls at sites NSnov09 and ’16 respectively during Phase 1. As these sites lie approximately 40 km from the nearest roost further west, it is not considered possible that PLNb originate from that roost. The timing of the closest calls to civil twilight suggests that the bats originate from the extended Iron Bridge project area while the call numbers suggest that these permanent pools are preferred foraging sites.

The results of the Phase 2 survey indicate that there are probable diurnal roost caves at NSjan05 (Joes Cave) and within the blue square at NSjan02 (Nickos Cave 1 complex). The two are 5 km apart which would take approximately 15 minutes for the bats to cover at their normal commuting flight speed. Timing of calls at each appears to be within 5 minutes of civil twilight although the detectors were not set out on the same nights. This indicates that the two roosts are separate and are both diurnal (but see the limitation of not having simultaneous detectors set). These two sites produced the highest call counts. Further survey work is required to confirm that either or both sites host permanent diurnal roosts.

No indication of a diurnal roost was found at cave NSfeb04 (Wayne manor Cave) or near South Star site NSfeb07 consistent with previous findings (Bat Call 2013).

In conclusion, several diurnal roosts have been identified within the survey area that may be permanent but this requires more work to be confirmed.

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Appendix A. SM2 Audio settings used during survey.

Parameter	Setting
Sample rate	384,000 kHz
Channel used	Left
Compression protocol	WAC2 (14 bit audio samples)
Gain - left channel	0.00
Digital high pass filter Left channel	Phase1: fs/4 giving 96 kHz minimum frequency Phase 2: fs/48 giving 8 kHz minimum frequency.
Triggering level Left channel	6SNR (adaptive +6 dB triggering)
Triggering window Left channel	1.0 sec.

Note: These settings are as recommended in Wildlife Acoustics (2010) except the high pass filter. This was set to 96 kHz in Phase 1 to target only Pilbara Leaf-nosed Bats that may be present.

Appendix C – FMGIB report

Report provided by Matt Dowling – Senior Environmental Advisor FMG

Survey methodology

Three days (25-28 March 2015) were spent searching the western cliff face of the North Star plateau for possible PLNB roost caves. Where a possible cave was observed, each cave was carefully entered to determine its extent and structure as suitable cave for PLNB. The western cliff face at North Star is very prospective for caves, with many cave openings observed from the available access tracks.

However, on closer inspection, almost all caves proved to be no more than shallow breakaways or blind-caverns with no internal structure suitable for PLNB. Of all caves inspected over the three days, only two caves were deemed suitable as diurnal roosting habitat for PLNB. These two caves were called Mammoth Cave and Chateau Cave.

Table 1 provides a description of the cave habitats and survey effort employed during the March 2015 field surveys. Figure 1 (in this Appendix) displays the sites surveyed by FMG during the March 2015 survey.

At the entrance to both caves, a Songmeter Bat (SM2 + bat) detector (Wildlife Acoustics) was positioned with microphone pointing in towards the back of the cave. Both detectors were set to record between 1800 hours and 0730 hours with files recorded in approximately 46 minute blocks. Detectors were set to record all bat calls at any frequency. However this report provides results from PLNB calls only.

Other bat species recorded on the SM2 include Gould's Wattled Bat (*Chalinolobus gouldii*), Common Sheath-tail Bat (*Taphozous georgianus*), Finlayson's Cave Bat (*Vespadelus finlaysoni*) and possibly Ghost Bat (*Macroderma gigas*). All of these species were visually observed in caves during the survey.

Table 2. Sites surveyed by FMG

Site Name/Survey Date	Location (GPS UTM coordinates)	Site Description, survey effort and observations
Borrow pit 24/03/15	712323.00 m E, 7649302.00 m S	SM2 unit. Cave is on the East face of a medium sized ridge that runs north south, The cave is a very large opening approximately 15 meters (m) high. There a several narrow tunnels at the back. Finlayson's Cave Bat and Common Sheath-tail Bat observed in the cave.
Chateau cave 5/03/15	[redacted]	SM2 unit. Infrared Acorn Camera set to record at 18:00 This cave has two entrances exiting the cliff face at North Star. The largest opening is approximately 3 m height to an initial chamber 5 m wide by 5 m depth. This opens up to a large hallway type chamber that runs 6 m. The end of the hallway splits to 3 chambers. The first chamber is a vertical shaft running approximately 6 m before vision is lost. The second chamber bends around a corner back in the same direction as the hallway approximately 4 m which then leads to the smaller of the two openings to the cliff face. The hallway roof then drops to a narrow aperture of approximately 60 cm which then opens out into a very large cavern (3rd chamber) with a roof height of approximately 3 m. The extent of this cavern cannot be

