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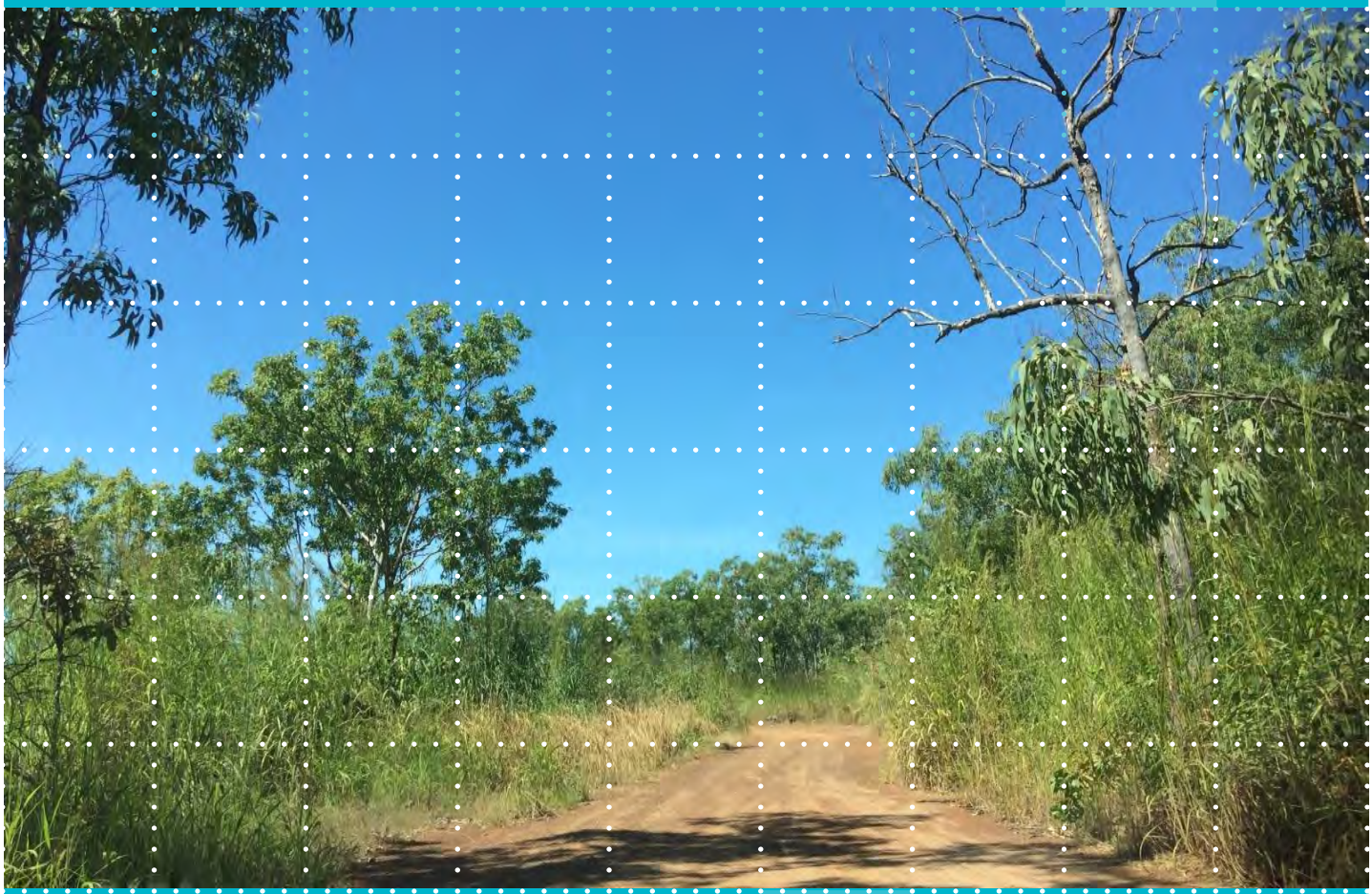
Final Report

Environmental Impact Statement: Lee Point Master-planned Urban Development

Prepared for

Defence Housing Australia

July 2018



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ACRONYMS AND ABBREVIATIONS

2CRU	2 Control and Reporting Unit
AAPA	Aboriginal Areas Protection Authority
ABS	Australian Bureau of Statistics
AHD	Australian Height Datum
BOM	Bureau of Meteorology
C	Commercial (Planning Zone)
CBD	Central Business District
CDU	Charles Darwin University
CEMP	Construction Environment Management Plan
CN	Conservation (Planning Zone)
CP	Community Purpose (Planning Zone)
CV	Caravan Park (Planning Zone)
DCA	Development Consent Authority (Darwin Division)
Defence	Department of Defence
DENR	NT Department of Environment and Natural Resources
DHA	Defence Housing Australia
DIPL	Northern Territory Department of Infrastructure, Planning and Logistics
DoEE	Commonwealth Department of the Environment and Energy
DoS	Degree of Saturation
DoT	Department of Transport
DRLUP	Darwin Regional Land Use Plan
EA Act	Northern Territory *Environment Assessment Act 1982*
EIS	Environmental Impact Statement
EP	Equivalent Persons
EPA	Northern Territory Environment Protection Authority
EPANGDS	Environment Protection Authority's Noise Guidelines for Development Sites in the Northern Territory
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
ESCP	Erosion and Sediment Control Plan
ESC	Ecological Sustainable Development
FD	Future Development (Planning Zone)
GDE	Groundwater Dependent Ecosystem
GP	Gross Pollutants
ha	Hectare
HR	High Density Residential (Planning Zone)
km	Kilometre

KPI	Key Performance Indicator
LOS	Level of Service
m	Metre
MD	Multiple Dwelling (Planning Zone)
MDR	Medium Density Residential (Planning Zone)
MSDS	Material Safety Data Sheet
MUSIC	Model for Urban Stormwater Improvement Conceptualisation
NAFI	Northern Australia Fire Information
NES	National Enviornmental Significance
NRET	NT Natural Resources, Environment and the Arts
NT	Northern Territory
OR	Organised Recreation (Planning Zone)
PER	Public Environment Report
PMST	Protected Matters Search Tool
The Project	Lee Point Master-planned Urban Development
Project footprint	Areas that could potentially be impacted by the project, i.e. 2CRU, Muirhead North, Sandy Creek, Buffalo Creek and Casuarina Beach.
Project site	2CRU (Lot 04873) and Muirhead North (Lot 09370)
PS	Public Open Space (Planning Zone)
PWC	Northern Territory Power and Water Corporation
SD	Special Use Darwin (Planning Zone)
SPS	Sewer Pump Station
TC	Tourist Commercial (Planning Zone)
TIA	Traffic Impact Assessment
TN	Total Nitrogen
ToR	Terms of Reference
TP	Total Phosphorous
TPWC Act	NT *Territory Parks and Wildlife Conservation Act*
TSS	Total Suspended Solids
UDIA	Urban Development Institute of Australia
WQO	Water Quality Objective
WM Act	NT *Weed Management Act 2001*
WoNS	Weed of National Significance
WSUD	Water Sensitive Urban Design

CONTENTS

1 INTRODUCTION 8
1.1 Background 8
1.2 Purpose 8
1.3 Structure 9
1.4 Defence Housing Australia (the proponent) 11
1.5 Supplement 12
2 PROJECT DESCRIPTION 13
2.1 General Information 13
2.2 Project Site 13
2.3 Climate 15
2.4 Project Description 18
3 RISK ASSESSMENT 22
3.1 Introduction 22
3.2 Method 22
3.3 Results 22
4 HYDROLOGY 28
4.1 Introduction 28
4.2 Existing Conditions 29
4.3 Risk Assessment 41
5 AIR QUALITY 54
5.1 Introduction 54
5.2 Existing Conditions 55
6 UTILITIES AND INFRASTRUCTURE 66
6.1 Introduction 66
6.2 Existing Conditions and Impacts 66
6.3 Risk Assessment 78
7 BIODIVERSITY AND HERITAGE 82
7.1 Introduction 82
7.2 Existing Conditions 83
7.3 Risk Assessment 145
7.4 Significant Impact Assessment 156
7.5 Environmental Offsets 169
8 SOCIAL ECONOMIC 176

8.1 Introduction 176
8.2 Legislation 177
8.3 Locality 178
8.4 Lee Point Master Planned Urban Development 180
8.5 Existing Conditions and Project Impact 186
8.6 Risk Assessment 207
9 NOISE 220
9.1 Introduction 220
9.2 Existing conditions and impacts 221
9.3 Risk Assessment 230
10 CONCLUSION 234
11 REFERENCES 236
APPENDIX A 243
Terms of Reference 243
APPENDIX B 245
Contributors 245
APPENDIX C 246
Risk Assessment 246
APPENDIX D 247
Construction Environmental Management Plan 247
APPENDIX E 248
Stormwater Management Plan – 2CRU 248
APPENDIX F 249
Stormwater Management Plan – Muirhead North 249
APPENDIX G 250
Biting Insect report 250
APPENDIX H 251
Noise Impact Assessment report – 2CRU 251
APPENDIX I 252
Noise Impact Assessment report – Muirhead North 252
APPENDIX J 253
Odour Impact Assessment report 253
APPENDIX K 254
Traffic Impact Assessment report - 2CRU 254

APPENDIX L 255
Traffic Impact Assessment report – Muirhead North 255
APPENDIX M 256
Black-footed Tree-rat report 256
APPENDIX N 257
Migratory Shorebird report 257
APPENDIX O 258
Water Quality Monitoring Plan 258
APPENDIX P 259
Supplement to the EIS 259
APPENDIX Q 303
Correspondence 303
APPENDIX R 304
Site Auditors Report (AECOM 2016) 304
APPENDIX S 305
Muirhead North: Stage 1 Preliminary Site Investigation 305
APPENDIX T 306
Water Discharge Licence WDL 147-05 Annual Audit and Compliance Report (December 2014) 306
APPENDIX U 307
Waste Discharge Licence 147-08 307

1 INTRODUCTION

1.1 Background

Defence Housing Australia (DHA) is proposing the Lee Point Master-planned Urban Development (the project) which will establish a residential, tourism, community and commercial precinct on a 132.5 hectare (ha) site (the project site) located on the outskirts of Darwin, in the suburb of Nightcliff. The project site consists of two properties bisected by Lee Point Road, including a former Department of Defence (Defence) installation that was operated by the 2 Control and Reporting Unit (2CRU) on the western side of Lee Point Road (referred to as the 2CRU site), and vacant crown land on the east side of Lee Point Road (referred to as Muirhead North) The project will provide for residential lots at a range of densities, providing much needed affordable housing for Defence families and for members of the public. The project will involve a Main Street precinct that will include a tourism activity centre containing restaurants, cafes, hotels, self-contained apartments and retail shops which will capitalise on its close proximity to Lee Point and the Casuarina Coastal Reserve, Darwin's most popular area of public open space. The project will also deliver serviced allotments to the NT Government that will be dedicated to a primary school, child-care centre and sporting oval.

The project will generate much needed economic stimulus for the Darwin region which is suffering declining growth as a result of the downturn in the mining, and oil and gas industries. It is estimated that the project will contribute $350 million to the local economy, and provide full-time employment for up to 964 employees in the construction industry, 117 full-time and part-time employees in the hospitality industry and 40 full-time employees in education. There will also be a focus on employing and training indigenous people.

Environmental impacts were considered during the planning phase, and the project was referred under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC 2015/7591). It was assessed on 18 December 2015 as a controlled action due to likely impacts on listed threatened and migratory species and as a Commonwealth action, and would be further assessed by Public Environment Report (PER). The project was also assessed under the Northern Territory *Environmental Assessment Act 1982* (EA Act) and the preparation of an Environmental Impact Statement (EIS) was requested on 18 January 2016 by the Northern Territory *Environment Protection Authority* (EPA) to assess the impacts of the project on threatened species, erosion, the Casuarina Coastal Reserve and biting insects.

While the bilateral assessment agreement between the Northern Territory and Australian Governments does not take effect in this instance, the NT EPA and Australian Government have coordinated the preparation of a combined Terms of Reference (ToR) which address both Commonwealth and Northern Territory assessment requirements. A draft ToR for the project was released for public comment on 23 April 2016 and finalised on 20 May 2016. A copy of the final ToR is provided in Appendix A.

1.2 Purpose

The EIS for the Lee Point Master-planned Urban Development (2CRU) has been prepared to address the ToR and thereby satisfy approval conditions under the EPBC Act and EA Act. The ToR broadly requires further information on the follow matters:

- The existing environmental conditions of the project footprint
- Infrastructure requirements to service the local community
- Assessment of impacts and risks to the environment, economy and local community
- Management measures to mitigate or avoid the likely impacts of the project.

Specialist consultants were engaged to undertake detailed engineering, environmental and social-economic studies and prepare reports that specifically address the ToR. The reports are included as appendices to the EIS. Information has also been drawn from previous assessments that were undertaken to support the initial EPBC Act referral and Notice of Intent lodgement.

To identify the key risks to the environment, community, economy and existing infrastructure, a detailed risk assessment was undertaken using international best practice standards (Australian and New Zealand Risk Management Standard AS/NZS ISO 3100:2009). This process informed the project activities that would require avoidance and mitigation measures to ensure impacts remained within regulatory requirements and where possible, community's expectations. The avoidance and mitigation measures proposed are detailed in a Construction and Environmental Management Plan (CEMP) that will be implemented during the construction phase of the project. The CEMP is supported by a number of sub-plans that relate to each environmental discipline that the CEMP addresses.

1.3 Structure

The EIS has been structured in a logical manner to reflect the information requested as part of the ToR, and to facilitate a range of different readers (e.g. referral agencies, utility companies, environmental groups and members of the community) to easily locate information in the EIS that is relevant to them. A detailed project description is provided in Chapter 2. The main technical chapters covering hydrology, air quality, utilities and infrastructure, biodiversity and heritage, social and economic and noise, can be found in Chapters 4 to 9 respectively. Each of these chapters is structured in the following manner:

1. Existing conditions
2. Project impacts
3. Risk assessment
4. Avoidance and mitigation measures.

Detailed technical reports supporting the findings and recommendations in the main body of the EIS are provided in Appendix E to Appendix O. The detailed risk assessment results are provided in Appendix C and summarised in each technical chapter, while Chapter 3 provides a description of how the risk assessment was applied. As requested by the NT EPA and DoEE, the final copy of the ToR is included in Appendix A and a list of contributors that assisted with the preparation of the EIS including the technical studies and risk assessments is provided in Appendix B.

Table 1. EIS Structure

Chapter No.	Title	Scope
1	Introduction	Introduction to the project, justification for preparing the EIS and basic information on the proponent.
2	Project Description	Describes in detail all aspects of the project including site history, development stages and timelines.
3	Risk Assessment	Methodology for completing the risk assessment
4	Hydrology	Technical chapter addressing existing surface water and groundwater conditions and proposed stormwater management plan.
5	Air Quality	Technical chapter addressing noise and odour impacts.
6	Utilities and Infrastructure	Technical chapter addressing potable water, sewerage, traffic, power and telecommunications.
7	Biodiversity and Heritage	Technical chapter addressing impacts to threatened species, migratory shorebirds land condition, and cultural and historic heritage.
8	Social Economic	Technical chapter addressing the social and economic impacts (positive and negative) of the project.
9	Noise	Technical chapter addressing the potential noise and vibration impacts associated with the project.
9	Conclusion	Summarises the key impacts of the project and how they will be addressed.
10	References	List of references cited in the EIS.
Appendix A	Terms of Reference	Copy of the final ToR and tabulated response to how each criteria in the ToR has been addressed.
Appendix B	Contributors	List of people who contributed to the preparation of the EIS
Appendix C	Risk Assessment	Detailed results of the Risk Assessment
Appendix D	CEMP	Construction Environmental Management Plan with sub-plans
Appendix E	Stormwater Management Plan – 2CRU	Technical document supporting Chapter 4
Appendix F	Stormwater Management Plan – Muirhead North	Technical document supporting Chapter 4
Appendix G	Biting Insect Report	Technical document supporting Chapter 4 and general design of Area Plan.
Appendix H	Noise Impact Assessment report – 2CRU	Technical document supporting Chapter 5
Appendix I	Noise Impact Assessment report – Muirhead North	Technical document supporting Chapter 5
Appendix J	Odour Impact Assessment report	Technical document supporting Chapter 5
Appendix K	Traffic Impact Assessment report – 2CRU	Technical document supporting Chapter 6
Appendix L	Traffic Impact Assessment report – Muirhead North	Technical document supporting Chapter 6
Appendix M	Black-footed Tree-rat Report	Technical document supporting Chapter 7
Appendix N	Migratory Shorebird report	Technical document supporting Chapter 7

Chapter No.	Title	Scope
Appendix O	Water Quality Monitoring Plan	Monitoring plan to assess impact of the development on adjoining waterways.
Appendix P	EIS Supplement	Response to comments received during the public exhibition period of the EIS.
Appendix Q	Correspondence	Copy of letter received from Parks and Wildlife Commission
Appendix R	Site Auditors Report	Auditors report for 2CRU
Appendix S	Muirhead North: Stage 1 Preliminary Site Investigation	Stage 1 contaminated land investigation for Muirhead North
Appendix T	Water Discharge Licence WDL 147-05 Annual and Compliance Report	Most recent monitoring report for Leanyer Sanderson Wastewater Treatment Plant
Appendix U	Water Discharge Licence 147-08	Conditions of current Water Discharge Licence for Leanyer Sanderson Wastewater Treatment Plant

1.4 Defence Housing Australia (the proponent)

Defence Housing Australia is a Commonwealth Government business responsible for providing housing and related services for Department of Defence members and their families. This includes providing an active role in the residential housing market by acquiring and developing land, and constructing and purchasing houses. They have undertaken a number of projects that have been referred and approved under the EPBC Act , including:

- North Weston Residential Development, ACT (EPBC# 2011/6163)
- Muirhead Subdivision, Northern Territory (EPBC# 2010/5525)
- RM Military College Duntroon, ACT (EPBC# 2001/374)
- Stirling – Weston Creek, ACT (EPBC# 2001/218)
- Darwin Residential Complex NT (EPBC# 2001/163).

In addition to the Lee Point Master-planned Urban Development, the Rawlings Road Deebing Heights project in Queensland (EPBC# 2016/7723) is currently being assessed under the EPBC Act.

Defence Housing Australia has shown to be an environmentally responsible organisation by complying with environmental approval and regulatory conditions for all their projects. They also show a commitment to the principles of Ecological Sustainable Development (ESD), as demonstrated at the Muirhead Breezes residential development which adjoins the Muirhead North site to the south. Muirhead Breezes has orientated lots to align with the prevailing breeze (hence the name 'Muirhead Breezes'), and focussed on a climatically-responsive small lot housing, which has resulted in a corresponding reduction in energy consumption. This innovative approach to environmentally sensitive housing has been recognised with the following industry awards:

- 2016 Urban Development Institute of Australia (UDIA) Northern Territory Award for Environmental Excellence
- 2016 UDIA Northern Territory Awards for Innovation in Design

- 2015 UDIA Northern Territory Award for Excellence in Masterplanned Development
- 2015 UDIA Northern Territory Award for Excellence for Environmentally Sustainable Development.

This approach to ESD has been carried through to the Lee Point Master-planned Urban Development.

Table 2. Proponents details

Title	Lee Point Master-planned Urban Development
Location	544 (Lot 9370) and 577 (Lot 4873) Lee Point Road, Nightcliff, Northern Territory
Proponent	Defence Housing Australia 1 Carey Street, Darwin, Northern Territory T 08 8901 7107 Contact: Chris Grimm

1.5 Supplement

In accordance with NT EPA and Commonwealth guidelines, the draft EIS was on display for public exhibition between 18 November 2017 and 1 February 2018. During this period, the public had an opportunity to review and provide comment on the draft EIS with comments received from ten Northern Territory Government advisory bodies and seventeen submissions from members of the public and non-government organisations. Comments received by DoEE were addressed prior to the draft EIS going on public exhibition.

The current version of the EIS has been updated to address comments received during the public exhibition period. A supplement to the EIS has been prepared and details how all comments received have been addressed (Appendix P).

2 PROJECT DESCRIPTION

2.1 General Information

Defence Housing Australia (DHA) is proposing the Lee Point Master-planned Urban Development to provide housing, a tourism precinct, community infrastructure and public open space on a 132.5 ha site located at 544 and 577 Lee Point Road, Nightcliff, North Territory. The project site is located approximately 14 kilometres (km) north-north-east of the Darwin Central Business District (CBD) and covers Lot 4873 (2CRU) and Lot 9370 (Muirhead North).

The project site is bisected by Lee Point Road with 2CRU located on the western side of Lee Point Road and Muirhead north on the eastern side. It is adjoined to the south of 2CRU by the Lyons residential development and by the Muirhead Breezes residential development to the south of Muirhead North. The Casuarina Coastal Reserve including Sandy Creek border the western boundary of 2CRU and the reserve extends to the northern boundary of 2CRU. Casuarina Coastal Reserve is Darwin's most popular public area of natural public open space and provides recreation facilities and public amenity including walking and mountain-bike trails (formal and informal), a surf-life saving club, military history, car-parking, toilets and access to the Casuarina Beach. Sandy Creek enters the Beagle Gulf through Casuarina Coastal Reserve and receives run-off from the western half of the 2CRU site.

The Lee Point Village Resort fronts onto the northern boundary of Muirhead North. Buffalo Creek is located to the east of Muirhead North and receives run-off from Muirhead North and the eastern half of 2CRU through culverts which drain into Muirhead North. Buffalo Creek flows into Shoal Bay and is considered to be the most polluted tributed discharging into Darwin Harbour.

2.2 Project Site

The Larrakia people are the traditional owners of the project site. The Larrakia Nation Aboriginal Corporation and Larrakia Development Corporation have been consulted during the development of the EIS.

The project site is zoned Future Development (FD) under the City of Darwin Planning Scheme (Figure 1).

The 2CRU site is located at Lot 04873 Town of Nightcliff, 577 Lee Point Road and was owned by the Commonwealth Department of Defence (Defence) until recently, when ownership transferred to DHA. The project site was used by Defence as a communication facility and was operated by 2CRU between 1959 and 2002. During this period it had an important role in the Malayan Emergency and also supported Australia's involvement in the Konfrontasi conflict. The project site was inactive between 1974 and 1981 as a result of the considerable damage caused by Cyclone Tracy. The site was purchased by DHA in May 2014. Since then the site has remained vacant; however, there are ongoing issues with illegal site access for motorbike riding and dumping of household and industrial waste. There is also a historical problem with gully erosion in the south-west of the project site that is contributing sediment to the nearby Sandy Creek and providing habitat for biting insects.

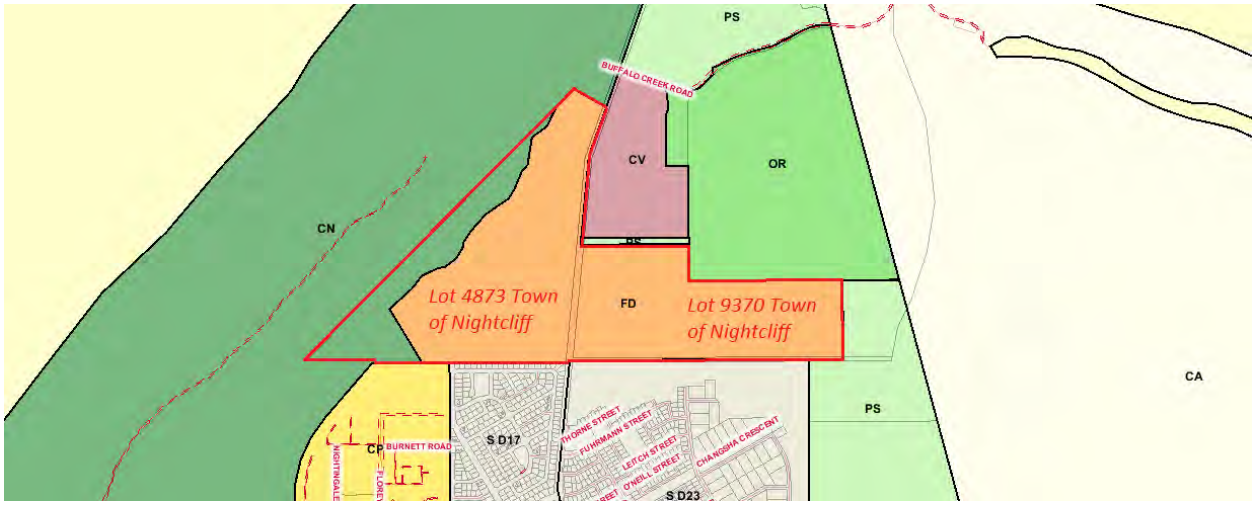


Figure 1. Planning zones

Most of the communication facilities installed by Defence have been removed from the project site, except for a cruciform anti-battery site located in the centre of the site, and an area to the north referred as 'The Bunkers' which contains remnants of missile foundations, a concrete bunker and explosives/ammunitions store. Most of the project site is covered by introduced grassland, or degraded bushland that has regenerated since Defence operations ceased, although the western boundary of the site is covered in mature Monsoon Vine-thicket.

There is a formal vehicle track from Lee Point Road into the middle of the site where a compound was once situated, with other less formal tracks, including from the former compound heading in a southerly direction, ultimately running adjacent to the southern site boundary and connecting with the trails in the Casuarina Coastal Reserve. Vehicle tracks and firebreaks are present along the eastern and southern property boundaries. There are numerous informal vehicle tracks within the site, along with evidence of itinerant camps. Fencing along the road frontage has been repeatedly vandalised to allow illegal access.

The adjoining Muirhead North site is located at Lot 09370 Town of Nightcliff, 544 Lee Point Road, on the eastern side of Lee Point Road. It is identified as vacant crown land, and with the exception of the telecommunications tower and associated equipment shelter, is void of built form. The site is covered with remnant vegetation, with natural and modified drainage paths occurring across the site to the Leanyer Swamp further east. There is some seasonal inundation in the very eastern extent of the site, although the majority of the site consists of well-drained soils. There are numerous informal vehicle tracks within the site, and evidence of recreational four-wheel drive and/or motorcycle/quad bike access.

Muirhead North gently slopes towards the east with small localised undulations located throughout the property. The eastern portion of 2CRU is similar, with a ridge line extending north-south in close parallel to Lee Point Road. The western portion of 2CRU falls sharply from an escarpment, with vegetation below the escarpment comprising Monsoon Vine-thicket that continues into the coastal reserve.

2.3 Climate

The project site experiences a tropical savannah climate, with a dry season extending from May to September and a wet season running from October to March. During the dry season, mean monthly rainfall varies between 1.1 millimetres (mm) in July and 21.6 mm in May and mean monthly relative humidity is below 50% and as low as 37% in July (see Figure 2). At the beginning of the wet season, mean monthly relative humidity continually rises until peaking in February at 72%. This pattern is broadly consistent with the mean monthly rainfall pattern which is also unimodal and peaks at 423.7 mm in January (see Figure 3). Monsoon conditions prevail from December to March when the mean monthly rainfall exceeds 250 mm and most days during this period receive rain.

Mean monthly maximum temperatures are warmest in the wet season and coolest in the dry season, but vary little between months ranging between 30.6 °C in July and 33.3 °C in October and November (Figure 2). The onset of monsoons results in a small but noticeable decrease in mean maximum temperatures between December and March. There is a larger variation in mean minimum temperatures which range between 19.3 °C in July and 25.3 °C in November and December.

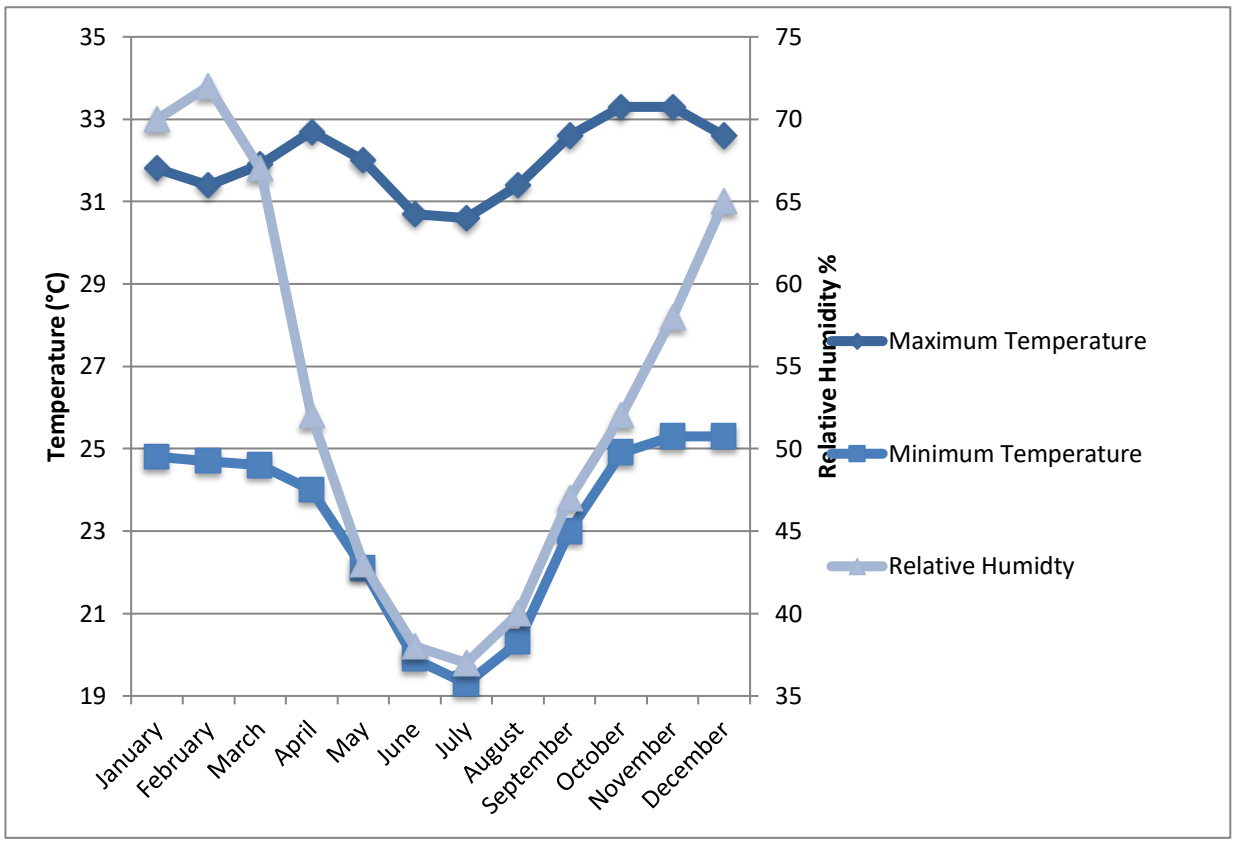


Figure 2. Temperate and relative humidity data (Bureau of Meteorology Darwin Airport)

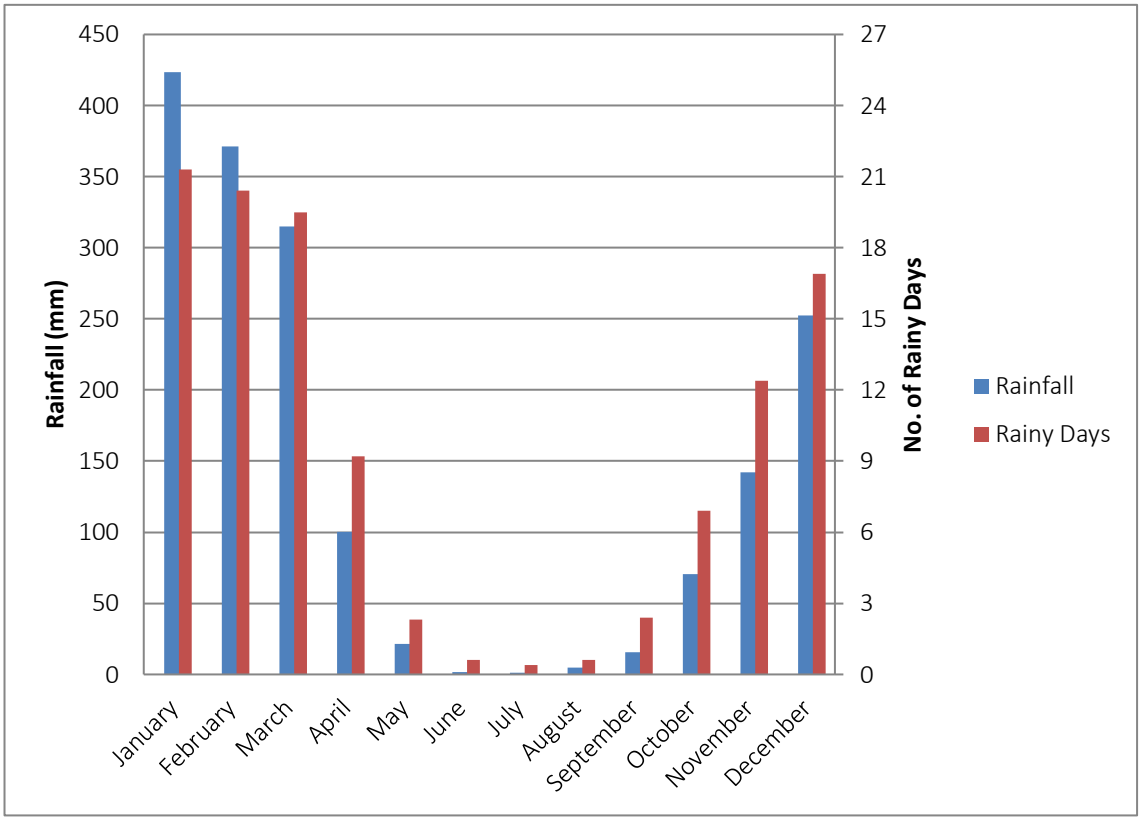


Figure 3. Rainfall data (Bureau of Meteorology Darwin Airport)

2.4 Project Description

The Lee Point Master-planned Urban Development will be developed in accordance with the Lee Point Area Plan and Planning Principle's as described in DHA's application to amend the NT Planning Scheme (PA2014/0922). It will accommodate approximately 700 ground-level dwellings, between 30 and 40 rural residential lots, and between 200 and 250 apartments (see masterplan and site plans overleaf).

The Lee Point Area Plan identifies a tourism and mixed use centre situated along a Main Street precinct in 2CRU running from Lee Point Road through the site in a north-westerly direction where it will terminate at a coastal esplanade. The area will provide most of the high density residence in 3-6 storey apartments. The coastal esplanade runs perpendicular to the Main Street precinct and parallel to the Casuarina Coastal Reserve. It will be an important area of public open space and provide bicycle and walking paths and other recreation facilities. There will also be a small area of open space in the north of the site as part of the preservation of local military history.

The Main Street precinct will provide a mixture of commercial, retail and community services. There are also four tourist sites to be established along the Main Street that will be transferred to the NT Government and will provide for hotel and apartment accommodation in buildings between 2-12 stories.

A Community Hub will be located in Muirhead North, and will include a primary school, child-care facility and sports facilities, covering approximately 3.7 ha. Immediately adjacent to the Community Hub will be an active recreation reserve including an AFL/cricket oval.

In addition to the coastal esplanade in 2CRU, other areas of public open space will include the preservation of 21.95 ha of Monsoon Vine-thicket and eucalypt woodland on the western side of 2CRU to conserve habitat for the endangered Black-footed Tree-rat and expand the area of the existing Casuarina Coastal Reserve. A further 1.6 ha within Muirhead North supporting sensitive Monsoon Rainforest vegetation will be protected. The treatment train of bioretention and detention basins to manage stormwater will be integrated into public open space, contributing an additional 10 ha (approximate). A series of parks and playground areas will be set-aside across the project site.

The current staging plan for the projects proposes a seven staged development, with commencement of civil works scheduled to commence in April 2019 (Table 3). Buildings and other facilities will be established once civil construction works are completed.

Table 3. Staging plan for Lee Point Master-planned Urban Development (dates are subject to change)

Stage	Estimated Start Date	Estimated Completion Date
1A	April 2019	November 2018
1B	April 2019	November 2019
2A	March 2020	December 2020
2B	March 2021	November 2021
3	March 2022	October 2022
4	April 2023	November 2023
5	March 2024	November 2024

NOTES

(1) This plan was prepared for the purpose and exclusive use of DEFENCE HOUSING AUSTRALIA as an Investigation into the Development Potential of the land described in the plan and is not to be used for any other purpose or by any other person or corporation.
JFP URBAN CONSULTANTS PTY LTD accepts no responsibility for any loss or damage suffered howsoever arising to any person or corporation who may use or rely on this plan in contravention to the terms of this clause or clauses 2, 3, 4, 5, 6 or 7 hereof.

(2) The contours on this plan are approximate and are suitable only for the purpose of this application. The accuracy of the contours has not been verified and no reliance should be placed upon such contours for any purpose other than for the purpose of this application.

(3) JFP takes no responsibility for any changes to the design concept that may arise as a consequence of the detailed vegetation assessment undertaken in the future. To increase certainty JFP recommends the appointment of suitable vegetation professionals to complete the vegetation assessment as soon as practical.

(4) This plan shall be read in conjunction with the JFP preliminary planning assessment prepared in relation to the site.

(5) The dimensions, areas, size and location of improvements, flood information (if shown) and number of lots shown on this plan are approximate only and may vary.

(6) Information sourced from third-parties has been utilised in the preparation of this plan.
JFP URBAN CONSULTANTS PTY LTD accepts no responsibility for the accuracy of the information sourced from third-parties. Futhermore it is noted that the boundaries and extents of the site have not been confirmed by survey and therefore cannot be relied upon until such survey is undertaken.

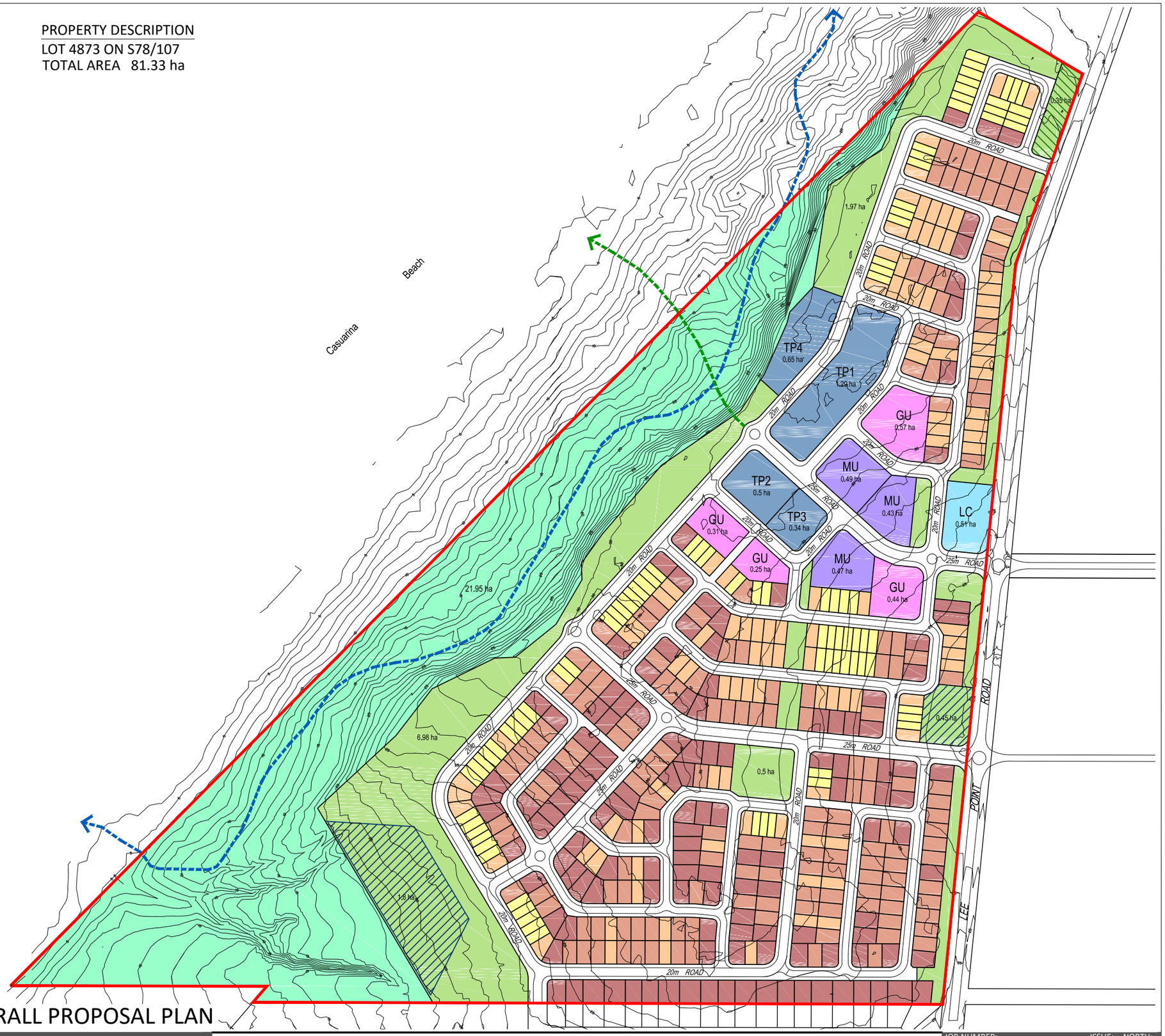
(7) This plan may not be photocopied unless this note is included.