		observed by torchlight and the aperture is too small for safe passage. At the time of inspection, it was very humid in the cave. Large amounts of guano was observed on the cave floor. Several small bats were observed in the cave, most likely Gould's Wattled Bat, Finlayson's Cave Bat or Common Sheath-tail Bat.
Mammoth Cave 25/03/15	712999.00 m E, 7648533.00 m S	SM2 unit. Cave is on the West face of a medium sized ridge that runs north south just as it bends around to a gully, The cave is a very large opening approximately 20 m height. There several narrow tunnels at the back. One large vertical chamber extends around 8 m before vison is lost, this chamber daylights to the top but may have horizontal shafts out of view. Finlayson's Cave Bat and Common Sheath-tail Bat observed in the cave.
Vertical Cave 28/03/15	703209.86 m E, 7650132.64 m S	Cave is on the east face of a medium sized wall in a small north south running valley. The cave has a medium sized opening to a 3 m x 2 m cavity that is 4 m high. The top of the cavity extends to another cavity that flattens out. Full extent of the back cavity was not explored as it is high and narrow. Finlayson's Cave Bat and Common Sheath-tail Bat observed in the cave.
Cliff Cave 28/03/15	703167.04 m E, 7650128.31 m S	Cave is on the east face of a medium sized wall in a small north south running valley. The cave has a very large opening with a wall at the back 2 m high. The top of the 2 m wall slopes back up towards the roof to a 1 m wide by 0.5 m high opening, this leads to a 5 m deep 5 m wide 5 m high cavity. Full extent of the back cavity was not explored. Finlayson's Cave Bat and Common Sheath-tail Bat observed in the cave.
Shale Cave 28/03/15		Very open approximately 4 m x 4 m x 4 m space. Approximately 12 Finlayson's Cave Bat and Common Sheath-tail Bat observed in the cave.
Wallaby Cave 26/03/15	709983.00 m E, 7650577.00 m S	Anabat unit. Infrared Acorn Camera set to record at 18:00. Cave is on the east face of a small shallow sized ridge that runs north south. Small opening approximately 1 m height to an initial chamber 5 m wide by 5 m depth 5 m height. This opens up to a small narrow chamber that runs 8 m. There is a second lower chamber that runs for approximately 3 m before vision is lost. Four Ghost bats exited the cave. Possible Finlayson's Cave Bat and Common Sheath-tail Bat.

Analysis method

Bat calls were recorded from the entrance of two caves named Mammoth Cave and Chateau Cave during field surveys using Songmeter Bat (SM2 + bat) detectors (Wildlife Acoustics). Data from SM2 + bat detectors at Chateau Cave and Mammoth was analysed using Song Scope V4.1.3A.

A call sequence is defined as multiple pulses with at least half a second between the completion of one sequence and the beginning of another sequence. No sequence recorded was greater than 1.5 seconds. Plate 1 below demonstrates a single pulse, while Plate 2 demonstrates a call sequence.

Plate 1: Pilbara Leaf-nosed Bat Pulse

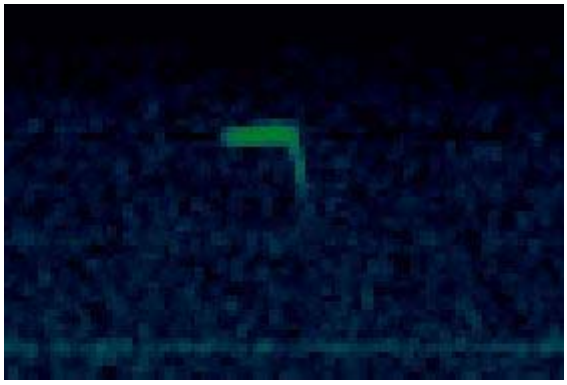
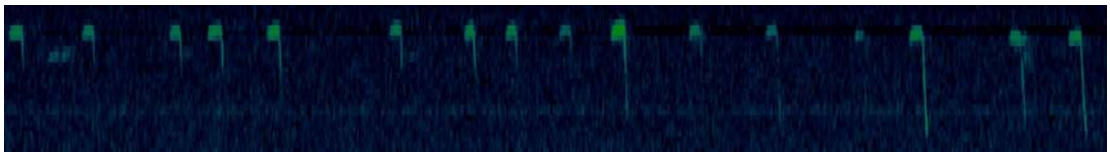


Plate 2: Pilbara Leaf-nosed Bat Call Sequence.



Results

Summary of results and survey effort

Microchiropteran bat surveys using SM2+ detectors were completed at two (2) sites for three nights at Mammoth Cave and 4 nights at Chateau Cave in the period 25-29 March 2015, totalling 7 nights within the study area. A total of 95 hours from 7 nights of recording survey effort (both sites combined) was completed.

Tables 2 provide a summary of the results for each site within the study area.

PLNB account

Both Mammoth Cave and Chateau Cave recorded Pilbara Leaf-nosed Bat activity. Calls attributed to *R. aurantia* recorded from the study area are characterised having flat pulses starting at approximately 119 kHz. Call sequences from the Mammoth Cave were generally long containing 20 or more pulses with stronger pulses containing a characteristic kink usually dropping to 100 kHz. Calls are undoubtedly *R. aurantia*, as no other Pilbara species exhibits calls at this 119 kHz frequency.

Table 2. Summary of Songscope analysis – Mammoth Cave and Chateau Cave Call Sequences

Species/Group	Mammoth Cave 25-28 March 2015	Chateau Cave 25-19 March 2015
Rhinonicteris aurantia call sequences	25	82
Approx. survey effort (hrs:min)	41.5	53.5
Start – finish time	1800-0730	1800-0730
Bat activity	1936 - 0052	1941 - 0406
Notes	Night (foraging) roost only	Night (foraging) roost only

Discussion

Mammoth Cave

This cave is a large cavern with a chute at the back of the cavern leading up to the surface of the North Star plateau. Dim daylight can be observed at the top of the chute. During inspection of the cave, several small bats were observed flying in the chute, most likely Gould's Wattled Bat, Finlayson's Cave Bat or Common Sheath-tail Bat.

Nine sequences were detected on 25-26 march, 14 sequences on 26-27 March and just two sequences on the 27-28 March. First call detection on 25 March was at 23:35 hours. First detection on 26 March was 19:36 hours and first detection on 27 March was 21:59 hours. Given the structure of the cave allowing humidity to escape (very large opening and daylighting to the surface), the low number of calls and the late timing for first call detection, it is concluded that Mammoth Cave is unlikely to be a diurnal or maternity roost cave and is likely to be a nocturnal roost cave.

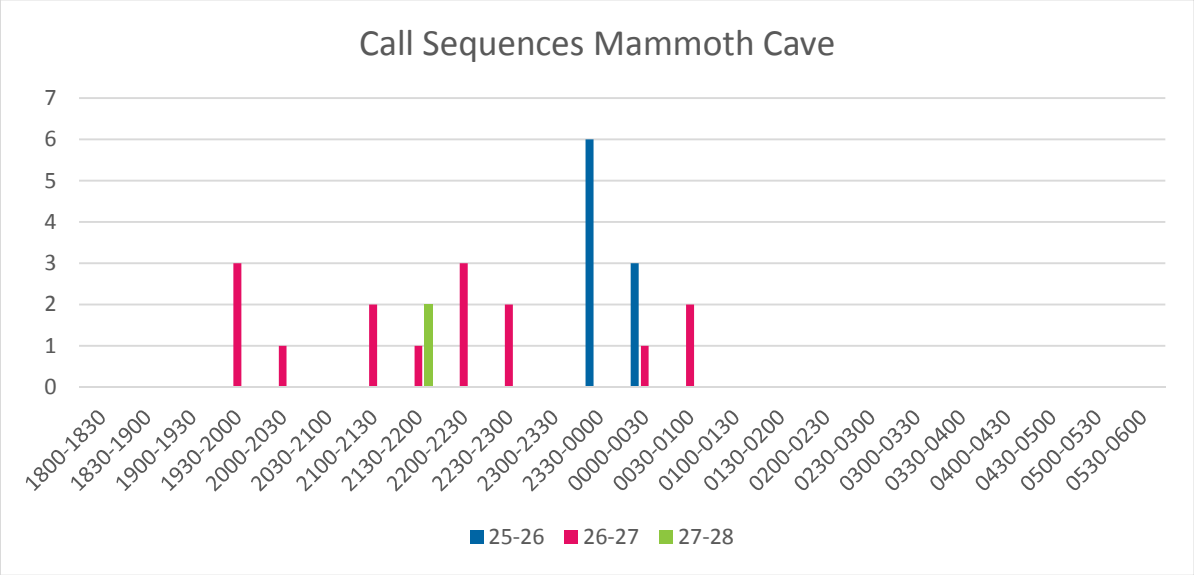
Chateau Cave.