LEGEND

- SUBJECT SITE
- LOTS 600m² & larger (20m x 30-31m) - 135 (28%)
- LOTS 540-599m² (18-19m x 30-31m) - 157 (32%)
- LOTS 450-539m² (15-17m x 30-31m) - 106 (22%)
- LOTS 300-449m² (10-12m x 30-31m) - 88 (18%)
- PARK/OPEN SPACE
- CONSERVATION AREA
- LC — LOCAL CENTRE (0.51 ha)
- TP — TOURISM PRECINCT (2.78 ha)
- MU — MIXED USE RESIDENTIAL (1.39 ha)
- GU — MEDIUM DENSITY RESIDENTIAL (1.57 ha)
- BIO-DETENTION BASIN
- WWII HERITAGE AREA
- PROPOSED MOUNTAIN BIKE TRAIL
- ACCESS TO BEACH

PROPERTY DESCRIPTION

LOT 4873 ON S78/107
TOTAL AREA 81.33 ha



OVERALL PROPOSAL PLAN

LEE POINT ROAD, LEE POINT, DARWIN
DEFENCE HOUSING AUSTRALIA

JFP URBAN CONSULTANTS

PLANNERS
URBAN DESIGNERS
SURVEYORS
ENGINEERS
LANDSCAPE ARCHITECTS

JOB NUMBER: M2737P_Overall Proposal
ISSUE: E
NORTH:
SCALE: 1:5000 @ A3
DATE: 13th September 2017

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PROPERTY DESCRIPTION
LOT 9370 ON S901068
TOTAL AREA 51.17 ha

LEGEND

- SUBJECT SITE
- LOTS 4000m² & larger (45m frontage min.) - 32 (12%)
- LOTS 600-700m² (20m x 30-31m) - 62 (24%)
- LOTS 540-599m² (18-19m x 30-31m) - 56 (22%)
- LOTS 450-539m² (15-17m x 30-31m) - 110 (42%)
- PARK/OPEN SPACE
- COMMUNITY USES

NOTES

(1) This plan was prepared for the purpose and exclusive use of DEFENCE HOUSING AUSTRALIA as an Investigation into the Development Potential of the land described in the plan and is not to be used for any other purpose or by any other person or corporation.
JFP URBAN CONSULTANTS PTY LTD accepts no responsibility for any loss or damage suffered howsoever arising to any person or corporation who may use or rely on this plan in contravention to the terms of this clause or clauses 2, 3, 4, 5, 6 or 7 hereof.

(2) The contours on this plan are approximate and are suitable only for the purpose of this application. The accuracy of the contours has not been verified and no reliance should be placed upon such contours for any purpose other than for the purpose of this application.

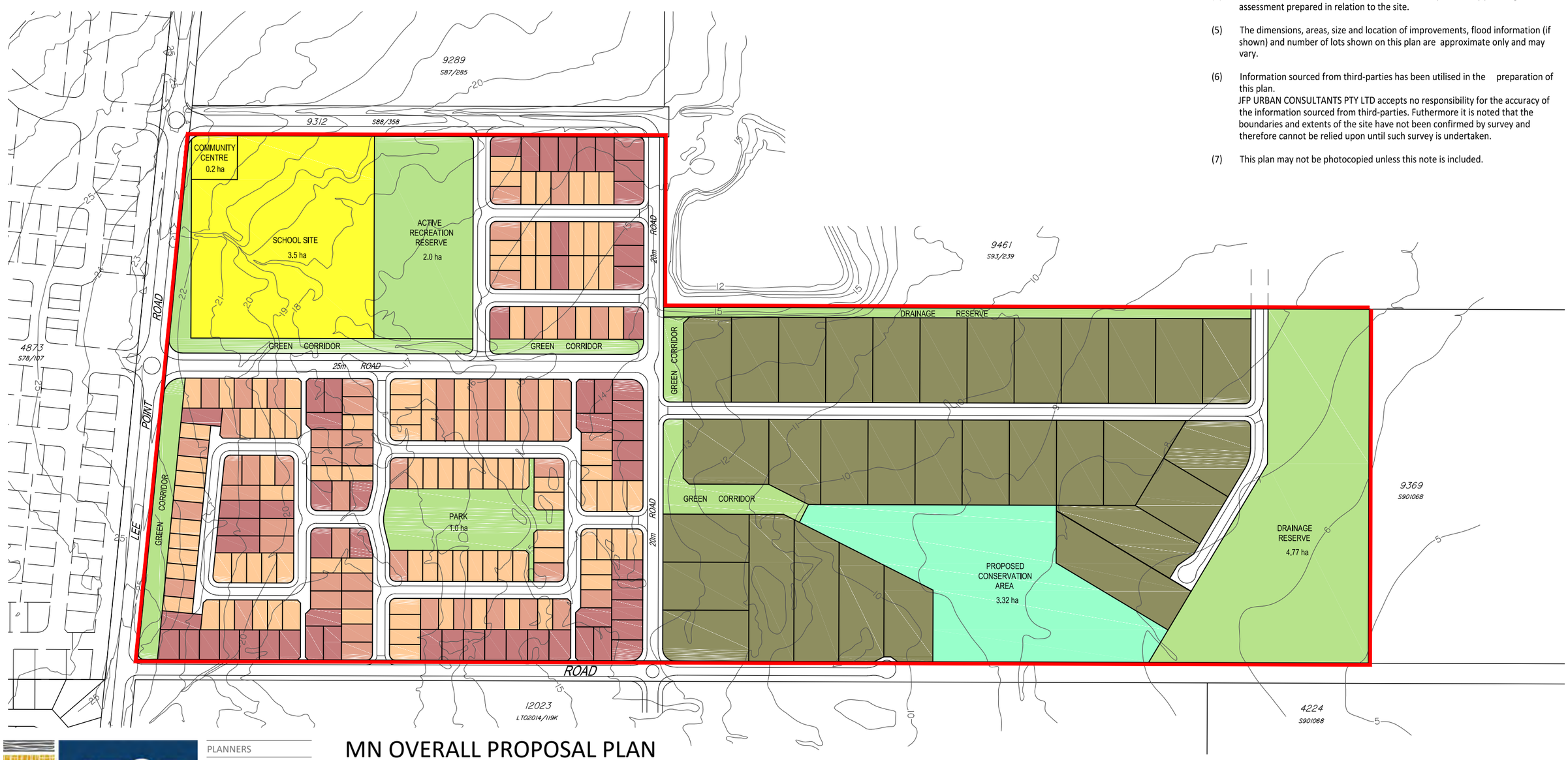
(3) JFP takes no responsibility for any changes to the design concept that may arise as a consequence of the detailed vegetation assessment undertaken in the future. To increase certainty JFP recommends the appointment of suitable vegetation professionals to complete the vegetation assessment as soon as practical.

(4) This plan shall be read in conjunction with the JFP preliminary planning assessment prepared in relation to the site.

(5) The dimensions, areas, size and location of improvements, flood information (if shown) and number of lots shown on this plan are approximate only and may vary.

(6) Information sourced from third-parties has been utilised in the preparation of this plan.
JFP URBAN CONSULTANTS PTY LTD accepts no responsibility for the accuracy of the information sourced from third-parties. Futhermore it is noted that the boundaries and extents of the site have not been confirmed by survey and therefore cannot be relied upon until such survey is undertaken.

(7) This plan may not be photocopied unless this note is included.



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PLANNERS
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MN OVERALL PROPOSAL PLAN

544 LEE POINT ROAD, LEE POINT, DARWIN
DEFENCE HOUSING AUSTRALIA

JOB NUMBER: M2737P MN_Overall Proposal A
ISSUE:
NORTH:
SCALE: 1:4000 @ A3
DATE: 29th September 2017

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LEGEND

- SUBJECT SITE
- PROPOSED STAGING BOUNDARY
- COMMUNITY USE - SCHOOL SITE
- COMMUNITY USE - COMMUNITY CENTRE
- OPEN SPACE
- ENCUMBERED OPEN SPACE
- PROPOSED CONSERVATION AREA
- MOUNTAIN BIKE TRAIL (INDICATIVE LOCATION)
- PARKING (WITHIN BASEMENT)
- PARKING (WITHIN CARCOURT)

DWELLING YIELD SUMMARY TABLE

LOT YIELD	TOTAL AREA (Ha)	NO. LOTS	AVERAGE LOT SIZE (m2)
Standard Residential Lots	35.30	704	494
Rural Lots	14.19	32	4305

STANDARD LOT TYPES	TOTAL AREA (m2)	NO. LOTS	% (TOTAL STANDARD RES. LOTS)
240 - 360 m2 (Medium Density)	30,000	100	14%
360 - 450 m2 (Small Lot)	63,990	158	22%
450 - 550 m2 (Medium Lot)	85,000	170	24%
550 - 650 m2 (Large Lot)	114,600	191	27%
650 - 750 m2 (Duplex)	59,500	85	12%
TOTAL STANDARD LOTS	353,090	704	100%

SPECIAL SITES - APARTMENTS	SITE AREA (m2)	DWELLINGS	TYPE
TOURISM PRECINCT - ACCOMMODATION	2.70	300	
TP1 - Height Limit 12 Storeys	1.12	180	Hotel/ serviced apartments
TP2 - Height Limit 12 Storeys	0.51	80	Hotel/ serviced apartments
TP3 - Height Limit 8 Storeys	0.42	40	Hotel/ serviced apartments
TP4 - No Residential Included	0.65	0	
MIXED USE - HEIGHT LIMIT 4 STOREYS	1.00	60	Private apartments
GENERAL URBAN - HEIGHT LIMIT 3 STOREYS	3.00	160	Private apartments
TOTAL APARTMENTS		520	

CASUARINA COASTAL RESERVE
BEAGLE GULF
2CRU BOUNDARY 82.03HA
PARK A 0.75Ha
RB 03 0.26 Ha
HERITAGE RESERVE 0.18Ha
RB 02 0.62 Ha
STAGE 5
TOURISM ACTIVITY AREA
ACCESS WAY TO THE BEACH
GREEN CORRIDOR
LINEAR RESERVE A 0.29 Ha
LEE POINT VILLAGE RESORT CARAVAN PARK LOT 9289
TP 4
TP 1
PARK B 0.52 Ha
LOT 4873 - TOWN OF NIGHTCLIFF
PROPOSED COASTAL RESERVE
TP 2
TP 3
PROPOSED COMMUNITY CENTRE 0.2Ha
PARK C 0.59 Ha
LINEAR RESERVE B 0.16 Ha
STAGE 2A
PARK E 0.52 Ha
STAGE 1A
PARK F 1.43 Ha
PARK D 0.31 Ha
LINEAR RESERVE C 0.10Ha
PARK G 0.92 Ha
RB 06/ GREEN CORRIDOR 0.51Ha
PARK H 0.51 Ha
STAGE 3
STAGE 4
PROPOSED CONSERVATION AREA
RB 01 3.74 Ha
PARK K 0.34Ha
PARK I 0.3 Ha
PARK J 0.11 Ha
LEE POINT ROAD
SCHOOL SITE 3.5Ha
ACTIVE RECREATIONAL RESERVE 2 Ha
PARK L 0.19 Ha
RB 07/ GREEN CORRIDOR 1.04 Ha
RB 08 0.56 Ha
STAGE 1B
PARK M 0.59 Ha
RB 09/ GREEN CORRIDOR 0.28 Ha
STAGE 2B
RURAL LOTS 14.19 Ha
DRAINAGE RESERVE (RB 04 +RB 05) 6.15Ha
RB 10/ GREEN CORRIDOR 0.26 Ha
PROPOSED CONSERVATION AREA
RB 11/ GREEN CORRIDOR 0.13 Ha
LOT 9370 - TOWN OF NIGHTCLIFF
MUIRHEAD NORTH 49.32HA
2CRU BOUNDARY (82.03HA)
ROYAL DARWIN HOSPITAL

DHA Defence Housing Australia

Lee Point | Master Plan
Lee Point Road, Lee Point
City of Darwin, Northern Territory

REF NO	DRAW NO	REV
DHA LEE	RD 3102	D

DRAFT

NOTES:
MP reference:
RD3003F Lee Point_Illustrative Master Plan_170215

Land budget reference:
RD4501E DHA LEE_ Preliminary_Land Budget_170215

REV	DESCRIPTION	DDMMYY	DRAWN	APPR'D
D	per SB 30.03.15 - RD3003F	310315	KT	EP
C	per SB 16.02.15 - RD3003F	170215	KT	EP
B	per SB 02.02.15 - RD3003E	110215	KT	EP
A	per SB 081214	101214	KT	EP

NPC NORTHERN PLANNING CONSULTANTS
smec urban Part of the SMEC Group

SCALE 1:2,500 SIZE A0
N
50 100 150 200 250 300m

RobertsDay planning·design·place

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3 RISK ASSESSMENT

3.1 Introduction

A comprehensive risk assessment of all potential project impacts has been undertaken in accordance with Australian and New Zealand Risk Management Standard AS/NZS ISO 3100:2009. The risk assessment provides a systematic process to quantify the severity of impact to the environment, community and local infrastructure the project is likely to cause, and identifies which project activities will require management controls or avoidance measures to ensure that any impact does not exceed regulatory thresholds and meets the public's expectations (where possible). The risk assessment was undertaken in the following manner:

1. Identify the risks to the environment
2. Identify the likely causes for risks to occur
3. Establish likelihood and consequence descriptors
4. Establish outcome descriptors
5. Quantify risk
6. Determine appropriate controls to reduce risk level to an acceptable level.

3.2 Method

The risk assessment was completed by specialist consultants responsible for preparing the detailed technical reports (Appendix B). After determining the potential risks to the environment, and what factors contribute to the risk, the risk level was quantified by determining the outcome, where outcome is calculated as:

- *Outcome = Likelihood x Consequence*

The tables below provide descriptions for the different levels of likelihood, consequence and outcome.

A description of the project activities that may contribute to impacts and were considered during the risk assessment is provided in Table 7.

3.3 Results

The detailed results of the risk assessment, including the recommended mitigation and avoidance measures are provided in Appendix C, and further explained in each relevant technical chapter of the EIS. A total of 98 risks were identified that have been assigned a management control.

Table 4. Consequence rating descriptors

Consequence	Hydrology	Air Quality	Utilities and Infrastructure	Biodiversity	Heritage	Social	Noise
Minimal	Negligible effect to the environment	Impacts to air quality below detectable levels.	No discernible impact on quality of service.	Small scale native vegetation or habitat loss.	Low-level repairable damage to commonplace structures.	Some people indirectly impacted.	Noise can barely be detected.
Minor	Minor effect, complaint from adjacent neighbours or community. Temporary impact on subterranean conditions, aquifer or Sandy Creek without long-lasting effects. Temporary disruption to water supply or effect on water quality.	Impact on local air quality is within allowable limits, no discernible impacts on health.	Available services cannot meet the need of local residents.	Small to medium scale native vegetation/habitat loss. Fragmentation of habitat for native species.	Minor damage to items of low cultural heritage significance. Mostly repairable. Minor infringement of cultural heritage values.	Some people directly impacted or several indirectly.	Noise detected, low-level of nuisance
Moderate	Localised impact, local media coverage, may trigger regulators involvement. Short term impact on sensitive environmental features, aquifer resource or Sandy Creek.	Temporary impact on local air quality exceeds allowable limit,, impact on respiratory health, loss of native vegetation.	Additional demand results in decline in service quality for wider community.	Potential significant impact on special/ecological communities, medium to large scale native vegetation loss/habitat fragment for native species.	Substantial damage to items of moderate cultural or heritage significance. Infringement of cultural heritage/sacred locations.	Several people directly impacted or many indirectly.	Temporary sleep disturbance, potential hearing injury, complaints from adjoining residents..
Major	Major impact, national media coverage, would	Damage to respiratory health	Additional demand results in health impacts for residents and wider	Significant impact on species/ecological communities	Major permanent damage to	Large number of people	Temporary hearing loss, ongoing sleep

Consequence	Hydrology	Air Quality	Utilities and Infrastructure	Biodiversity	Heritage	Social	Noise
	trigger regulators involvement.	requiring specialist medical treatment, local-regional media coverage, significant remediation works required.	community. Local/regional media attention.		items of high cultural or heritage significance. Significant infringement and disregard of cultural heritage values.	directly impacted.	disturbance, damage to buildings and structures, local/reigional media attention.
Catastrophic	Extensive off-site contamination and changes to level of groundwater, or quality of Sandy Creek. Sustained damage to the environment/human health and remediation not possible. National to international media coverage, regulators involved.	Permanent damage to respiratory health, national media coverage, irrevocable damage to regional air quality.	Additional demand results in deaths in local community. National media attention.	Extinction of species/ecological communities	Total destruction of items of high cultural or heritage significance. Highly offensive infringements of cultural heritage.	Loss of life.	Permanent hearing loss, damage to buildings. National media attention.

Table 5. Likelihood rating descriptors.

Likelihood	Description	Probability	Community attitude
Remote	May occur in exceptional circumstances	<1%	Few people interested
Unlikely	Not expected to occur in most circumstances	1-20%	Some people affected
Possible	May occur	21-49%	Many people affected
Likely	Probability will occur	50-85%	Most people affected
Almost Certain	Expected to occur	>85%	Almost everyone affected

Table 6. Environmental outcome descriptors

LIKELIHOOD	OUTCOME					
		MINIMAL	**MINOR**	**MODERATE**	**MAJOR**	**CATASTROPHIC**
	REMOTE	Negligible	Negligible	Very low	Low	Medium
	UNLIKELY	Negligible	Very low	Low	Medium	High
	POSSIBLE	Very low	Low	Medium	High	Very high
	LIKELY	Low	Medium	High	Very high	Significant
	ALMOST CERTAIN	Medium	High	Very high	Significant	Significant

Table 7. Project activities considered as part of the risk assessment

Biodiversity	Heritage	Hydrology	Noise and Air Quality	Social and Economic	Utilities
Habitat loss	Ground excavation	Surface water quality	Traffic (operation)	Housing and accommodation	Potable water
Habitat fragmentation	Site occupation	Surface water flow rates	Plant (construction)	Workforce	Sewerage
Habitat degradation		Erosion	House lighting	Social Infrastructure	Traffic
Edge effects		Flooding	Acid sulphate soils	Amenity and Safety	Telecommunications
Altered hydrology		Groundwater depth	Chemical spills	Economic/Business Development	Power
Water quality		Groundwater contamination	Odour (Leanyer Sanderson Wastewater Treatment Plan)		
Erosion and sedimentation		Acid sulphate soils			
Soil compaction		Litter, rubbish entering creeks and eventually Bay.			
Inappropriate/ineffective rehabilitation					
Groundwater contamination					
Impacts on surface and groundwater systems					
Waste material					
Traffic (construction)					
Traffic (occupancy)					
Weeds and pest animal invasion					

Biodiversity	Heritage	Hydrology	Noise and Air Quality	Social and Economic	Utilities
Dust					
Noise					
Human disturbance					
Domestic pets					

4 HYDROLOGY

4.1 Introduction

This chapter addresses the hydrological criteria of the ToR. Information has been collected from a number of sources including desktop review, field assessments and modelling. The chapter is presented in the following structure:

- Section 4.2 – Existing Conditions. This section focusses on the pre-development condition of the project site and adjoining water bodies. Details are provided of the current condition of groundwater and surface water including description of any dependent ecosystems. Information on the likelihood of flooding is also provided.
- Section 4.3 – Risk Assessment. Identifies the key risks to surface water and groundwater based on the detailed hydrological risk assessment (Appendix C) and describes the avoidance and mitigation measures that are proposed to reduce the risk of any impacts occurring to water values including off site at Sandy Creek and Buffalo where stormwater from the detention basis will be discharged. The mitigation measures are included in the Stormwater Management Plans (Appendix E and Appendix F), Erosion and Sediment Control Plan (ESCP), Water Quality Monitoring Plan (Appendix O) and CEMP (Appendix D).

4.2 Existing Conditions

4.2.1 Geology

According to the Darwin 1:250 000 Geological Series map, the project site is underlain by late cretaceous kaolinitic claystone and Tertiary pisolitic and mottled laterite (Figure 7). Quaternary alluvium, when found in drainage line and lower elevations are sand, silt and clay.

A review of the Northern Territory bore database identified a number of bores in the neighbourhood. The stratigraphy information associated with the bore records supported the understanding of the regional hydrostratigraphy.

The regional hydrogeology is defined by an upper lateritic clay formation of up to 40 m depth which has the potential to be water bearing. It is underlain by consolidated fine alluvium formations, reportedly shales, siltstones, slate or conglomerates.

Groundwater was encountered regionally in some of the consolidated formation, however, bore yields have reportedly been limited. A few bores in the database and the newly drilled bores at the site reported shallow groundwater in the laterite.

Previous site geotechnical studies reported the absence of groundwater in nearby bores. This is inconsistent with the records, however, the observations could simply be associated to the slow recovery of newly built bores (i.e. not yielding water quick enough to observe on the day) or the need for redevelopment of older bores.

Testing for acid sulphate soils has not been undertaken. Despite the proximity of the project site to the coastline, the elevation of the site is likely to preclude the presence of acid sulphate soils (GHD 2010). If present, acid sulphate soils are most likely to occur in the lowest elevations of the site, which occurs in the south-east of Muirhead North. It should be noted that no acid sulphate soils were encountered in the adjoining Muirhead Breezes development. Nonetheless, test pits will be dug in the south-east of Muirhead North prior to any soil disturbance occurring as part of Stage 2B, to determine the presence of acid sulphate soils. If acid sulphate soils are encountered than an acid sulphate soils management plan will need to be prepared.

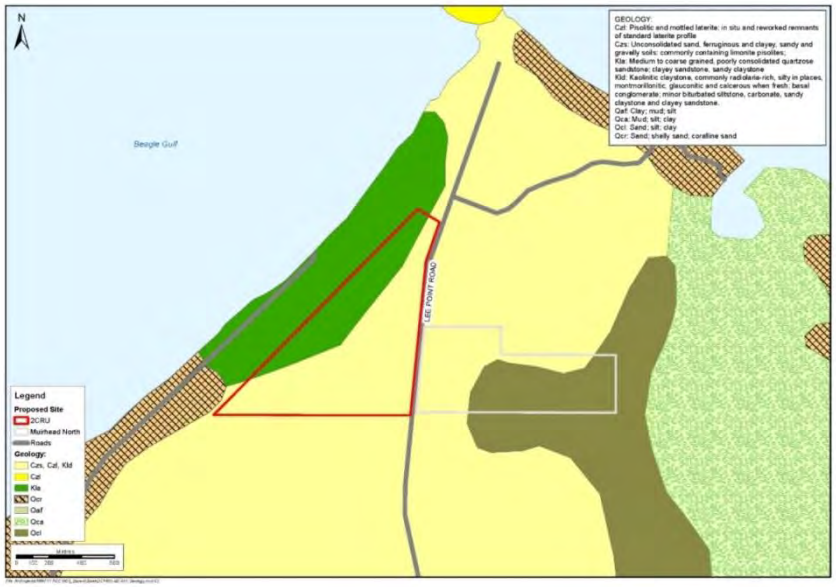

Figure 7. Site geology

4.2.2 Project Site

4.2.2.1 Groundwater

Site geology is informed by borehole information collected during previous investigations (Douglas Partner 2009, SMEC 2015) and in the recent investigation. The geotechnical investigations over the Muirhead North and 2CRU sites documented the site geology to a maximum depth of three metres. The spread of the boreholes provides a relatively good site cover. The geological settings are consistent across 2CRU and Muirhead North. On the Muirhead North site, a recent investigation focused on the area up-gradient of the Monsoon Rainforest and investigated the site geology to depth of 12 metres, which contributed to the assessment of this site by providing a reference depth to groundwater for the area.

The project site geology can be summarised as follow:

- An upper sand and silt unconsolidated formation of brown, yellow or red colour observed up to 4.5 m depth, but more generally to 2-3 m depth. Small gravels of ferricrete (locally referred to as coffee rock) or layers of ferricrete can be found in the first couple of metres. At the site, their distribution appears to be quite discontinuous.
- An underlying clay formation, forming the upper part of the laterite profile. The clay can be silty at times, mottled, with gravels or "coffee rock" gravels. The clay is not cohesive and shows heavy staining between small pieces. The colour of the clay is predominantly brown and white but was also found to be red and grey in places. The thickness of the clay in the closest bore (RN22618) was reported to reach 33 metres.
- Underlying siltstones and shales.

The aquifer of interest is associated with the laterite profile. The finding is consistent with the heavy staining observed through the mottled clay during drilling and the signs of hydro-chemical processes associated with the presence of groundwater. Based on the nature of the formation and the slow recovery of the wells during development and testing, the laterite aquifer would be associated with low yields. A deeper aquifer has been reported within the fractured consolidated rock formation in some of the bores drilled in the area. Again here, yields were rather low.

The aquifer is expected to respond to rainfall events, especially those of the wet season. The water table level can be expected to increase a few metres after recharge (Foo, 2004, Foo1987, Vanden Broek 1980). Groundwater is expected to be discharged through evaporation and through direct discharge at Sandy Creek (western section of 2CRU), and Buffalo Creek (Muirhead North and eastern section of 2CRU). Discharge is expected to be greater in the first part of the dry season due to higher water table levels and thus, stronger hydraulic gradients.

In terms of discharge through groundwater usage, the supply bores located in close vicinity of the site have either been decommissioned or are abandoned.

The Bureau of Meteorology (BOM) Groundwater Dependent Ecosystems (GDE) Atlas was accessed to inform the potential presence of GDEs within the project site. Parts of the western and southern sections of 2CRU as well as large portions of the adjoining Casuarina Coastal Reserve, are identified as having a moderate potential

to support GDEs reliant on subsurface expression of groundwater (Figure 8) which is broadly consistent with the extent of high ecological value Monsoon Vine-thicket identified by EcOZ (2014) who postulated that the community may be groundwater dependent. Sandy Creek, located west of 2CRU site is not classified as a GDE.

Most of Muirhead North is mapped as having a potential to sustain GDEs. The potential for groundwater interaction is variable over the site, with a low potential on the western part of the site corresponding with the most elevated part of the site, a medium potential for groundwater dependent ecosystems in the north-east section and a high potential in the south east corner of the site (Figure 8). The mapping of potential GDEs does not match well with the location of the Monsoon Rainforest patch however it highlights the potential for groundwater dependency of vegetation in the lower slopes of the site, which were mapped by EcOz (2014) as supporting Lophostemon and Pandanus Open Woodland.

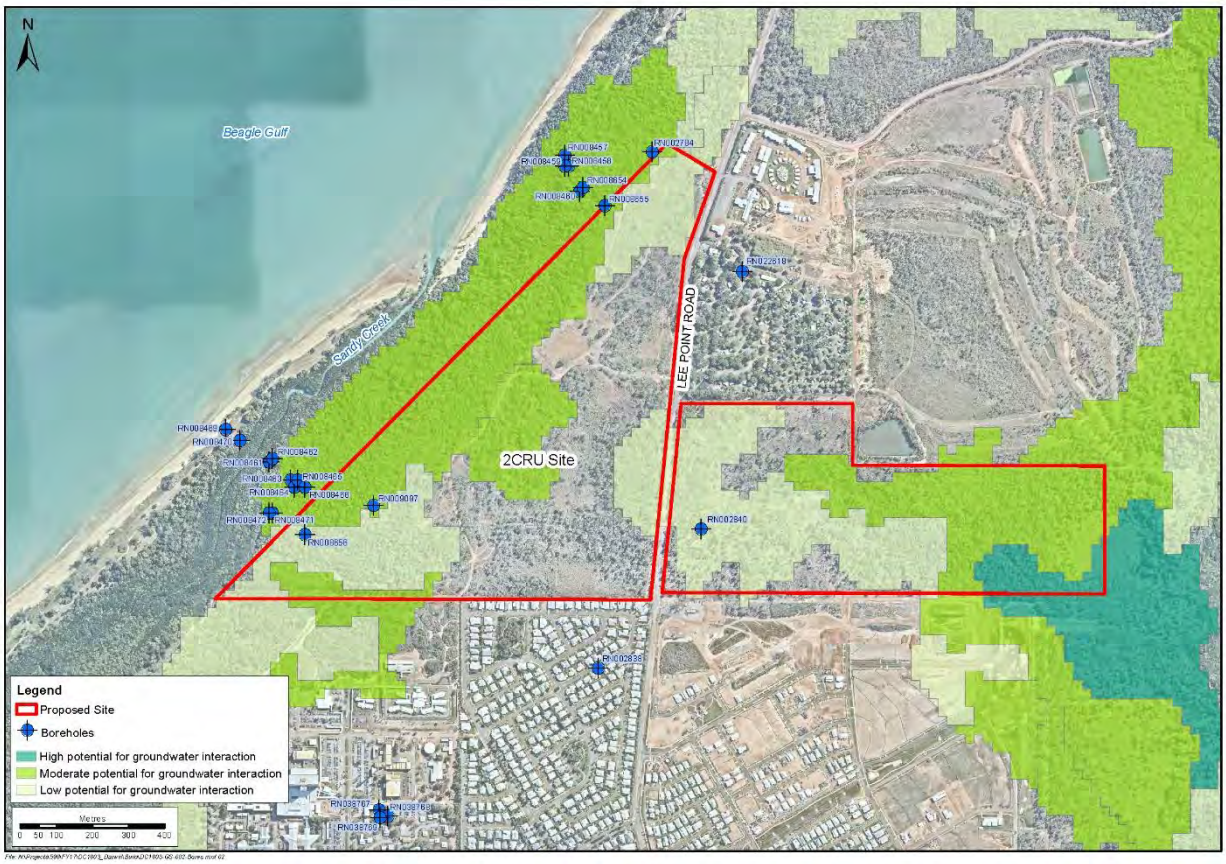

Figure 8. Bureau of Meteorology GDE Atlas and borehole locations

The characteristics of the groundwater system are provided in the below groundwater conceptual model (Table 8) and illustrated in Figure 9.

All the elements of the groundwater system were assembled together in a hydrogeological conceptual model. A hydrogeological conceptual model is a representation of a groundwater system in words, figures and/or maps. The hydrogeological conceptual model is then used as a key tool for the assessment of the risk to

groundwater from the project and, if necessary, the development of suitable management and mitigation measures where an impact or potential impact associated with the project has been identified.

Consistent with the data and information available, a simplified conceptual hydrogeological model was prepared. The hydrogeological conceptual model describes the following:

- The aquifer(s) and aquitard(s) of the study area
- The groundwater flow (depth to water and flow direction)
- The groundwater recharge and discharge process, and connectivity between water bodies
- The groundwater environmental values.

Table 8 – Groundwater Conceptual Model – 2CRU

Element of the conceptual model	Characteristics
Hydrostratigraphy (aquifers & aquitards)	The aquifer of concern is the water table aquifer found in the upper part of the lateritic profile. The laterite clays are some 30 m deep and are underlain by shales and siltstones formations. Some of those consolidated formations support minor aquifers.
Water table	The water table can be expected to be found in excess of seven metres depth at the end of the dry season over the elevated section of the site. The water table is expected to rise significantly during the wet season. No data is available at this stage to characterise the seasonal variability. The water table aquifer is separated from underlying aquifers through the presence of aquitard formations. Deeper aquifers are not of interest to this assessment as they do not interfere with environmental values due to depth from surface.
Groundwater quality	A review of site activities and site contamination was performed by GHD (2014). The report indicates there is no gross contamination of soils or groundwater. The site has been unoccupied since this assessment and the situation would have remained unchanged since.
Groundwater use	Bores located in close vicinity of the site have either been decommissioned or are abandoned.
Groundwater values	The monsoon vine thicket area located on the western slope was identified in previous studies as likely to be groundwater dependent. This is most likely in the lower half of the slope. The GDE would be supported by the water table aquifer, accessed by the plants through their root systems. The GDE is not a Matter of National and Environmental Significance Due to low yield, groundwater bore usage is not a groundwater value in the area of the proposed development. There are no groundwater values of national environmental significance in the project site.
Groundwater flow direction	Groundwater flow is inferred to mirror the topography. On the project site, the topographical high will act as a groundwater divide, with groundwater flow to the west being inferred towards the coastal plains and groundwater flows to the east of the divide being directed to the Muirhead North site.
Groundwater recharge	The site area is recharged directly through rainfall infiltration. The upper unconsolidated silty formation is highly permeable and will transmit groundwater flows to the underlying weathered laterite.
Groundwater discharge	Groundwater is expected to discharge through seepage at the foothill of the hill. The water table at the end of the dry season appears to be fairly flat resulting in reduced discharge towards the coastal plain. Following recharge, a higher groundwater gradient will result in added flow, however, due to the nature of the laterite, the flow is expected to remain small.

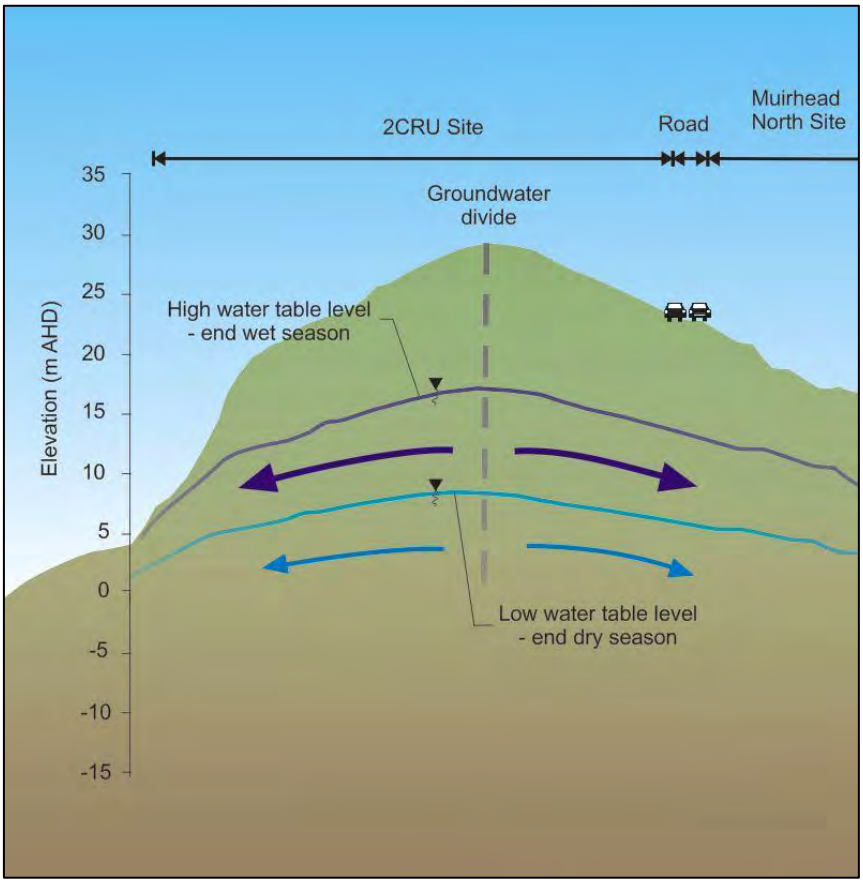

Figure 9. Groundwater Model Cross Section

Table 9. Groundwater Conceptual Model - Muirhead North

Element of the conceptual model	Characteristics
Hydrostratigraphy (aquifers & aquitards)	The aquifer of interest is the water table aquifer found in the upper part of the lateritic profile. Deep aquifers are not of interest to this assessment as they do not interfere with environmental values due to depth from surface. The laterite clays are some 30 m deep and are underlain by shales and siltstones formations. Some of those consolidated formations support minor aquifers. The water table aquifer is separated from underlying aquifers through the lower part of the laterite profile which acts as an aquitard and the presence of aquitard formations further at depth.
Water table	Depth to the water table has been measured at the end of the dry season and found to be 5 to 7 m below ground directly upgradient of the rainforest patch. The water table is expected to be very close to ground level in the eastern part of the site corresponding with the lower part of the rainforest and low lying area.
Groundwater quality	No groundwater contamination is known on site.
Groundwater use	There are no remaining groundwater users in the vicinity of the site.
Groundwater values	A patch of monsoon rainforest has been identified in the eastern part of the site along the drainage line. In its lower reaches, it is expected to be groundwater dependent. The GDE would be supported by the water table aquifer during the dry season. During the wet season water ponding in the rainforest would be the primary source of water supply. The GDE is not Matter of National and Environmental Significance

Element of the conceptual model	Characteristics
	Due to low yield, groundwater bore usage is not a groundwater value in the area of the proposed development. Buffalo Creek is another sensitive value. Due to low yield, groundwater bore usage is not a groundwater value in the area of the proposed development.
Groundwater flow direction	Groundwater flow is inferred to mirror the topography, i.e. a general eastwards direction.
Groundwater recharge	The site area is recharged directly through rainfall infiltration. The upper unconsolidated silty formation is highly permeable and will transmit groundwater flows to the underlying weathered laterite. Higher recharge is expected in the rainforest area during the wet season when water ponding is observed.
Groundwater discharge	Groundwater discharges through seepage at the foothill as observed in the area between the eastern site boundary and the rainforest patch. The water table at the end of the dry season appears to be fairly flat resulting in reduced discharge towards the Buffalo Creek. Following recharge, a higher groundwater gradient will result in added flow.

4.2.2.2 Surface water

2CRU

The 2CRU site is currently unoccupied but previously was used for a Royal Australian Air Force transmission facility situated in the northern half of the site. This facility previously included buildings, sealed roads and car parking together with cleared unsealed areas. The buildings and car parking areas have since been removed with only some sealed roads remaining. A number of unsealed tracks also traverse the site. The vegetation on the project site is predominantly casuarina forest and open woodland with densities increasing along the western boundary where the land drops off sharply towards Sandy Creek and Beagle Gulf. .

Topography across the site ranges from approximately 33 m (Australian Height Datum 'AHD'), at the highest point of the ridge which traverses the middle of the site in a roughly south to north alignment, down to the lowest point of 4.5 m AHD in the south west corner. The lowest point along the Lee Point Road eastern frontage is approximately 22.5 m AHD located 200 m to the south of the Lee Point Village Resort southern boundary. Gradients across the site are generally less than 3%, although there are steep slopes along the western boundary and within the south western corner where runoff from the local site catchment conveys flows to Sandy Creek.

While the majority of surface runoff across the site is conveyed as relatively shallow sheetflow and surface flow, there are some minor gullies where surface runoff is concentrated in defined gullies and excavated drains. These include natural gullies within the south west corner and also open drains located along the former sealed road entrance to the former RAAF facility. The drain along the former RAAF facility entry road conveys flows to Lee Point Road via twin box culverts and a lined opened drain.

Figure 10. Entry road to 2CRU

Flows are conveyed across Lee Point Road via 2 x 1200W x 450H RCBCs into an unlined drain that runs along the Lee Point VillagevResort southern boundary before discharging into a large rural dam. A second culvert crossing of Lee Point Road is located 115m further south and consists of 5 x 750 RCPs that conveys flows collected within the road side drain to the east. The second culvert crossing is shown in the figure below.

Figure 11. Culvert cross of Lee Point Road 115m south of the Lee Point Resort (Nearmap 2016).

The local catchment conveying flows to the south west corner via local gullies discharges into Sandy Creek which runs parallel to the coast in a north-easterly direction before joining the Beagle Gulf. There is also a relative small catchment in the northwest corner of the site which conveys local runoff via the Casuarina Coastal Reserve and beach frontage to Beagle Gulf. It appears that this flow is conveyed as relatively shallow sheet flow down the escarpment.

There are no identifiable external catchments contributing to flows across the site with the Royal Darwin Hospital and Lyons Estate adjacent to the southern boundary effectively forming a catchment divide with flows from the site being conveyed via open drains along this boundary to both Sandy Creek and Lee Point Road.

Muirhead North

The site is currently undeveloped, predominately consisting of casuarina forest and open woodland. An environmentally significant rainforest area exists within the centre of the site. A number of unsealed tracks traverse the site, and a rural dam exists immediately to the north.

Topography across the site ranges from approximately 5 to 25 m AHD, generally grading from west to east before discharging into Buffalo Creek. Surface runoff from the site is relatively shallow, and is mainly conveyed via sheet flow and surface flow, in some areas runoff is concentrated in defined gullies. These include naturally occurring gullies within the centre of the site.

A proportion of the 2CRU catchment drains through the subject site, via 3 culverts as can be seen in Appendix F – Figure 2.

4.2.2.3 Flooding

Notwithstanding inundation across the project site from local catchment runoff resulting in shallow sheet flow and concentrated gully flows, other potential sources of inundation could occur due to storm tide inundation given the proximity of the site to Beagle Gulf.

Reference to the *'High Resolution Storm Tide and Climate Change Impacts Study – 2010'* prepared by System Engineering Australia for the Northern Territory Department of Lands and Planning identifies the following storm tide levels for Lee Point detailed in Table 10.

Table 10. Total Storm Tide Level (m AHD) at Lee Point

Year	Estimated Return Period of Total Storm Tide Level				
	50y	100y	500y	1000y	10000y
2010	4.5	4.7	5.2	5.4	5.8
2050	4.9	5.1	5.6	5.8	7.1
2100	5.4	5.6	6.1	6.5	7.4

The above levels for 2100 have been mapped by GHD in 2014 based on the latest topographic information (2009 and 2011) as part of the Northern Territory Storm Surge Mapping with the area containing the site extracted below in Figure 12. The storm surge mapping shows that the entire site is above the 100 year

Average Recurrence Interval (ARI) storm tide level for 2100, except for a small area in the south-west corner of 2CRU and south-east corner of Muirhead North.