This cave has two entrances exiting the cliff face at North Star. The largest opening is approximately 3 m height to an initial chamber 5 m wide by 5 m depth. This opens up to a large hallway type chamber that runs 6 m. The end of the hallway splits to 3 chambers. The first chamber is a vertical shaft running approximately 6 m before vision is lost. The second chamber bends around a corner back in the same direction as the hallway approximately 4 m which then leads to the smaller of the two openings to the cliff face. The hallway roof then drops to a narrow aperture of approximately 60 cm which then opens out into a very large cavern (3rd chamber) with a roof height of approximately 3 m. The extent of this cavern cannot be observed by torchlight and the aperture is too small for safe passage. At the time of inspection, it was very humid in the cave. Large amounts of guano was observed on the cave floor. Several small bats were observed in the cave, most likely Gould's Wattled Bat, Finlayson's Cave Bat or Common Sheath-tail Bat.

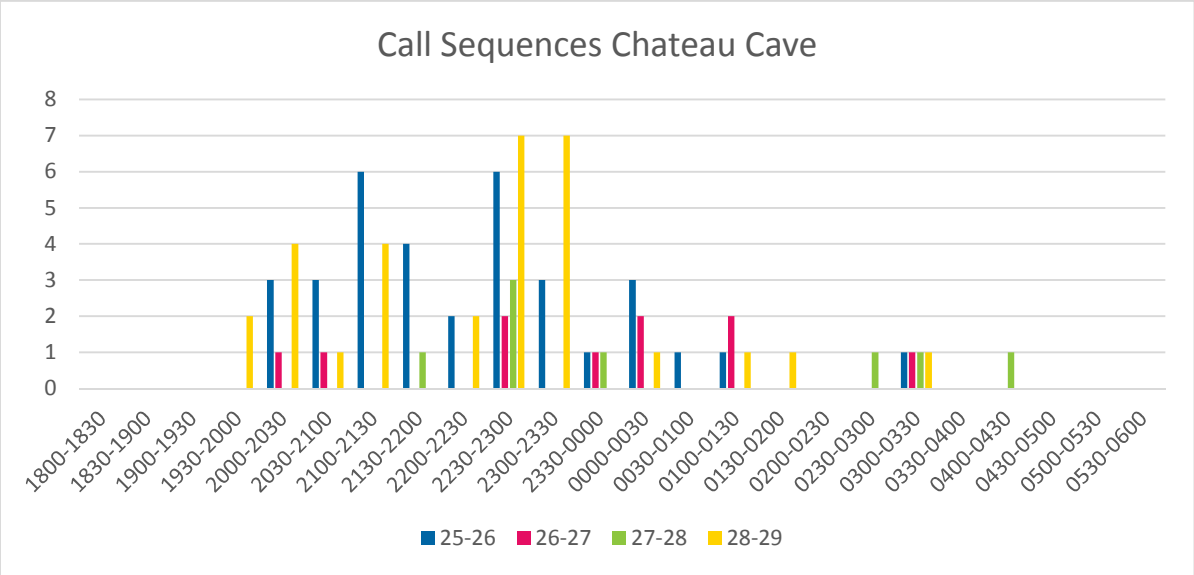
Thirty three (33) call sequences were detected on 25 March beginning at 20:24. Most activity was detected between 21:00 and 00:30 hours. The latest call was detected at 03:25 hours. Nine (9) call sequences were detected on 26 March beginning at 20:23 hours. The latest call was detected at 03:20 hours. Eight (8) call sequences were detected on 27 march beginning at 21:54 hours. The last call was detected at 04:06 hours. Thirty two (32) call sequences were detected on 28 March with the first call detected at 19:41 and the last call detected at 03:19 hours.