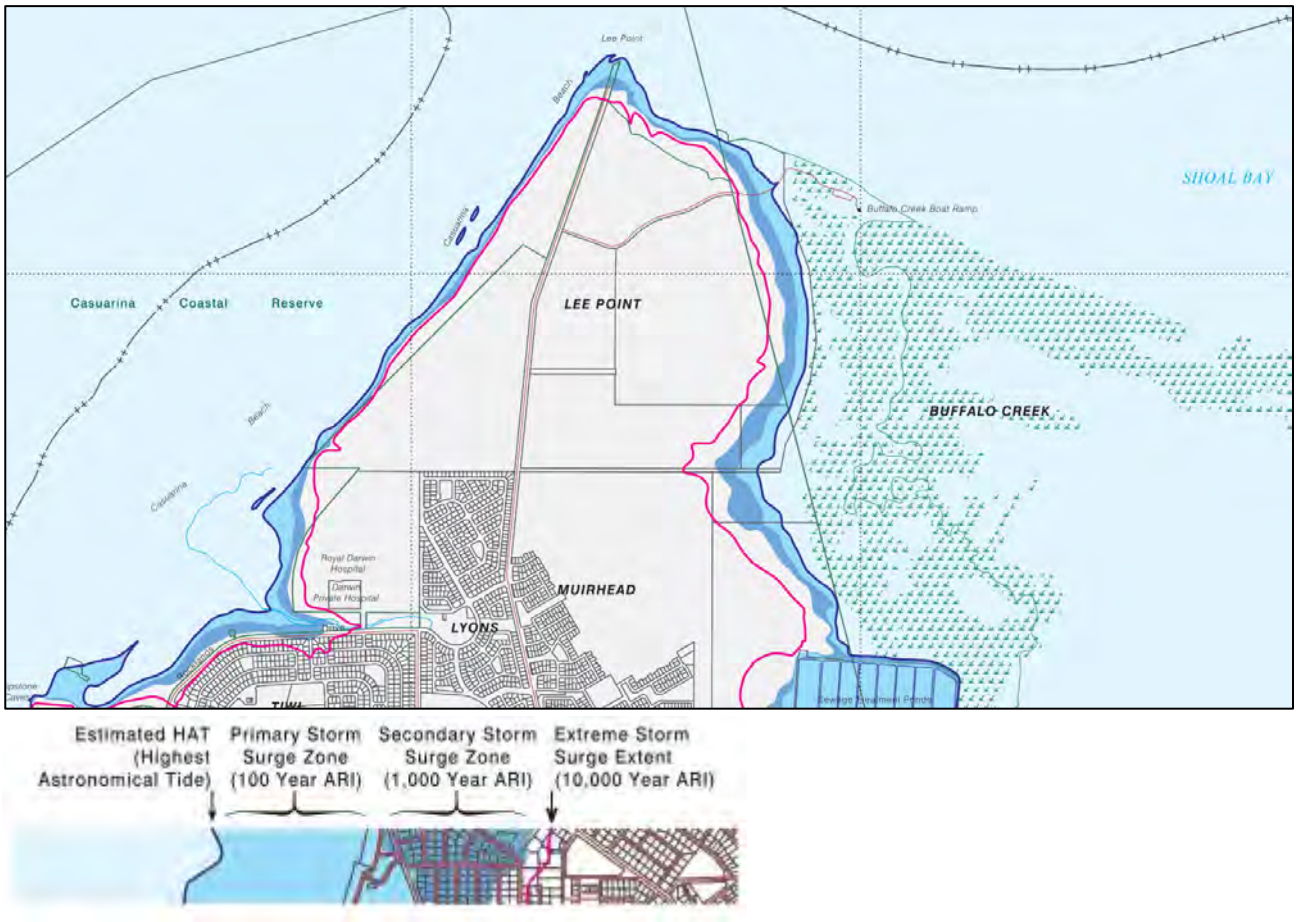

Figure 12. Darwin Area Storm Surge Inundation for 2011 (Copyright: Northern Territory Government, GHD and SEA)

4.2.3 Casuarina Coastal Reserve

The Casuarina Coastal Reserve comprises 1,361 ha and includes a strip of 8 km of coastline to the west of Lee Point (Figure 13). The Reserve includes extensive sandy beaches, tidal flats, estuaries, dune systems, mangrove communities, Casuarina forests, fringing monsoon forest and an offshore marine area. As noted in the Management Plan, "*The hydrological resources of a park are a critical element of the park's ecosystems and the maintenance of their integrity is crucial*" (Parks and Wildlife Commission of the Northern Territory, 2002).

Large portions of the reserve are identified by the Australian Groundwater Dependent Atlas as having a moderate potential to support GDEs reliant on subsurface expression of groundwater. The mapping of GDEs across the reserve is broadly consistent with the extent of high ecological value Monsoon Vine-thicket.

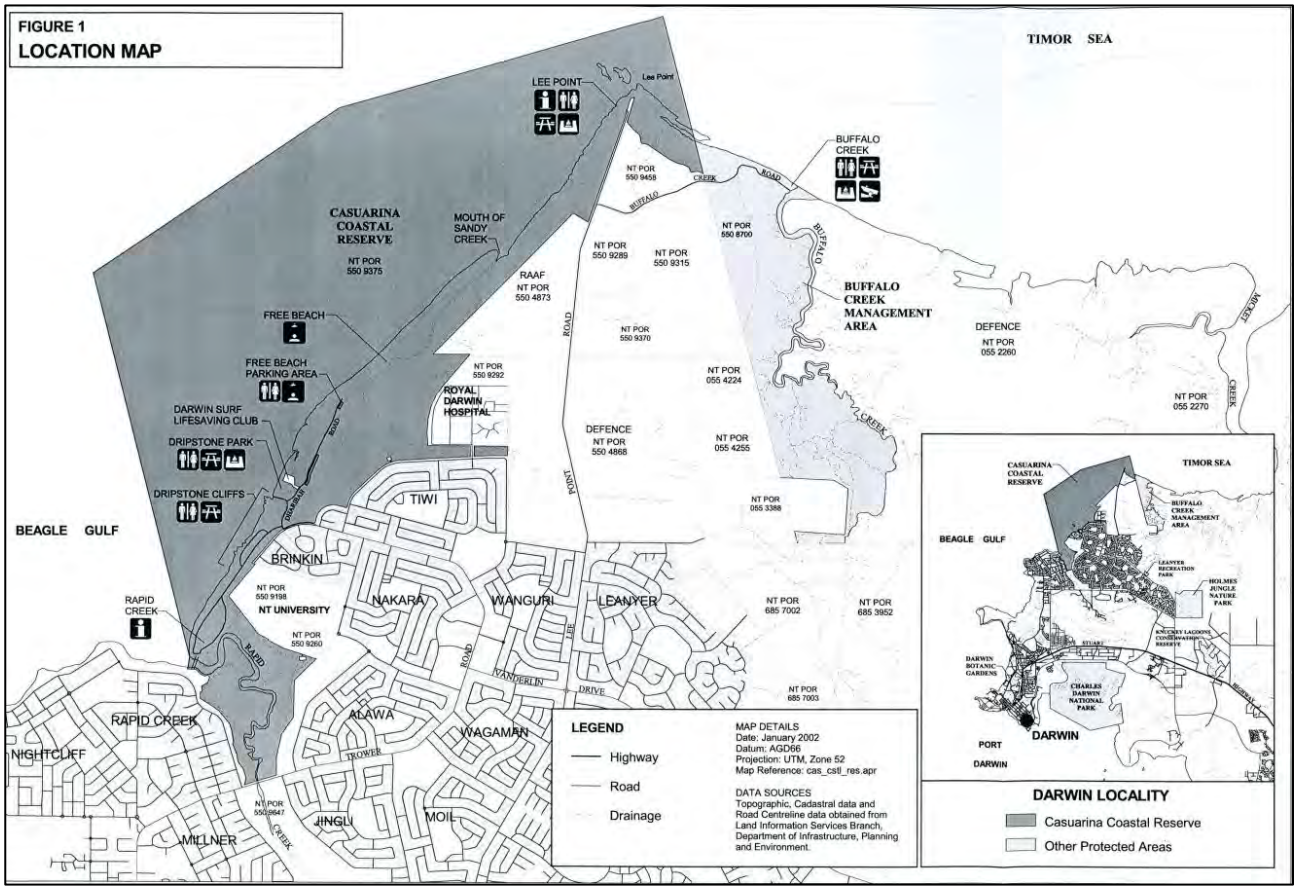

Figure 13, Casuarina Coastal Reserve (Casuarina Coastal Reserve Management Plan: Parks and Wildlife Commission of the Northern Territory 2002).

4.2.4 Sandy Creek

Sandy Creek is a sensitive ecosystem containing some mangroves, rainforest and dense vegetation and forms part of the Casuarina Coastal Reserve described above. The Sandy Creek catchment area includes the urbanised areas of Muirhead (South), Tiwi, Lyon and the Royal Darwin Hospital precinct. The western portion of the project site discharges to the Sandy Creek catchment at the south-west corner of the 2CRU site where the creek continues in a northerly direction for approximately 1 km parallel to Casuarina Beach before discharging into the sea.

The Northern Territory Government does not collect any water quality data on Sandy Creek. Upstream, the creek receives discharge from Royal Darwin Hospital, urban areas and roads. It is assumed that the water quality is similar to the ANZECC parameters for a slightly-moderately disturbed waterway in tropical Australia.

4.2.5 Buffalo Creek

The Buffalo Creek catchment flows into Shoal Bay to the north-east of Muirhead North. It is understood to be the most polluted tributary discharging into Darwin Harbour. This is due to the following present and past land-uses within the catchment:

- The Leanyer-Sanderson Sewerage Treatment Plant that discharges treated sewage directly into Buffalo Creek
- Discharge of untreated urban stormwater from existing urban development
- Construction activities
- Existing and historic landfills
- Recreational activities
- A historic quarry mine.

The latest 2016 report card for Darwin Harbour which includes monitoring of Buffalo Creek and Shoal Bay is shown below:

	Harbour region								
Indicator	Outer Harbour			Inner Harbour				Tidal creeks	
	Outer Darwin Harbour	Shoal Bay	Middle Darwin Harbour	Blackmore	East Arm	Elizabeth	West Arm	Buffalo Creek	Myrmidon Creek
Water clarity	✔	✔	✔	✔	✔	✔	✔	✖	✔
Dissolved oxygen	✔	✔	✔	✔	✔	✔	✔	✖	✔
Algae	✔	✔	✔	✔	✔	✔	✔	✖	✔
Nutrients	✖	✖	✔	✔	✔	✔	✔	✖	✖
	Report Card grades								
2016	B	B	A	A	A	A	A	E	B
2015	B	A	B	B	B	B	B	E	B

Figure 14. Darwin Harbour Region Report Card 2016

Treated sewerage from Leanyer Sanderson Wastewater Treatment Plant is discharged into Buffalo Creek in accordance with Water Discharge Licence WDL 147-08. In accordance with licence condition 18, Power and Water Corporation are responsible for ensuring that discharges must not:

- Contain any visible matter, floating oil and grease or petroleum hydrocarbon sheen or scum, or litter or other objectionable matter;
- Cause or generate odours which would adversely affect the use of surrounding waters;
- Cause visible change in the behaviour of fish or other aquatic organisms;
- Cause mortality of fish or other aquatic organisms; or,
- Cause adverse impacts on plants.

In accordance with the WDL, Power and Water Corporation are required to undertake period monitoring and report of water quality of Buffalo Creek. The last annual audit and compliance report available for Leanyer Sanderson Wastewater Treatment Plant is from December 2014 and relates to WDL 147-05. Condition 8 of the report addresses the following requirement '*the licensee must, without limiting any other condition of this Licence in conducting the Activity do all things reasonable and practicable to ensure the Activity does not adversely affect the Declared Beneficial Uses and Objectives as declared from time to time..,*'. Power and Water Corporation provided the following response:

'PWC does all things reasonable and practical to protect BUs (Beneficial Uses) *within the constraints of the existing WSP technology and for discharge in this location i.e. poorly flushed estuary (legacy issues over 40 years). The WwTP performs well in reduction of loads and prevention of direct faecal contamination. PWC periodically undertakes necessary operational changes to ensure the optimum capacity and functioning of the WSPs. Major operational changes such as desludging of ponds are accompanied by tasks specifics ERAs prior to commencement to prevent environmental harm…Buffalo Creek is considered a highly disturbed aquatic ecosystem and likely to remain in this state without significant infrastructure investment that will require government/public consultation".*

There are no other publicly available monitoring reports related to WDL 147. Power and Water Corporation have also not provided any additional monitoring reports or other information on the condition of Buffalo Creek to DHA.

4.3 Risk Assessment

4.3.1 Risk assessment summary

A summary of the risk assessment findings of the potential impacts the project will have on hydrological values is provided below in Table 11. The summary includes those impacts which are considered to be of High or Medium risk and necessitates mitigation measures to reduce the risk to an acceptable level. The full results of the risk assessment are provided in Appendix C. The risk assessment was completed in accordance with the methods described in Section 3.

Further information on the nature of the potential impacts and the type of mitigation measures proposed is provided below in Section 4.3.2.

The potential for further decline in the health of Buffalo Creek as a result of increased effluent discharge is low. Please see Section 6.3.1.1 for further information.

Table 11. Summary of risk assessment

Impact	Description	Mitigation measures
Surface water quality	The development of the site has the potential to impact on the water quality of the downstream receiving waters. Typical pollutants generated from development of the site include an increase in nutrient loads, sediments, gross pollutants and heavy metals and hydrocarbons for commercial/industrial land uses.	To mitigate the impacts of the development on discharged water quality it is proposed to incorporate Water Sensitive Urban Design (WSUD) principles and a stormwater treatment strategy that includes the use of bioretention basins, and vegetated swales/buffers for treatment. For more intense land-uses or areas that have limited space for treatment there is the potential to use proprietary treatment devices. Water Quality Monitoring will be undertaken to ensure the project does not impact Sandy Creek.
Surface water flow rates	The increased impervious areas and drainage network incorporating underground pipes has the potential to increase peak flows discharging from the site into Sandy Creek..	It is proposed to incorporate on-site detention measures in the form of end-of-line detention basins and online detention utilising internal road crossings of drainage channels.
Erosion	Erosion and sedimentation during construction and post-development	Erosion and Sediment Control Plan (ESCP), which will also include rehabilitation of large erosion gullies in the south-west of 2CRU.
Flooding	Notwithstanding inundation across the site from local catchment runoff resulting in shallow sheet flow and concentrated gully channel flows, other potential sources of inundation could occur due to storm tide inundation given the proximity of the site to Beagle Gulf.	The detailed drainage design of the development will incorporate both underground pipes and open channels to convey the site runoff though the development. To mitigate the potential increases in peak flows, on-site detention measures are also proposed. The design levels for the adjacent lots and roads will ensure adequate freeboard and trafficability

Impact	Description	Mitigation measures
		respectively during the applicable design flood events. The majority of the site is above the 100 year Average Recurrence Interval (ARI) storm tide level for 2100.
Litter, rubbish entering creeks and eventually Bay.	The development of the site has the potential to impact on the water quality of the downstream receiving waters. Typical pollutants generated from development of the site include gross pollutants.	The stormwater quality treatment measures proposed include the use of bioretention basins and vegetated swales/buffers. In addition, for more intense land uses, proprietary products including Gross Pollutant Traps (GPTs) are proposed. .
Groundwater quality	Contamination through uncontrolled release during construction works	Preparation & implementation a CEMP which would include special response spill containment and response measures
Groundwater quality	Contamination though sewage leaks/release	Site residences are connected to main sewage network, no septic systems. Design of sewerage system in accordance with City of Darwin and PWC's requirements.
Lower groundwater recharge	Lower groundwater recharge as a result of reduction of natural surfaces over the site potentially affecting GDEs	Reserve area on western side of the development. Retain Monsoon Rainforest patch in Muirhead North. Optimise natural areas throughout the area by the presence of natural reserves, parks and gardens. Water recharge increased through water infiltration at stormwater detention basin.
Acid sulphate soils	Acid sulphate soils have a low-medium potential to occur at the lowest elevations of the project site, that being the south-east corner of Muirhead North.	Complete test drilling in south-east corner of Muirhead Nort prior to commencing construction. If acid sulphate soils are encountered, prepare an acid sulphate soils management plan.

4.3.2 Description of impacts and mitigation

Mitigation measures proposed for the development include the use of WSUD principles.

The stormwater quality treatment measures to be adopted for the development include the use of bioretention basins and vegetated swales/buffers. High density areas within the development such as the commercial precinct may also incorporate proprietary treatment devices such as the Stormwater360 treatment system.

The impact of the development on stormwater quantity is to be mitigated by on-site by detention measures in the form of end-of-line detention basins and online detention utilising internal road crossings of drainage channels. Suitable scour and erosion protection measures will be incorporated at the outlets to any basins and

at locations where velocities are such that they have the potential to cause significant scour, such as downstream of culvert crossings of roads. These scour protection measures will be in the form of a combination of rock protection, gabions and/or flow spreaders.

The risks to groundwater are considered to be low. Standard spill management procedures will be implemented as part of the CEMP. In the highly unlikely event that pollutants enter the groundwater they could be removed using standard remediation procedures. There is unlikely to be any change in recharge, and as such GDEs should not be affected.

4.3.2.1 Groundwater

Potential impacts from groundwater can be classified in three chronological categories:

- Impacts arising from previous activities, primarily associated with potential contamination
- Impacts to groundwater during construction activities
- Impacts to groundwater arising from residential use of the site.

The risks associated with previous site activities have been assessed (GHD 2014). GHD reviewed the site historical activities and potential contamination and concluded that there was no soil and groundwater contamination at the site.

Risks to groundwater during construction activities are associated with accidental spills and contamination. The contaminant would need to enter the subsurface and then propagate down through the laterite profile to the water table and affect water quality of the aquifer and receiving water bodies.

The risk to groundwater from residential activities lays more with the disposal of sewage than inhabitants' activities themselves.

Impacts to water quality groundwater during construction activities

The site auditors report for 2CRU considered that the risks to groundwater from site activities as low and that no further investigation was necessary (AECOM 2016). However, some uncertainty remains around the quality of groundwater on site and the use of groundwater for beneficial uses should be prohibited until further investigation is undertaken (AECOM 2016).

In the case of uncontrolled spills, the chemical characteristics of the contaminant are most likely to be from the hydrocarbons family and as such can easily be identified from natural groundwater and surface water settings.

It is highly unlikely that an accidental spill would result in an impact on groundwater quality at the site for the following reasons:

- Any construction activity would have to follow the CEMP which would include special response spill containment and response measures.
- The contamination would initially be limited to the soil and upper unsaturated aquifer profile, where remediation by removal of the contaminated soil/rock is very effective.

- Should the regional groundwater be affected, the chemical release is estimated to be quite minor (small source of contamination over a very short period) and through natural attenuation would rapidly become insignificant or undetectable.

For the same reasons, it is highly unlikely that an accidental spill would result in an impact to aquifer water quality.

As a result, there will be no impact to groundwater from construction activities provided suitable spill response and control measures are in place during construction.

Impacts to water quality arising from residential use of the site

The project site is planned to be developed as residential development, commercial development, community facilities and conservation areas. The development will benefit from the connection to main sewer services. As a consequence, there is no risk associated with on-site treatment of sewage.

Impacts to groundwater dependent ecosystems

Impacts to GDEs that potentially occur along the western boundary of 2CRU, and the eastern section of Muirhead North, could be associated with a decrease of supply (i.e. decrease of the level of the water table) due to a reduced area for groundwater recharge. The development proposal will retain the Monsoon Vine-thicket area as part of the Casuarina Coastal Reserve, and the Monsoon Rainforest patch in Muirhead North. The GDE Atlas identifies other vegetation types in the eastern section of Muirhead North, which is likely to be partially cleared as part of the rural alotments. It should be noted that groundwater dependency will require the rooting system to reach to the water table. This is only likely to occur at low and mid-slope in the Monsoon Vine-thicket area.

The reduction in recharge due to the replacement of permeable surfaces with hardstand areas will reduce recharge, although this will be counterbalanced by reduced evapotranspiration and localised recharged at utility trenches. In addition, the proposed development optimises the use of natural areas and the presence of bio-retention basins upstream of the Monsoon Vine-thicket and Monsoon Rainforest patch (see Figure 5 in Appendix E and Appendix F) will provide added recharge to the groundwater system. As a result, the likelihood of a significant recharge reduction is estimated to be low. The risk of impact to GDEs is rated low (Rare likelihood x Major consequence). The “major” consequence classification relates to the interest of the Northern Territory in maintaining this type of vegetation.

Ongoing monitoring of the health of the Monsoon Vine-thicket and Monsoon Rainforest patches will be conducted to infer any potential impact associated with reduced groundwater recharge (see Section 7.3.2.10).

4.3.2.2 Stormwater

Development of the project site has the potential to:

- Release sediment and potential contaminants into receiving waters as a result of vegetation clearing and/or excavation
- Adversely impact fish and other aquatic species that may inhabit Sandy Creek due to increased turbidity and/or release of contaminants during construction, or increased pollutant loads from road runoff during operation

- Impact roosting and feeding habitat for migratory shorebirds at the mouth of Sandy Creek
- Contaminate water in the event of fuel or oil spills during construction and operation.

The potential for the development to impact on Buffalo Creek is considered low, given the existing poor condition of Buffalo Creek, and stormwater treatment and ESCP measures that will be implemented.

The majority of potential water quality and quantity related impacts can be adequately managed with effective implementation of the mitigation measures outlined in the following section to meet specific Water Quality Objectives (WQOs). These measures include bioretention systems, vegetated swales/buffers, erosion and sediment control and proprietary devices. Water quality will also be monitored at the three discharge locations as well as in Sandy Creek and Buffalo Creek (Appendix O).

Construction Phase Water Quality

During the construction phase, the potential exists for increases in the amount of pollutants, particularly sediment, exported from the site. During this period, an ESCP will be referred to as part of the overall CEMP prepared for the construction phase.

It is considered that the completion of construction activities in accordance with an ESCP developed using latest version of the following guidelines will minimise the nature of any adverse impacts during the construction phase and allow the design objectives to be achieved:

- IECA.2008, *Best Practice Erosion and Sediment Control- Engineering Guidelines for Queensland Construction Sites.*
- Institution of Engineers Australia.1996, *Soil Erosion and Sediment Control, Engineering Guidelines for Queensland Construction Sites. June.*

Please refer to Appendix D for further details of the ESCP.

Post-Construction Phase Water Quality

The formulation and implementation of the stormwater quality management plan for the development is based on the following key principles:

- Adoption of WSUD principles where feasible.
- Management and control of water quality both during and after construction. A detailed ESCP will be developed in accordance with recognised standards during the detailed design phase and implemented on site during the subdivision construction process.

A copy of the Stormwater Management Plan is provided in Appendix E (2CRU) and Appendix F (Muirhead North).

Proposed Stormwater Quality Treatment Train

The treatment measures outlined in the Stormwater Management Plan include the use of Ecosol Net Guards, bioretention basins and vegetated swales/buffers. High density areas within the development such as the tourism/commercial precinct may also incorporate proprietary treatment devices such as the Stormwater360 treatment system. The preliminary locations for the proposed treatment measures are shown in the Stormwater Management Plans (Appendix E and Appendix F).

To minimise the size of the bioretention areas, it is proposed to incorporate the proprietary treatment product by Ecosol being the Net Guard as pre-treatment to the bioretention basins. The Net Guard will primarily treat the Total Suspended Solids (TSS) and Gross Pollutants (GP) with some additional pollutant removal of Total Nitrogen (TN) and Total Phosphorus (TP). The recommended pollutant removal efficiencies have been provided by the manufacturer and listed below:

- TSS – 40% removal
- TN – 30% removal
- TP – 35%
- GP – 93%

The preliminary details of the bioretention basins are detailed in Table 12 with the locations of the bioretention basins are shown in the Stormwater Management Plans (Appendix E and Appendix F).

The bioretention basins and stormwater treatment devices will be designed to allow for effective maintenance. The maintenance of stormwater management assets will be considered as part of the Conservation and Offset Management Plan to be prepared for the Conservation Area, so as not to compromise to ability undertake management and address any biting insect issues.

Table 12. Bioretention details for 2CRU (Bio-Basin A-E) and Muirhead North (Bio-Basin F-I)

Parameter	Bio-Basin A	Bio-Basin B	Bio-Basin C	Bio-Basin D	Bio-Basin E	Bio-Basin F	Bio-Basin G	Bio-Basin H	Bio-Basin I
Extended Detention Depth (m)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Surface Area (m^2)	900	700	700	900	650	750	1050	600	600
Filter Media Surface Area (m^2)	900	700	700	900	650	750	1050	600	600
Saturated Hydraulic Conductivity (mm/hr)	200	200	200	200	200	200	200	200	200
Filter Depth (m)	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
TN Content (mg/kg)	400	400	400	400	400	400	400	400	400
Orthophosphate Content (mg/kg)	30	30	30	30	30	30	30	30	30

It should be noted that the maximum bioretention area is recommended to be 800m^2 for both ease of maintenance and to aid the survival of bioretention vegetation during extended dry periods. The limiting pollutant in sizing most of the bioretention areas is TSS, with the use of proprietary pre-treatment devices such as Ecosol's Net Guard product, the overall size of the bio-retention basins could be reduced.

It is noted that the use of rainwater tanks for re-use of rainwater could also potentially reduce the pollutant loads discharging from the site while also reducing demand on town water supply. However, imposing this requirement on potential property buyers is not easily enforced and has therefore not been included as part of the treatment train.

The stormwater treatment train has been designed to discourage breeding and providing habitat for biting insects. The Stormwater Management Plans have been developed to comply with the recommendations set out in the Biting Insect Report prepared specifically for this project (Appendix G). This includes by ensuring all water within the detention basin drains within 24 hours of a rain event, that stormwater is discharged within the tidal section of both creeks (i.e. less than 3 m AHD).

Design and Performance of Treatment Measures

In order to determine the effectiveness of the adopted treatment train in meeting the WQOs, a stormwater quality analysis was performed using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) Version 6.

The model requires the user to specify meteorological data (rainfall and evaporation), soil properties and pollutant loads for each catchment. Suitable parameters for the MUSIC model have been adopted in accordance with the recommendations within the *Water Sensitive Urban Design Stormwater Quality Modelling Guide, May 2009* prepared by the Northern Territory Department of Planning and Infrastructure.

The Urban Residential Source node has been adopted within the MUSIC modelling. Further, the development has been divided into roof areas, road areas and general urban based on the applicable Source Node land use. The pollutant export parameters adopted are shown in Table 13.

The rainfall data applied to the MUSIC model was for the Darwin Airport rainfall station for the period 1987-1996. A 6 minute time step was considered for the analysis.

Table 13. Stormwater Quality Parameters for MUSIC Source Nodes

Source Node		TSS (log_{10} values)		TP (log_{10} values)		TN (log_{10} values)	
		Mean	**St. Dev.**	**Mean**	**St. Dev.**	**Mean**	**St. Dev.**
Baseflow	Roof	1.1	0.17	-0.82	0.19	0.32	0.12
	Roads	1.1	0.17	-0.82	0.19	0.32	0.12
	General Urban	1.1	0.17	-0.82	0.19	0.32	0.12
Stormflow	Roof	1.55	0.39	-0.92	0.29	0.42	0.19
	Roads	2.38	0.40	-0.60	0.50	0.42	0.19
	General Urban	2.20	0.32	-0.45	0.25	0.42	0.19

Catchment Areas

Catchment areas and percentage impervious values were determined as part of the Stormwater Management Plans (see Appendix E and Appendix F). The adopted catchment characteristics are given in Table 14.

Table 14. Catchment areas for 2CRU (Catchment A-E) and Muirhead North (Catchment F-I)

Catchment	Total	% Impervious
A	14.33	42
B	11.91	49
C	9.43	67
D	12.26	67
E	9.37	60
F	12.20	50
G	16.24	57
H	10.70	16
I	9.81	17

The results of the MUSIC modelling, shown as total annual loads, are presented in Table 15 (2CRU) and Table 16 (Muirhead North). The results demonstrate that the proposed stormwater treatment measures for the development will satisfy the adopted WQO for all pollutants modelled in MUSIC. Stormwater Quality and therefore the COD criteria for water quality have been appropriately addressed.

Table 15. Predicted Pollutant Load Reductions – 2CRU

Parameter	Generated Load	Post-development (Mitigated) Load	% Reduction
TSS (kg/yr)	123000	24200	80.3
TP (kg/yr)	256	71.3	72.1
TN (kg/yr)	1850	791	57.1
Gross Pollutants (kg/yr)	14100	1.24	99.9

Table 16. Predicted Pollutant Load Reductions – Muirhead North

Parameter	Generated Load	Post-development (Mitigated) Load	% Reduction
TSS (kg/yr)	83000	16100	80.6
TP (kg/yr)	177	48.1	72.8
TN (kg/yr)	1300	545	58
Gross Pollutants (kg/yr)	9460	0	100

Stormwater Quantity

The intensified development of the site has the potential to increase local site runoff due to the increase in impervious areas associated with the development. This potential increase in local peak flows can ultimately result in increased peak discharges within the adjacent waterways that can result in increased flood levels, erosion of the waterway and affect bank stability.

To limit the adverse impacts external to the developed site, it is required to limit post-development flows from the site to less than pre-development levels using appropriate mitigation measures where possible.

To mitigate the potential increase in flows discharging from the project site, it is proposed to include end-of-line detention basins at the outlet to the site's three major outlets located as shown in the Stormwater Management Plan for 2CRU (Appendix E) and Muirhead North (Appendix F).

Modelling undertaken as part of the Stormwater Management Plans showed that without mitigation the peak flows would increase at three out of five of the outlets (Table 17). When considering the impact of the development on both the rainforest patch and rural dam, it is anticipated that the volume of the more frequent runoff events would be the critical hydrologic factor in maintaining the health and demand for the respective receiving environments. Given that the antecedent catchment condition is considered the same in both the pre and post-development scenarios, there should ultimately be no impact on runoff volume to the respective receiving locations if the contributing catchment area is maintained.

It should be noted that the health of the Monsoon Rainforest patch will be monitored to infer whether stormwater flows are appropriate for sustaining the patch. If the stormwater flows are not considered tolerable than changes to the stormwater treatment system will be considered, which most likely would include removing bioretention basins and replacing with Gross Pollutant Traps to increase baseflows in to the Monsoon Rainforest whilst still treating stormwater for nitrogen and phosphorous pollution.

Table 17. Impact on 100 Year ARI Peak Flows for 2CRU (RP01 and RP04) and Muirhead North (RP05, RP06 and RP5)

Sub-catchment Outlet	Pre-development XPRAFTS Q100 Peak Flow (m^3/s)	Post-development (Unmitigated) XPRAFTS Q100 Peak Flow (m^3/s)	Increase in Peak Flows (m^3/s)	Impact (%)
RP01 – North West	2.51	4.50	1.99	79
RP04 – South West	9.46	19.26	9.80	104
RP05 – To Rainforest Patch	7.44	3.46	-3.98	-53
RP06 – To Rural Dam	3.92	1.86	-2.06	-53
RP5 – Buffalo Creek outlet	27.07	31.23	4.16	15.4

The Stormwater Management Plans includes mitigation in the form of bioretention and detention basins to ensure that peak flows are not impacted by the project. To ensure the rural dam supply is maintained by regular runoff from the upstream catchment, it is proposed to divert all flows up to the 2 year ARI event ($1.86m^3/s$ and $3.46m^3/s$) to the existing drains that conveys flows to the rural dam and rainforest patch in Muirhead North respectively. The 2 year ARI peak flow was selected based on the existing cross drainage culvert of Lee Point Road expected to have a minimum 2 year ARI capacity and preliminary estimates of the capacity of the drain. The balance flows from the developed catchment will be diverted to link with the main drainage path to the south.

Preliminary design of the detention basins has been undertaken assuming the following criteria:

- 1 in 6 batters to facilitate maintenance of the batters, assumed to be turfed;
- Basins initially assumed to be trapezoidal with a width:length ratio of 1:2;
- Maximum depth within each basin to be 1.2m for the 20 year ARI event for public safety. Deeper basins may be possible with appropriate signage and fencing and approval from the City of Darwin; and
- Post-development peak flows to be mitigated to pre-development peak flows for all events from the 2 to 100 year ARI.

For the catchment discharging to the south-west corner of the 2CRU, two individual detention basins have been designed to maintain existing peak flows in the two defined gullies immediately downstream rather than a single outlet which would potentially result in additional erosion in a single gully.

For the catchment discharging to the north of the project site, a detention basin has been designed to maintain existing peak flows.

The detention basin outlets are detailed in Table 18 with the stage-storage relationships shown in Table 19.

Table 18. Detention Basin Details

Basin ID	Outlet Pipes	High Flow Weir Width at 100 Year Level (m)	20 Year Depth in Basin (m)	100 Year Depth in Basin (m)	Surface Area at 100 Year Level (m^2)	Volume at 100 Year Level (m^3)
Basin 1	1 / 1200 x 600 RCBC	1.80	1.07	1.33	3,300	3,600
Basin 2	1 /1200 x 600 RCBC	1.80	1.04	1.25	3,200	3,350
Basin 3	2 / 1200 x 600 RCBC	1.80	1.04	1.45	15,950	22,050
Basin 4	7 / 1.5 x 0.9 RCBC	1.80	1.18	1.26	12,800	15,714

Table 19. Proposed Detention Basin Stage-Storage Relationships

Stage (m)	Basin 1 Storage (m^3)	Basin 2 Storage (m^3)	Basin 3 Storage (m^3)	Basin 4 Storage (m^3)
0.00	0	0	0	0
0.20	511	511	3,451	3,451
0.40	1,021	1,021	6,696	6,696
0.60	1,526	1,526	9,702	9,702
0.80	2,018	2,018	12,422	12,422
1.00	2,551	2,551	15,194	15,194
1.20	3,149	3,149	18,177	18,177
1.40	3,799	3,799	21,277	21,277
1.60	4,508	4,508	24,500	

The resulting mitigated peak flows at each reporting point for all design events are presented in Table 20 to Table 22 and demonstrate that the detention basins will attenuate the increase in run-off associated with the increase in impervious areas, and maintain peak flows at or slightly below pre-development levels.

Table 20. 100 and 50 Year ARI Peak Discharge (m^3/s)

Reporting Point	100 Year ARI			50 Year ARI		
	Pre-developed	Mitigated Post-developed	Impact	Pre-developed	Mitigated Post-developed	Impact
RP01	2.51	2.05	-0.46	2.21	1.88	-0.33
RP02	2.91	2.27	-0.64	2.58	2.09	-0.49
RP03	6.38	4.70	-1.67	5.67	4.15	-1.53
RP04	9.46	6.90	-2.56	8.44	6.17	-2.27
RP05	7.44	3.46	-3.98	6.58	3.46	-3.12
RP06	3.92	1.86	-2.06	3.48	1.86	-1.62

Table 21. 20 and 10 Year ARI Peak Discharge (m3/s)

Reporting Point	20 Year ARI			10 Year ARI		
	Pre-developed	Mitigated Post-developed	Impact	Pre-developed	Mitigated Post-developed	Impact
RP01	1.85	1.66	-0.19	1.56	1.46	-0.10
RP02	2.25	1.89	-0.36	1.94	1.67	-0.28
RP03	4.83	3.44	-1.39	4.09	2.66	-1.43
RP04	7.27	5.24	-2.03	6.22	4.22	-2.00
RP05	5.64	3.46	-2.18	4.84	3.46	-1.38
RP06	3.02	1.86	-1.16	2.59	1.86	-0.73

Table 22. 5 and 2 Year ARI Peak Discharge (m^3/s)

Reporting Point	5 Year ARI			2 Year ARI		
	Pre-developed	Mitigated Post-developed	Impact	Pre-developed	Mitigated Post-developed	Impact
RP01	1.41	1.32	-0.09	1.11	1.05	-0.06
RP02	1.76	1.51	-0.24	1.44	1.21	-0.23
RP03	3.66	2.01	-1.66	2.97	0.75	-2.23
RP04	5.60	3.39	-2.21	4.54	2.05	-2.49
RP05	4.33	3.46	-0.87	3.46	3.46	0.00
RP06	2.32	1.86	-0.46	1.86	1.86	0.00

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Staging

The proposed staging plan (Table 3) implies the commencement of civil works prior to proper construction of a functioning stormwater management system. Construction of the detention basins and drainage system as outlined in the Stormwater Management Plans (Appendix E and Appendix F) will be brought forward to ensure compliance with the Stormwater Management Plan during construction. Run-off from Stage 1A and 3 will be diverted to Muirhead North, and therefore will require development of the detention basin in Stage 2B beforehand. Likewise, the detention basin in Stage 4 would need to be functioning prior to development of Stage 2A.

4.3.2.3 *Acid Sulphate Soils*

Testing for acid sulphate soils has not been undertaken. Despite the proximity of the project site to the coastline, the elevation of the site is likely to preclude the presence of acid sulphate soils (GHD 2010). If present, acid sulphate soils are most likely to occur in the lowest elevations of the site, which occurs in the south-east of Muirhead North, which relates to Stage 2B. It should be noted that no acid sulphate soils were encountered in the adjoining Muirhead Breezes development. Nonetheless, test pits will be dug in the south-east of Muirhead North to determine the presence of acid sulphate soils prior to the development of Stage 2B. If acid sulphate soils are encountered than an acid sulphate soils management plan will need to be prepared and implemented.

5 AIR QUALITY

5.1 Introduction

This chapter assesses the potential impacts of the project on air quality, or existing air quality issues that may affect the amenity for future residents. The chapter specifically focusses on dust generation and odour and addresses the following criteria of the EIS ToR:

- Potential impact from odour related to the proximity to the Leanyer Sanderson Wastewater Treatment Ponds, supported by on site sampling and undertaken by a suitably qualified and experienced consultant in accordance with AS/NS 4232.3:2001 or other demonstrated industry best practice methodology.
- Discuss the risks from dust and other particulate matter during construction activities and the proposed mitigation of those risks.

The chapter is structured in the following manner:

- Description of the methods used to model the magnitude of odour impacts, and likely impacts from dust (Section 5.2).
- A summary of the Identified odour and dusk risks to sensitive receivers and future residents and a list of practical and appropriate mitigation measures to avoid any unacceptable dust or odour disturbance that may occur during the construction or operation phase of the project (Section 0).

The full risk assessment is provided in Appendix C. The findings of odour impacts are based on the Odour Impact Assessment prepared by The Odour Unit (2017), which is provided in Appendix .

5.2 Existing Conditions

5.2.1 Odour methods

The methods used to establish the impact from odour focussed on the plume extent and odour intensity, both of which were undertaken using industry best-practice standards. Field staff who undertook odour measurements in the field are registered assessors in accordance with AS/NZS4323.3:2001 Dynamic Olfactometry. Meteorological data was also recorded during the assessment to aid interpretation.

5.2.1.1 Plume extent

Establishing the plume extent was based on the internationally recognised European Standard: EN 16841-2:2016 using the dynamic plume method. At least 20 single measurements were taken at different distances downwind from the Leanyer Sanderson Wastewater Treatment Plant by at least two assessors in order to define at least six transition points and the odour plume extent. Assessors walked in a zig-zag fashion into and out of the defined plume to prevent adaptation to the odour. The maximum extent of the plum is determined by assessors repeatedly crossing the plume at different distances from the source. The spatial location of each measurement point is recorded, along with the time and whether or not the odour could be detected.

5.2.1.2 Odour Intensity

Once the plume extent was defined, the assessors determine the odour intensity based on the internationally recognised German Standard: VDI 3940, 3882 Part 1. Assessors conducted measurements at discrete points downwind of the Leanyer Sanderson Wastewater Treatment Plant, involving 60 grab measurements for 10 sections for a single measurement cycle of 10 minutes. Each measurement provided a single odour sample, where assessors determined the presence, character and intensity of the odour.

The odour intensity is determined using the categories in the table below.

Table 23. German Standard VID 3940, 3882 Part 1 – Odour Intensity Categories

Odour Strength	Intensity Rank (code)	Interpretation
Not detectable	0	No odour detected.
Very weak	1	Odour recognised and assigned to the odour source (recognition).
Weak	2	Odour is weak but not yet distinct.
Distinct	3	Odour is clearly distinct.
Strong	4	Strong odour detectable.
Very strong	5	If offensive, observer may consider moving from the area.
Extremely strong	6	Odour is sufficiently over-powering that assessor moves from area.

5.2.2 Odour impacts

The potential odour impacts from Leanyer Sanderson Waste Treatment Plant were determined in accordance with the methods specified in the ToR. An independent odour specialist (The Odour Unit) completed an odour impact assessment for the project, focussing on odour emanating from the Leanyer Sanderson Wastewater Treatment Plant. The odour assessment was completed over six days between 23 and 28 February 2018 and in accordance with the methods outlined in the following international standards:

- Determination of Plume Extent (European Standard EN: 16841-2:2016).
- Determination of Odour Intensity (German Standard: VDI 3940; 3882 Part 1).

The timing of the assessment was considered optimal for establishing the extent and intensity of the plume, due to the lack of rainfall preceding the assessment which would limit dilution of odour. The assessments were also undertaken between 6 am and 9 am to coincide with peak morning inflows.

The odour assessment noted that the conditions at the Waste Treatment Plant were essentially baseline, that is, the process conditions were static with no process maintenance taking place, and in particular no noticeable sludge cleanout activities. The findings of the odour assessment therefore reflected an odour emissions scenario where there no upset conditions or any type of process interruptions of maintenance.

An odour plume was detected on 25 and 26 February when prevailing winds were from the east and south-east. On both days the plume extent was determined to be approximately 600 metres length by 150 metres width. This plume extent was found to be consistent with the odour extent determined by GHD (2015) from the Leanyer Sanderson Wastewater Treatment Plan for or a proposed subdivision in Sanderson.

It was concluded that based on the results of the assessment, under those process conditions at the time of the odour assessment, the likelihood of odour impact on 2CRU or Muirhead Development was negligible or nil (Appendix J). However, it was acknowledged by The Odour Unit that the extent and intensity of odour impacts may increase under certain upset conditions that would relate to process operations of the treatment plant and not the typical day-to-day running of a modern waste-water treatment plant and infiltration and evaporation ponds. The Odour Unit identified the following upset conditions as factors that could lead to a greater plume extent or intensity than assessed:

- Poor performance of Leanyer Sanderson Wastewater Treatment Plant.
- Inlet works breakdown.
- Drying out of ponds where sludge may be exposed.
- Poor control of sludge.
- Presence of anaerobic conditions where algal blooms may occur.

The NT EPA released the Recommended Land Use Separation Distance Guidelines in October 2017 (NT EPA 2017) to provide guidance on potential impacts of emissions from industrial sources on sensitive land-uses. Specifically, the guidelines purpose is "*to recommend separation distances between industry and sensitive land uses to ensure off-site emissions of offensive odour, noise, smoke, dust or fumes do not adversely impact on people"* (NT EPA 2017). It is primarily for the use of the NT EPA when preparing advice on development plans

and strategic land use plans but can also be used by the NT EPA during environmental assessments to minimise off-site emissions and impacts.

The proposed separation distance for odour impacts from sewerage treatment plants using pond systems is based on the following formula which has been adopted from the Victorian EPA:

$= 10 \times (EP)^{0.5}$

Based on this formula the proposed separation distance from the Leanyer Sanderson Wastewater Treatment Plant is 2,236 metres and 2,300 metres based on current EPs (50,000 EPs) and at project completion (52,904 EPs) respectively. Under both scenarios the proposed separation distance would cover all the Muirhead North site and most of 2CRU in addition to other sensitive land-uses in the local area including existing residential developments, schools and the Darwin Hospital. It is important to note that no odour was recorded in these areas during the assessment by The Odour Unit (Appendix J – Figure 5). These separation distances are also nearly four-fold greater than the plume extent established by The Odour Unit (Appendix J) and GHD (2015), and the PWC's 700 metre odour buffer around Leanyer Sanderson Wastewater Treatment Plant.