The cave structure at Chateau Cave would lend itself to being suitable as a diurnal roost cave for PLNB. However, the pattern of call detections, commencing well after sunset (peak activity well after sunset, between 9 pm and 12 am) and the low numbers of calls suggest that at the time of survey, the cave was being used as a night foraging roost cave only.

Graph 1: Call patterns at Mammoth Cave

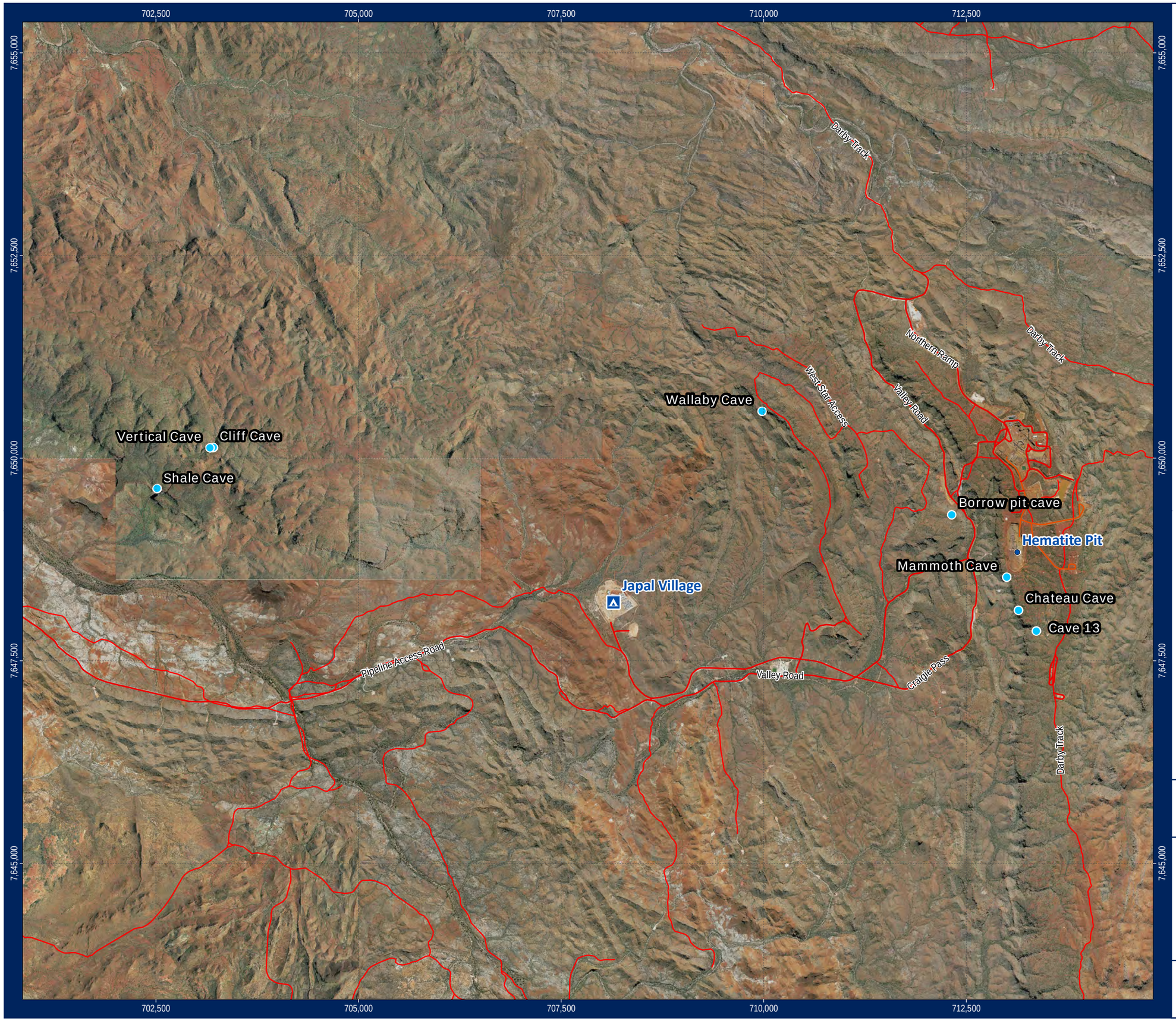


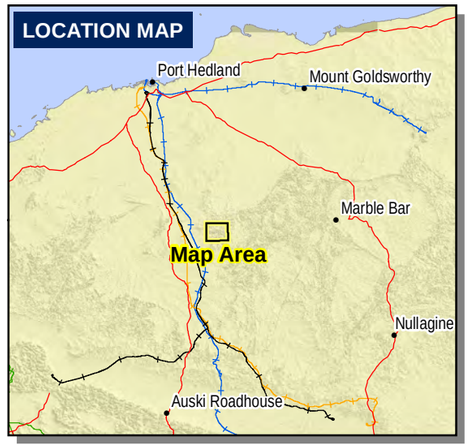
Graph 2: Call patterns at Chateau Cave



Other Caves.

No PLNB call sequences were detected at Borrow Pit Cave or Mammoth Cave.





Map Legend

- Bat Habitat Survey Points
- Camp
- Infrastructure
- Roads

Data Source(s):
All data FMG Sourced

N

0 500 1,000 1,500 2,000 2,500
metres

Bat Habitat Survey March 2015
North Star - Iron Bridge Project

Requested By: Matthew Dowling
Drawn By: A. McGonagle
Revised By: amcgonagle
Approved By: Paul Mastalir
Scale: 1:45,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: 661MI_0000_MP_EN_0015.001_r1

Date: 6/10/2015
Size: A3L
Revision: 1
Confidentiality: 0

Iron Bridge

Appendix E – Photographs of caves / sites

Location / site name/ date	Plate number	
Blue square		
Site 1 8/1/15	Plate 1	  
Site 2 8/1/15	Plate 2	

		
Site 8 9-10/1/15	Plate 3	 Cave entrance  Looking into cave from entrance 

Site 10 10/1/15	Plate 4	 
Site 11 10/1/15	Plate 5	 

Site 12 10/1/15	Plate 6	 
Site 13 10/1/15	Plate 7	 
Blue Square / Nicko's Gorge		