Site-based assessment data can be used instead of the separation distance specified in the guidelines to inform the appropriate land-use separation distance. For instance, page 9 of the guidelines states that *"The Guideline is not intended to replace site-specific assessments or the consideration of site-specific circumstances which may result in a requirement for a separation distance which is larger or smaller than the distance proposed in the Guidelines*" (NT EPA 2017). As such, the plume extent determined by The Odour Unit (Appendix J) is considered a more accurate assessment of the appropriate land-use separation distance from Leanyer Sanderson Wastewater Treatment Plan under standard operating conditions than what is specified in the guidelines.

The NT EPA have provided information that odour complaints have been received in suburbs outside the plume extent determined by The Odour Unit as well as the separation distances inferred from the guidelines (NT EPA 2017). As these complaints are part of an ongoing EPA investigation, information on the location, date and time of day of the complaints cannot be disclosed until the investigation has been concluded. It is therefore not possible to establish the cause of the odour impacts, although, it is speculated that they are likely to be the result of one or more of the upset conditions listed above, or odour emanating from other sources such as stagnant water.

Subsequent to the odour assessment completed by The Odour Unit and the complaints received by the NT EPA, Power and Water Corporation have committed to improving infrastructure at the Leanyer Sanderson Wastewater Treatment Plant that are expected to substantially reduce the odour impacts. Works have commenced on a $16.2 million inlet works upgrade that will remove unwanted bathroom products and kitchen waste that restricts the natural treatment process of the ponds and contributes substantially to odour impacts. The upgrade is expected to be completed by November 2018.

In addition to specifying land-use separation distances for wastewater treatment ponds, the guidelines also specify separation distances from sewerage pumping stations (NT EPA 2017). The Lyons and Muirhead sewerage pumping stations are within the general vicinity of the project. The guidelines propose a separation distance of 100 metres from these types of pumping stations (NT EPA 2017). It is shown below (Figure 15) that the 2RU and Muirhead North are well outside the separation distances for both pumping stations.

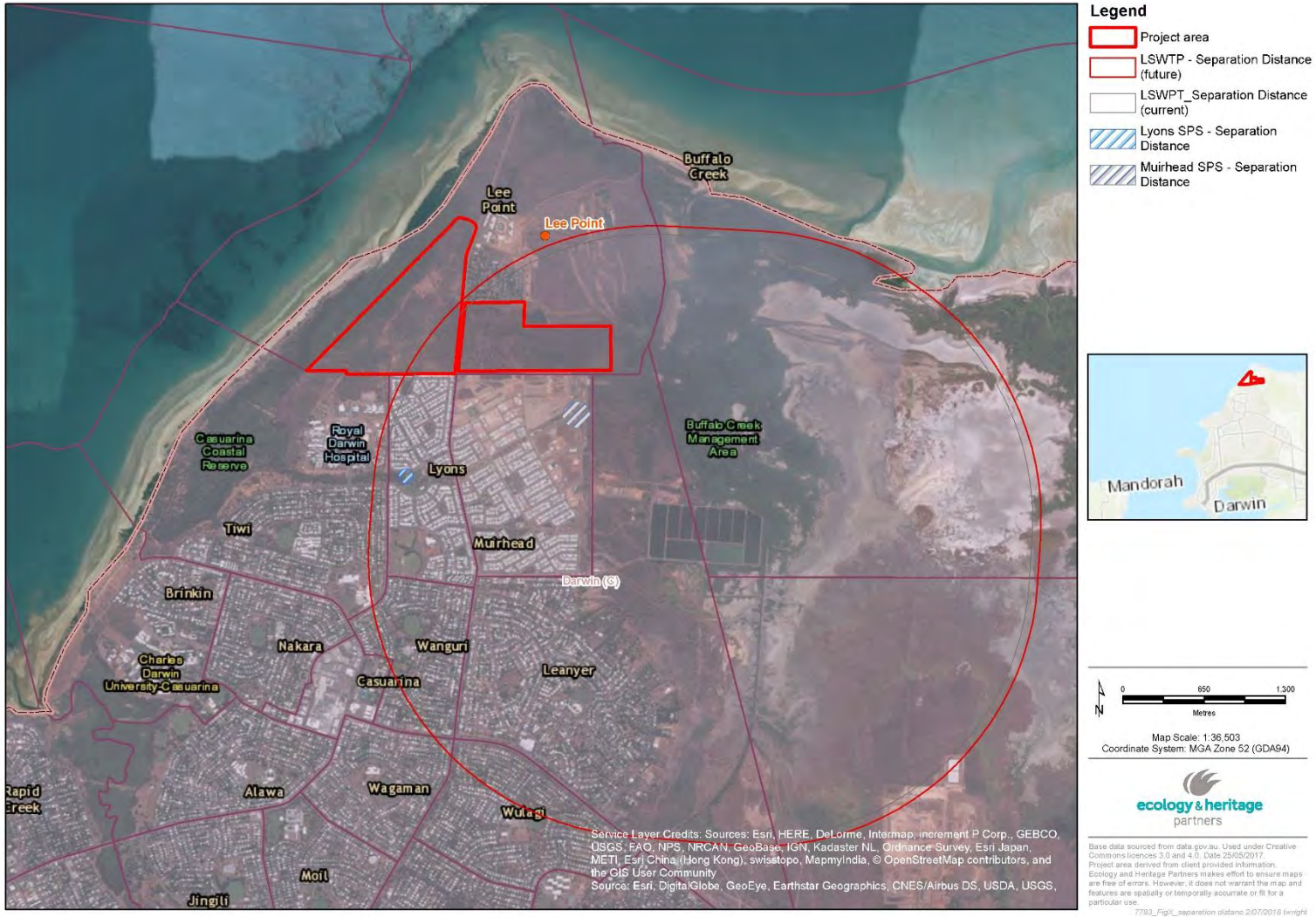

Figure 15. Land use separation distances for Leanyer Sanderson Wastewater Treatment Plant, and Sewerage Pumping Stations

5.2.3 Dust

5.2.3.1 Overview

Dust generation can occur during the construction phase of urban development projects. It is more likely to occur in the dry season when drier soils and particulate matter more readily become airborne during disturbance. The likely causes of dust generation for this project are:

- Clearing vegetation
- Construction works
- Vehicle movements
- Erosion.

The risks and impacts of dust generation associated with this project have been established from referring to projects of a similar nature and guidelines for dust prevention in Australia. The potential impacts of dust generation can include:

- Human health (respiratory problems)
- Exposure to contaminants (e.g. asbestos)
- Vegetation smothering restricting carbon uptake and transpiration
- Loss of amenity
- Sedimentation leading to reduced water quality.

Depending on the extent of the dust plume, onsite workers and adjoining residents can be affected during construction, while if proper remediation and mitigation solutions are not in place, dust management problems can remain after the construction phase.

5.2.3.2 Potential contamination

Contamination from asbestos and other pollutants that could potentially become airborne during construction were considered from 2CRU by GHD (2010). Twenty-five shallow soil boreholes were drilled across 2CRU to a maximum of 0.8 metre depth and analysed for potential contaminants including within the Conservation Area and Casuarina Coastal Reserve. No imported fill materials were noted within the boreholes; however, some surface soil samples appeared to be reworked natural material.

GHD (2010) found that heavy metals concentrations did not exceed the Health-based soil Investigation Levels (HILs) for residential use as per the *National Environment Protection (Assessment of Site Contamination) Measure* (NEPM 1999). They also did not identify any hydrocarbon odours or soil staining.

Given the low contaminant levels at 2CRU, GHD (2010) did not recommend any further investigate Source – Pathway – Receptor linkages as part of a Conceptual Site Model.

Asbestos containing materials were not observed within soils during the investigation, although it was noted that asbestos is known to occur within site compound (GHD 2010). Areas of Potential Environmental Concern (APEC), including potential asbestos containing material (ACM) have subsequently been removed from 2CRU.

DHA engaged SERS to remediate contamination at 2CRU. These works were undertaken in a staged manner as follows:

- Stage 1 – removal of all observed ACM prior to the demolition of above ground structures as per the Asbestos Removal Control Plan (ARCP) protocols:
    - All ACM products present within the buildings were removed by licences asbestos removalist in accordance with current legislation and Worksafe NT and Comcare procedures.
    - Any ACM observed was collected and placed in a plastic asbestos disposal bag and sealed with PCV tape then placed into another bag of same quality and sealed (double bagged).
    - Upon completion of the ACM removal works the building and structures were inspected by a qualified asbestos assessor and any open space grid walked three time in each axis to confirm successful removal of all AMC prior to demolition.
    - Once asbestos assessor was satisfied that all ACM had been removed, a clearance certificate was issued and the demolition work proceeded.
- Stage 2 – demolition of building and structures with the exception of APEC G (Electrical Transformer), APEC J (Underground Petroleum Storage System) and APEC K (Septic System) to the following protocols:
    - All demolition activities were carried out in accordance with NT and federal legislation.
    - Above ground structures were deconstructed first, followed by concrete slabs and hard standing areas.
    - All demolition works were notified to Worksafe NT and undertaken by SERS nominated subcontractor BDS in accordance with the safety documentation provided.
- Stage 3 -removal of APEC G (Electrical Transformer), APEC J (UPSS) And APEK K (Septic System) structures and associated contaminated soil under the supervision and direction of SERS as follows:
    - Prior to the remediation of the APEC's, SERS surveyed and pegged the site structures in preparation of demolition to ensure that all impacted areas would be addressed during the remediation.
    - Two steel twin skinned tanks were removed from APEC J (UPSS – both tanks were noted to being empty prior to removal) and inspected for breaches prior to being loaded onto a truck for disposal at Shoal Bay Waste Facility.
    - Removal of one concrete dual chamber tank from APEC K (Septic System). The chambers were excavated using the onsite excavator and placed on adjacent hard standing area for inspection prior to crushing. No liquid was noted as being present in the septic system prior to removal.
    - Excavation of contaminated soils from the relevant APEC (G, J and K) to a depth of 300 mm below any structure or observed visual of olfactory evidence of contamination. All excavated materials were placed on plastic sheeting lined hard stand and covered with plastic sheeting

while laboratory analysis were performed on representative samples. Soils excavated from each APEC were stockpiled separately to prevent cross contamination.

- Sampling and analysis of the excavations were performed from the base and side walls to validate that any potential contamination has been removed from the APEC. Upon completion of the remedial works, all final samples recorded concentrations below the adopted soil criteria.
- Upon receipt of the chemical analysis, results for the stockpiled soils were compared to the ASC NEPM 2013 threshold values. Results determined:
  - Soils from APEC J (UPSS) and APEC K (Septic System) were considered suitable for reuse on site and used to back fill respective excavation pit.
  - Soils from APEC G (Transformer) were considered unsuitable and underwent waste classification and ultimately offsite disposal at Shoal Bay Waste Facility.

- Stage 4, Stage 5 and Stage 6 – upon completion of the building and infrastructures, each APEC was cleared for near surface ACM to the following protocols:
  - The entire site was separated into seven areas to make asbestos remediation manageable.
  - Each area in turn was grid walked three times in each axis in line formation by a team of no less than three competent asbestos removalist/assessors.
  - Any ACM observed was collected and placed within a plastic asbestos disposal bag and sealed with PVC tape and then placed into another bag of the same quality and sealed.
  - During the process, ACM recovered was weighed and aesthetic quality (colour, foreign material) were visually assessed. Once no ACM was observed, this stage of the asbestos remedial works was considered complete and validation sampling of exposed soils were undertaken.

During the decommission of the 2CRU site, there was an unexpected find of ACM piping, which was removed by SERS and their subcontractor BDS in the following manner:

- Soils from above the ACM piping were carefully removed using an excavation and shovels and stockpiled adjacent to the sludge beds.
- All ACM pipes were then removed manually as to prevent breakages and placed directly into lined bins for removal from site and disposal to landfill.
- Approximately 98% of pipeline was removed with no minor breakages. In case of minor breakages, which occurred in particular areas around the joints of the pipeline, BDS and SERS personnel manually removed any remaining fragments by hand picking and the was inspected by SERS post removal of ACM fragments.
- In area where ACM pipeline came into direct contact with soil surrounding area was manually dug out to 300 mm below impacted area and disposed as asbestos waste.

The Site Auditor confirmed that the remediation works were generally undertaken in accordance with the Remediation Action Plan and NT guidelines (AECOM 2016). A copy of the Site Auditors reports is provided in Appendix .

A Stage 1 Preliminary Site Investigation has been completed for Muirhead North (EcOz 2015) and is included in Appendix S. It found Muirhead North has always been Vacant Crown Land and there has been no significant developments within the area. Illegally dumped household rubbish, car bodies, soil piles and building materials (i.e. steel, concrete, etc) were observed in some areas, which were mainly concentrated near access tracks, particularly in the western section of the site. A small amount of ACM was observed at one location. EcOz (2015) concluded that it is unlikely that there is any extensive contamination of ACM (but noted the possibility of additional areas of minor ACM contamination) and did not recommend a Stage 2 Detailed Site Investigation.

The NT Parks and Wildlife Commission have also noted areas within the Conservation Area where there has been rubbished dumped. The Commission is unaware of the source of this rubbish, given the history of illegal access to the site. Risk Assessment

5.2.4 Risk assessment summary

The section summarises the findings of the detailed risk assessment, and identifies those risks which require management and mitigation measures to reduce the level of risk of dust generation and odour to the environment and human health, to an acceptable level.

Based on the results of the odour assessment, the risk of odour impact on the project development is low-negligible during normal operating procedures. The odour plume was measured as extending up to 600 metres from the Leanyer Sanderson Wastewater Treatment Plant, and at low intensity (i.e. distinct/not very distinct and not offensive). The closest point-to-point distance between the project site and the Leanyer Sanderson Wastewater Treatment plant is approximately 1 km. The NT EPA have received odour complaints likely to originate from the treatment plant from suburbs outside the established odour plume, and the separation distances designated in the Recommended Land Use Separation Distance Guidelines(NT EPA 2017). It is assumed that these complaints were received during maintenance periods (e.g. sludge removal) or a breakdown in treatment processes. Current inlet work upgrades are likely to substantially reduce the odour impacts from the plant. Further mitigation measures to reduce odour impacts are proposed below; however, given that sewerage treatment is the responsibility of Power and Water Corporation, DHA cannot provide certainty that the proposed mitigation measures would be implemented.

A summary of the moderate to high risks of dust impacts are summarised in Table 24. The potential for dust generation to result in contamination is unlikely, as the original site sheds have been demolished and removed in accordance with standard Occupational Health and Safety procedures to avoid any potential exposure to contaminants, such as asbestos. However, two 450 metre long parallel asbestos pipes remain in 2CRU and will be removed as part of the development. The site auditors report for 2CRU assessed the site as suitable for residential purposes subject to the preparation of a CEMP that addresses potential for unexpected findings including asbestos containing materials (AECOM 2016).

The full risk assessment results for dust impacts are provided in Appendix D.

Table 24. Summary of risk assessment for dust impacts and recommended mitigation measures

Impact	Description	Considered Mitigation Measures
Human health (workers and adjoining residents).	Dust plumes causing respiratory problems.	• An emu bog grid walk to identify any asbestos containing materials within 2CRU, Muirhead North and Conservation Area • All rubbish to be removed and site audit completed of Conservation Area completed prior to Parks and Wildlife Commission hand-over • Removal of 450 m long parallel asbestos pipes in 2CRU to be done by a trained and certified asbestos removal company. • Notify adjoining residents prior to works commencing • Vegetation cleared in a staged manner • Limit the amount of excavation required to clearing vegetation • Watering on haul roads, and exposed areas • Vehicles obey speed limits and stick to formed road • Trafficable areas clearly marked • Stabilise long exposed areas • Rehabilitate as soon as possible.
Vegetation	Dust plumes smother vegetation preventing adequate carbon sequestration and transpiration.	• Vegetation cleared in a staged manner • Limit the amount of excavation required to clearing vegetation • Watering on haul roads, and exposed areas • Vehicles obey speed limits and stick to formed road • Trafficable areas clearly marked • Stabilise long exposed areas • Rehabilitate as soon as possible. • Water foliage of affected vegetation as part of watering plan.
Sedimentation of waterways	Reduction in water quality due to erosion and sedimentation.	• Vegetation cleared in a staged manner • Limit the amount of excavation required to clear vegetation • Watering on haul roads, and exposed areas • Vehicles obey speed limits and stick to formed road • Trafficable areas clearly marked • Stabilise long exposed areas • Rehabilitate as soon as possible • WSUD • Avoid clearing in wet season during monsoonal rains • Water quality monitoring of detention basins and Sandy Creek.

Impact	Description	Considered Mitigation Measures
Human health (future residents)	Exposed areas remain after construction has been completed causing ongoing dust impacts	• All exposed soil areas are covered either by hard surface (roads, pathways or buildings) or vegetation. • Ongoing maintenance of public open space will include rehabilitation of any exposed areas through revegetation or passive regeneration of existing vegetation.
Human health (existing and future residents)	Odour impacts from Leanyer Sanderson Wastewater Treatment Plant	• Current inlet upgrade works are expected to substantially reduce odour impacts recorded around the treatment plant. • DHA to lobby Power and Water Corporation to undertake activities which are likely to increase odour impacts when prevailing wind is from the west, or on mostly still days.

5.2.5 Description of impacts and mitigation measures

The types of mitigation measures proposed are consistent with responses for other urban development projects of a similar scale in the Northern Territory. The potential of dust impacts are most prevalent during the construction phase, when plant operation and vegetation clearing can result in dust generation particularly during the dry season. To ensure that dust generation is contained and that site workers and adjoining residents are not affected, the following mitigation measures are considered sufficient:

- Complete an emu bob grid walk to identify any asbestos containing materials
- Notify residents prior to works commencing
- Clearing vegetation in a staged manner
- Water haul roads and exposed areas
- Vehicles obey speed limits and stick to form roads
- Stabilise any long-exposed areas
- Rehabilitate as soon as possible.

The emu bob gird walk will be undertaken in accordance Western Australian Asbestos Guidelines (WA DoH 2009) where accredited asbestos assessors will walk across a grid-formation manually picking up any fragments of asbestos containing materials. The inspections will be undertaken on a monthly basis until no asbestos is detected. The inspections will occur in 2CRU, Muirhead North and the Conservation Area. Any asbestos identified will need to be removed by a licensed asbestos contractor in accordance with NT WorkSafe requirements.

In addition, the proposed removal of 450 m long parallel asbestos pipes in 2CRU represents a significant risk to human health and will only be done by a trained and certified asbestos removal company.

These mitigation measures are further detailed in the ESCP which forms part of the over-arching CEMP (Appendix D).

Dust generation can also result in the sedimentation of waterways. The treatment train of bioretention and detention basins that will be established throughout the project site have been designed to remove up to 80%

of the sediment captured from the project area, and will assist with mitigating any dust impacts from the project. See the Stormwater Management Plan for 2CRU (Appendix E) and Muirhead North (Appendix F) for further detail.

Dust generation can also impact on biodiversity by smothering vegetation and preventing adequate exchange of carbon and water through leaf stomata. The retention of 21.95 ha of remnant vegetation along the western boundary of the site will buffer the interior of the Casuarina Coastal Reserve against any dust impacts. Any affected vegetation along the edge of the retained area, and any other areas where native vegetation will be retained, will be watered if signs of dust impacts become apparent.

Prior to the Conservation Area being handed over to the Parks and Wildlife Commission for management, DHA will remove any litter and rubbish. A site audit will also be completed of the Conservation Area for asbestos and any other contaminants.

Power and Water Corporation is responsible for the operation of the Leanyer Sanderson Wastewater Treatment Plant, and therefore ultimately responsible for addressing odour impacts emanating from the plant. The current inlet upgrade works that will remove items from sewerage which interfere with the natural treatment process is expected to substantially reduce the size of the odour plume. Another practical measure would be for any maintenance works that may contribute to odour impacts, be staged to occur on days when wind is predominantly still or from the west. DHA will lobby Power and Water Corporation on behalf of existing and future residents in Lee Point, for this to occur.

6 UTILITIES AND INFRASTRUCTURE

6.1 Introduction

This chapter describes the utilities and infrastructure that will be required to service the future inhabitants and users of the project site. It covers the following service requirements:

- Potable water
- Sewerage
- Transport
- Power
- Telecommunications.

The chapter is structured in the following manner:

- Existing conditions and impacts – an assessment of the future demand requirements for potable water (see Section 6.2.1), sewerage (see Section 6.2.2), transport (see Section 6.2.3), power (see Section 6.2.4) and telecommunications (see Section 6.2.5); whether existing services can meet this demand, and what impact increased demand is likely to have on the local community.
- Risk assessment – a summary of the detailed risk assessment identifying key risks that require mitigation or management measures, such as augmenting existing services or improving traffic safety (see Section 6.3).

As part of the preparation of this chapter, the following people from Power and Water Corporation (PWC) were consulted:

- Ian Jong – Services Development Engineer
- Jack Foster –Water Systems Engineer.

Further consultation was undertaken with the following PWC staff following public exhibition period for the EIS on 26 March 2018:

- Ian Jong
- Bokhtiar Meelky
- Teresa Tian

6.2 Existing Conditions and Impacts

6.2.1 Potable Water

The proposed development is located within the Casuarina Water Supply Zone (WSZ). Storage for the zone is facilitated by the Marrara and Casuarina Reservoirs. A trunk network extends along Lee Point Road to supply

the network. In particular a DN (Diameter Nominal/Nominal Diameter) 450 main extends along Lee Point Road in the vicinity of the existing Lyons and Muirhead developments.

In regard to network planning, PWC has advised that no new trunk services are proposed in the vicinity of the site. This includes both storages and trunk mains. New storages are proposed at the Marrara Complex; however, no bulk strategic planning will impact the proposed development.

Supply to the proposed development will be via the existing trunk main network along Lee Point Road.

PWC provided boundary conditions that reflected hydraulic grades at the agreed offtake points to the development. PWC provided boundary conditions for both the existing and ultimate network conditions. The existing conditions nominally represent the network as it is in operation now. The ultimate conditions represent network conditions infrastructure to service demand up to 50 years in the future. The advised grades are:

- Existing: Peak Hour 51.4m Australian Height Datum (AHD), Fire Flow 53.9m AHD
- Ultimate: Peak Hour 48.46m AHD, Fire Flow 51.6m AHD.

Based on this information, a water supply network model has been developed that includes the agreed offtake points, supply mains from the offtake point to the development and an internal reticulation network.

The water supply network was built in the hydraulic modelling software, Bentley WaterGEMS. This software allows the infrastructure to service the development to be sized according to the PWC design criteria.

A new DN450 trunk main was assumed to continue from the proposed connection along Lee Point Road to the second proposed junction, corresponding to a location immediately south of the Lee Point Village Resort. In addition, a second connection to the existing DN300 main along Damabila Drive (south of the project site in the Lyons development) was also assumed. An internal trunk main connected both the DN450 and DN300 mains via a looped DN300 trunk main.

Smaller reticulation services ranging in size from DN200 to DN150 are proposed. The network in the vicinity of the proposed tourist precinct includes looped DN300 and DN200 mains to maintain fire flow requirements.

The analysis of the existing network against the full demand indicated that sufficient pressure can be maintained for both peak hour and fire flow events in the described network without augmentation. It is noted that areas above 28 m AHD experienced pressures in the order of 19 m and 20 m. These are limited to the northern lots. Headwork upgrades are required to service development about 28.0 m AHD. DHA will be responsible for any headwork upgrades.

The network proposed for the existing scenario was assessed for the ultimate scenario with the reduced level of hydraulic grade at the nominated offtake point. Analysis has indicated that the minimum level of service could not be maintained, based on both growth and topography. Based on the adopted development layout and external supply configuration, the creation of a high level zone (HLZ) for the entire site is proposed.

Advice from PWC indicates a preference for storage over direct inline pressure boosting only. To accommodate this preference the use of a break of head tank prior to boosting is proposed.

It is proposed that a HLZ be created to ensure the entire site receives a service level that satisfy PWC's requirements. This HLZ will be serviced via a small break of head tank with 650 kL storage, based on the minimum fire flow requirements.

6.2.2 Sewerage

The existing wastewater network in the vicinity of the project site includes the Lyons and Muirhead sewer pump stations (SPS). These pump stations convey flows to the trunk sewer mains that discharge to the Leanyer Sanderson Wastewater Treatment Plant. Treated effluent will be discharged from Leanyer Sanderson Wastewater Treatment Plant into Buffalo Creek in accordance with Waste Discharge License (WD147).

PWC adopt Equivalent Persons (EP) as the basis for sewerage planning. Based on the adopted master plan, the proposed development comprises 2,904 EP.

PWC has advised that no future trunk network augmentations have been identified downstream of the site and that there are no plans to upgrade the existing plant apart from its current investment of $15.4 million in constructing new inlet works. The existing capacity of the plant is approximately 72,000 EPs.

Based on the topography of the site, the development site falls within two pump station catchments, the Muirhead SPS and the Lyons SPS. The majority of the development (2,053 EP) will discharge to the existing Muirhead SPS catchment and the remainder (567 EP) will discharge to the Lyons SPS catchment. The EP loading discharging to the Lyons SPS exceeds the capacity of the pump station by 3%. Minor upgrade works will be undertaken by DHA to increase the capacity of the Lyons SPS to accommodate any exceedance of EP load due to the project.

A network model of the reticulation internal to the development site and the gravity mains connecting the development to the two sewer pump stations was developed in Microsoft Excel to allow the gravity network to be sized utilising the PWC design criteria. The gravity mains were sized based on the following assumptions:

- Gravity mains at minimum grade
- Sized for pipe full.

An internal gravity network ranging in size from DN150 to DN375 is proposed for the site. The eastern part of the catchment (2,106 EP) will drain to the Muirhead SPS via a DN375 trunk main and the western part of the catchment (410 EP) will drain to the Lyons SPS via a DN225 trunk main.

An assessment was undertaken to determine the impact of the development on the existing infrastructure.

The existing Muirhead SPS was designed with consideration for the proposed development. The design of the Muirhead SPS adopted a load of 2,747 EP for all future development in the catchment. The proposed development, a projected 2,106 EP, will be discharging to the Muirhead SPS. Therefore the existing pump station is within the original limits. The pump station was designed for a peak design flow of 103 L/s and an emergency storage volume of 331 m^3. The requirement (incorporating the reduction in the allowance from the proposed development) is a peak design flow of 92 L/s and an emergency storage volume of 273 m^3. Therefore, the existing Muirhead SPS can accommodate the sewerage load from the proposed development.

The existing Lyons SPS was also designed with consideration for the proposed development. The design of the Lyons SPS adopted a load of 550 EP from the proposed development, compared with the 410 EP for this

assessment. Therefore the existing pump station is within the original limits. However, a number of issues were raised with the design as shown in Table 25. The analysis shows that although the design allowed for up to 550 EP from the proposed development, this was not allowed for in construction. Therefore additional emergency storage is required to satisfy PWC's design criteria.

Table 25. Analysis of Lyons Sewer Pump Station (SPS)

Parameter	Design	Requirement	Comment	Recommendation
Peak Design Flow	88 L/s	85 L/s	Projected design flow is below previous design. However, installed capacity is below design capacity.	
Design Capacity	61 L/s (Single Pump) 88 L/s (Projected Dual Pump)	85 L/s	Installed design capacity based on single pump capacity	Confirm pump arrangement. To accommodate peak design flow a duty/assist configuration would be required.
Emergency Storage Volume	290 m^3	305 m^3	Installed storages below original design requirement 315m^3	Install additional 15m^2 of emergency storage. Additional redundancy may be included with provision of a hardstand for mobile generator for power outage.

6.2.3 Transport

A full Transport Impact Assessment (TIA) was conducted with the purpose of determining the overall impact of the development on the surrounding road network along with the performance of nearby intersections and the overall amenity of the area. The TIA has been prepared in accordance with the Austroads Guide to Traffic Management Part 12: Traffic Impacts of Development. A summary of the main findings of the report have been provided in the section below with the full reports available in Appendix .

6.2.3.1 Existing Traffic Conditions

The existing road network within the vicinity of the project site is limited, with the main road network formed by Lee Point Road located to the east and Buffalo Creek Road located to the north.

A direct count traffic survey for the access to Lee Point Village Resort was conducted by SMEC in March 2015 (SMEC 2015). The traffic surveys indicated that the AM and PM peak hours for the Lee Point Resort access road occurred from 7:30am – 8:30am and 5:45pm – 6:45pm, respectively. Traffic volumes at the Lee Point Road/Buffalo Creek Road intersection were estimated using the volumes collected for the Lee Point Resort access. The table below provides a summary of the existing traffic volumes.

Table 26. Traffic volumes for surrounding road network (SMEC 2015).

Location	Date	Average Two-way Traffic Volumes	
		Vehicles per AM Peak Hour	Vehicles Per PM Peak Hour
Lee Point Village Resort	March 2015	16	15
Buffalo Creek Road	March 2015	28	58

Location	Date	Average Two-way Traffic Volumes	
Lee Point Road (At Lee Point Village Resort)	March 2015	35	94
Lee Point Road (At Buffalo Creek Road)	March 2015	18	48

These traffic volumes indicate that congestion is not an issue in its current form for day-to-day operation. This is a result of low levels of development within the area with the only traffic generators being the Lee Point Village Resort, the beach at the northern end of Lee Point Road and the fishing spot at the western end of Buffalo Creek Road.

6.2.3.2 Future Traffic Conditions (Post development)

The proposed development at 2CRU is expected to generate approximately 753 vehicles (two-way) to and from the development during the peak hour periods. The Muirhead North development is expected to generate approximately 409 vehicles (two-way) during the AM peak period and 319 vehicles (two-way) during the PM peak to peak to period. The distribution of traffic to/from the 2CRU and Muirhead North has been determined based on the location of the site in relation to nearby employment/commercial areas and attractions. As the project site is located on the northern fringe of Darwin, it is assumed that the majority of traffic generated will likely travel south towards the Darwin Town Centre. A small percentage of traffic is expected to travel north to the Casuarina Coastal Reserve and Buffalo Creek boat ramp. In addition, vehicle trips between the Muirhead North and 2CRU sites have only been considered for the school and active recreation reserve land uses.

SIDRA Intersection 6.1 was used to evaluate the impact of the increased volumes anticipated for background and full buildout scenarios. SIDRA Intersection is a software package used to analyse the capacity and performance of road intersections. SIDRA outputs for each approach are presented in the form of Degree of Saturation (DOS), Average Delay, Level of Service (LOS) and 95th Percentile Queue. These characteristics are defined as follows:

- Degree of Saturation (DOS): is the ratio of the arrival traffic flow to the capacity of the approach during the same period. The Degree of Saturation ranges from close to zero for varied traffic flow up to one for saturated flow or capacity. The theoretical intersection capacity is exceeded for an un-signalised intersection where DOS > 0.80.
- 95% Queue: is the statistical estimate of the queue length up to or below which 95% of all observed queues would be expected.
- Average Delay: is the average of all travel time delays for vehicles through the intersection. An unsignalised intersection can be considered to be operated at capacity where the average delay exceeds 40 seconds for any movement.
- LOS: is the qualitative measure describing operational conditions within a traffic stream and the perception by motorists and/or passengers. The different levels of service can generally be described in the table below.

Table 27. Level of Service (LOS) descriptions

LOS	Description	Signalised Intersection	Unsignalised Intersection
A	Free-flow operations (best condition)	≤10 sec	≤10 sec
B	Reasonable free-flow operations	10-20 sec	10-15 sec
C	At or near free-flow operations	20-35 sec	15-25 sec
D	Decreasing free-flow levels	35-55 sec	5-35 sec
E	Operations at capacity	55-80 sec	35-50 sec
F	A breakdown in vehicular flow (worst condition)	≥80 sec	≥50 sec

The following intersections were analysed:

- Lee Point Road/Buffalo Creek Road
- Lee Point Road/Lee Point Village Resort
- Lee Point Road/Access Road 1
- Lee Point Road/Access Road 2
- Lee Point Road/Access Road 3.

A summary of the LOS outputs for 2CRU have been provided in the table below (Table 28). The results show that all intersections performed satisfactorily in the AM and PM peak periods for all analysis scenarios. For further details in regards to degree of saturation, 95% queue and average delay outputs, refer to the full TIA report for 2CRU (Appendix).

Table 28. Summary of Level of Service Outputs – 2CRU

INTERSECTION	LEVEL OF SERVICE (LOS)			
Intersection	**2017 without development (AM/PM)**	**2027 without development (AM/PM)**	**2017 with development (AM/PM)**	**2027 with development (AM/PM)**
Lee Point Road / Buffalo Creek Road	LOS A/LOS A	LOS A/LOS A	LOS A/LOS A	LOS A/LOS A
Lee Point Road / Lee Point Village Resort	LOS A/LOS A	LOS A/LOS A	LOS A/LOS A	LOS A/LOS A
Lee Point Road / Access Road 1	N/A	N/A	LOS A/LOS A	LOS A/LOS A
Lee Point Road / Access Road 2	N/A	N/A	LOS A/LOS A	LOS A/LOS A
Lee Point Road / Access Road 3	N/A	N/A	LOS A/LOS B	LOS A/LOS B

A summary of the LOS outputs for Muirhead North have been provided in the table below. For further details in regards to degree of saturation, 95% queue and average delay outputs, refer to the Muirhead North Transport Impact Assessment report (Appendix L). The results show that all intersections performed satisfactorily in the AM and PM peak periods for all analysis scenarios.

Table 29. Summary of Level of Service Outputs – Muirhead North

Intersection	Level of Service (LOS)			
Intersection	**2019 without development (AM/PM)**	**2029 without development (AM/PM)**	**2019 with development (AM/PM)**	**2029 with development (AM/PM)**
Lee Point Road / Buffalo Creek Road	LOS A/LOS A	LOS A/LOS A	LOS A/LOS A	LOS A/LOS A
Lee Point Road / Lee Point Village Resort	LOS A/LOS A	LOS A/LOS A	LOS A/LOS A	LOS A/LOS A
Lee Point Road / Access Road 1	LOS A/LOS A	LOS A/LOS A	LOS A/LOS A	LOS A/LOS A
Lee Point Road / Access Road 2	LOS A/LOS A	LOS A/LOS A	LOS B/LOS A	LOS B/LOS A
Lee Point Road / Access Road 3	LOS A/LOS B	LOS A/LOS B	LOS B/LOS B	LOS B/LOS B
Lee Point Road / Access Road 4	N/A	N/A	LOS C/LOS C	LOS C/LOS C

6.2.3.3 Proposed Road Network Upgrades – 2CRU

The proposed development at 2CRU introduces several upgrades within the surrounding area which include the following:

- Three new accesses to the project site along Lee Point Road. The configuration of these accesses are as follows:
    - Lee Point Road/Access 1 – stop priority intersection
    - Lee Point Road/Access 2 – roundabout intersection
    - Lee Point Road/Access 3 – roundabout intersection
- An additional fourth access south of the project site connecting to Damabila Drive.
- Improved amenity for right turn movements along Lee Point Road with the construction of medians and right turn pockets at existing and proposed stop and give way priority intersections.
- Cycling lanes along both side of Lee Point Road, this includes lanes passing through the roundabouts.
- Shared/pedestrian footpaths along both sides of the road.
- A local road network providing access to the residential dwellings as shown in the Site plan (Figure 16).

The locations of the existing and proposed intersections near the project site are shown in Figure 17.

Figure 16. Internal road network – 2CRU

Figure 17. Existing and proposed access points – 2CRU

The timing for construction is intended to commence in the 2017 dry season and nominally one stage per year to be released. The staging and timing are subject to change due to the environmental approvals process and commercial assessment. It is likely that all transport related infrastructure listed above will be constructed alongside the development.

The road network, bus routes, pedestrian paths and bicycle paths will be constructed by the developer in conjunction with each stage of the development over a nominal 4 year period. The City of Darwin will be responsible for maintenance of the road and path network. Public bus services are provided by the NT Government. The proposed bus route is along the collector road on the western perimeter of the development.

The Northern Territory's public transport services are managed by the Department of Transport (DoT) and operated by a range of contractors. There are currently no public transport services along the section of Lee Point Road fronted by the proposed development. Future development within the area may create opportunities for new services or extensions of existing services towards the project site.

A bus route has been proposed by the DoT connecting with Lyons development along Damabila Drive and Coastal Esplanade.

There is currently no pedestrian and cycling infrastructure along the section of Lee Point Road fronted by the proposed development. The master plan promotes a sense of cycling, walkability and accessibility throughout the area. Shared pedestrian/cycling paths have been included in the illustrative master plan on the eastern boundary of the proposed site. The adjoining Casuarina Coastal Reserve Experience Development Plan (2015) has proposed the following:

- Construction of a new track from Lee Point through to Buffalo Creek allowing for visitors to ride or walk from Rapid Creek to Lee Point and onto Buffalo Creek.
- A mountain bike trail along the western boundary of the proposed development.[1]

6.2.3.4 Proposed Road Network Upgrades – Muirhead North

The proposed development at Muirhead North introduces several road infrastructure upgrades which include the following:

- Upgrades along Lee Point Road expected to be completed during the construction of the 2CRU development
- Three new accesses to the Site along Lee Point Road. The configuration of these accesses are as follows (note Access 1 will not serve the Muirhead development, it is only for access to the 2CRU development):
    - Lee Point Road/Access 2 – addition of the eastern leg at the roundabout intersection
    - Lee Point Road/Access 3 – addition of the eastern leg at the roundabout intersection
    - Lee Point Road/Access 4 – new give way priority intersection
- An additional fourth access south of the Site connecting to an unnamed road.
- A local road network providing access to the residential dwellings as shown in the Site plan detailed below.

The locations of the existing and proposed intersections near the Muirhead development are shown in the figure below.

[1] The Northern Territory Department of Infrastructure, Planning and Logistics is proposing the construction of a mountain bike through Casuarina Coastal Reserve. DHA has discussed providing assistance to the project; however, the NT Government will be responsible for separate environment and planning approvals for the project.

Figure 19. Internal road network Muirhead North

Figure 18. Existing and proposed access points – Muirhead North

The Muirhead North development is intended to commence after the completion of the 2CRU development and nominally one stage per year to be released. The staging and timing are subject to change due to the environmental approvals process and commercial assessment. It is likely that all transport related infrastructure listed above will be constructed alongside the development.

The road network, bus routes, pedestrian paths and bicycle paths will be constructed by the developer in conjunction with each stage of the development over a nominal 4 year period. The City of Darwin will be responsible for maintenance of the road and path network. Public bus services are provided by the NT Government. The proposed bus route is along the collector road on the western perimeter of the development.

There are currently no public transport services along the section of Lee Point Road fronted by the Muirhead North development. Future development within the area may create opportunities for new services or extensions of existing services towards Muirhead North.

There is currently no pedestrian and cycling infrastructure along the section of Lee Point Road fronted by the Muirhead North development. The master plan promotes a sense of cycling, walkability and accessibility throughout the area. Shared pedestrian/cycling paths have been included in the illustrative master plan on the eastern boundary of the 2CRU development and on the western boundary of the Muirhead North development.

6.2.4 Power

The project will require 3.6 Megavolt amperes (MVA) of load to service 400 residential lots and the proposed commercial and neighbourhood precincts. This demand is likely to exceed the capacity of existing circuits for Muirhead and Lyons. It is understood that PWC is planning a Lee Point Zone substation that is expected to provide additional capacity to service the proposed development, and other future developments in the area.

Design of the internal High Voltage and Load Current reticulation will be undertaken once base supply has been determined.

6.2.5 Telecommunications

The proposed development will be serviced by the National Broadband Network (NBN Co). The rollout of services in the northern suburbs of Darwin has commenced. Compliant pit and pipe infrastructure will be provided as part of the development and will be designed in conjunction with electrical reticulation.

6.3 Risk Assessment

6.3.1 Risk assessment summary

A detailed risk assessment has been undertaken to identify the potential risks associated with the infrastructure requirements for the project (Appendix C). A summary of the risk assessment is presented below (Table 30), along with mitigation measures that have been identified to ensure future residents infrastructure needs are adequately met, safe use of roads and paths, and there is no impact to the wider community.

6.3.1.1 Sewerage discharge into Buffalo Creek

During the public exhibition period, further information was requested on the potential for further deterioration in the quality and health of Buffalo Creek due to increased effluent discharge. It is unlikely that any additional effluent discharged from the project would cause further decline in the quality and health of Buffalo Creek for the following reasons:

- Buffalo Creek is the most polluted tributary of Buffalo Creek and consistently fails water quality standards assessed as part of the Darwin Harbour water quality monitoring (see Figure 14).
- The project is likely to increase sewerage volumes by only 6% (i.e. 47,000 EPs pre-construction versus 51,000 EPs post-construction).
- The Leanyer Sanderson Wastewater Treatment Plant reduces pollutants discharging into Buffalo Creek including nitrogen (57% reduction), phosphorous (34%), ammonia (75%), biochemical oxygen demand (67%) and copper (94%) and a four order decrease in the prevalence of *E. coli.* The plant also has capacity of 72,000 EPs and therefore can treat the increase sewerage inflows from the project.
- Power and Water Corporation are responsible for ensuring discharge of treated sewerage into Buffalo Creek does not exceed the conditions of Water Discharge Licence WDL 147-08 (see Appendix U).. These conditions include ensuring no objectionable matter is discharge, no adverse odours are generated, and the health of flora and fauna dependent on the creek is maintained.
- In accordance with licence conditions for WDL 147-08, Power and Water Corporation are required to undertake fortnightly/monthly monitoring of water quality and submit periodic reports at the end of the wet season (June) and dry season (November), and notify the NT EPA of any non-compliance (see Appendix U)..
- In accordance with licence condition 38 of WDL 147-08, Power and Water Corporation must develop and implement a plan to conduct further investigations to characterise the risk to human health relating to algal toxins in aquatic fauna harvested from Buffalo Creek for human consumption (see Appendix U).
- In addition to the monitoring required by Power and Water Corporation, DHA will be undertaken independent studies of Buffalo Creek water quality (see Appendix O).

Table 30. Risk assessment summary for infrastructure requirements

Impact	Description	Mitigation measures
Sewerage – surface and groundwater	Sewer overflows from development caused by extreme weather events, including first flush and wet season influences	Lyons SPS - Capacity upgrade (by DHA) to buffer the inadequate emergency storage. LSWTP proposed augmentation (by PWC) has allowed for development load.
Sewerage – disruption of service	Disruption of existing sewerage service with the provision of sewerage to the development	Lyons SPS - Capacity upgrade (by DHA) to buffer the inadequate emergency storage. LSWTP proposed augmentation (by PWC) has allowed for development load.
Sewerage – capacity	Inadequate capacity and/or treatment of wastewater treatment facilities	PWC have advised that the Leanyer STP will be included in planned augmentations within the next five (5) years. Additional ponds are proposed to accommodate growth in the catchment. PWC future planning has accounted for projected loads from the development.
Potable Water – security of supply	Disruption of existing potable water supply with the provision of reticulated water to the development	Existing network - adequate. Ultimate network - proposed new service reservoir and booster pump station to service a small elevated area within the site (by DHA).
Potable Water – source water availability	Inadequate source water capacity	The proposed development is located within the Casuarina Water Supply Zone (WSZ), where water is supplied by the Marrara and Casuarina Reservoirs. Source water is obtained from the Darwin River Dam, which offers a secure water supply. There is a low risk of inadequate supply from this catchment.
Potable Water – capacity	Inadequate capacity and/or treatment of water treatment facilities	PWC have not identified or advised of any deficiency in regard to the provision of treated water within the supply network.
Traffic - Future Road Capacity	Traffic growth over a long period of time may result in the road network being unable to accommodate with the traffic demand.	The traffic analysis shows that the road network is able to accommodate the traffic demand 10 years after the completion of the development. However if additional developments are to be proposed within the area a separate traffic assessment is required to determine its impacts.
Traffic - Road Safety	Increased frequency of road accidents.	The design of roads and intersection will follow the relevant standards and guidelines.
Traffic - Accessibility	Inconvenience for drivers.	Multiple Site accesses are available and are conveniently located.
Traffic – Wayfinding	Poor wayfinding and longer travel times for drivers.	Ensure appropriate wayfinding and signage strategies are implemented.
Traffic - Cyclist Safety	Increased risk of accidents and deters cyclists from riding due to perceived hazards.	Dedicated cycling infrastructure has been proposed along Lee Point Road.
Traffic - Pedestrian Safety	Increased risk of accidents.	Safe pedestrian infrastructure such as crossings and good quality paths shall be provided.
Traffic - Peak Period Traffic	Peak road network operation leading to increased congestion.	The traffic analysis shows that the road network is able to accommodate the peak period traffic without issues.

Impact	Description	Mitigation measures
Traffic - Traffic Speeds	Higher speed increase the risk and severity of accidents.	The speed limit is suitable for the surrounding environment. Lower speed limits should be applied to residential access roads and areas where a school is located.
Traffic - Heavy Vehicles Access	Accessibility constraints for heavy vehicles.	Road and intersection geometry to be capable of accommodate heavy vehicle turning movements.
Traffic - Public Transport	Over-reliance on private vehicular transport.	Explore potential opportunities to extend bus service to the 2CRU Site.
Traffic - Construction	Road improvements on existing roads may lead to delays, congestion and overall inconvenience for other drivers.	Ensure that a construction traffic management plan is implemented during the construction phase.
Power supply	Power demand to exceed the available capacity within the network.	Consult with PWC to determine the timing of the Lee Point Zone substation.

6.3.2 Description of impacts and mitigation measures

6.3.2.1 Potable water

The assessment of the development for both the existing and ultimate potable water network identified that the supply to the surrounding community within the Casuarina Water Supply Zone can be maintained at all times. However, a new onsite service reservoir and booster pump station is required to service the development area. No further network augmentations are required to service the site. The identified infrastructure provides capacity for the ultimate development yield.

Headwork upgrades are required to service development above 28.0 m AHD.

Supply to existing properties in the vicinity of the network remains as per the current configuration, with no augmentation required.

6.3.2.2 Sewerage

The Leanyer Sanderson Water Treatment Plant has enough capacity to accommodate the existing 2,904 EP generate from the project (the plant has capacity for an additional 22,000 EPs). Minor upgrade works will be required to increase the capacity for the Lyons SPS. Additional EP loading to the Muirhead SPS will not exceed the capacity of the pumping station.

6.3.2.3 Traffic

As is common with many non-strategic roads (e.g. local roads, access roads), there is always a risk of infrequent congestion occurring due to extreme or unforeseen circumstances (e.g. extreme weather, road accident, traffic signal failure). The occurrence of these circumstances is extremely rare and unpredictable which makes it difficult to manage practically. Therefore the most effective method is to manage this on a case by case basis. Through this method, a database of mitigation measures can be accumulated for extreme cases which can be referenced to when similar congestion issues occur somewhere else.

Road safety is another residual risk which cannot be completely mitigated even when a road is well designed and meets standards. Driver judgement and behaviour plays an important role in this and is not easily changed.

The most effective method of managing this residual risk is to continually promote safe driving habits. Examples include ongoing media campaigns, driver education classes, promoting the dangers of drinking and driving and harsher consequences during pubic holiday periods (e.g. double demerit points).

Other road safety measures which could be implemented include the installation of traffic calming devices such as speed humps, slow points and roundabouts.

6.3.2.4 Power

The lack of capacity within the existing power grid to service the proposed development is likely to be addressed through the new Lee Point Zone sub-station which is scheduled for construction in 2017-2018. Ongoing consultation with PWC will ensure that the power requirement post construction can be achieved.

7 BIODIVERSITY AND HERITAGE

7.1 Introduction

This chapter addresses the biodiversity and heritage criteria of the ToR. Information has been collected from several sources, including biodiversity databases, previous surveys of the project site, field assessments and consultation with species' experts. The chapter is presented in the following structure:

- Section 7.2 – Existing Conditions. Details the pre-development biodiversity and heritage values found at the site, describes how the methods used as part of desktop and field studies confirm with Government guidelines.
- Section 7.3 – Risk Assessment. Identifies the key risks to biodiversity and heritage values based on the detailed risk assessment (Appendix C) and describes the avoidance and mitigation measures that are proposed in the CEMP (Appendix D) to reduce the level of risk to an acceptable level.
- Section 0 – Significant Impact Assessment. Describes the biodiversity impacts of the project in accordance with the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and the NT *Territory Parks and Wildlife Conservation Act* (TPWC Act), *Weed Management Act 2001 (*WM Act) and *Aboriginal Sacred Sites Act.*

7.2 Existing Conditions

7.2.1 Background

The project site lies within the Darwin Coastal bioregion, which comprises gently undulating plains on lateritised Cretaceous sandstones and siltstones. Soils are sandy and loamy, red and yellow earths and siliceous sands. The most notable feature of the bioregion is the extensive and diverse floodplain environment associated with the lower reaches of the many large river systems. There are also extensive areas of mangroves, and rainforest and other riparian vegetation fringing the rivers. Inland from the coast the main vegetation type is eucalypt tall open forest, typically dominated by Darwin Woollybutt *Eucalyptus miniata* and Darwin Stringybark *Eucalyptus tetrodonta*. The Darwin Coastal bioregion is not divided into sub-bioregions.

The project site occurs on land that slopes gently from undulating upland areas in the west (2CRU) to lowland coastal plains in the east (Muirhead North). The key landscape features of the site are:

- A known population of the threatened flora species – Darwin Cycad *Cycas armstrongii*.
- Suitable habitat for the endangered Black-footed Tree-rat *Mesembriomys gouldii gouldii*
- A low escarpment (a few metres high) that separates the project site from Casuarina Coastal Reserve.
- Sandy Creek, which lies adjacent to the project site and receives surface-water runoff from the site. Sandy Creeks flows into Darwin Harbour at Casuarina Beach, which is considered to have international significance due to the number of migratory shorebirds it supports.
- A minor drainage line that flows through Muirhead North into a monsoon rainforest patch located towards the centre of the site, prior to discharge across the southern site boundary.
- Casuarina Coastal Reserve which directly adjoins the western boundary of 2CRU and protects 1,368 ha of coastal habitats between Rapid Creek and Buffalo Creek (of which 1026 ha are marine habitats). The reserve features 8 km of sandy beaches, as well as mangroves, Monsoon Vine-thicket and eucalypt woodlands. At high tide, migratory shorebirds roost near the mouth of Sandy Creek, and at low tide they forage in the inter-tidal zone of the reserve and surrounds.
- Military heritage items along Lee Point Road and Aboriginal stone scatters.

7.2.2 Survey summary

Between 2008 and 2016 there have been 15 desktop and field-related biodiversity and heritage studies across 2CRU and Muirhead North (Table 31). The methodologies used in these surveys are presented in Section 7.2.3 and the results are presented in Section 7.2.4.

Table 31. Biodiversity and heritage assessments undertaken within, or in the vicinity to the project site

Site	Survey type	Year	Source
Desktop assessments			
2CRU	Archaeological Sites Register, Australian Heritage Council heritage lists and Northern Territory Heritage Register.	2010	Begnaze Pty Ltd (2010)
Muirhead North	NT *Heritage Conservation Regulations 1999*, NT heritage register, register of the National Estate	2015	Ellengowan Enterprises (2016)

Muirhead North	Flora and fauna records, threatened species likelihood of occurrence	2008	VDM-EcOz (2008)
2CRU	Flora and fauna records, threatened species likelihood of occurrence	2010	GHD (2010)
Muirhead North and 2CRU	Updating flora and fauna records, threatened species likelihood of occurrence	2014	EcOz (2014)
Muirhead North and 2CRU	Updated Protected Matters Search	2016	DoE (2016)
Field assessments			
2CRU	Archaeological survey	2010	Begnaze Pty Ltd (2010)
Muirhead North	Archaeological survey	2015	Ellengowan Enterprises (2016)
Muirhead North	Flora, fauna and vegetation	2008	VDM-EcOz (2008)
2CRU	Ecology (baseline)	2010	GHD (2010)
Casuarina Beach/Sandy Creek	Shorebird counts of Sandy Creek	2013-16	Lilleyman (2016) – see Appendix N
Muirhead North	Vegetation mapping	2014	EcOz (2014)
Muirhead North and 2CRU	Cycad density mapping	2015	EcOz (2015)
Muirhead North	Rainforest hydrology review	2015	SMEC (2015)
Muirhead North and 2CRU	Targeted search for Typhonium praetermissum	2015 (Feb)	EcOz (2015)
Muirhead North and 2CRU	Black-footed Tree-rat camera trapping and habitat assessment	2016	EcOz (2016) – see Appendix M
Muirhead North and 2CRU	Recording of bat calls to detect Bare-rumped Sheath-tailed Bat	2015-16	Specialised Zoology (2015, 2016)

7.2.3 Methods

This section describes the survey methods undertaken to establish the ecology of the project site, determine the likelihood that threatened and migratory species are present, and to address any other information requirements of the EIS/PER.

7.2.3.1 Desktop assessment

Data sources

The biodiversity and heritage desktop studies that have been undertaken across the project site have used the following publically-available resources:

- Archaeological Sites Register held by the Department of Tourism and Culture.
- The Heritage list maintained by the Australian Heritage Council.
- The Northern Territory Heritage Register held by the Heritage Branch of the Department of Tourism and Culture.

- The EPBC Act Protected Matters Search Tool (PMST), an online tool managed by the Commonwealth Department of the Environment and the Environment (DoEE), which identifies the presence of likely presence of matters of National Environmental Significance (NES) listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The search area was based on a 5 km buffer from a centroid within the project site (-12.3457 130.8912) to ensure that all relevant matters of NES were included. In July 2016, EcOz acquired an up-to-date EPBC Protected Matters Search Report.
- The NT Department of Environment and Natural Resources (DENR) Flora and Fauna Atlas – a dataset of point location records for flora and fauna species (and other details) identified through biological surveys (either as validated observations or voucher specimens) conducted in the Northern Territory under a Wildlife Permit. This was applied over a tailored search area that covers the project footprint.
- The Atlas of Living Australia – an online enquiry tool containing information on all the known species in Australia aggregated from a wide range of data providers: museums, herbaria, community groups, government departments, individuals and universities. Australia-wide, it contains more than 50 million occurrence records based on specimens, field observations and surveys. This was applied over a tailored search area that covers the project footprint.
- Google Earth imagery to delineate potential vegetation communities for ground-truthing.
- *Conservation Values of the Parks and Reserves of the Greater Darwin Area Report* (Armstrong and Price 2007) – a report containing a list of the species recorded in Casuarina Coastal Reserve.
- The Atlas of Groundwater Dependent Ecosystems that displays the ecological and hydrogeological information on both known groundwater-dependent ecosystems and ecosystems that potentially use groundwater.

Threatened species' likelihoods

Following completion of the desktop assessment, the following procedure was used to determine the likelihood of occurrence of threatened species within the project site and adjoining areas that could potentially be impacted (i.e. Casuarina Beach), and thereby identify which species should be included for targeted field surveys:

1) Describe habitat types of the sites using land unit and vegetation mapping (refer to Section 7.2.4.2).
2) Tabulate all threatened species known to occur in the Darwin Coastal bioregion, along with any extra species identified in the EPBC Protected Matters Search Tool (DoEE 2016).
3) Eliminate from further assessment all species that have a very low likelihood of occurring within the project area – i.e. there is no suitable habitat and it is not expected that the species will pass through (because they are habitat specialists or have a restricted range), or they are extinct from the bioregion – as per Baker et al. (2005).
4) For the remaining species, apply and justify the likelihood of occurrence based on a combination of ecological knowledge of the area and species, and records from the NT Flora and Fauna Atlas, using the following categories:
    - Known – there are recent records of the species occurring within the footprint.

- Likely – core habitat for the species occurs within the footprint and there are recent records of the species occurring in the surrounding areas.
- May – core habitat for the species occurs within the footprint but there are no recent records of the species occurring within the footprint or in the surrounding areas.
- Unlikely – there is no core habitat for the species within the footprint and recent records of the species occurring within the footprint or in the surrounding areas.

The results of this assessment are presented in Section 7.2.4.3.

7.2.3.2 Field assessment

General flora and fauna survey

There have been two field studies undertaken to describe the general flora and fauna attributes of the site. Details of this study are provided in Table 32.

Table 32. Description of general flora and fauna surveys

Survey	Location	Date	Objectives	Survey techniques
VDM-EcOz (2008)	Muirhead North	8 – 11 December 2008	Determine the dominant flora. Undertake a comprehensive baseline fauna survey.	Two quadrats (50m x 50m) surveyed by a botanist in accordance with *Guidelines for the Terrestrial Biodiversity Component of Environmental Impact Assessment* (the relevant document at the time of the surveys). Both quadrats were also surveyed using 20 Elliot traps, 4 cage traps and 4 pitfall traps over 3 nights; as well as active searches, bird surveys and spot-lighting – in accordance with the abovementioned guidelines.
GHD (2012)	2CRU	20 August 2010	Describe the fauna diversity.	A combination of habitat assessments, standardised bird surveys, opportunistic fauna observations, records of wildlife traces, spotlighting and call-playback for nocturnal fauna, remote cameras and Anabat detectors.

Threatened ecological communities and vegetation-type survey

Two field studies have been undertaken to map the extent of vegetation communities and identify the presence of threatened ecological communities on the site. Consideration was given to relevant policy statements and listing advice when determining the presence of threatened ecological communities

In the NT vegetation can be classed as a 'sensitive vegetation type', which includes monsoon rainforest, riparian vegetation, mangrove, sandsheet heath and wetlands. These vegetation types are either unique to the region and/or have high biodiversity values. Sensitive vegetation types are considered significant under the *Northern Territory Land Clearing Guidelines 2009*.

Table 33. Description of vegetation type surveys

Survey	Location	Dates	Objectives	Survey techniques
GHD (2012)	2CRU	20 August 2010	Map the type and extent of vegetation communities.	The characteristics of vegetation communities were recorded using the NRETAS 'road notes' method (Brocklehurst *et al.* 2007) and the boundaries of the habitat types were ground-truthed where possible.
EcOz (2014)	Muirhead North	26 June 2014	Map the type and extent of vegetation communities.	Twenty representative vegetation sites were chosen within the lot boundary, and information was collected on the dominant flora species and structural formation. Sites were selected based on preliminary vegetation polygons that were created using high resolution aerial imagery and previous vegetation mapping of the Darwin municipality (Brocklehurst 1991)

Threatened species' survey

A preliminary threatened species 'likelihood of occurrence' assessment (using the methodology detailed in Section 7.2.4) identified that the following threatened species had a reasonable potential (i.e. Likely or Known) to occur on site or in areas that could potentially be impacted by the project, i.e. Sandy Creek, Casuarina Beach and Buffalo Creek:

- Two plant species
    - Darwin Cycad *Cycas armstrongii* (EPBC Act - not listed; TWPC Act - Vulnerable)
    - *Typhonium praetermissum* (EPBC Act not listed; TWPC Act – Vulnerable)
- Three marine turtle species
    - Olive Ridley *Lepidochelys olivacea* (EPBC Act – Endangered; TWPC Act – Vulnerable)
    - Green Turtle *Chelonia mydas* (EPBC Act – Vulnerable; TWPC Act – Near Threatened)
    - Flatback Turtle *Natator depressus* (EPBC Act – Vulnerable; TWPC Act – Data Deficient)
- Up to eight migratory shorebird species
    - Eastern Curlew *Numenius madagascariensis* (EPBC Act – Critically Endangered/Migratory; TWPC Act – Vulnerable)
    - Curlew Sandpiper *Calidris ferruginea* (EPBC Act – Critically Endangered/Migratory; TWPC Act – Vulnerable)
    - Bar-tailed Godwit subspecies *Limosa lapponica baueri* and *Limosa lapponica menzbieri* (EPBC Act – Vulnerable/Migratory; TWPC Act – Vulnerable)
    - Great Knot *Calidris tenuirostris* (EPBC Act – Critically Endangered/Migratory; TWPC Act – Vulnerable)
    - Greater Sand Plover *Charadrius leschenaultii* (EPBC Act – Vulnerable/Migratory; TWPC Act – Vulnerable)
    - Lesser Sand Plover *Charadrius mongolus* (EPBC Act – Endangered/Migratory; TWPC Act – Vulnerable)

- Red Knot *Calidris canutus* (EPBC Act – Endangered/Migratory; TWPC Act – Vulnerable)
- Asian Dowitcher *Limnodromus semipalmatus* (EPBC Act – Migratory; TWPC Act – Vulnerable)

- Three fish species
  - Dwarf Sawfish *Pristis clavata* (EPBC Act – Vulnerable; TWPC Act – Vulnerable)
  - Green Sawfish *Pristis zijsron* (EPBC Act – Vulnerable; TWPC Act – Vulnerable)
  - Freshwater Sawfish *Pristis microdon* (EPBC Act – Vulnerable; TWPC Act – Vulnerable)

- Two mammal species
  - Black-footed Tree-rat *Mesembriomys gouldii gouldii* (EPBC Act – Endangered; TWPC Act – Vulnerable)
  - Bare-rumped Sheath-tailed Bat *Saccolaimus saccolaimus nudicluniatus* (EPBC Act – Vulnerable; TWPC Act – Near Threatened)

Targeted surveys for most of these species were undertaken to determine presence/absence and map suitable habitat. The methods undertaken in these targeted surveys are presented below.

Targeted surveys were not undertaken for several threatened/migratory species listed above for the following reasons:

1) For migratory shorebirds, there is sufficient data collected by shorebird experts as part of regional counts (summarised in Section 7.2.4.3 and presented in Appendix N).
2) For marine turtles, there is sufficient existing data. Casuarina Beach has been monitored by Parks and Wildlife for turtle nesting each year since the mid-1990's, with all nests being recorded from the 1999 season to present (Chatto and Baker 2008, Chatto pers. comm.).
3) Surveys for sawfish are difficult as these species have a very low detectability; most records come from the netting activities of fishermen (DSEWPAC 2011). It is more efficient to assume some sawfish species are occasionally present within the project footprint, and undertake a risk assessment accordingly.

Black-footed Tree-rat

Status

The Kimberley and mainland Northern Territory sub-species of Black-footed Tree-rat *gouldii* is listed as Endangered under the EPBC Act and Vulnerable under the TPWC Act.

Description and ecology

The Black-footed Tree-rat is a large (500 to 900 g), nocturnal rodent, that is restricted to open forests and woodlands near coastal areas in the Kimberley and the Northern Territory (Friend and Calaby 1995, Rankmore 2003). The species has a robust body with grizzly grey fur, and large black feet and ears (see Figure 20). The most distinctive feature is a long hairy tail, 30 to 40 cm long, that has a brush of white hairs at the end.

Black-footed Tree-rats forage on the ground and in trees, with an average home range in un-fragmented open forests of 67.3 ± 10.4 hectares and in fragmented habitat of 27.1 ± 8.4 ha (Rankmore 2006). They are predominantly frugivorous – preferring both fleshy and hard fruits and seeds, with Pandanus *Pandanus spiralis*

fruit a particular favourite (Friend and Calaby 1995). The diet also includes some invertebrates, flowers and grass (Morton 1992, Rankmore 2006, Rankmore and Friend 2008).

Being nocturnal, Black-footed Tree-rats prefer to nest in tree hollows during the day, but have also been recorded nesting in Pandanus where hollows are limited (Pittman 2003). The species prefers open forests and woodlands dominated by Darwin Woolybutt and Darwin Stingybark with a developed shrubby understorey (Friend and Taylor 1985, Friend 1987). A well-formed understory with large diameter trees is typical of a low frequency or intensity of fires; and frequent, intense fires may be detrimental to this species by reducing the abundance of hollow-bearing large trees (Price et al. 2005).

Originally considered to be a solitary species (Friend 1987), evidence now suggests Black-footed Tree-rats are more gregarious. During a radio-tracking study of the species, the majority of radio collars removed were damaged through chewing, which could not be attributed to the collared individual (Rankmore pers. comm.). Moreover, recent camera trapping studies have frequently captured images of multiple individuals at a bait station (Brydie Hill, Flora and Fauna Branch of the NT DENR, pers. comm.).

Distribution

The Kimberley and mainland Northern Territory sub-species of Black-footed Tree-rat occur in the Top End of the Northern Territory and the Kimberley in the Western Australia (Hill 2012). Early distribution records from Eastern Arnhem Land and the Gulf of Carpentaria suggest that the species' distribution has contracted in the Northern Territory (Friend and Calaby 1995).

Threats

Declines in the population of Black-footed Tree-rat have been reported for the Kakadu area (Woinarski *et al.* 2001, Woinarski *et al.* 2010), and more broadly across the Top End of the Northern Territory (Ziembicki *et al.* 2013). The driver for this decline is unknown, but is thought to be related to changes in fire regime. In contrast to other parts of its range, the Black-footed Tree-rat may be relatively abundant in the Darwin rural area (Price et al. 2005). In an analysis of small mammals in the Darwin region from 2001 to 2014, Stokeld and Gillespie (2015) found that capture rates of Black-footed Tree-rat have been relatively consistent around Darwin, in comparison to most other species which had declined.

Figure 20. Black-footed Tree-rat (Brooke Rankmore 2016)

Survey methodology – presence

Because of the species' recent listing under the EPBC Act (the species was listed in June 2015), there are no Commonwealth-approved survey methods specifically for Black-footed Tree-rat. The *Survey Guidelines for Australia's Threatened Mammals* (DSEWPaC 2011) presents an overview of survey techniques to detect medium-sized ground-dwelling mammals. Advice on minimum sampling requirements was also sought from the NT DENR. It was advised that a suitable survey methodology should be based on the use of camera traps as Black-footed Tree-rat is likely to have a high detectability on camera traps (e.g. Stokeld and Gillespie 2015). The NT DENR recommended that the methodology should include one site per 20 ha of suitable habitat, with one camera installed per site for 4 weeks. As the survey site is located on the edge of suburban Darwin, there is a high level of people utilising the area for recreational activities and as an itinerant camping site.

A survey methodology was designed and implemented by EcOz (2016) that complied with the *Survey Guidelines for Australia's Threatened Mammals* (DSEWPaC 2011) and the advice provided by NT DENR. Twenty-four cameras were installed across 20 sites, of which eight cameras were installed at 2CRU and sixteen cameras were installed at Muirhead North. To reduce interference and theft of camera traps the number of cameras per unit area was increased to reduce the length of survey required to four days/nights. This approach was discussed with NT DENR before proceeding. In total there were 96 camera trap days with 32 camera trap days for 2CRU and 64 camera trap days for Muirhead North. The greater intensity of survey effort at Muirhead North reflected greater availability of suitable habitat for Black-footed Tree-rat then at 2CRU.

Camera installation was based on Gillespie et al. (2015), with reference to Meek and Fleming (2014). Cameras were predominantly located in areas that were considered likely habitat for Black-footed Tree-rats (abundance of mid-storey fruiting trees, and/or large hollows in Darwin Stringybark and Darwin Woolybutt and were also located to give a spread across the project area.

In addition to camera trap surveys, ecologists kept a look-out for chewed Pandanus seeds (EcOz 2014, 2016), which are a useful indicator of the presence of Black-footed Tree-rat.

Survey methodology – habitat assessment

Using vegetation mapping (i.e. GHD 2012, EcOz 2014) and field observations of the location and extent of Gamba Grass *Andropogon gayanus* infestations – the project site was divided into broad categories of Black-footed Tree-rat habitat quality. Thirteen sites were selected to undertake on-ground habitat quality assessment of which three sites were located within 2CRU and ten site were located in Muirhead North. Sites were selected to provide replication across the broadly-defined habitat quality categories and to provide a spread across the project site. As 2CRU comprised recently burnt and/or low diversity vegetation, less detailed habitat assessments were undertaken than at Muirhead North.

Three key habitat criteria were selected to measure the quality of habitat available for Black-footed Tree-rat:

- Presence and availability of denning/nesting sites – measured by the number of large trees, number of hollows observed, and presence of Pandanus.
- Presence of plant species known to be food resources for Black-footed Tree-rat.
- Density and composition of ground cover and grassy weed cover (high-density ground-cover restricts the mobility of Black-footed Tree-rat).

Each habitat survey site was ranked out of a score of three, with the highest quality habitat onsite receiving a score of three and the poorest quality habitat a score of zero. To receive a habitat quality score of three, the site had to have many large trees with hollows present and/or the presence of Pandanus, known food plants present at the site, and lower levels of ground cover and limited invasion by grassy weeds.

While ranking the sites provides information on the distribution and quality of habitat within the site, it does not inform how the habitat compares in a broader context. Using expert knowledge of Black-footed Tree-rat habitat requirements, habitat quality categories were developed using a scale of one to ten (with ten the highest possible quality).The habitat at the site was then compared against these broader habitat quality categories.

Table 34. Survey methodology for Black-footed Tree-rat

Survey guidelines	Surveys completed	Survey technique	Total survey effort	Adequate survey effort to determine presence
Guidelines for the Terrestrial Biodiversity Component of Environmental Impact Assessment (the relevant document at the time of the surveys)	EcOz (2008) in Muirhead North only as part of a baseline fauna survey.	Two sites using 20 Elliot traps and 4 cage traps over 3 nights; as well as active searches and spot-lighting	3 nights	Survey complied with guidelines; however, subsequent studies for Black-footed Tree-rat (i.e. Stokeld and Gillespie 2015) indicates a more intensive survey effort using camera traps is required to detect Black-footed Tree-rat.

Survey guidelines	Surveys completed	Survey technique	Total survey effort	Adequate survey effort to determine presence
Survey Guidelines for Australia's Threatened Mammals (DSEWPaC 2011) Interim advice provided by DENR (Brydie Hill)	EcOz (2016)	Camera trapping and habitat quality assessment	96 camera trap days	Yes (the species was detected at Muirhead North)

Bare-rumped Sheath-tail Bat

Status

The Bare-rumped Sheath-tailed Bat *Saccolaimus saccolaimus* is listed as Vulnerable under the EPBC Act and Data Deficient under the TPWC Act.

Description and ecology

The Bare-rumped Sheath-tailed Bat is a microbat with reddish-brown to dark brown fur that has white flecking. Specimens in the NT often lack a pronounced bare rump.

This is a nocturnal, high-flying species that feeds predominantly on insects using echo-location techniques. It is known to roost during the daytime in hollow trees and has been found in Pandanus woodland, eucalypt forests/woodlands, rainforests and caves (Friend and Braithwaite 1986, Churchill 1998, Duncan et al. 1999). Little is known about other behavioural aspects such as home range, preferred foraging height (although it is thought to forage for insects at, or above, the canopy level), seasonal activity and breeding.

Distribution

The Bare-rumped Sheath-tailed Bat is widely distributed from India through south-eastern Asia to the Solomon Islands, including north-eastern Queensland and the Northern Territory. The north-eastern Australian population is described as the subspecies *Saccolaimus saccolaimus nudicluniatus*, although it is not clear whether this should be applied to the NT population which is currently known as *Saccolaimus saccolaimus saccolaimus* (Milne *et al.* 2009). Within the NT this species is known from a few records from Pandanus woodland and eucalypt tall open forests (Friend and Braithewaite 1986, Churchill 1998, Milne *et al.* 2009) where it roosts in tree hollows and caves (Duncan *et al.* 1999). The most recent local records of this species came from Howard Springs in December 2006, where a dead tree containing a colony of about 100 individuals was blown over during a storm (Milne *et al.* 2009). This colony is considered highly significant as it is the only known roost site in the NT, and contained neonates and juveniles (Milne et al. 2009).

Threats

As the distribution, habitat preferences and biology of the Bare-rumped Sheath-tailed Bat are poorly known, the identification of known and likely threats facing this species are incomplete (DoE 2015). Habitat loss is identified as a threat; particularly as it relates tree hollow availability. There is a recovery plan for this species (Schulz and Thompson 2007).

Survey methodology

The following survey method for Bare-rumped Sheath-tailed Bat is based on information presented in the *Survey Guidelines for Australia's Threatened Bats* (DEWHA 2010). For previous surveys for this species by

ecological consultants EcOz in the Darwin region, advice has been sought from experts (Damian Milne of DENR and Dr Kyle Armstrong of Specialised Zoological) to design a survey program that provides the optimal opportunity for detecting this species.

Bare-rumped Sheath-tailed Bat is difficult to detect due to the high-flying nature of this species (which complicates capture in mist or harp nets) and that calls of this species are similar to the more common species Yellow-bellied Sheath-tailed Bat *Saccolaimus flaviventris*. Recent advances in the use of broadband bat detectors for distinguishing calls of Bare-rumped Sheath-tailed Bat have greatly increased the capability of detecting this species (Dr Kyle Armstrong, Specialised Zoological pers. comm.). Additionally, Dr Kyle Armstrong has created a set of criteria to attribute indicative and diagnostic call types related to Bare-rumped Sheath-tailed Bat.

Surveys were carried out 15 May 2015 at 2CRU and 25 July 2016 at Muirhead North by Specialised Zoological and EcOz. The following techniques were conducted to detect the species and to identify the extent of its potential occurrence throughout the project site

- Target habitat. Land unit and vegetation maps were inspected to identify potential roosting areas, which for this project area was identified as open forest with Darwin Woollybutt where hollows were abundant. Therefore, the entire project site was assumed to be potential foraging habitat for the species.
- Acoustic detection. Wildlife Acoustics SM2BAT+ bat detectors were used to record bat calls within the project site, and were programed to optimise the chance of detecting the Bare-rumped Sheath-tailed Bat. Detectors were set to automatically record between sunset and sunrise. Four sites were surveyed for one night each. Site selection was focused on Darwin Woollybutt forest.
- Analysis of calls. The recordings were analysed using specialised software (SCAN'R version 1.7.7 – Binary Acoustic Technology) by Specialised Zoological. This was then compared to representative and reference calls from northern Australia. Species were identified based on accepted literature (i.e. Milne 2002, Van Dyck *et al.* 2013, Reardon *et al.* 2015) and unpublished reference calls (Dr Kyle Armstrong pers. comms.).

Table 35. Survey methodology for Bare-rumped Sheath-tailed Bat

Survey guidelines	Surveys completed	Survey technique	Total survey effort	Adequate survey effort to determine presence
Survey Guidelines for Australia's Threatened Bats (Commonwealth of Australia 2010) Advice from experts (Damian Milne of NT DENR and Dr Kyle Armstrong of Specialised Zoological)	Specialised Zoology (2015, 2016)	Acoustic detection using Wildlife Acoustics SM2BAT+ bat detectors.	4 nights	Yes – this methodology is in line with that previously accepted for similar projects.

Migratory shorebirds

Status and ecology

The Darwin region supports a high diversity of migratory shorebirds. There have been 25 migratory shorebird species recorded within the Darwin Harbour region, of which eight are also listed as threatened under the EPBC Act (Table 36).

Most shorebirds in Australia are long-distance migrants that breed in the northern hemisphere and visit Australian shores in their thousands in the austral summer. On arrival in Australia, shorebirds spend the duration of the summer seeking out high-quality food resources on the intertidal zone of coastlines. Tidal cycles dictate foraging and roosting times for most coastal shorebirds that feed on exposed mudflats during low tide. At high tide, when the foraging grounds are submerged, shorebirds retreat to roosts on sandy beaches, mangroves, rocky reefs and ponds, where they typically rest.

Distribution

The shorebirds that occur in Darwin Harbour also occur in suitable habitat throughout Australia, although the abundances of some species are higher in the tropics.

Threats

Migratory shorebirds are a highly threatened group of birds. In the East Asian-Australasian Flyway these birds are rapidly declining largely due to the loss of intertidal habitat through reclamation development projects in the Yellow Sea region (MacKinnon *et al.* 2012, Moores *et al.* 2016, Murray *et al.* 2014). They also face threats such as hunting, impacts from climate change and sea-level rise, pollution and disturbance (Harding *et al.* 2007). In Australia, the key threats to migratory shorebirds are coastal development that destroys habitat and disturbance that disrupts their normal activities (Harding *et al.* 2007)

Survey methodology

Information on migratory shorebirds presence adjoining Sandy Creek along Casuarina Beach was compiled by Lilleyman (2016) as part of a broader study of the Darwin harbour. Data was collected between 2013 and 2016. Data collected by Lilleyman (2016) for the Sandy Creek area is considered more comprehensive than previous survey work undertaken as part of the Shorebirds 2020 program (Figure 21). The survey methodology used for the collection of the dataset is described in detail in Appendix N and is more than adequate to meet the requirements of the *EPBC Act Policy Statement 3.21 – Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species* (DoE 2015b).

Table 36. Migratory shorebird species that have been recorded in Darwin Harbour

Common name	Scientific name	EPBC Act	TPWC Act
Pacific Golden Plover	*Pluvialis fulva*	-	-
Grey Plover	*Pluvialis squatarola*	-	-
Little Ringed Plover	*Charadrius dubius*	-	-
Lesser Sand Plover	*Charadrius mongolus*	EN	VU
Greater Sand Plover	*Charadrius leschenaultii*	VU	VU

Common name	Scientific name	EPBC Act	TPWC Act
Oriental Plover	*Charadrius veredus*	-	-
Black-tailed Godwit	*Limosa limosa*	-	-
Bar-tailed Godwit (Northern Siberian sub-species)	*Limosa lapponica menzbieri*	CR	VU
Bar-tailed Godwit (Western Alaskan sub-species)*	*Limosa lapponica baueri*	VU	VU
Little Curlew	*Numenius minutus*	-	-
Whimbrel	*Numenius phaeopus*	-	-
Eastern Curlew	*Numenius madagascariensis*	CR	VU
Terek Sandpiper	*Xenus cinereus*	-	-
Common Sandpiper	*Actitis hypoleucos*	-	-
Grey-tailed Tattler	*Tringa brevipes*	-	-
Common Greenshank	*Tringa nebularia*	-	-
Marsh Sandpiper	*Tringa stagnatilis*	-	-
Wood Sandpiper	*Tringa glareola*	-	-
Ruddy Turnstone	*Arenaria interpres*	-	-
Asian Dowitcher	*Limnodromus semipalmatus*	-	VU
Great Knot	*Calidris tenuirostris*	CR	VU
Red Knot	*Calidris canutus*	EN	VU
Sanderling	*Calidris alba*	-	-
Red-necked Stint	*Calidris ruficollis*	-	-
Sharp-tailed Sandpiper	*Calidris acuminata*	-	-
Curlew Sandpiper	*Calidris ferruginea*	CR	VU

* The two subspecies of Bar-tailed Godwit are known to occur in the Darwin region but were not distinguished during the 2013-2016 surveys. Subspecies *menzbieri* is considered more common.

Table 37. Survey methodology for migratory shorebirds

Survey guidelines	Surveys completed	Survey technique	Total survey effort	Adequate survey effort to determine presence
EPBC Act Policy Statement 3.21 – Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species (DoE 2015b)	Lilleyman (2016)	High tide roost surveys by an experienced surveyor	55 counts (Sandy Creek)	Yes – presence, abundance and behaviour all determined

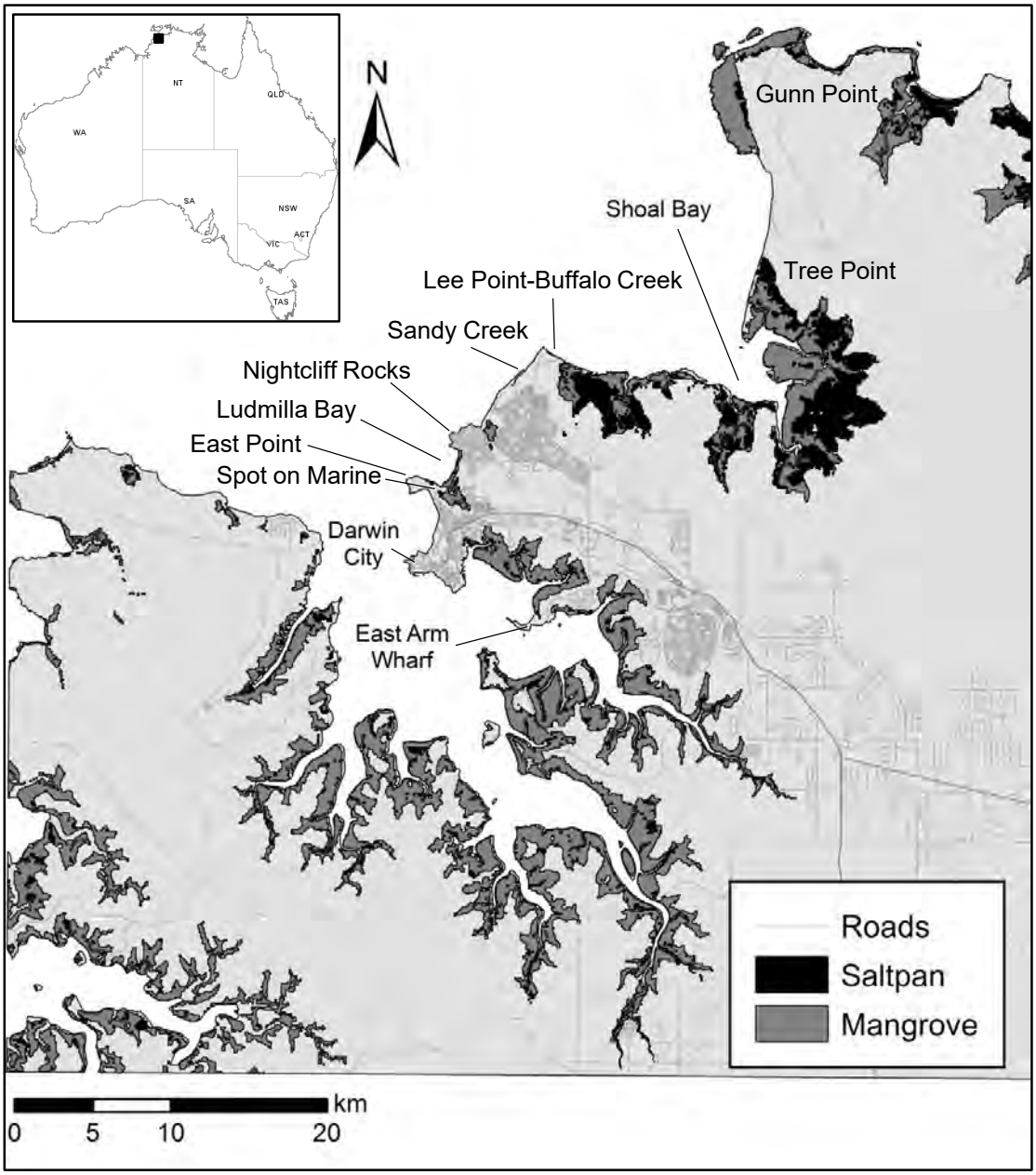

Figure 21. Map of the monitored shorebird roosting and feeding sites in the Darwin Harbour region (reproduced from Lilleyman 2016)

Darwin Cycad

Status

The Darwin Cycad is classified as Vulnerable under the TPWC Act, and is not listed under the *EPBC Act*.

Description and ecology

This species is a small to medium-sized cycad with a slender trunk (Kerrigan *et al.* 2006) – Figure 22.

The species occurs in open grassy woodlands where adequate draining appears to be a limiting factor (Kerrigan et al. 2006), and on rocky outcrops, undulating hills and plains (Holmes *et al.* 2005). Prime cycad habitat has deep loamy, well-drained soil, and the species is frequently associated with Darwin Woollybutt and Darwin Stringybark (Liddle 2009).

Distribution

The Darwin Cycad is endemic to the Top End – with abundant populations occurring throughout the greater Darwin region, often forming dense stands (Kerrigan *et al.* 2006). Current distribution of the species extends from the Adelaide River west to the Finniss River and south to the township of Adelaide River, with patchy occurrences further south to Hayes Creek. Additional populations also occur on the Tiwi Islands and Cobourg Peninsula (Kerrigan *et al.* 2006).