Site 14 11/1/15	Plate 8	 
Site 15 11/1/15	Plate 9	
Site 16 11/1/15	Plate 10	

Site 17 11/1/15	Plate 11	 Cave entrance  Looking into cave from entrance along passage 
Site 18 11/1/15	Plate 12	

Site 19 11/1/15	Plate 13	 Entrance to cave (bat detector)  Looking into cave from entrance – note opening to small chamber 
Site 20 12/1/15	Plate 14	

Site 21 12/1/15	Plate 15	
Zane's Gorge		
Site 22 21/2/15	Plate 16	 Cave 1 above pool  Cave entrance 

Site 23 21/2/15	Plate 17	 Cave 2 entrance  Looking into cave from entrance 
Site 24 21/2/15	Plate 18	Looking at entrance to Joe's Cave behind trees 

Joe’s Cave entrance

Looking into passage into main chamber from entrance

Small chamber at back of Joe’s Cave

Main chamber of Joes Cave near back wall – note low ceiling

		
Site 25 21/2/15	Plate 19	Looking up into Owl Cave  Chamber of Owl Cave 
Site 26 21/2/15	Plate 20	Twin Peaks Cave entrance

		 Ghost Bat scats Twin Peaks Cave 
North-east of NS operations		
Site 27 21/2/15	Photos	Entrance Wayne Manor (note SM2 detector at entrance)  View from entrance into main chamber

Small sub-chamber off rear wall of middle chamber of Wayne Manor

Small sub-chambers off rear wall of middle chamber of Wayne Manor

GHD

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Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A	C. Grabham	-	-	-	-	-
0	C. Grabham	D. Farrar		D. Farrar		02/11/2015

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