Threats

The main threats associated with this species are land clearing for urban development in Darwin, horticulture, agriculture and forestry. The species' prime habitat comprises deep, loamy soil which is considered suitable for horticulture and agriculture (Kerrigan *et al.* 2006). Altered fire regime and introduced perennial grasses also appear to be threatening processes (Kerrigan *et al.* 2006). Although the Darwin Cycad is locally abundant in the Darwin region, long-term conservation has to be considered as the species is long-lived, has a slow reproductive rate and a localised distribution (Liddle 2009). Moreover, less than 1 % of the Darwin Cycad population is included in conservation reserves.

Figure 22. Photograph of a Darwin Cycad

Survey methodology

EcOz (2015) assessed cycad density within the proposed development area based on habitat mapping and field observations, and assigned each land unit a density class:

- None
- Low (less than 1 plant per 75 m^2)
- Moderate (between 1 plant per 25 m^2 and 1 plant per 50 m^2)
- High (greater than 1 plant per 50 m^2).

Table 38. Survey methodology for Darwin Cycad

Survey guidelines	Surveys completed	Survey technique	Total survey effort	Adequate survey effort to determine presence
None	EcOz (2015)	Desktop density mapping using observed associations in the field between land units and abundance.	N/A	Yes – this methodology is in line with that previously accepted for similar projects by NT DENR.

Typhonium praetermissum

Status

The species is listed as Vulnerable under the TPWC Act. It is not listed under the EPBC Act.

Description and ecology

Typhonium praetermissum is a small, herbaceous geophyte (Holmes *et al.* 2005) – Figure 23. The species is seasonally-dormant, emerging annually from underground tubers, bulbs or corms (Cowie and Westaway 2012). Fruits occur at ground level and, in some cases, are found partially underground. Fruiting takes place during the beginning of the wet season between November and January (Holmes *et al.* 2005), which constitutes the best time for the species' detection. Field identification is often difficult due to the very short flowering period. Most *Typhonium praetermissum* plants are sterile when encountered and leaf material must be collected for correct identification using DNA analysis (Cowie and Westaway 2012).

Suitable habitat for *Typhonium praetermissum* is open woodland in soil types ranging from red-brown, clay soil to shallow or gravelly lateritic soil, either on the plateau edge or bordering with sandsheet and drainage areas, which occur in localised areas in lowlands (Cowie and Westaway 2012).

Distribution

Typhonium praetermissum is endemic to the Top End. It has been recorded in at least eight locations within the Darwin-Litchfield region including Virginia, Karama, the Palmerston escarpment, Holtze, Mandorah, Lloyd Creek and Humpty Doo (Cowie and Westaway 2012). Only a small number of populations have been found within these areas, and most are located in areas suitable for rural or residential development (Cowie and Westaway 2012).

Threats

Current populations are vulnerable to impacts from habitat loss and fragmentation due to development of the greater Darwin region (Cowie and Westaway 2012). Invasive weed species that out-compete post-fire regeneration and altered fire regimes also pose a threat (Cowie and Westaway 2012).

Figure 23. *Typhonium praetermissum* (David van der Hoek, 2015)

Survey methodology

There are no formalised survey guidelines available for *Typhonium praetermissum.* To inform previous surveys of this species, EcOz has consulted with the NT Herbarium (Ian Cowie) and DENR (David Liddle) about an optimal methodology. The advice of those experts informed the survey for this development. It was decided that surveys within the project area should take place on the edges of Eucalypt woodlands with potentially suitable habitat, and in similar habitat bordering on drainage areas.

Surveys for *Typhonium praetermissum* were conducted within the project area on 18 February 2015 by EcOZ (2015). The surveys were not aligned with the fruiting period for this species; however, leaf samples would be collected for identification via DNA analysis.

Reference was also made to this species' 'Known Extent of Occurrence' map recently produced by the Flora and Fauna Division of DENR (DENR 2015), which includes known records, confirmed absences and potential habitat.

Table 39. Survey methodology for *Typhonium praetermissum*

Survey guidelines	Survey completed	Survey technique	Total survey effort	Adequate survey effort to determine presence
Advice provided by NT Herbarium (Ian Cowie) and DENR (David Liddle).	EcOz (2015)	Transect undertaken by a botanist experienced in assessing habitat suitability for this species.	1 day	Yes – this methodology is in line with that previously accepted for similar projects.

Archaeological survey

Separate archaeological surveys were completed for 2CRU and Muirhead North. The archaeological survey for 2CRU was completed by Begnaze Pty Ltd (2010) to locate and record any archaeological objects or places and comply with the objects of the *Northern Territory Heritage Conservation Act 1999,* EPBC Act and *Environment and Heritage Legislation Amendment Act (No 1) 2003.*

The survey involved a qualified archaeologist working transects 50 metres apart searching for:

- Artefact scatters which may contain flaked or ground artefacts and hearthstones. They occur as surface scatters of materials or as stratified deposits when they have been prepeated occupations.
- Stone arrangement which range from simple cairn to more elaborate arrangements. These stone arrangements were used in ceremonial activities and represent sacred or totemic sites. Other stone arrangements were constructed for route or territory markers, the walls of huts, fish traps or small walls to stop water from entering a rock shelter or retain the floor.
- Stone quarries are generally sites where stone for flaked or edge ground artefacts have been extracted from an outcropping source of rock.
- Knapping sites are discrete scatters of artefacts consisting of the remains of a single reduction event associated with the fabrication of implements.
- Shell middens contain mollusc material in the form of surface scatters or mounded deposits and represent the remains of human meals.

The archaeological survey for Muirhead North was completed by Ellengowan Enterprises (2016). The purpose of the assessment was to:

- Identify and prescribed archaeological object or places as defined under the Northern Territory *Heritage Act 2012,* and any archaeological sites located within the survey area.
- Assess the nature, distribution and significance of these objects or places and discuss possible constraints to the works posed by the presence of archaeological and historic sites and an indication of what sites are likely to the most sensitive in this respect.

The study included a review of the National Trust heritage register, the Register of the National Estate, and places and objects prescribed under the NT *Heritage Conservation Regulations 1999.* A field survey was conducted on 31 May 2015, by walking along tracks, laterite ridges and creek banks and walking transects through areas of open field.

Table 40. Survey methodology for archaeology

Site	Survey guidelines	Survey completed	Survey technique	Total survey effort	Adequate survey effort to determine presence
2CRU	Based on past survey techniques approved by regulatory authorities.	Begnaze Pty Ltd (2010)	Transect survey undertaken by experienced archaeologist.	1 day	Yes – sufficient effort to identify any sites of heritage significance.
Muirhead North	Based on past survey techniques approved by regulatory authorities.	Ellengowan Enterprises (2016)	Transect survey undertaken by experienced archaeologist.	1 day	Yes – sufficient effort to identify any sites of heritage significance.

7.2.4 Results

7.2.4.1 General flora and fauna

The *Conservation Values of the Parks and Reserves of the Greater Darwin Area Report* (Armstrong and Price 2007) contains a list of the flora and fauna species recorded in Casuarina Coastal Reserve. It is considered that this list, combined with the results of desktop and field surveys, is indicative of the species suite for the project site and surrounds, given that analogous habitats are present.

The flora and fauna assemblages identified from desktop and field surveys are largely typical of those found in the savannah woodlands of tropical Australia, albeit somewhat depauperate due to the high degree of weed infestation and fire frequency across the project area. Although much of the area proposed for development has evidently experienced burning at a high frequency, the small-scale of this burning means it does not show up on Northern Australia Fire Information (NAFI) fire mapping.

There have been no systematic surveys of the marine and aquatic environments that occur around the project site, i.e. Sandy Creek, Buffalo Creek and Casuarina Beach. There are; however, some species records for the marine environment and these are discussed in the relevant sub-sections of Sections 7.2.4.3.

Weeds and pest animals

Three exotic fauna species have been recorded within the project site. One dog *Canis familiaris* was photographed by a remote camera. Cane Toads *Rhinella marina* are common in the area. The Asian House Gecko *Hemidactylus frenatus* was heard and is likely to be ubiquitous, especially given the project site's proximity to urban areas.

Weeds are widespread across the project site, although weed infestations are more extensive at 2CRU, and are most prevalent along tracks and in previously cleared and disturbed areas. Grassy weeds make up the majority of the weed impact – particularly Gamba Grass and Mission Grass *Cenchrus polystachios*. These two species are declared under the NT WM Act as Class A (to be eradicated) and Class B (to be controlled), respectively. Gamba Grass is also a Weed of National Significance (WoNS). Hyptis *Hyptis suaveolens* and Snakeweed *Stachytarpheta* spp. are also Class B weeds and have been recorded in the project area.

Non-declared weed species recorded in the project area include:

- Red Natal Grass *Melinis repens*
- Purple Top Chloris *Chloris inflata*
- Wild Passion Fruit *Passiflora foetida*
- Stylos *Stylosanthes sp*.
- Centro *Centrosema molle*
- Calopo *Calopogonium mucunoides*
- Coffee Bush *Leucaena leucocephala*.

The majority of these introduced plants are located along the highly disturbed boundaries of the sites.

7.2.4.2 *Threatened ecological communities and vegetation types*

The project area contains a mix of remnant and regenerated vegetation communities that are common in the Top End; however, not all are well-represented in the Darwin area because of previous clearing for urban development.

GHD (2010) identified five vegetation communities within the project site:

- Monsoon vine forest[2] (20.6 ha)
- *Eucalyptus tetrodonta* woodland (11.7 ha)
- Low *Eucalyptus tetrodonta* woodland (15.6 ha)
- Disturbed *Eucalyptus tetrodonta* woodland with *Calytrix exstipulata* shrubland (28.1 ha)
- Disturbed *Acacia auriculiformis* woodland with grassy weeds (2.9 ha).

EcOz (2014) identified eight vegetation communities within the Muirhead North site:

- Dry monsoon rainforest (mixed species) (0.88 ha)
- *Eucalyptus tetrodonta* and *Eucalyptus miniata* open forest with *Sarga intrans* and *Heteropogon contortus* grassland understorey (9.3 ha)
- *Eucalyptus tetrodonta* open woodland with *Sarga intrans* grassland understorey (5.0 ha)
- *Eucalyptus sp.* and *Corymbia sp.* open woodland (mixed species) over introduced grasses (5.0 ha)
- *Melaleuca viridiflora* woodland over introduced grasses (7.0 ha)
- *Lophostemon lactifluus* and *Pandanus spiralis* Woodland over *Sarga intrans* and introduced grasses (11.6 ha)
- *Acacia* shrubland with scattered *Eucalyptus tetrodonta* over introduced grassland (8.4 ha)
- Grassland (introduced species) (3.7 ha).

The Atlas of Groundwater Dependent Ecosystems indicates that portions of the project site mapped as supporting Monsoon Vine-thicket and Eucalypt woodland have a moderate to high potential for groundwater interaction (Figure 27).

[2] This is better described as monsoon vine thicket given the low canopy height of 7 m and dense shrub layer.

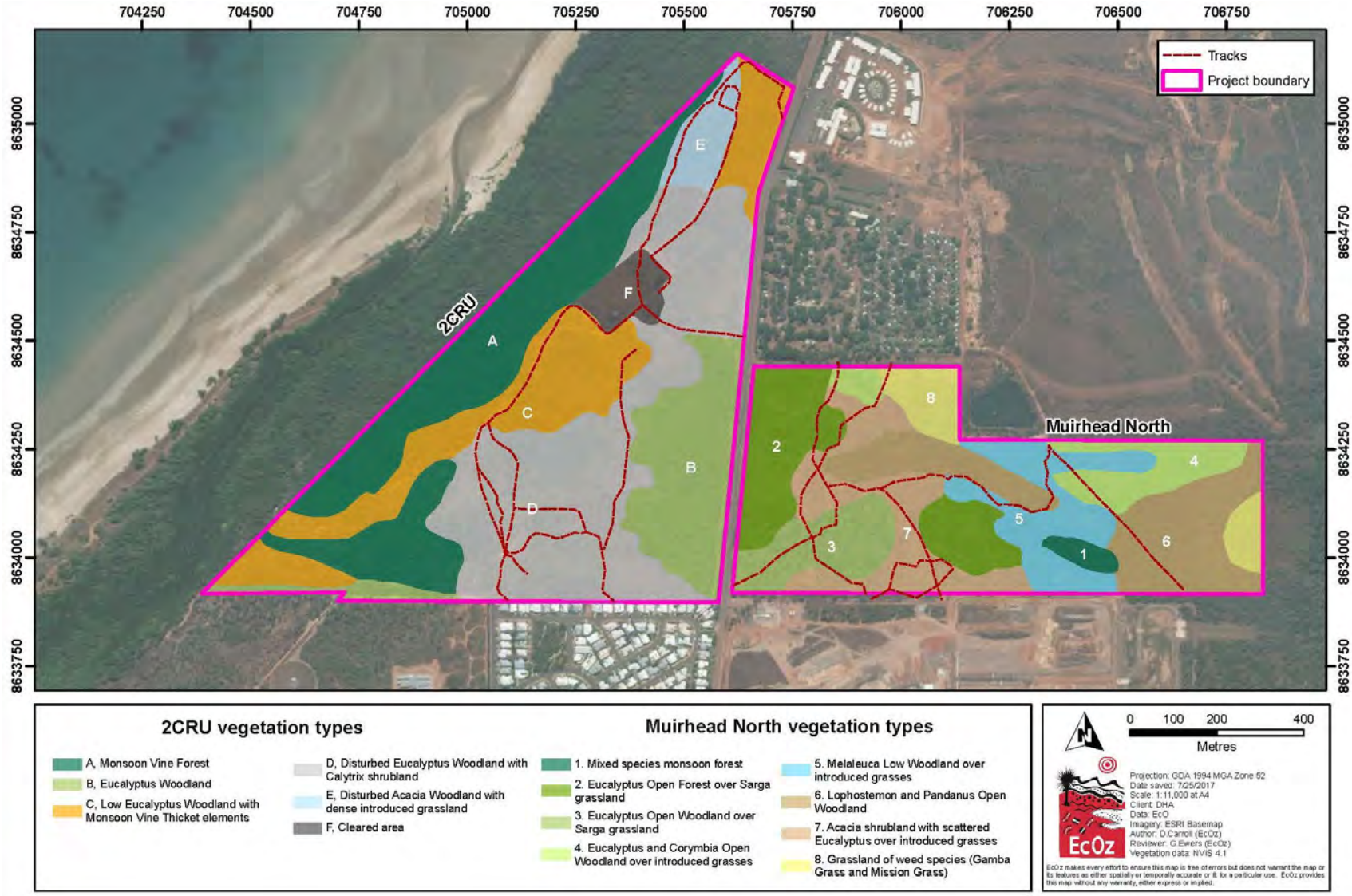

Figure 24. Map of vegetation communities within the project site

Environment Protection and Biodiversity Conservation Act 1999

No ecological communities listed as threatened under the EPBC Act were recorded on the project site (GHD 2010, EcOz 2014). Furthermore, the PMST does not predict the presence of any listed ecological communities within the project area (DoE 2016).

Northern Territory

The *Map of Remnant Vegetation Darwin Municipality* compiled by Brock (1995) identified monsoon vine thicket on the western edge of 2CRU and a small patch of monsoon forest centrally located within Muirhead North. Field surveys confirmed the existence and extent of this sensitive vegetation type – Figure 25.

The 2CRU site contains 20.6 ha of Monsoon Vine-thicket (canopy to 7 m) on the western side that adjoins the vine-thicket community within Casuarina Coastal Reserve. There is an isolated patch of monsoon rainforest (canopy 15 to 20 m) present in Muirhead North. Although small (0.88 ha), this patch is significant because its structure and the species present (especially the presence of native palms) resemble the spring-fed rainforests of Holmes Jungle and Howard Springs; however, no permanent freshwater is evident. The monsoon rainforest patch is fed by a seasonal drainage line that transects the lot from the north-west to south-east. This seasonal watercourse would appear to have a role in providing the water required to sustain the species of plants within the patch. This onsite vegetation is considered to be of high ecological value because of its limited distribution in the greater Darwin region.

Figure 25. Monsoon Vine-thicket (2CRU)

Figure 26. Monsoon Rainforest (Muirhead North)

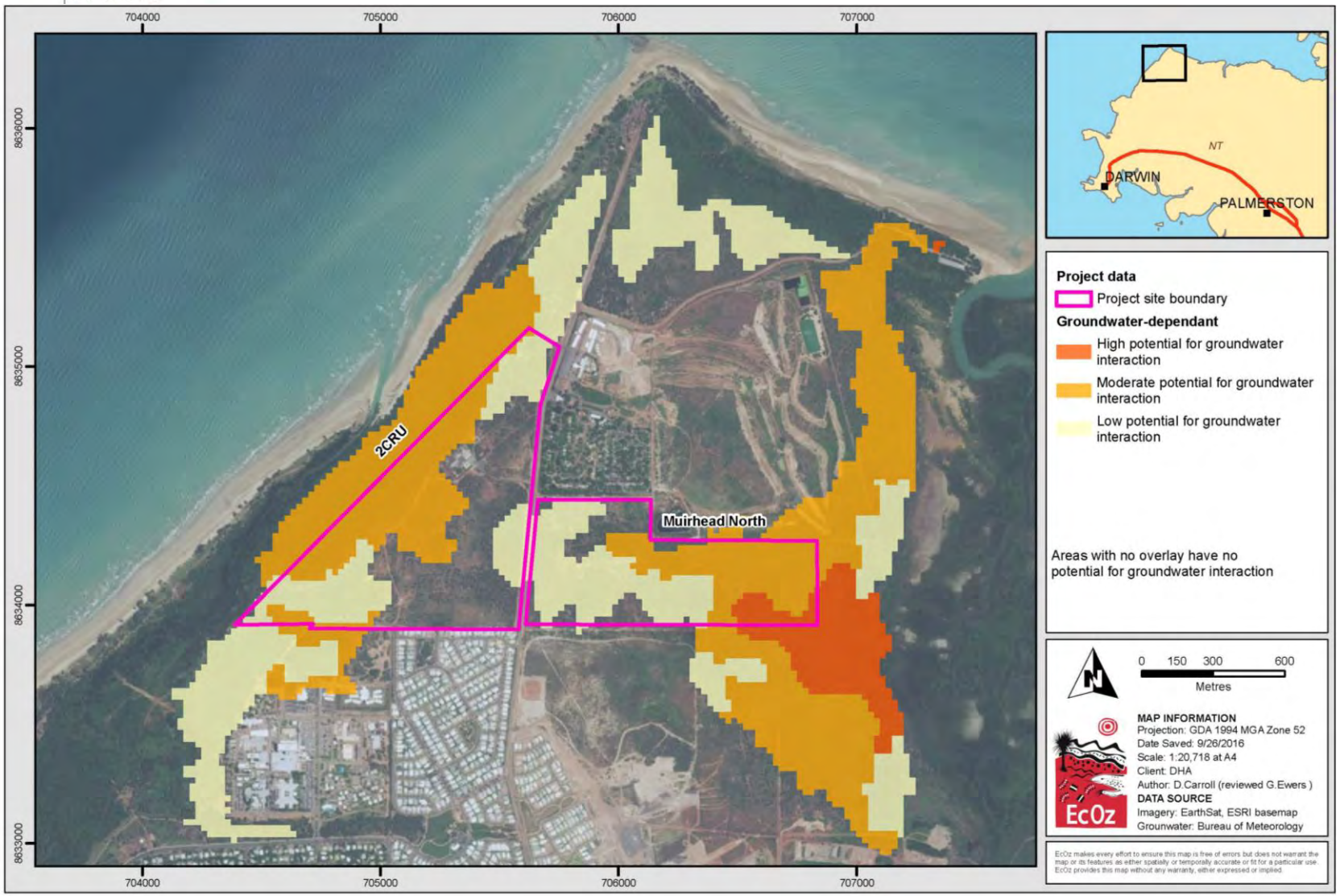

Figure 27. Map showing possible groundwater-dependent ecosystems within and surrounding the project site

7.2.4.3 *Threatened and Migratory species*

This section presents the results of the targeted surveys that were undertaken for the threatened and migratory species identified in a preliminary 'likelihood of occurrence' assessment as having a reasonable chance of occurring (i.e. known or likely to occur) within the project footprint. It also includes the results of previous targeted surveys that were not commissioned as part of this project, but focussed on threatened or migratory species considered as having a reasonable change of occurring (see Section Likelihood of occurrence below). The findings of the targeted surveys detailed in this Section inform the likelihood of a 'significant impact' on threatened and migratory species in accordance with the EPBC Act (Section 7.4.1).

Environment Protection and Biodiversity Conservation Act 1999

Black-footed Tree-rat

Detailed findings of the Black-footed Tree-rat survey is contained in Appendix M. Black-footed Tree-rat was recorded at three sites on four cameras in Muirhead North. Two of the sites are located in the west of Muirhead North near Lee Point Road. The third site where Black-footed Tree-rat was recorded was located along the south-eastern boundary of Muirhead North. No Black-footed Tree-rats were recorded in 2CRU. All records for Black-footed Tree-rat were in areas with a habitat quality score of 5-7/10 (Figure 29).

To ascertain the potential for Black-footed Tree-rat to occur in 2CRU, additional information sources were reviewed as explained in the Black-footed Tree-rat report (Appendix M) including:

- Radio-tracking study of Black-footed Tree-rats around 2CRU and adjoining Defence land (Griffiths *et al.* 2002).
- Live trapping study of 2CRU and adjoining Defence land (Rankmore *et al.* 2001).
- Live trapping and camera trapping of small-mammals in the Lee Point area including 1 kilometre south-west of the study area (Stokeld and Gillespie 2015).
- Consultation with CDU who undertake periodic monitoring of Black-footed Tree-rat in woodland adjoining their campus.

The radio-tracking study by Griffiths *et al.* (2002) tracked three Black-footed Tree-rats moving between the current Lyons residential development, Royal Darwin Hospital and 2CRU. From 92 observations over a four month period, Griffiths *et al.* (2002) located Black-footed Tree-rat in the development section of 2CRU on six occasions, while the majority of records were in the Monsoon Vine-thicket section of 2CRU (45 observations) which will be protected and Royal Darwin Hospital (33 records). The tracked animals showed a high fidelity to nesting trees, with two animals returning to the same eucalypt trees on numerous occasions. The six records from within habitat to be removed at 2CRU were in the south of the site.

The trapping study by Rankmore *et al.* (2001) did not identify Black-footed Tree-rat in 2CRU, but did locate the species in the adjoining Lyons site, in a similar location to Griffiths *et al.* (2002) highlighting the importance of this area for Black-footed Tree-rat. Stokeld and Gillespie (2015) did not record Black-footed Tree-rat at a study site near 2CRU on the opposite side of Sandy Creek using both live and camera-trapping methods. Although Stokeld and Gillespie (2015) did record the species near the Buffalo Creek boat ramp on camera traps but not

via live trapping. Charles Darwin University recorded Black-footed Tree-rat using both camera traps and live-trapping methods in woodland adjoining the campus as recently as October 2016 (Appendix M).

The habitat assessment identified that Muirhead North has better quality habitat than 2CRU for Black-footed Tree-rat (Table 41; Figure 29), which is reflected in the results of the camera-trap surveys and the number of habitat assessments undertaken across the two sites.

Based on the descriptions of the habitat categories and results of the targeted surveys, habitat with a quality score of 5/10 or greater is potentially suitable habitat for Black-footed Tree-rat. Habitat with a quality score of 4/10 or less does not have any large trees, and has a high cover of Gamba Grass with limited or no food plants (Table 41). It is unlikely that Black-footed Tree-rat would persist in these locations due to the absence of nesting trees, while the dominance of Gamba Grass is likely to limit or preclude the movement of Black-footed Tree-rat.

While Black-footed Tree-rat was not recorded in 2CRU during camera-trap surveys, there is potential (albeit low) that the species may occur on the site in areas to be developed given the previous findings of Griffiths *et al.* (2002). If present, the species is likely to occur in patches of better quality habitat that adjoin the Royal Darwin Hospital, the Lyons Development and Casuarina Coastal Reserve. Areas of suitable habitat for Black-footed Tree-rat in 2CRU that will be removed include an isolated 5.5 ha patch along Lee Point Road.

There is also suitable habitat in the south-west of the site and along the western boundary abutting the Monsoon Vine-thicket, and linking up with Royal Darwin Hospital and the Lyons Development covering approximately 7.5 ha (Figure 29). This area will be retained as public open space; however, some modification, including removal of some trees, may be required to comply with the Biting Insect Management Plan (Appendix G). The Biting Insect Management Plan recommends that canopy cover be reduced to approximately 10% to act as a buffer against biting insect moving into the development site for potential breeding locations along Sandy Creek. It is estimated that half of the overstorey trees would need to be removed to achieve 10% canopy cover, noting that many of the trees in this area are small and that the smallest trees will be selected for removal.

The majority of 2CRU is highly degraded as a result of past and ongoing disturbance (e.g. illegal site access and use such as off-road driving, rubbish dumping and camping), and does not support any large trees. The ground-layer is devoid of Black-footed Tree-rat's preferred food plants, and is dominated by dense Gamba Grass restricting the movement of the species through this area.

Across the 51.7 ha Muirhead North site, there is approximately 17.5 ha of suitable habitat for Black-footed Tree-rat (i.e. habitat quality score of 5/10 or greater; Figure 29). Habitat is confined to approximately two patches, located along the western boundary with Lee Point Road that connects up to Lee Point Resort Village, and in the central-eastern sections connecting up with Lee Point Resort Village and suitable habitat along Buffalo Creek.

Based on the results of this study as well as Stokeld and Gillespie (2015), Griffiths *et al.* (2002) and ongoing monitoring by Charles Darwin University, it is assumed that the Black-footed Tree-rat population occurs as two distinct sub-populations separated by Lee Point Road. To the west of Lee Point Road, the species moves throughout the Casuarina Coastal Reserve linking up with areas of eucalypt woodland at Charles Darwin University, The Royal Darwin Hospital and potentially 2CRU. East of Lee Point Road, there are extensive areas of eucalypt woodland along Buffalo Creek, the back of Lee Point Village Resort as well as Muirhead North. The

population(s) at Lee Point are likely to be isolated from populations elsewhere. Areas adjoining Lee Point to the south such as Rapid Creek, Tiwi, Wulagi, Nakara, Casuarina and Alawa are heavily developed with no suitable habitat for the species. While Buffalo Creek would provide a natural barrier to the species moving east of Muirhead North.

The closest Stokeld and Gillespie (2015) record of Black-footed Tree-rat to the population at Lee Point is at Darwin Airport, approximately seven kilometres to the south. The population west of Lee Point Road is unlikely to be connected to this population. While the airport links up to Rapid Creek, the habitat along Rapid Creek is dominated by Monsoon Vine-thicket and unlikely to support Black-footed Tree-rat dispersal. The distance between the two populations is also greater than the species' range of dispersal (Rankmore 2006).

The results of Stokeld and Gillespie (2015) also suggest that the population of Black-footed Tree-rat east of Lee Point Road is also unlikely to be connected to the nearest known population at Darwin Airport. Areas of suitable habitat between Muirhead North and Darwin Airport located within Holmes Jungle Nature Reserve were included in targeted surveys; however, Black-footed Tree-rat was not recorded.

A map showing the area of suitable habitat for Black-footed Tree-rat within the greater Darwin region is shown below (Figure 29). It is overlayed with the results of the Stokeld and Gillespie (2015) survey, showing areas where Black-footed Tree-rat was recorded. This map shows the location of Black-footed Tree-rat populations at Lee Point within a regional context, and shows there is a lack of habitat/records providing connectivity for populations at Lee Point with other populations in the wider Darwin region.

Table 41. Black-footed Tree-rat habitat quality assessment (see Appendix M)

Site	Rank	Quality score*	Description
M01	3.00	7	Many large trees & hollows, food, high mobility, low Gamba Grass
M02	2.75	7	Some large trees & hollows, food, high mobility, low Gamba Grass
M14	2.75	7	Some large trees & hollows, food, high mobility, low Gamba Grass
M18	2.50	6	Few large trees & hollows, food, mobility, low Gamba Grass
M11	2.25	6	Few large trees & hollows, food, moderate mobility, moderate Gamba Grass
M12	2.00	5	No large trees but pandanus, no hollows, food, mobility, moderate Gamba Grass
M03	2.00	5	Few large trees, no hollows, food, mobility, low Gamba Grass
M09	1.75	4	No large trees but pandanus, no hollows, food, reduced mobility, moderately high Gamba Grass
M07	1.50	4	No large trees but pandanus, no hollows, food, low mobility, moderately high Gamba Grass
M13	1.25	4	No roosting sites, food, moderate mobility, moderate Gamba Grass
M05	1.00	3	Few large trees, limited hollows, no food, low mobility, high Gamba Grass cover
M06	0.50	3	A large tree, no pandanus, no hollows, no food, low mobility, moderate Gamba Grass
M08	0.25	2	No large trees, no pandanus, no hollows, no food, limited mobility, total Gamba Grass cover
M17	0.00	1	No large trees, no pandanus, no hollows, no food, limited mobility, total Gamba Grass cover

Figure 28. Photograph of potentially-suitable Black-footed Tree-rat habitat that is infested by Gamba Grass

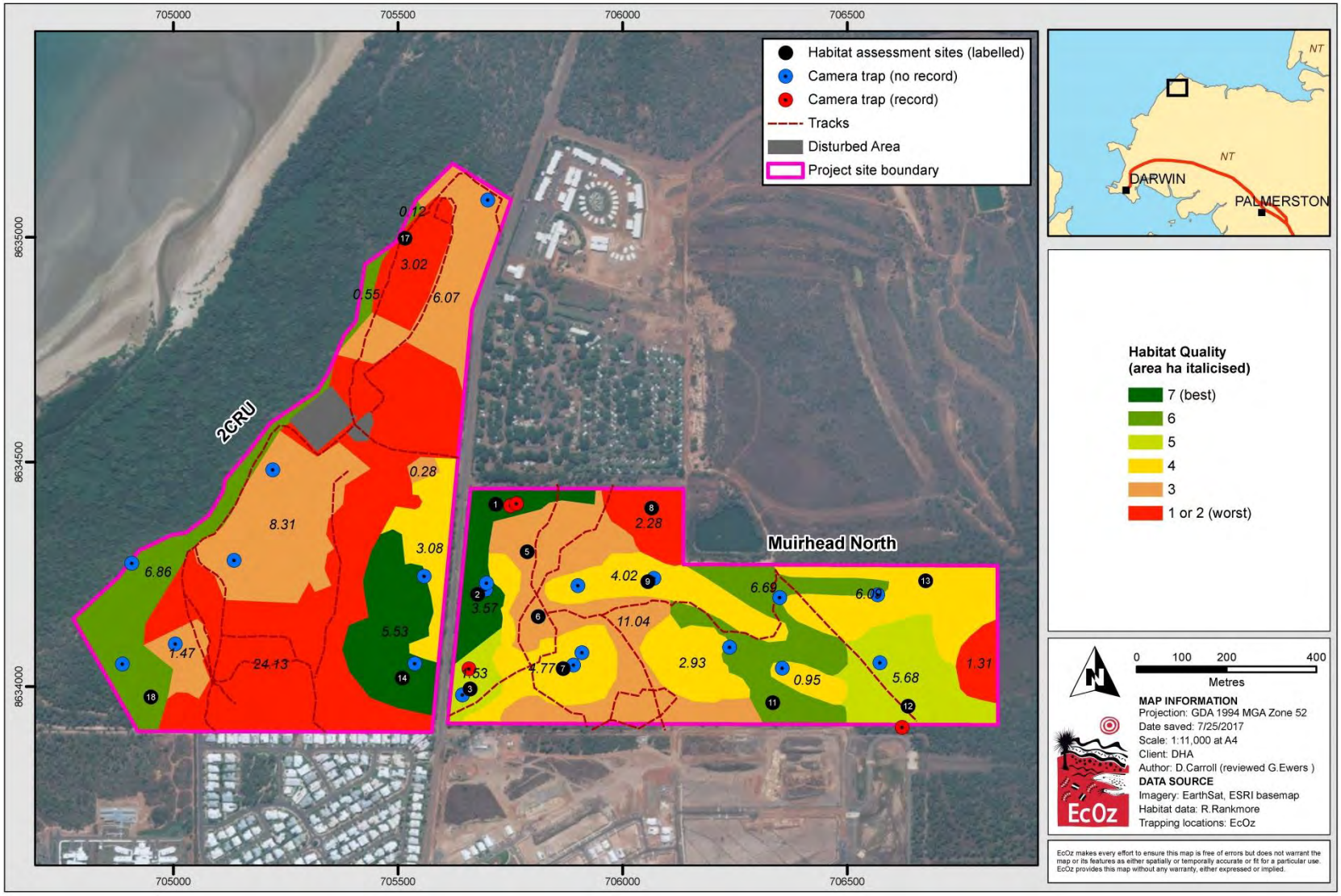

Figure 29. Map of Black-footed Tree-rat survey results (records and habitat quality)

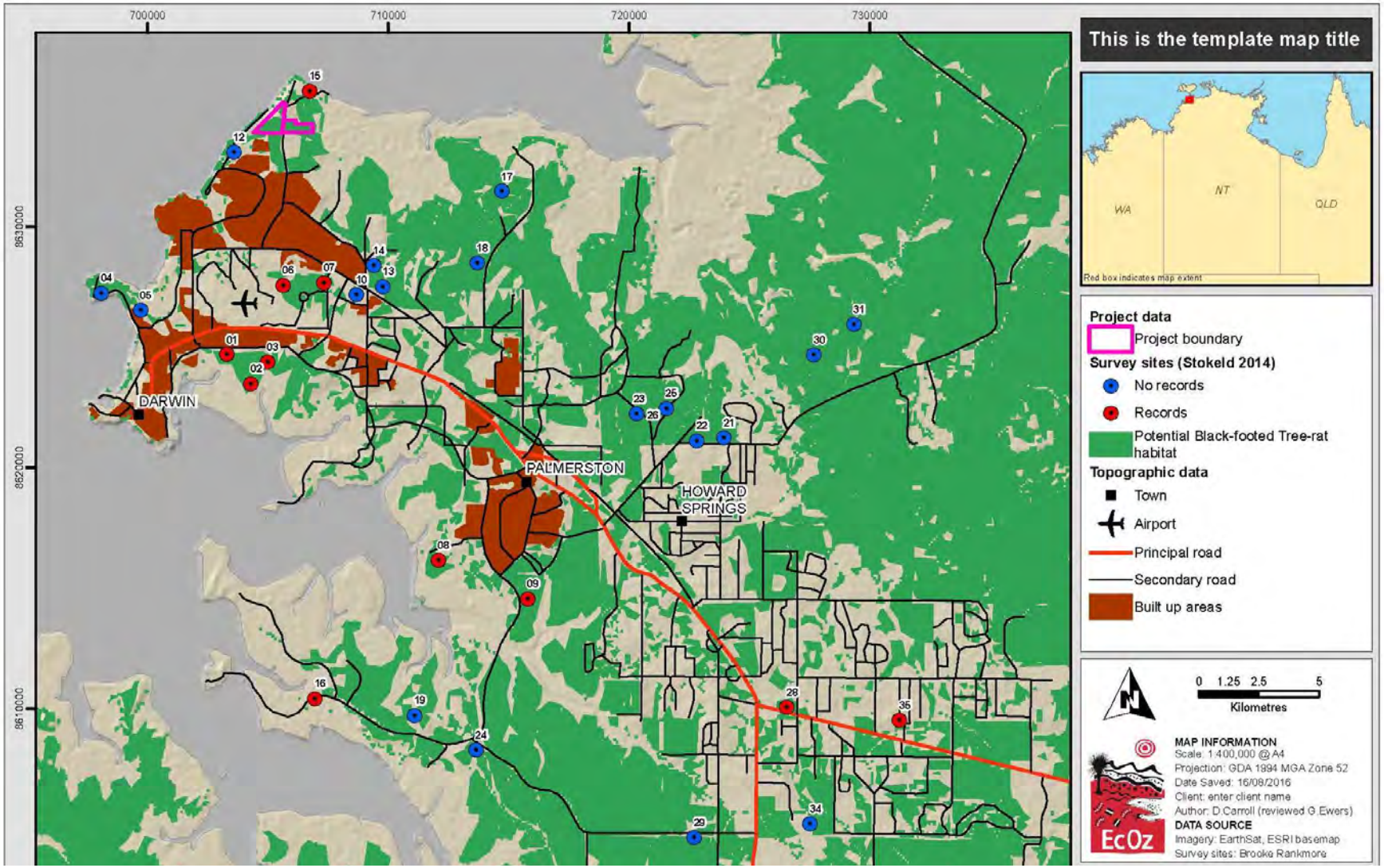

Figure 30. Black-footed Tree-rat potential habitat (eucalypt woodland) in greater Darwin region. Site numbers refer to survey locations from Stokeld and Gillespie (2015).

Bare-rumped Sheath-tailed Bat

Bare-rumped Sheath-tailed Bat was not detected during the survey program. Anabats were located in the project site in suitable habitat for the species, but none of the recordings were consistent with the Bare-rumped Sheath-tailed Bat call (Figure 32). The conclusion is that it is unlikely that the species roosts within the project site, but it may forage on occasion.

Shorebirds

Results of the migratory shorebird study for Sandy Creek by Lilleyman (2016) are summarised below (see Table 42). These results show that habitat along Casuarina Beach near the mouth of Sandy Creek would be considered under the *EPBC Act Policy Statement 3.21 – Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species* (Commonwealth of Australia 2015) as 'internationally important' habitat for Great Knot and 'nationally important' habitat for Greater Sand Plover, Red Knot and Sanderling. A number of migratory species also listed as threatened under the EPBC Act were recorded near the mouth of Sandy Creek, including:

- Bar-tailed Godwit
- Eastern Curlew
- Great Knot
- Greater Sand Plover
- Lesser Sand Plover
- Red Knot.

Lilleyman (2016) states that shorebirds prefer to roost along Casuarina Beach on the western side of Sandy Creek in mangroves and Casuarina trees (Figure 33). Roosting can also occur on the eastern side of Sandy Creek but is rare. In addition, while shorebirds usually select Buffalo Creek tidal flats at low tide for feeding, the extensive tidal flats along Casuarina Beach are important feeding grounds at certain times of the year, possibly due to unreliable food resources at other sites.

Lilleyman (2016) also found that shorebirds move between the Sandy Creek and Lee Point at high tide if there is a disturbance at a site and the birds are seeking refuge elsewhere, or if the tide becomes too high at Sandy Creek and the birds have no space to roost.

In regards to site fidelity, Lilleyman (2016) refers to catch and banding results which showed that most tagged shorebirds return to monitored sites, and also high fidelity of birds within the austral summer, with records of individual birds feeding at low tide at Buffalo Creek and Sandy Creek and then roosting at high tide at Lee Point and at the Sandy Creek roost.

Table 42. Frequency and abundances of shorebird records (2013-2016) at Sandy Creek

Shorebird	EPBC Act	TWPC Act	Maximum count^	No. times counted	% present in counts	1 % threshold*	0.1 % threshold**
Bar-tailed Godwit	CR/VU	VU	13	34	62	3000	300
Black-tailed Godwit	-	-	14	3	5	1470	147

Common Greenshank	-	-	6	20	36	660	66
Common Sandpiper	-	-	3	15	27	2520	252
Eastern Curlew	CR	VU	8	44	80	310	31
Great Knot	CR	VU	4640	28	51	3250	325
Greater Sand Plover	VU	VU	980	37	67	1660	166
Grey Plover	-	-	14	39	71	790	79
Grey-tailed Tattler	-	-	9	12	22	610	61
Lesser Sand Plover	EN	VU	31	7	13	1470	147
Marsh Sandpiper	-	-	5	1	2	940	94
Oriental Plover	-	-	1	1	2	2320	232
Pacific Golden Plover	-	-	12	3	5	1250	125
Red Knot	EN	VU	390	15	27	1010	101
Red-necked Stint	-	-	114	21	38	4660	466
Ruddy Turnstone	-	-	17	6	11	300	30
Sanderling	-	-	139	36	65	340	34
Sharp-tailed Sandpiper	-	-	3	2	4	850	85
Terek Sandpiper	-	-	4	8	15	460	46
Whimbrel	-	-	8	34	62	640	64

^ Values in red represent counts that exceed 0.1 % and/or 1% of the flyway population of the species.
* Internationally important habitat for migratory shorebirds is recognised if the habitat supports at least 1 per cent of the flyway population of a single species.
** Nationally important habitat for migratory shorebirds is recognised if the habitat supports at least 0.1 per cent of the flyway population of a single species

Figure 31. Photograph of migratory shorebirds feeding at Sandy Creek intertidal sand flats in March 2015, 10 days before departing for their northward migration

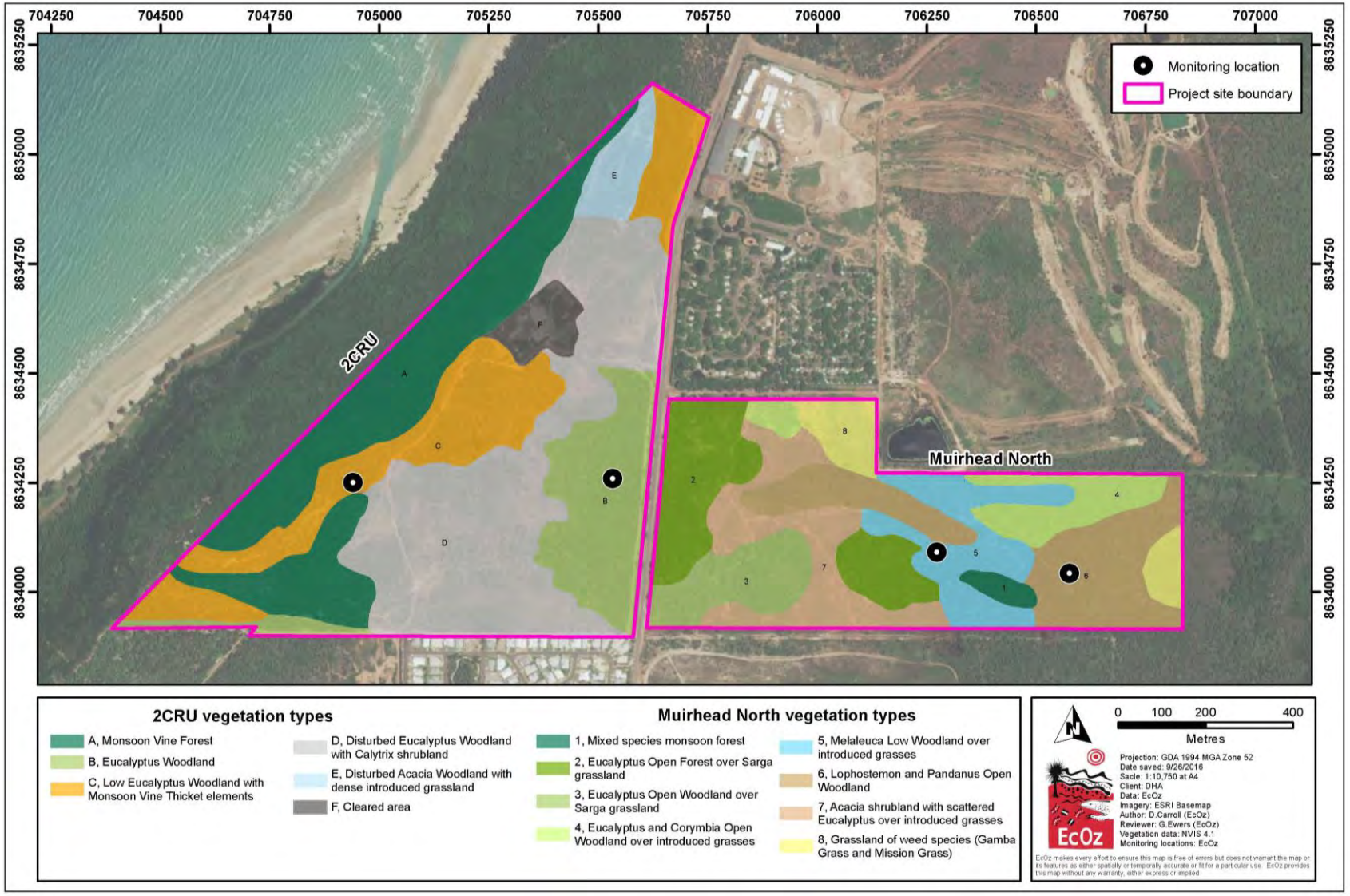

Figure 32. Location of anabat and songmeters for Bare-rumped Sheath-tail Bat survey

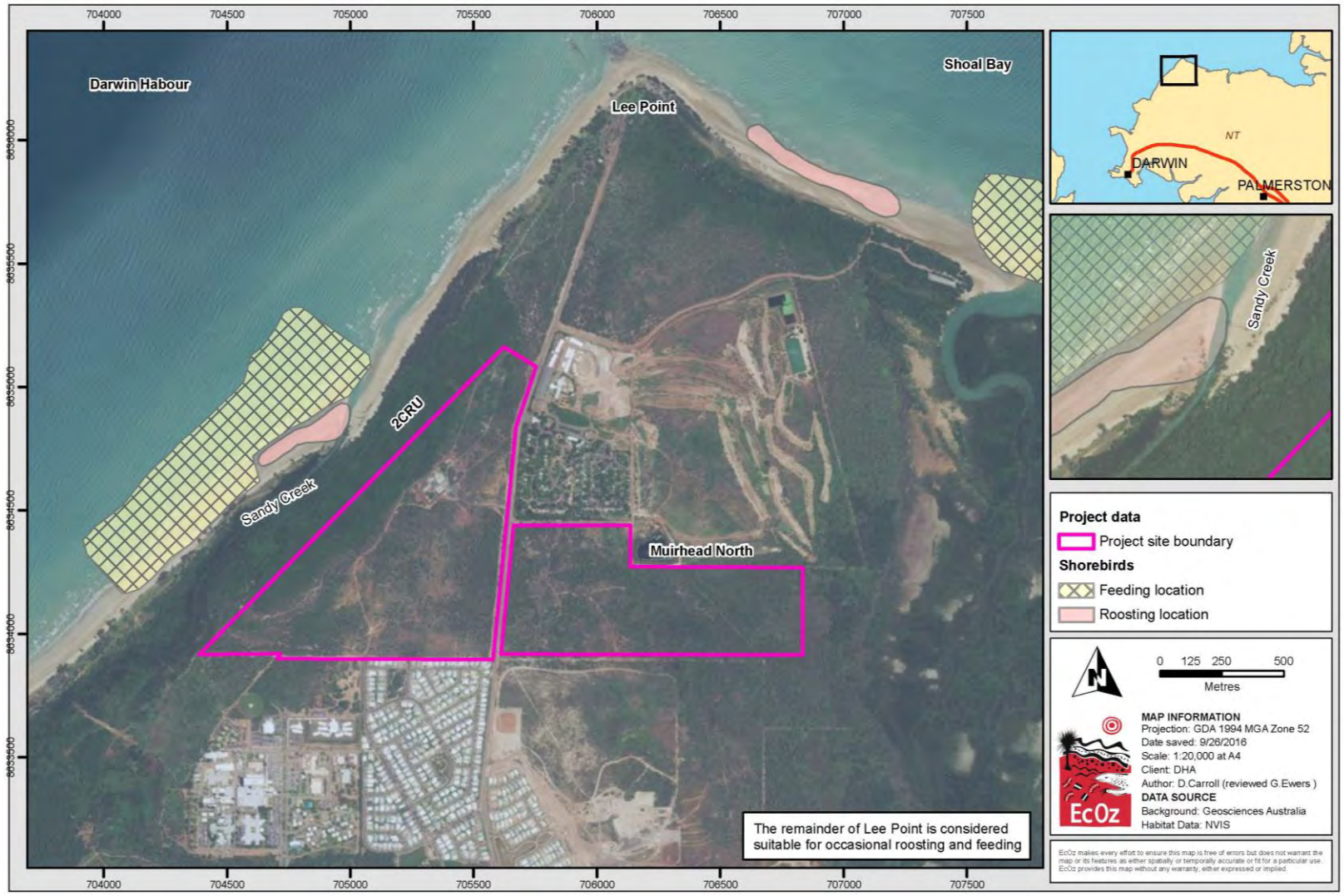

Figure 33. Feeding and roosting locations of migratory shorebirds in the Lee Point area.

Marine turtles

The turtle nesting data compiled by the NT Parks and Wildlife show that turtle nesting may occur anywhere in the Lee Point area between Rapid Creek and Buffalo Creek side. Since consistent monitoring of Casuarina Beach began in 1999, the number of Flatback Turtle nests recorded during each dry season (all months between March and November) varied from 5 (in 2012) to 20 (in 2006). Most nesting occurred in the month of September (39), followed by August (26), October (18), June (17), May (15) and July (15). Fewer nests were found in March (7) and April (1).

Given that over a period of at least 15 years, there are only three nesting records (out of 155 records) for Olive Ridley on Casuarina Beach, it is reasonable to consider that this species occurs only as a vagrant within the area.

Since 1999, there have been between 7 and 20 nesting records for Green Turtle and Flatback Turtle on Casuarina Beach.

Sawfish

Sawfish generally inhabit both marine and estuarine habitats, entering estuarine or fresh waters to breed during the wet season and moving into marine waters following the wet season (Peverell 2005). The main threatening processes for sawfish in Australia are fishing (targeted and incidental capture) and habitat degradation (Cavanagh *et al.* 2003).

Two specimens of Dwarf Sawfish were recovered from Buffalo Creek in 1997, as were five specimens of Green Sawfish – four in 1997 and one in 2002. Green Sawfish was also recorded in 2016 near the mouth of Sandy Creek. The Freshwater Sawfish has not been recorded in the area, but has similar habitat requirements and so would likely occur in Buffalo Creek.

Sandy Creek is much shorter and more affected by tides than Buffalo Creek. Nonetheless, given the recent record for Green Sawfish near the mouth of Sandy Creek, there is potential for threatened sawfish species to utilise the creek although the likelihood of breeding in the creek is low due to the tidal nature of the creek.

Territory Parks and Wildlife Conservation Act

This section addresses species listed as threatened under the *TPWC Act* only. NT-listed species that are also listed under the *EPBC Act* have already been considered.

Typhonium praetermissum

Typhonium praetermissum was not detected within the project area and a field habitat assessment concluded that there is no suitable habitat within the project footprint (Figure 34). This finding concurs with the 'Known Extent of Occurrence' map recently produced by the Flora and Fauna Division of DENR (www.ntlis.nt.gov.au/mpds/get_file?file_id=7085) which does not show any potential habitat within the project site.

Darwin Cycad

Darwin Cycad density across the 2CRU and Muirhead North sites is provided in Figure 35. The species is present in low to medium densities across 2CRU, and in low densities in the western half of Muirhead North – with a

medium density cycad patch in the centre of the Muirhead North. Darwin Cycads do not occur in the eastern parts of Muirhead North, probably due to the presence of poorly-drained soils.

Darwin Cycad occurs throughout the project site as part of a population that is likely isolated from other populations in the Darwin area because of the urban development to the south, the sea to the west, and the mangrove and riverine habitat to the east. As this isolation has occurred only recently it is unlikely for this long-lived species, that the Darwin Cycad population present in the proposed development area contributes significantly to the species' genetic diversity, or that the population has any significance by being at the limit of its northern mainland range. Likewise, this populations' isolation precludes it from being a key source population either for breeding or dispersal. For the above reasons, any population within the area proposed for development is not considered necessary for a species' long-term survival and recovery.

Table 43. Summary of Darwin Cycad results.

Density	Area (ha)
Low (<1 plant per 75 m2)	61.0
Moderate (>1 plant per 75 m2; <1 per 50 m2)	4.4

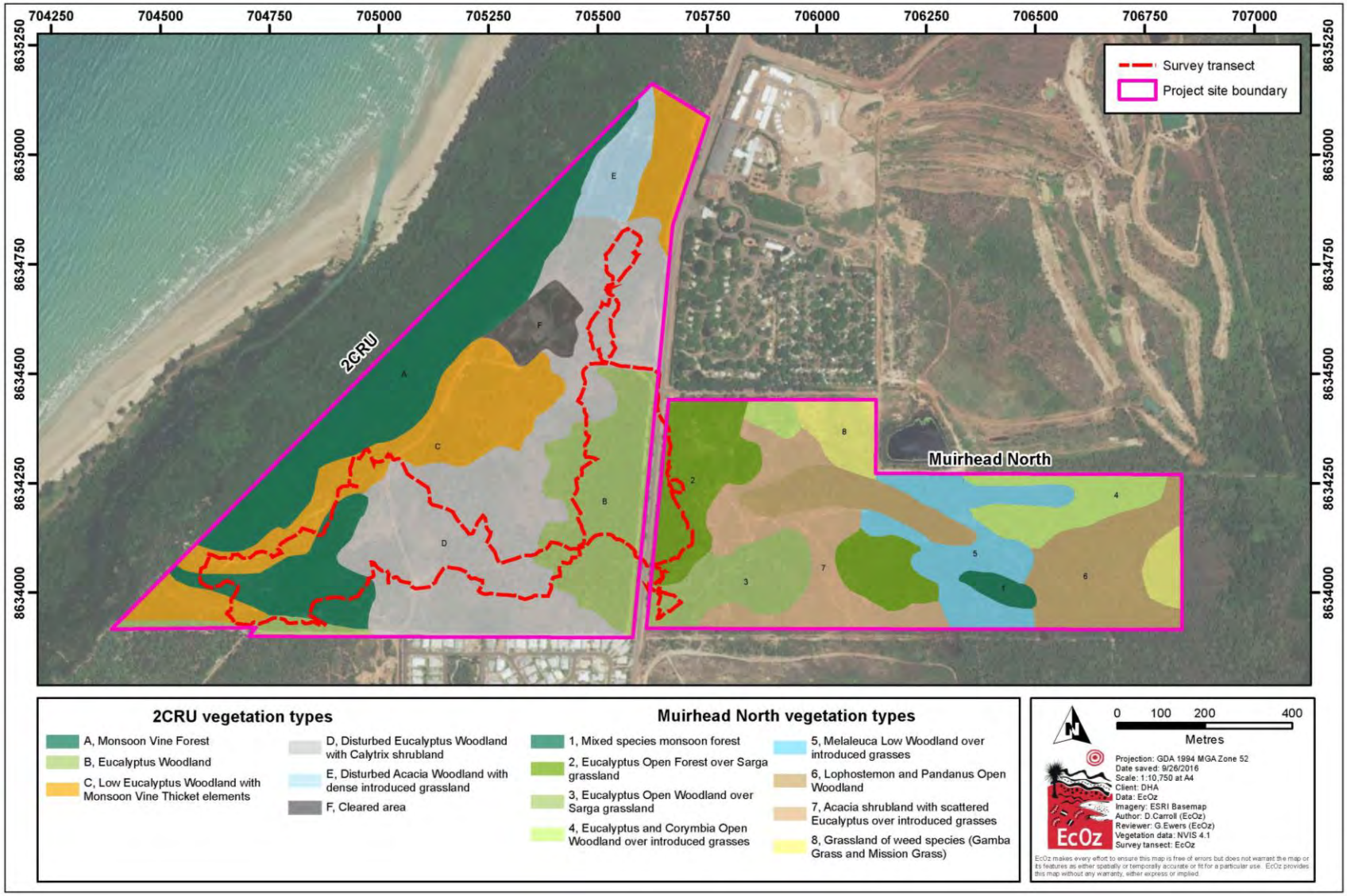

Figure 34. *Typhonium praetermissum* survey transects

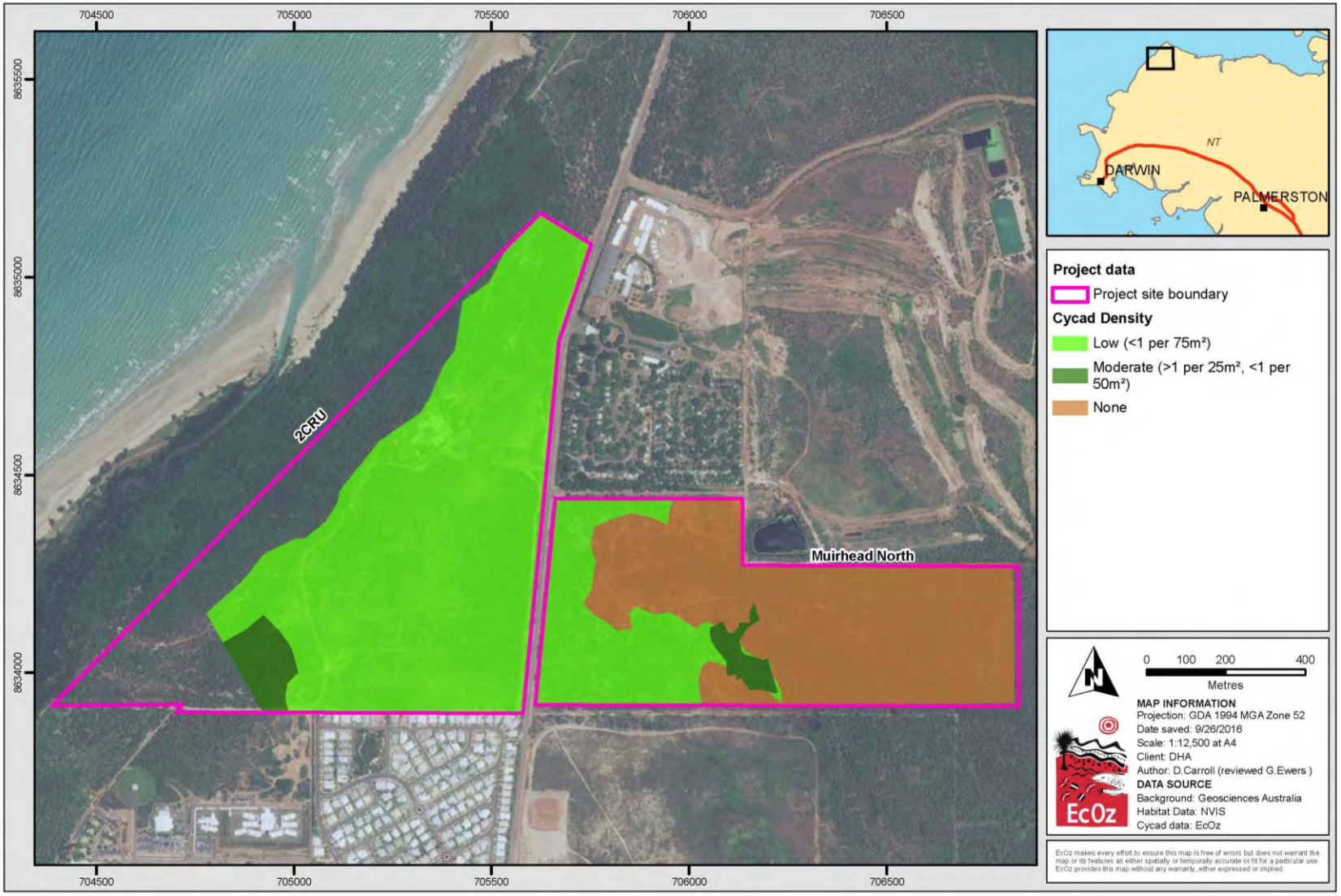

Figure 35. Darwin Cycad density within the project site

7.2.4.4 *Likelihood of occurrence*

Threatened species

Seventy-one threatened species were identified during a desktop study as occurring or potentially occurring within close proximity to the project site. Some of those species are considered very unlikely to occur within the project site, due to one or more of the following factors:

- There is no suitable habitat for the species
- The species is only an occasional visitor to the area
- The species is considered to be locally-extinct.

Therefore, those species were discarded from further assessment (see Table 45 for a justification).

The remainder of the species – together with those identified in the PMST and ToR – were assigned one of the following rankings of likelihood of occurrence within the project footprint (using the methodology described in Section 7.2.3.1):

- Known – there are recent records of the species occurring within the project footprint
- Likely – core habitat for the species occurs within the project footprint and there are recent records of the species occurring in the surrounding areas
- May – core habitat for the species occurs within the project footprint, but there are no recent records of the species occurring within the project footprint
- Unlikely – there is no core habitat for the species within the project footprint; however, the species may be present on occasion.

The results of the assessment are detailed in Table 44.

Table 44. Threatened species' likelihood of occurrence assessment

Species	Conservation status		Habitat description	Within the project area, Sandy Creek, Buffalo Creek and Casuarina Beach			
	EPBC	TWPC		Desktop records[1]	Surveys undertaken[2]	Recorded	Likelihood of occurrence
PLANTS							
Typhonium praetermissum	-	VU	Open woodlands in soil types ranging from red brown clay soil and shallow or gravelly lateritic soil, either on the plateau edge or bordering with sandsheet and drainage areas, which occur in localised areas in the lowlands.	-	Yes	No	**NOT PRESENT** – critical habitat for the species was not detected within the project footprint during the targeted survey.
Darwin Cycad *Cycas armstrongii*	-	VU	Occurs in open, grassy woodland where adequate drainage appears to be a limiting factor (Kerrigan *et al.* 2006). Prime habitat has deep, loamy soil (Liddle 2009).	3, 1968	Yes	Yes	**KNOWN** – this species is widespread in Muirhead North and in patches on 2CRU.
REPTILES							
Flatback Turtle *Natator depressus*	VU	DD	Prefers shallow, soft-bottomed, sea-bed habitats away from reefs (DoE 2014). Nests on virtually all nesting beaches around the entire NT coastline and offshore islands. Has the most widespread breeding range in the NT of all sea turtle species (Chatto 1998).	18, 1977	Yes	Yes	**KNOWN** – there are many nesting records of this species for Casuarina Beach.
Green Turtle *Chelonia mydas*	VU	NT	Occurs in tropical and subtropical waters. In the NT, nests mainly on wide beaches backed by large dune systems (Chatto 1998).	1, unknown	Yes	Yes	**LIKELY** – there is a single nesting record of this species for Casuarina Beach (Chatto 1998).
Olive Ridley *Lepidochelys olivacea*	EN	VU	Occurs in tropical and subtropical, preferring shallow protected waters. In the NT, breeds at a wide range of sites on islands and less commonly, mainland beaches (Chatto 1998).	4, 1991	Yes	Yes	**KNOWN** – there are a few nesting records of this species for Casuarina Beach.

Loggerhead Turtle *Caretta caretta*	EN	VU	Pelagic feeder, nests on sandy beaches.	-	Yes	No	**UNLIKELY** – although this species occurs in NT waters, and there are two records a few kilometres off Casuarina Beach, there are no records of it nesting on Casuarina Beach or approaching near to shore.
Hawksbill Turtle *Eretmochelys imbricata*	VU	VU	Tropical, sub-tropical and temperate waters. Nests mainly on narrow beaches where they frequently go under vegetation to nest.	-	Yes	No	**UNLIKELY** – although this species occurs in NT waters, and there are few records in Darwin Harbour, there are no records of it nesting on Casuarina Beach or approaching near to shore.
Mertens' Water Monitor *Varanus mertensi*	-	VU	This semi-aquatic monitor occupies edges of watercourses and lagoons, but is seldom seen far from water (Christian 2004).	-	No	No	**UNLIKELY** – this species requires extensive freshwater areas and there are no verified records of it occurring in the coastal Darwin area (Trembath pers. comm. 2015). Apparent records of this species in suburban Darwin are of the similar Mitchell's Water Monitor (Trembath pers. comm. 2015).
Floodplain Monitor *Varanus panoptes*	-	VU	Occurs in broad range of habitats – from coastal beaches to savannah woodlands (Christian 2004).	2, 2001	No	No	**MAY** – suitable habitat occurs within the project footprint and there are records in greater Darwin; however, numbers have significantly reduced since the arrival and establishment of Cane Toads. Not recorded during field surveys or camera trap surveys. Occurs close to Darwin, persistence is generally in coastal areas (unsuitable for Cane Toads) or those protected by development from Cane Toads. Anecdotal information suggests the species can prosper in residential areas due to cane toad management. Most likely to be found in wetter areas along Buffalo Creek and Sandy Creek that won't be developed. Species likely to disperse from site at its own accord.
Mitchell's Water Monitor *Varanus mitchelli*	-	VU	Swamps, lagoons, inland rivers, and other bodies of water.	2, 1997	No	No	**UNLIKELY** – the riparian zone of Buffalo and Sandy Creeks comprises suitable habitat but, due to the nature of project activities, is not

							considered part of the project footprint (only the waters of those creeks are).
BIRDS							
Masked Owl (northern) *Tyto novaehollandiae kimberli*	VU	VU	Occurs mainly in eucalypt tall open forests (especially those dominated by *Eucalyptus miniata* and *Eucalyptus tetrodonta*), but also roosts in Monsoon Rainforests, and forages in more open vegetation types, including grasslands (Woinarski and Ward 2006).	-	No	No	**UNLIKELY** – there are a few records within Darwin, but core nesting or foraging habitat does not occur within the project footprint.
Eastern Curlew *Numenius madagascariensis*	CE	VU	Coasts and estuaries, as well as mangroves. Also occurs in salt lakes and brackish wetlands near coasts. Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide (Higgins and Davies 1996).	44[3]	Yes	Yes	**KNOWN** – there are many records of this species roosting at Sandy Creek.
Curlew Sandpiper *Calidris ferruginea*	CE	VU	Coasts and estuaries, especially intertidal mudflats, as well as beaches, rocky shores and around lakes, dams and floodwaters (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	-	Yes	No	**UNLIKELY** – there are no records of this species roosting at Sandy Creek.
Bar-tailed Godwit *Limosa lapponica baueri*	VU	VU	Coasts and estuaries, especially intertidal sand flats and mudflats, and coastal lagoons. Also occurs in salt lakes and brackish wetlands near coasts, sandy ocean beaches, rock platforms, and coral reef-flats (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	34[3]	Yes	Yes	**KNOWN** – there are many records of this species roosting at Sandy Creek. These records have not been identified to the subspecies level.
Bar-tailed Godwit *Limosa lapponica menzbieri*	CR	VU					
Great Knot *Calidris tenuirostris*	CE	VU	Sheltered coasts and estuaries with intertidal mudflats and sand-flats, especially in mangrove areas (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	28[3]	Yes	Yes	**KNOWN** – there are many records of this species roosting at Sandy Creek.

Greater Sand Plover *Charadrius leschenaultii*	VU	VU	Coasts and estuaries with intertidal sand and mudflats as well as nearby beaches, rocky shores, salt lakes, brackish swamps and shallow freshwater wetlands (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	37[3]	Yes	Yes	**KNOWN** – there are many records of this species roosting at Sandy Creek.
Lesser Sand Plover *Charadrius mongolus*)	EN	VU	Coastal littoral and estuarine, especially large intertidal sand flats or mudflats in sheltered bays, harbours and estuaries, and occasionally sandy ocean beaches, coral reefs, wave-cut rock platforms and rocky outcrops (Marchant and Higgins 1993). Sometimes in short saltmarsh or among mangroves. Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide	7[3]	Yes	Yes	**KNOWN** – there are a few records of this species roosting at Sandy Creek.
Red Knot *Calidris canutus*	EN	VU	Coasts and estuaries with tidal mudflats (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	15[3]	Yes	Yes	**KNOWN** – there are some records of this species roosting at Sandy Creek.
Asian Dowitcher *Limnodromus semipalmatus*	-	VU	Sheltered coastal environments, such as bays, coastal lagoons, estuaries and tidal creeks, also in exposed mudflats or sand flats or at near-coastal swamps, lakes or beaches (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	-	Yes	No	**UNLIKELY** – there are no records of this species roosting at Sandy Creek.
Red Goshawk *Erythrotriorchis radiatus*	VU	VU	Prefers tall open eucalypt forest and riparian areas. Nests in large trees, frequently the tallest and most massive in a tall stand, and nest trees are invariably within 1 km of permanent water (Debus *et al.* 1988; Aumann *et al.* 1991).	-	No	No	**UNLIKELY** – despite a few records within Darwin, and suitable habitat occurring within the project footprint, this species' current geographic extent indicates a low probability for its occurrence within the project footprint.

Partridge Pigeon (eastern) *Geophaps smithii smithii*	VU	VU	Occurs in open forests and woodlands with an understorey of grasses (Woinarski 2006).	2, 2009	No	No	**UNLIKELY** – there are a few records surrounding Darwin, but core habitat does not occur within the project footprint. The nearest recent records are from Noonamah.
Gouldian Finch *Erythrura gouldiae*	EN	VU	Prefers annual and perennial grasses (especially Sorghum), a nearby source of surface water and, in the breeding season, unburnt hollow-bearing *Eucalyptus* trees (especially *E.ucalyptus tintinnans, E.ucalyptus brevifolia* and *Eucalyptus. leucophloia*) (Tidemann 1996; Higgins *et al.* 2006).	-	No	No	**UNLIKELY** – there are a few records within Darwin, but core feeding and breeding habitat does not occur within the project footprint.
FISH							
Dwarf Sawfish *Pristis clavata*	VU	VU	Marine and estuarine habitats, entering estuarine or fresh waters to breed during the wet season and moving into marine waters following the wet season (Peverell 2005)	2, 1997	No	Yes	**KNOWN** – two specimens have been recovered from Buffalo Creek.
Green Sawfish *Pristis zijsron*	VU	VU	A range of aquatic habitats, including marine inshore waters, estuaries, lagoons and freshwater. However, the majority of records are from marine or estuarine waters (Thornburn *et al.* 2003). Enters estuarine or fresh waters to breed during the wet season and moves back into marine waters following the wet season (Peverell 2005).	6, 2016	No	Yes	**KNOWN** – five specimens have been recovered from Buffalo Creek. One recent record from mouth of Sandy Creek.
Large-tooth Sawfish *Pristis pristis* – EPBC Freshwater Sawfish *Pristis microdon* – TWPC	VU	VU	Range of habitats, including marine inshore waters, estuaries, lagoons and freshwater. However, the majority of records are from marine or estuarine waters (Thornburn *et al.* 2003). The species enters estuarine or fresh waters to breed during the wet season and moves back into marine waters following the wet season (Peverell 2005).	-	No	No	**LIKELY** – closely-related species have been recorded in Buffalo Creek (see above).
MAMMALS							

Black-footed Tree-rat *Mesembriomys gouldii gouldii*	EN	VU	Inhabits tropical woodlands and open forests, with hollow-bearing trees and a well-developed mid-storey.	5, 2016	Yes	Yes	**KNOWN** – species recorded on four occasions in Muirhead North. Suitable habitat for the species in Muirhead North and 2CRU (Section 7.2.4.3)
Bare-rumped Sheath-tailed Bat *Saccolaimus saccolaimus nudicluniatus*	VU	NT	NT records are from pandanus woodland and eucalypt tall open forests (Friend *et al.* 1986; Churchill 1998). Roosts in tree hollows and caves (Duncan *et al.* 1999).	-	Yes	No	**UNLIKELY** – suitable habitat occurs within the project footprint; however, it was not recorded during targeted surveys and appears to be a naturally-rare species in the Top End.
Pale Field-rat *Rattus tunneyi*	-	VU	Historically occurred in a wide range of habitats, but is now primarily found in dense vegetation along creeks (Aplin *et al.* 2008).	-	No	No	**UNLIKELY** – the riparian zone of Buffalo and Sandy Creeks comprises suitable habitat but, due to the nature of project activities, is not considered part of the project footprint (only the waters of those creeks are).
Water Mouse *Xeromys myoides*	VU	DD	Requires mangrove communities and associated saltmarsh, sedgelands, clay pans, heathlands and freshwater wetlands with intact hydrology that provide adequate nest sites and prey resources (DEWHA 2009).	-	No	No	**UNLIKELY** – there is no suitable habitat within the project footprint.
Fawn Antechinus *Antechinus bellus*	-	EN	Occurs in tall open forest dominated by eucalypts (Friend 1985) where it was historically quite common (Watson *et al.* 2008).	-	No	No	**UNLIKELY** – suitable habitat occurs within the project footprint; but a declined range from this species' historical extent, and the poor condition of the project area, indicates a relative low probability for its occurrence within the project footprint.

[1] Desktop records (3, 1979) = 3 records since 1979; [2] From Lilleyman (2016) [3] From Lilleyman (2016).

Table 45. Threatened species that occur within the bioregion but have a very low/no likelihood of occurrence within the project footprint

Scientific name	Common name	Status		Reason for not occurring in the project footprint
		EPBC	TPWC	
PLANTS				
Atalaya brevialata	a sub-shrub	CR	-	**Restricted range** – known from only five places near Elizabeth River (Virigina) and Amy's Creek
Cleome insolata	Spiderflower	-	VU	**Restricted range** – known from only a few locations in the Elizabeth River catchment
Crepidium marsupichila	an orchid	-	VU	**Restricted range** – known in NT from one population at Gunn Point
Endiandra limnophila	Native Walnut	-	VU	**Restricted range** – mainland specimens only from Wadeye
Freycinetia excelsa	Narrow-leaf Climbing Pandan	-	VU	**No habitat** – occurs in spring-fed, lowland rainforest
Habenaria rumphii	a ground orchid	-	EN	**No habitat** – occurs in sand plains adjacent to spring-fed rainforest
Luisia corrugata	Luisia Orchid	-	VU	**Restricted range** – mainland specimens only from Black Jungle Conservation Reserve.
Dienia montana	a ground orchid	-	VU	**Restricted range** – single known population in Kakadu
Monochoria hastata	Arrowleaf Monochoria	-	VU	**Restricted range** – floodplains of the Finniss, Reynolds and Wildman River
Ptychosperma macarthurii	Darwin Palm	-	EN	**No habitat** – occurs in spring-fed dense rainforest
Stylidium ensatum	a trigger plant	EN	EN	**No habitat** – wet margins of drainage flats in heavy clay or peaty soils that are damp well into the dry season (June-Aug)
Typhonium taylori	a typhonium	EN	EN	**Restricted range** – grassland on the edge of the Howard River floodplain
Utricularia dunstaniae	a bladderwort	-	VU	**No habitat** – occurs in *Melaleuca nervosa* woodland
Utricularia singeriana	a bladderwort	-	VU	**No habitat** – occurs on margins of wet sandy flats and swamps
Zeuxine oblonga	a ground orchid	-	VU	**Restricted range** – nearest population Adelaide River
AMPHIBIANS				
Uperoleia daviesae	Howard River Toadlet	-	VU	**Restricted range** – Howard Springs area
REPTILES				
Acanthophis hawkei	Plains Death Adder	VU	VU	**No habitat** – occurs on large floodplains
Bellatorias obiri	Arnhem Land Skink	EN	EN	**No habitat** – occurs in sandstone country

Dermochelys coriacea	Leatherback Turtle	EN	CR	**Vagrant** – there are only a few records of this species in NT waters, and none of these are of individuals feeding or nesting near Darwin
Morelia oenpelliensis	Oenpelli Python	-	VU	**No habitat** – occurs in sandstone country
Lucasium occultum	Yellow-snouted Gecko	EN	VU	**Restricted range** – Wildman River and north-west Kakadu
BIRDS				
Epthianura crocea tunneyi	Yellow Chat (Alligator Rivers)	EN	EN	**No habitat** – occurs in wetlands within floodplain depressions and channels
Rostratula australis	Australian Painted Snipe	EN	VU	**No habitat** – occurs in wetlands
Falcunculus frontatus whitei	Crested Shrike-tit (northern)	VU	NT	**Reduced range** – nearest records are Kakadu and Pine Creek
Falco hypoleucos	Grey Falcon	-	VU	**Vagrant** – there is one record for Darwin, but core foraging and nesting habitat for this species does not occur within the development footprint
Fregata andrewsi	Christmas Island Frigatebird	VU	NE	**Vagrant** – there are only a few records of this species in NT waters; if present in the area, this species would only be flying over and would not land on site.
Amytornis woodwardi	White-throated Grasswren	VU	VU	**No habitat** – occurs in sandstone country
FISH				
Carcharodon carcharias	Great White Shark	VU	-	**Vagrant** – there have been no verified sightings of this species in the NT
Glyphis glyphis	Speartooth Shark	CR	VU	**Vagrant** – there are only a few records of this species in NT waters; these are in proximity to large rivers, and none of the records are from near Darwin
Glyphis garricki	Northern River Shark	EN	EN	**Vagrant** – there are only a few records of this species in NT waters; these are in proximity to large rivers, and none of the records are from near Darwin
Rhincodon typus	Whale Shark	VU	DD	**Vagrant** – there are only a few records of this species in NT waters and none of the records are from near Darwin
MAMMALS				
Conilurus penicillatus	Brush-tailed Rabbit-Rat	VU	EN	**Locally extinct**
Balaenoptera musculus	Blue Whale	EN	-	**Vagrant** – there are only a few records of this species in NT waters and none of the records are from near Darwin
Dasyurus hallucatus	Northern Spotted Quoll	EN	CR	**Locally extinct** – historic records exist around the development footprint; but, since the arrival of Cane Toads, this species has experienced a marked declined in range

Megaptera novaeangliae	Humpback Whale	VU	LC	**Vagrant** – there are only a few records of this species in NT waters and none of the records are from near Darwin
Phascogale pirata	Northern Brush-tailed Phascogale	VU	EN	**No records** near Darwin – mostly Kakadu
Zyzomys maini	Arnhem Rock-rat	VU	VU	**No habitat** – occurs in sandstone country
Macroderma gigas	Ghost Bat	VU	NT	**Vagrant** – there are only a few records of this species in the greater Darwin region, and no known roost sites
Hipposideros inornata	Arnhem Leaf-nosed Bat	EN	VU	**No habitat** – occurs in sandstone country
Hipposideros stenotis	Northern Leaf-nosed Bat	-	VU	**No habitat** – occurs in sandstone country
Petrogale concinna	Nabarlek	EN	VU	**No habitat** – occurs in sandstone country

Migratory species

The PMST identified 44 species of migratory species listed under the EPBC Act (not including the threatened species examined above) that may occur in the project site or adjoining areas such as Casuarina Beach. They include:

- 26 migratory wetlands species
- 2 migratory marine birds
- 10 migratory marine species
- 6 migratory terrestrial species.

These species were assigned one of the following rankings of likelihood of occurrence within the project footprint (using the methodology described in Section 7.2.3):

- Known – there are recent records of the species occurring within the footprint.
- Likely – core habitat for the species occurs within the footprint and there are recent records of the species occurring in the surrounding areas.
- May – core habitat for the species occurs within the footprint, but there are no recent records of the species occurring within the footprint or in the surrounding areas.
- Unlikely – there is no core habitat for the species within the footprint; however, the species may be present on occasion.

The results of the assessment are summarised in Table 46.

When assessing if a project will significantly impact upon a migratory species, the key consideration under the *EPBC Act Significant Impact Guidelines 1.1* (DoE 2013) whether the action will significantly impact on important habitat or an ecologically-significant proportion of a population of a migratory species is involved.

An area of important habitat for a migratory species is:

- Habitat utilised by a migratory species occasionally or periodically within a region that supports an ecologically-significant proportion of the population of the species, and/or

- Habitat that is of critical importance to the species at particular life-cycle stages, and/or
- Habitat utilised by a migratory species which is at the limit of the species range, and/or
- Habitat within an area where the species is declining.

What constitutes an ecologically-significant proportion of a population of a listed migratory species varies species to species. Relevant factors include the species' population status, genetic distinctiveness and species-specific behavioural patterns (e.g. site fidelity and dispersal rates).

For 37 migratory shorebird species, the definition of important habitat is defined in *EPBC Act Policy Statement 3.21 – Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species* (Commonwealth of Australia 2015). For these 37 species, important habitat can be of international importance or national importance, whereby 'international important habitat' is defined as:

- 1 per cent of individuals in a population of one species or subspecies, OR
- a total abundance of at least 20,000 birds (Commonwealth of Australia 2015).

'Nationally important habitat' is defined as:

- 0.1 per cent of the flyway population of a single species or migratory shorebird, OR
- 2,000 migratory shorebirds, OR
- 15 migratory shorebird species.

Table 46 includes an assessment of whether important habitat or an ecologically-significant proportion of a population of each species occurs within the project footprint.

Table 46. Likelihood of occurrence of EPBC Act listed migratory species

Species	Habitat description	Within the project footprint…			
		Desktop records[1]	Likelihood of presence	Important habitat?	Ecologically-significant proportion?
Migratory wetlands species[2]					
Eastern Curlew[3] *Numenius madagascariensis*	Coasts and estuaries, as well as mangroves. Also occurs in salt lakes and brackish wetlands near coasts. Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide (Higgins and Davies 1996).	44	KNOWN – there are many records of this species roosting at Sandy Creek.	No	No
Curlew Sandpiper[3] *Calidris ferruginea*	Coasts and estuaries, especially intertidal mudflats, as well as beaches, rocky shores and around lakes, dams and floodwaters (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	-	UNLIKELY – there are no records of this species roosting at Sandy Creek.	No	No
Bar-tailed Godwit[3] *Limosa lapponica baueri*	Coasts and estuaries, especially intertidal sand flats and mudflats, and coastal lagoons. Also occurs in salt lakes and brackish wetlands near coasts, sandy ocean beaches, rock platforms, and coral reef-flats (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	34	KNOWN – there are many records of this species roosting at Sandy Creek. These records have not been identified to the subspecies level.	No	No
Bar-tailed Godwit[3] *Limosa lapponica menzbier*				No	No

Species	Habitat description	Within the project footprint...			
		Desktop records[1]	Likelihood of presence	Important habitat?	Ecologically-significant proportion?
Great Knot[3] *Calidris tenuirostris*	Sheltered coasts and estuaries with intertidal mudflats and sand-flats, especially in mangrove areas (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	28	KNOWN – there are many records of this species roosting at Sandy Creek.	Yes (see Table 42)	N/A
Greater Sand Plover[3] *Charadrius leschenaultii*	Coasts and estuaries with intertidal sand and mudflats as well as nearby beaches, rocky shores, salt lakes, brackish swamps and shallow freshwater wetlands (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	37	KNOWN – there are many records of this species roosting at Sandy Creek.	Yes (see Table 42)	N/A
Lesser Sand Plover[3] *Charadrius mongolus*	Coastal littoral and estuarine, especially large intertidal sand flats or mudflats in sheltered bays, harbours and estuaries, and occasionally sandy ocean beaches, coral reefs, wave-cut rock platforms and rocky outcrops (Marchant and Higgins 1993). Sometimes in short saltmarsh or among mangroves. Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	7	KNOWN – there are a few records of this species roosting at Sandy Creek.	No	No
Red Knot[3]	Coasts and estuaries with tidal mudflats (Higgins and Davies	15	KNOWN – there are some records of this species roosting at Sandy Creek.	Yes (see Table 42)	N/A

Species	Habitat description	Within the project footprint...			
		Desktop records[1]	Likelihood of presence	Important habitat?	Ecologically-significant proportion?
Calidris canutus	1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.				
Asian Dowitcher[3] *Limnodromus semipalmatus*	Sheltered coastal environments, such as bays, coastal lagoons, estuaries and tidal creeks, also in exposed mudflats or sand flats or at near-coastal swamps, lakes or beaches (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide.	-	UNLIKELY – there are no records of this species roosting at Sandy Creek.	No	No
Black-tailed Godwit *Limosa limosa*	Coastal, wetlands	3	KNOWN – three roosting records at Sandy Creek	No	No
Common Greenshank *Tringa nebularia*	Coastal, inland lakes	20	KNOWN – roosts at Sandy Creek and may forage along the Casuarina Coastal Reserve coastline	No	No
Common Sandpiper *Actitis hypoleucos*	Banks, rocks near water	15	KNOWN – roosts at Sandy Creek and may forage along the Casuarina Coastal Reserve coastline	No	No
Grey Plover *Pluvialis squatarola*	Beaches, mudflats, may be inland	39	KNOWN – roosts at Sandy Creek and may forage along the Casuarina Coastal Reserve coastline	No	No
Grey-tailed Tattler *Tringa brevipes*	Estuaries, rocky coasts, reefs	12	KNOWN – roosts at Sandy Creek and may forage along the Casuarina Coastal Reserve coastline	No	No
Oriental Plover *Charadrius veredus*	Dry inland plains, occasionally coastal	1	KNOWN – one roosting record at Sandy Creek	No	No

Species	Habitat description	Within the project footprint...			
		Desktop records[1]	Likelihood of presence	Important habitat?	Ecologically-significant proportion?
Red-necked Stint *Calidris ruficollis*	Coastal, inland shorelines	21	KNOWN – roosts at Sandy Creek and likely forages along the Casuarina Coastal Reserve coastline	No	No
Ruddy Turnstone *Arenaria interpres*	Rocky shores	6	KNOWN – roosts at Sandy Creek and may forage along the Casuarina Coastal Reserve coastline	No	No
Sanderling *Calidris alba*	Beaches, rarely inland	36	KNOWN – roosts at Sandy Creek and likely forages along the Casuarina Coastal Reserve coastline	Yes (see Table 42)	N/A
Sharp-tailed Sandpiper *Calidris acuminata*	Inland waters, coastal	2	KNOWN – some roosting records at Sandy Creek and may forage along the Casuarina Coastal Reserve coastline	No	No
Terek Sandpiper *Xenus cinereus*	Coastal mudflats, occasionally inland	8	KNOWN – some roosting records at Sandy Creek and may forage along the Casuarina Coastal Reserve coastline	No	No
Whimbrel *Numenius phaeopus*	Estuaries, mudflats, mangroves, sand spits, occasionally inland	34	KNOWN – roosting records at Sandy Creek and may forage along the Casuarina Coastal Reserve coastline	No	No
Great Egret *Ardea alba*	Floodwaters, rivers, shallows of wetlands, intertidal mudflats	-	UNLIKELY – the seasonally-inundated areas within Muirhead North comprises monsoon rainforest and Melaleuca wetland with a grass understorey, and so are too densely vegetated to support this species	No	No
Pectoral Sandpiper *Calidris melanotos*	Prefers inland swamps	-	UNLIKELY – no suitable habitat or records at Sandy Creek or along the Casuarina Coastal Reserve coastline; nearest records are from Leanyer Sewerage Treatment Plant	No	No
Long-toed Stint *Calidris subminuta*	Inland swamps, rarely coasts	-	UNLIKELY – no suitable habitat or records at Sandy Creek or along the Casuarina Coastal	No	No

Species	Habitat description	Within the project footprint...			
		Desktop records[1]	Likelihood of presence	Important habitat?	Ecologically-significant proportion?
			Reserve coastline; nearest records are from Leanyer Sewerage Treatment Plant		
Little Ringed Plover *Charadrius dubius*	Shores, marshes. Vagrant in Australia.	-	**UNLIKELY** – the only known location in the NT is at Leanyer Sewage Works and so a record attributed to the project footprint is probably a geo-spatial error	No	No
Swinhoe's Snipe *Gallinago megala*	Wet grasslands; open, wooded swamps	-	**UNLIKELY** – the seasonally-inundated areas within Muirhead North comprises Monsoon rainforest and Melaleuca wetland with a grass understorey, and so are too densely vegetated to support this species	No	No
Pin-tailed Snipe *Gallinago stenura*		-			
Oriental Pratincole *Glareola maldivarum*	Open plains, bare ground around swamps, claypans	-	**UNLIKELY** – no suitable habitat or records at Sandy Creek or along the Casuarina Coastal Reserve coastline; nearest records are from Leanyer Sewerage Treatment Plant	No	No
Wandering Tattler *Tringa incana*	Reefs, rocks	-	**UNLIKELY** – no suitable habitat or records at Sandy Creek or along the Casuarina Coastal Reserve coastline; nearest records are from Leanyer Sewerage Treatment Plant	No	No
Broad-billed Sandpiper *Limicola falcinellus*	Coastal mudflats, occasionally inland	-	**UNLIKELY** – no records at Sandy Creek or along the Casuarina Coastal Reserve coastline	No	No
Little Curlew *Numenius minutus*	Open plains, grasslands, mudflats	-	**UNLIKELY** – no suitable habitat or records at Sandy Creek or along the Casuarina Coastal Reserve coastline	No	No
Pacific Golden Plover *Pluvialis fulva*	Beaches, mudflats, may be inland	3	**KNOWN** – a few records at Sandy Creek	No	No

Species	Habitat description	Within the project footprint...			
		Desktop records[1]	Likelihood of presence	Important habitat?	Ecologically-significant proportion?
Wood Sandpiper *Tringa glareola*	Fresh water, marsh with light cover	-	**UNLIKELY** – no suitable habitat or records at Sandy Creek or along the Casuarina Coastal Reserve coastline	No	No
Marsh Sandpiper *Tringa stagnatilis*	Coastal, inland lakes	1	**KNOWN** – one record at Sandy Creek	No	No
Oriental Reed-Warbler *Acrocephalus orientalis*	Dense reedy vegetation near water	-	**UNLIKELY** – no suitable habitat or records	No	No
Osprey *Pandion haliaetus*	Mangroves, rivers and estuaries, inshore seas, coastal islands	58, 1982	**KNOWN** – forages in the waters of Casuarina Coastal Reserve; may roost at both Muirhead North and 2CRU, but no nests observed	No	No
Migratory marine birds					
Little Tern *Sterna albifrons*	Coasts, sometimes inland watercourses	227, 1982	**KNOWN** – forages (and may roost) along the Casuarina Coastal Reserve coastline	No	No
Fork-tailed Swift *Apus pacificus*	Aerial, over a variety of habitats	-	**LIKELY** – regularly recorded flying over Darwin during its north-south migration	No	No
Migratory marine species					
Salt-water Crocodile *Crocodylus porosus*	Brackish waters along the coastlines, freshwater rivers, swamps and billabongs	-	**LIKELY** – regularly recorded in Darwin Harbour, and occasionally on or near the Casuarina Coastal Reserve coastline	No	No
Indo-Pacific Humpback dolphin *Sousa chinensis*	Shallow near shore waters, often at the mouths of estuaries and in tidal channels	21, 2000	**KNOWN** – regularly recorded in Darwin Harbour, and occasionally Casuarina Coastal Reserve	No	No
Bryde's Whale *Balaenoptera edeni*	Tropical and warm temperate oceans	-	**UNLIKELY** – rarely recorded in NT waters	No	No

Species	Habitat description	Within the project footprint...			
		Desktop records[1]	Likelihood of presence	Important habitat?	Ecologically-significant proportion?
Dugong *Dugong dugon*	Shallow coastal waters	5, 1988	**KNOWN** – regularly recorded in Darwin Harbour, and occasionally Casuarina Coastal Reserve	No	No
Irrawaddy Dolphin *Orcaella brevirostris/* Australian Snubfin Dolphin *Orcaella heinsohni*	Riverine, estuarine and coastal waters	2, 2008	**KNOWN** – occasionally recorded in Darwin Harbour, including Casuarina Coastal Reserve	No	No
Giant Manta Ray *Manta birostris*	Tropical and temperate waters	-	**UNLIKELY** – rarely recorded in NT waters	No	No
Reef Manta Ray *Manta alfedi*	Tropical and subtropical waters	-	**UNLIKELY** – rarely recorded in NT waters	No	No
Killer Whale *Orcinus orca*	All oceans and most seas	-	**UNLIKELY** – rarely recorded in NT waters	No	No
Spotted Bottlenose Dolphin *Tursiops aduncus*	Inshore areas such as bays and estuaries, near shore waters, open coast environments, and shallow offshore waters including coastal areas around oceanic islands	5, 2004	**KNOWN** – regularly recorded in Darwin Harbour, and occasionally Casuarina Coastal Reserve	No	No
Narrow Sawfish *Anoxypristis cuspidata*	Inshore waters including bays and estuaries	1, 1997	**KNOWN** – there is a record from the mouth of Buffalo Creek	Yes	Yes
Migratory terrestrial species					
Barn Swallow *Hirundo rustica*	Open country, cultivated land, urban areas	-	**LIKELY** – suitable habitat but no records	No	No

Species	Habitat description	Within the project footprint...			
		Desktop records[1]	Likelihood of presence	Important habitat?	Ecologically-significant proportion?
Rufous Fantail *Rhipidura rufifrons*	Wet forests, occasionally more open forests. Resident in the Top End.	1, 2009	KNOWN – suitable habitat and records	No	No
Red-rumped Swallow *Cecropis daurica*	Open areas, woodlands	-	MAY – suitable habitat but no records and a rare vagrant to the Top End	No	No
Oriental Cuckoo *Cuculus optatus*	Forests and woodlands (in the summer)	2, 1999	KNOWN – suitable habitat and records	No	No
Grey Wagtail *Motacilla cinerea*	Prefers higher altitudes near water but may be found elsewhere	-	UNLIKELY – no suitable habitat and a rare vagrant to Australia	No	No
Yellow Wagtail *Motacilla flava*	Salt works, paddocks, marshes	1, 2000	UNLIKELY – no suitable habitat and so the record is probably a geo-spatial error, given that the main locations for this vagrant to the Top End are Leanyer Sewage Works and Knuckeys Lagoons	No	No

[1] Desktop records (3, 1979) = 3 records since 1979; [2] From Amanda Lilleyman's dataset (2012-2016) described in Appendix N.

7.2.4.5 Heritage

No natural places with protection under the EPBC Act or NT Heritage Act occur within or near the project site. There are no places or items of cultural heritage listed under the EPBC Act or NT Heritage Act within the project site.

The Larrakia People are the traditional owners of the project site. The AAPA have confirmed that there are no registered sacred sites on the project site. The AAPA have been approved by DHA to commence liaising with traditional owners to identify any sacred sites yet to be identified/registered on the site. Following consultation with the Larrakia Development Corporation (Nigel Browne – Chief Executive Office) on 13 March 2018, areas of cultural significance including registered sacred sites in areas adjacent to the project siteincluding along Casuarina Beach and at Lee Point were discussed. These sites will be further investigated by AAPA. Actions to preserve and protect sites identified by AAPA are discussed further below (Section 7.3.2.12) .

The project was presented to the Larrakia Nation Aboriginal Corporation at their board meeting on 25 June 2018 to receive feedback on the proposal. The Larrakia Nation Aboriginal Corporation did not provide any comments regarding the project.

A background scatter of isolated Aboriginal stone artefacts was recorded in the northern section of 2CRU. Military instalments that remain on the project site and are considered to provide heritage value include the Konfrontasi Cruciform anti-aircraft gun position and the Lee Point Bunkers within 2CRU. There is a heritage site identified in Muirhead North also belonging to the Konfrontasi period, that being a defensive gun pit surrounded by 44 gallon drums located along Lee Point Road.

Figure 36. Historical sites

7.3 Risk Assessment

7.3.1 Risk assessment summary

A summary of the risk assessment findings of the potential impacts the project will have on biodiversity and heritage values is provided below (Table 47). The summary includes those impacts which are considered to be of High or Medium risk. The full results of the risk assessment are provided in Appendix C. The risk assessment was completed in accordance with the methods described in Section 3.

Table 47. Summary of potential impacts and mitigation measures

Impact	Description	Mitigation measures
Biodiversity		
Vegetation clearance	Loss of a sensitive vegetation type (Monsoon Rainforest and Vine-thicket). Loss of habitat and flora species.	Protect 21.95 ha area of Monsoon vine thicket and Low Eucalyptus Woodland in 2CRU and transfer to NT Parks and Wildlife Conservation (CN) as part of Casuarina Coastal Reserve. Reserve the Monsoon rainforest (0.88 ha) within a 1.5 ha area zoned Conservation (CN) in Muirhead North Survey and peg site boundaries prior to construction. Fence areas of native vegetation to be retained. Retain native vegetation within Open Space areas and parkland, where practical. Revegetate along the erosion gullies in the south-west of 2CRU, and areas of disturbance within the 21.95 ha of Monsoon vine thicket and Low Eucalypt Woodland in 2CRU.
Direct mortality	Loss of individual Darwin Cycads due to land-clearing activities. Loss of individual Black-footed Tree-rats due to land-clearing activities. Loss of sawfish species due to increased fishing rates in Sandy Creek and Buffalo Creek.	Salvage, and relocate Darwin Cycad plants for use in landscaping Open Space areas and parkland. Ongoing management of relocated Darwin Cycad plants. Utilise a fauna spotter-catcher during construction activities to relocate individual Black-footed Tree-rats or other native fauna that might be harmed. Remove habitat in a staged manner to give fauna an opportunity to relocate at their own accord. Include educational signage to assist with identification of threatened sawfish species and to describe appropriate capture and release technique. Animal proof fencing to be established around each stage with identified Black-

Impact	Description	Mitigation measures
		footed Tree-rat habitat, to prevent species from accessing site during construction.
Habitat fragmentation	Increased isolation of native vegetation adjoining the project site.	Protect 21.95 ha area of Monsoon Vine-thicket and Low Eucalyptus Woodland in 2CRU and transfer to NT Parks and Wildlife Conservation (CN) as part of Casuarina Coastal Reserve. Use native canopy species in landscaping where practical.
Edge effects	Reduced quality of a sensitive vegetation type (monsoon rainforest and vine thicket) due to increased exposure.	Protect 21.95 ha area of Monsoon Vine-thicket and Low Eucalyptus Woodland in 2CRU and transfer to NT Parks and Wildlife Conservation (CN) as part of Casuarina Coastal Reserve.
Water quality impacts	Reduced threatened and migratory shorebird roosting and feeding habitat quality due to reduced surface water quality in Sandy Creek and Buffalo Creek from onsite contaminants. Reduced quality of riparian, wetland and aquatic habitat that receive water from the project area due to onsite contaminants.	An ESCP will be implemented to prevent erosion and remediate areas where erosion is an issue (Appendix D). Discharge flows into Sandy Creek and Buffalo Creek will be maintained at pre-construction levels. Water Sensitive Urban Design (WSUD) initiatives that remove sediment, pollutants and contaminants from water run-off will be implemented (see Appendix E and Appendix F). Construction spill management. Rehabilitation of erosion gullies in south-west of 2CRU.
Groundwater contamination	Impacts to GDE (Monsoon Vine-thicket and Monsoon Rainforest) due to reduced groundwater water quality from onsite contaminants.	Construction spill management
Weed and pest invasion	Reduced quality of sensitive vegetation types (Monsoon Rainforest and Monsoon Vine-thicket) due to weed infestation and/or proliferation. Reduced habitat quality in surrounding areas due to the introduction and/or proliferation of weeds. Note: The area, being proximate to urban development, already suffers from broad scale weed infestations and feral cats/dogs.	Weed infested areas will be removed during construction (control of Gamba Grass has been ongoing since early 2016). Ensure all plant, equipment, vehicles and soil coming to and from site is treated for noxious weeds. Control Gamba Grass on site along the boundary that interfaces with the Casuarina Coastal Reserve. Ongoing weed management within the expanded Casuarina Coastal Reserve will be the responsibility of the NT Government.
Dust (during construction)	Reduced quality of sensitive vegetation types (Monsoon Rainforest and Monsson Vine-thicket), as well as vegetation in general, due smothering of vegetation.	Dust control measures (e.g. water-trucks, protection of soil stock-piles) will be implemented during the dry season.

Impact	Description	Mitigation measures
Human disturbance	Loss of shorebird roosting and feeding habitat due to disturbance by recreational beachgoers from increased use of Casuarina Beach. Reduced habitat quality in Casuarina Coastal Reserve due to increased human visitation.	Implement community awareness and engagement program involving pamphlets and public information sessions. Provide one formal access point from the project site to Casuarina Beach, and rehabilitate all informal tracks between the project site and Casuarina Beach. Install barrier fencing 100 metres on the western and eastern side of Sandy Creek. Install signage at beach access point from project site, as well as other access points off site, to inform beach users of the threat posed by human disturbance (walking, driving, motorbike riding) and dogs on roosting and feeding shorebirds. Undertake shorebird monitoring project.
Domestic pets Note: Currently dogs must be on a lead when on the beach 100 m either side of Sandy Creek (to protect shorebirds)	Loss of shorebird roosting and feeding habitat due to disturbance by pet dogs from increased human use of Casuarina Beach. Note: The shorebirds roost on the south-western side of Sandy Creek at high tide. However, dogs have been observed swimming across the creek and harassing roosting birds.	
Biting Insects	Dense vegetation can aid the dispersal of biting insects across the landscape.	Create a 50 metre buffer between conservation reserve and buildings at 2CRU, within which overstorey cover will be thinned to 10%.
Lighting	Light from commercial buildings in 2CRU impact turtles.	Buildings taller than four storeys will be fitted with special lighting (reduced brightness) and will face downward to reduce impacts to turtles
Heritage		
Construction	Destruction of Aboriginal stone scatters or unidentified items of cultural significance.	Apply for a work approval under Section 72 of the NT *Heritage Act* before carrying out any works within the area of the stone scatters. The stone scatters will be removed by the Larrakia Development Corporation (LDC). The LDC will also undertake heritage monitoring during initial clearing to identify any salvage any artefacts that were not identified during the initial heritage assessment. Aboriginal Areas Protection Authority (AAPA) is liaising with traditional owners to identify any sacred sites not currently registered.
Post-construction	Destruction of military heritage sites.	Retain the Lee Point bunkers and Konfrontasi Cruciform. Work with local NT Heritage Branch to develop signage and interpretation material of Lee Point Bunkers and Konfrontasi Cruciform.

7.3.2 Description of impacts and mitigation measures

This sections describes the management actions that will be implemented to mitigate impacts to biodiversity and heritage. Threats associated with increased domestic animals, particularly cats, are not considered to be a High or Medium Risk, which is discussed further in Section 7.3.2.13.

7.3.2.1 Conservation areas and retention of native vegetation

The most significant mitigation measure for this project is the retention of 21.95 ha of Monsoon Vine-thicket and Low Eucalyptus Woodland in 2CRU which was rezoned to Conservation as part of the rezoning process and will be eventually handed over to NT Parks and Wildlife Commission. Works will be carried out by DHA to reduce the spread of noxious weeds, rehabilitate areas that have been damaged by erosion and revegetate with indigenous species to improve the quality of habitat for native fauna including the Black-footed Tree-rat. To assist with preventing human disturbance to the conservation area a fence will be established along the top of escarpment separation the conservation area from the esplanade. The escarpment fence is planned to be a 1.3 m high balustrade style fence with vertical panelling to ensure it complies with Australian standard safety design whilst considering the use of appropriate materials for the Darwin Coastal region and maximising airflow and environmental visibility. Fencing will be similar to what has been installed along the Nightcliff foreshore which meets both City of Darwin and NT Government approval.

In addition, a further 1.57 ha of native vegetation supporting 0.88 ha of Monsoon Rainforest will be protected in Muirhead North. Monsoon Rainforest is considered a sensitive vegetation type in NT. In addition to preserving the patch, works will be undertaken to sustain the species hydrological requirements. This includes designing stormwater drainage up-catchment of the Monsoon Rainforest patch (including within 2CRU) to maintain similar flow volumes as pre-development conditions. While stormwater peak flows are estimated to be lower at 5, 10, 20, 50 and 100 year ARI peak discharge events post-development, there is expected to be no impact of the project on the most frequent 2 year ARI peak discharge events (see Table 20 to Table 22). Furthermore, the volume of flow is considered to be the critical hydrological factor for sustaining the ecological requirements of the Monsoon Rainforest patch, which is expected to be unaltered given that no change in the catchment conditions is proposed. A bioretention basin is located immediately upstream of the Monsoon Rainforest patch which will assist with managing peak flows and removing pollutants.

Native vegetation will also be retained in areas of public open space where practical. A linear park will run parallel to the boundary of the conservation area, referred to as a coastal esplanade, and most vegetation will be retained in this area. Approximately half the trees will need to be removed to comply with the Biting Insect Management Plan, which recommends a tree canopy cover of 10% or less to act as a buffer (see Appendix G). In addition, it is expected that native vegetation in the rural lots located on the eastern section of Muirhead North, will be partially retained given the large size of the lots, although this cannot be enforced.

The protection of all sensitive vegetation within the project site into conservation areas, as well as the retention of native vegetation elsewhere is an important avoidance and mitigation measure to reduce the extent of vegetation loss, as well as minimise the impacts of fragmentation and edge-effects, and conserve the integrity of significant areas of biodiversity values in adjoining areas, such as Casuarina Coastal Reserve.

A detailed Conservation and Offset Management Plan will be prepared prior to construction commencing outlining works to be carried out in the conservation reserve and other areas to be retained across the project site. The plan will include:

- Objectives.
- Management actions.
- Responsibilities (i.e. DHA, City of Darwin, NT Parks and Wildlife or Casuarina Coastal Reserve Landcare Group).
- Timing.
- Monitoring and Review.

The plan will be prepared in consultation with City of Darwin, NT Parks and Wildlife Commission and Casuarina Coastal Reserve Landcare Group. Prior the Parks and Wildlife Commission taking responsibility for management, all rubbish and litter will be removed and a site audit will be done to determine exposure to asbestos. The Conservation Area will be managed by DHA until an agreed hand-over to Parks and Wildlife Commission take responsibility.

The Parks and Wildlife Commission have given their in-principal support for the mitigation measures proposed in the Conservation and Offset Management Plan (see correspondence in Q)

7.3.2.2 Darwin Cycad salvage and translocation

Darwin Cycads are a threatened species that can be successfully salvaged and translocated as demonstrated during the Lyons and Muirhead Breezes residential development projects. While it will not be possible to preserve all Darwin Cycads on site, it is expected that most will be able to be salvaged and reincorporated into landscaping and areas of public open space.

7.3.2.3 Fauna salvage and translocation

During vegetation clearance, there is potential for native fauna to be harmed or killed. Prior to the commencement of each stage, animal proof fencing will be established around each stage to prevent ground-based fauna from accessing area. Tree collars will be established around any tree outside of fenced area that has connecting canopy with trees inside fenced area, to prevent animals accessing site.

A fauna spotter will be on site immediately prior to vegetation clearance, and after animal-proof fencing has been established, to salvage and relocate any native fauna that could potentially be harmed or injured. The fauna spotter will require a permit under the *Territory Parks and Wildlife Conservation Act* to undertake any salvage and translocate any native fauna, and will take records of any animals handled including species, number and location of salvage and translocation. Species will be relocated into suitable habitat nearby, e.g. Conservation Area or habitat alongside Buffalo Creek.

7.3.2.4 Erosion and Sediment Control Plan

The ESCP will be prepared to address how the risk of erosion and sedimentation will be managed during construction, so as to preserve the quality of sensitive receptors such as Sandy Creek and Buffalo Creek. The ESCP will also detail how the erosion gullies in the south-west of the 2CRU will be rehabilitated. These gullies

are a major source of sediment to Sandy Creek, and once rehabilitated there is likely to be an improvement in water quality in Sandy Creek. There is some minor gully erosion in Muirhead North, but not to the significant extent as at 2CRU.

The ESCP will be approved by the Parks and Wildlife Commission and the Land Management Unit of DENR.

Both the gully erosion at both sites is close to Sandy Creek and Buffalo Creek and enhances conditions for biting insect breeding. The infilling and rehabilitation of gully erosion will address the recommendations within the biting insect report (Appendix G).

7.3.2.5 Water Quality Monitoring Plan

The Water Quality Monitoring Plan (Appendix O) will be implemented at Sandy Creek to monitor the physical and chemical parameters to establish whether there have been any changes in the creek as a result of the project. The parameters to be monitored will help understand what impact (if any) there has been to migratory shorebird habitat. Monitoring will be done at several locations in the vicinity of the discharge point into Sandy Creek due to the mixing influence of tides.

It is expected that due to the rehabilitation of erosion gullies, and other erosion and sediment control actions carried out across 2CRU, the quality of water entering Sandy Creek will improve.

Due to the existing poor condition of Buffalo Creek (see Section 4.2.5), water quality monitoring is not proposed as it is highly unlikely that monitoring would detect any changes that could be attributed to the project.

7.3.2.6 Weed control

Weeds are prevalent throughout the project area, although more prominent at 2CRU. A weed eradication program at 2CRU has been in place for over twelve months and will continue during the construction phase of the project and be expanded onto Muirhead North. The objectives of weed control will be to control and eradicate noxious weeds in accordance with the WM Act, as well as to improve habitat for Black-footed Tree-rat in the Conservation Area adjoining the Casuarina Coastal Reserve.

7.3.2.7 Migratory shorebird disturbance avoidance

The location of the access track[3] between 2CRU and Casuarina Beach has been decided after considering expert advice from a local migratory shorebird expert (Appendix N). While migratory shorebirds can be found feeding or roosting all along Casuarina Beach, the main area of sensitivity is on the western side of Sandy Creek (see Figure 33) . As such, the access track will be located on the eastern side of Sandy Creek and will access the beach at least 100 m away from the mouth of Sandy Creek which is the considered to be a safe buffer to avoid disturbance (Appendix N).

There will also be barrier fencing installed between the access point onto the beach and the mouth of Sandy Creek to minimise human disturbance to migratory shorebirds in this area.

[3] There will be no net loss of vegetation within the Conservation Area due to the construction of the access track. Informal tracks will be revegetated. The access track will follow already disturbed areas to minimise impacts to native vegetation.

The barrier fencing will be funded by DHA and will be designed and installed in consultation with NT Parks and Wildlife Commission who have experience implementing similar barrier fencing in the Lee Point area.

The NT Parks and Wildlife Commission have given their in-principal support for the mitigation measures designed to avoid and minimise disturbance to migratory shorebirds (see correspondence in Appendix Q).

7.3.2.8 Migratory shorebird education and monitoring

The project will invest in improving the local community's knowledge on the importance of Casuarina Beach as habitat for migratory shorebirds. Signage is located throughout the Casuarina Coastal Reserve and Casuarina Beach focussing on the military history, mountain-bike facilities, public access and beach safety, but surprisingly there is nothing informing the community that Casuarina Beach is 'internationally important' habitat for migratory shorebirds. There is some signage that informs the public that dogs must be on lead near the mouth of Sandy Creek, but these signs do not make any connection with migratory shorebird habitat and the threat posed by dogs (Figure 37).

The project will fund the installation of signage at four existing access points to Casuarina Beach that are the focal point for the estimated 935,000 visitors that Casuarina Coastal Reserve receives each year. In addition, signage will also be constructed along the proposed access track between 2CU and Casuarina Beach. The signage will include information on:

- List of migratory shorebird species that occur in Casuarina Beach area.
- Description of the migration patterns of shorebirds, including breeding grounds in northern hemisphere.
- Type of threats to migratory shorebirds both locally (e.g. human disturbance, dogs off lead, off-road driving, pollution) and at breeding grounds (e.g. habitat loss), and what can be done to preserve migratory shorebird habitat and minimise disturbance.

A 'citizen science' monitoring program will also be undertaken along Casuarina Beach and between Lee Point and Buffalo Creek to assess whether there has been any impact on migratory shorebirds due to the project. The framework for a monitoring program has been developed as part of the independent Migratory Shorebird report (Appendix N). The monitoring program will involve monthly visits around dawn and dusk during the peak periods that migratory shorebirds are present, with the program to continue for five years after the access track between 2CRU and Casuarina Beach has been opened. The monitoring will be undertaken by local bird-watching groups, with DHA lending financial support and resources to assist with organising monitoring and to encourage local residents and visitors to participate in the monitoring events.

The shorebird education and monitoring program will be implemented in consultation with NT Parks and Wildlife Commission, who have considerable experience addressing migratory shorebird issues and interaction with human disturbance in the Lee Point area.

Figure 37. Sign at access point to Casuarina Beach at Lee Point (left) and information sign on mountain bike trails within Casuarina Coastal Reserve (right).

7.3.2.9 Sawfish education

Several threatened sawfish species occur, or have potential to occur in Sandy Creek and Buffalo Creek, such as Dwarf Sawfish and Green Sawfish. There is likely to be an increase in fishing levels at Sandy Creek and Buffalo Creek as a result of the project, which would increase the probability of threatened sawfish being caught or potentially injured or killed. Signage will be installed at local popular fishing spots informing the public about the threatened status of sawfish found in the creeks, identification guide, catch and release methods and contact details of NT Government to report siting.

7.3.2.10 Monitoring health of remnant vegetation

While it is unlikely that changes in groundwater recharge and surface-water flows would impact on native vegetation to be retained within the site, monitoring is proposed given the sensitive vegetation types on site. The Monsoon Rainforest patch in Muirhead North and Monsoon Vine-thicket in 2CRU will be monitored twice a year (once in the wet season and once in the dry season) for a ten year period to determine if changes in hydrology are impacting on the health of these communities. Monitoring will be completed by trained botanists to be appointed by DHA and will focus on monitoring changes in the health of species most susceptible to hydrological changes.

For the Monsoon Vine-thicket patch in 2CRU, monitoring will involve:

- Establishing two transects running from the top of the slope to the bottom
- One transect will be located immediately downstream of the detention basin in the south-west corner, the other transect will be located approximately half-way between the detention basin in the south-west corner and the detention basin in the north-west corner
- At one metre interval along the transect, the following parameters will be recorded
    - Percentage cover of total cover and percentage live/dead cover within the following strata:
        - Ground layer
        - Shrub layer
        - Overstorey layer.

The findings will be compared separately for the two transects between seasons and between years to see if there has been any change in species composition, and in what location. If changes are driven by groundwater recharge then shallow-rooted species are likely to be replaced by deeper-rooted species over time.

For the Monsoon Rainforest patch, monitoring will involve:

- Establish permanent monitoring points at five locations throughout the patch and collect a chrono-sequence of photos over the 10 year monitoring period
- Mapping the boundary of Monsoon Rainforest
- Estimated the canopy cover of the overstorey species
- Identify all species present and allocate a cover abundance rating using the Braun-Blanquet method (i.e.. + = < 5% cover few individuals, 1 = < 5% cover many individuals, 2 = < 25% cover, 3 = < 50% cover, 4 = <75% cover, 5 = < 100% cover).

The findings will be compared between seasons and between years to see what change (if any) there has been in the composition of the Monsoon Rainforest patch. If the patch is affected by groundwater recharge than signs of poor health would be apparent during the dry-season in shallow-rooted species, whereas deeper-rooted overstorey species should persist. If the changes are being driven by lack of surface water flows, than the extent of the patch is likely to diminish, and shallow and deeper-rooted specie may be equally affected.

The trigger for a management response is a 10% or greater decline in any of the measured parameters for any monitoring event. The management response will be formulated in conjunction with experts on groundwater

dependent ecosystems from DENR, and may result in changes to Stormwater Management Plan to alter volume/frequency of flow to Monsoon Rainforest patch or groundwater inception for the benefit of the Monsoon Vine-thicket.

An annual report will be prepared by an independent consultant appointed by DHA, describing the results of the monitoring for the previous twelve months. The report will be provided to the NT EPA and DoEE.

7.3.2.11 Lighting impacts to turtles

Artificial light in coastal environments is recognised as a known disturbance to migratory turtle species. Flatback Turtle and Olive Ridley are known to nest on Casuarina Beach. Most light pollution emanating from the project site will be buffeted by Casuarina Coastal Reserve and Conservation Area. However, it is possible that buildings that are taller than vegetation within the reserve may have light shining directly on Casuarina Beach.

For these reasons, any building over four storeys in height will have its lighting adapted in accordance with the Western Australian Environmental Assessment Guidelines for Protecting Marine Turtles from Light Impacts (WA EPA 2010). This is likely to include all lighting directed downwards or away from the beach, and to be of a reduced brightness.

7.3.2.12 Heritage preservation

There are several places of heritage significance located throughout the project site related to the Konfrontasi period of military activity in the area that will be preserved. Local military historians will be engaged to assist landscape architects develop preservation areas and signage that will maintain the connection of the site with its military history. This approach has been used by DHA for the Lyons development.

The LDC will be engaged to collect and store the stone scatters recorded on site. In addition, the LDC will be engaged during clearing to identify any items of cultural significance not detected during the initial heritage assessment.

The LDC will be engaged to prepare interpretive signage around the project site to inform residents of the cultural significance of the area.

As part of the process to obtain an Authority Certificate from AAPA, AAPA consults with custodians of sacred sites to include conditions of what activities cannot be undertaken within registered sacred sites. It is understood that AAPA will discuss with custodians any approval conditions to ensure the protection of sacred sites outside of the project site along Casuarina Beach.

7.3.2.13 Increased population of domestic cats

Concerned was raised during the public exhibition period about the impact increased numbers of domestic cats would have on native fauna within the Casuarina Coastal Reserve. Cats are already abundant throughout Casuarina Coastal Reserve. The Reserve is located in an urbanised environment and backs onto residential development at Rapid Creek, Nakara, Tiwi, Alawa, Jingili and Lyons. The NT Parks and Wildlife Commission (Dean McKay pers. comm. A/District Manager Darwin Urban Parks) advised that many of the cats within Casuarina Coastal Reserve are likely to have come from these areas. The proposed development at Lee Point

may increase the number of cats in Casuarina Coastal Reserve, but only marginally given the territorial nature of cats, and would not greatly increase the threat to native fauna.

- Cat owners will be required to comply with Darwin City Council By-Laws regarding the registration and containment of cats. The City of Darwin Animal Management Plan (City of Darwin 2014), explains how these by-laws are implemented and what actions are being taken by Council to improve animal management. The Animal Management Plan states that cats must be:Registered with Council;
- Micro-chipped;
- Properly contained within the owner's property; and,
- Require a license to keep more than two cats.

Rangers from Council are responsible for trapping cats at large if a complaint is received from the public and the owner will not cooperate or be identified. Owners of cats at large can be fined in accordance with By Law 67(1).

7.4 Significant Impact Assessment

The purpose of this section is to describe the impact of the project under relevant environmental legislation and policy. The impacts considered are those which have come out of the risk assessment as of highest risk, after avoidance and mitigation measures have been considered, and have potential to trigger a significant impact on biodiversity and heritage.

7.4.1 *Environment Protection and Biodiversity Conservation Act 1999* – matters of National Environmental Significance

The EPBC Act establishes a Commonwealth process for the assessment of proposed actions (i.e. project, development, undertaking, activity, or series of activities) that are likely to have a significant impact on matters of national environmental significance (NES). An action, unless otherwise exempt, requires approval from the Commonwealth Environment Minister if it is likely to have a significant impact on a matter of NES.

7.4.1.1 Threatened ecological communities

No ecological communities that are listed as threatened under the EPBC Act occur on the project site, or are likely to occur in the adjoining areas. In addition, the PMST report did not identify any threatened ecological communities. As such, the project will not have a significant impact on threatened ecological communities.

7.4.1.2 Threatened species

Through a combination of detailed review of desktop information, targeted field surveys and habitat assessments, the following EPBC Act-listed threatened species were assessed as having potential to occur (i.e. likelihood of occurrence rating 'Known', 'Likely' or 'May' – Section 7.2.3):

- Black-footed Tree-rat
- Six migratory shore-bird species:
    - Bar-tailed Godwit
    - Eastern Curlew
    - Great Knot
    - Greater Sand Plover
    - Lesser Sand Plover
    - Red Knot.
- Three sawfish species in Buffalo Creek
    - Dwarf Sawfish
    - Green Sawfish
    - Freshwater Sawfish.

An assessment of whether the project will have a significant impact on these species is provided in the sub-section below in accordance with the EPBC Act significant impact guidelines for threatened species (DoE 2013).

These assessments have been made after taking into consideration the avoidance and mitigation measures proposed in Section 7.2.4.5.

Black-footed Tree-rat

The likelihood of the project having a significant impact on Black-footed Tree-rat has been assessed below (Table 48) in accordance with the EPBC Act Significant Impact Guidelines for Critically Endangered and Endangered species (DoE 2013). It is concluded that the proposed action is likely to have a significant-impact on Black-footed Tree-rat due to the loss of habitat. The species was recorded in Muirhead North during targeted surveys, and suitable habitat for the species occurs on both Muirhead North and 2CRU.

Table 48. Significant impact assessment for Black-footed Tree Rat

Action is likely to…	Response
Lead to a long-term decrease in the size of a population.	No. Black-footed Tree-rat was recorded in Muirhead North but not 2CRU. There is suitable habitat for the species on both sites. Black-footed Tree-rat was recorded on four cameras in Muirhead North over the four day survey period. The purpose of the survey was to establish presence and not population size; however, based on the number of records and non-records, as well as the findings of Stokeld and Gillespie (2015), it is expected that the population of Black-footed Tree-rats in the vicinity of the project site is small (i.e. <5 individuals). Based on the area of habitat to be removed, and the availability of Black-footed Tree-rat habitat in the surrounding landscape, there is unlikely to be a long-term decrease in the size of the population, as the species could be sustained in adjoining areas.
Reduce the area of occupancy of the species.	Yes. The project would result in the loss of approximately 23 ha of suitable habitat for Black-footed Tree-rat including 5.5 ha in 2CRU and 17.5 ha in Muirhead North. There would also be the removal of approximately half the canopy trees along the western boundary of 2CRU with the conservation reserve to comply with the Biting Insect Management plan recommendation to provide a buffer against biting insect migratory by reducing the canopy cover to 10%. Specifically, smaller trees will be selected for removal to minimise impact to Black-footed Tree-rat habitat.
Fragment an existing population into two or more populations.	No. The Lee Point population of Black-footed Tree-rat would retain connectivity to areas north and south of the project site, due to availability of habitat corridors along Casuarina Coastal Reserve (west of 2CRU) and Buffalo Creek (east of Muirhead North). The Casuarina Coastal Reserve is part of the Connecting Coastal Corridors of Green program acknowledging the role it plays in facilitating wildlife movements through the landscape (Parks and Wildlife Commission of the Northern Territory 2016).
Adversely affect habitat critical to the survival of a species.	No. The project site contributes medium quality, fragmented habitat for Black-footed Tree-rat. Better quality habitat occurs in adjoining areas (e.g. Royal Darwin Hospital) which is more important to the survival of the species.
Disrupt the breeding cycle of a population.	No. There is a sufficient area of habitat in areas adjoining the project site to sustain breeding. Rankmore (2006) determined that Black-footed Tree-rat could persist in an area of 27.1 ha in a fragmented landscape such as Lee Point.
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.	No. There is a sufficient area of habitat in areas adjoining the project site to sustain any individuals using habitat to be removed.

Action is likely to…	Response
Result in the invasive species that are harmful to the species becoming established in the species' habitat.	**No.** Predation by Feral Cats is considered a plausible but not demonstrated threat to Black-footed Tree-rat (DoE 2015). Feral Cats are already well-established in the area. Clearing vegetation as part of the project may reduce the area of occupancy of Feral Cats in the region.
Introduce disease that may cause the species to decline.	**No.** Disease is not listed as a threatening process for this species. There is no literature on diseases that could be introduced by the project and that would detrimentally affect this species.
Interfere with the recovery of the species.	**No.** There is no approved recovery plan for Black-footed Tree-rat.

Shorebirds

Six shorebird species listed as threatened under the EPBC Act have been recorded roosting and feeding along Casuarina Beach near the mouth of Sandy Creek. The potential for the project to have a significant impact on the threatened shorebirds is assessed below (Table 49). Bar-tailed Godwit, Eastern Curlew, Great Knot, Lesser Sand Plover and Red Knot have been assessed against the Significant Impact Guidelines (DoE 2013) for Critically Endangered and Endangered species.

Greater Sand Plover is listed as Vulnerable under the EPBC Act. The EPBC Act Significant Impact Guidelines (DoE 2013) assess significant impacts to 'important populations' of Vulnerable species, where important populations are defined as:

- Key source populations either for breeding or dispersal
- Populations that are necessary for maintaining genetic diversity, and/or
- Populations that are near the limit of the species range (DoE 2013).

The population of Greater Sand Plover along Casuarina Beach is not considered to qualify as 'important population' of Vulnerable Species, and as such a significant impact assessment was not undertaken. However, as the species is also listed as migratory under the EPBC Act, a significant assessment was undertaken in accordance with the EPBC Act significant impact guidelines for migratory species (Section 7.4.1.3).

It is concluded that the project is unlikely to have a significant impact upon threatened shorebirds. The project will not result in the loss or degradation of habitat to shorebirds; however, there will be in an increase in the number of people visiting Casuarina Beach due population growth within the area.

Casuarina Coastal Reserve has approximately one million visitors a year and the project is predicted to result in a 2% increase in the number of visitors to Casuarina Coastal Reserve (see Section 8.5.1.4). This increase would be concentrated near the project site due to the access track to be provided between 2CRU and Casuarina Beach, whereas visitors predominantly access Casuarina Coastal Reserve from Lee Point or the Surf Life Saving Club. Any impact to shorebirds as a result of the project would be addressed by the proposed avoidance and mitigation measures, which include locating the beach access to areas of less sensitivity for threatened shorebirds (i.e. east of the mouth of Sandy Creek), enforcing fencing barricades around the mouth of Sandy Creek, undertaking a community education program through better signage throughout the entire Casuarina Coastal Reserve, and involving the local community in a 'Citizen Science' program to assist with the ongoing monitoring of shorebird populations in the Lee Point area.

Table 49. Significant impact assessment for Critically Endangered and Endangered shorebirds: Bar-tailed Godwit, Eastern Curlew, Great Knot, Lesser Sand Plover and Red Knot.

Action is likely to…	Response
Lead to a long-term decrease in the size of a population.	**No.** There are no envisaged impacts on the population size of Bar-tailed Godwit, Eastern Curlew, Great Knot, Lesser Sand Plover and Red Knot would be sustained.
Reduce the area of occupancy of the species.	**No.** Project unlikely to increase visitation rates to the west of Sandy Creek mouth, which is the most sensitive habitat for migratory shorebirds along Casuarina Beach.
Fragment an existing population into two or more populations.	**No.** Threatened shorebirds are highly mobile, and currently move between local habitat sites within Darwin Harbour. Any increased anthropogenic disturbance is unlikely to fragment the regional population into two or more populations.
Adversely affect habitat critical to the survival of a species.	**No.** The most important habitat for threatened shorebirds in the Lee Point area is between Lee Point and Buffalo Creek, which is outside the project footprint. The most sensitive area near the project site is west of the mouth of Sandy Creek. Access to the beach from the project will be to the east of the Sandy Creek mouth. In addition, local signage and community education programs are intended to dissuade local residents and visitors from taking dogs too close to Sandy Creek.
Disrupt the breeding cycle of a population.	**No.** Threatened migratory shorebirds use Darwin beaches as roosting and feeding sites during the non-breeding season. Potential anthropogenic disturbance of roosting sites from increased pedestrian traffic would not affect the species' breeding habitat or breeding cycle, unless individual birds are unable to obtain sufficient body mass (through feeding) prior to migrating to northern hemisphere breeding grounds. There is no evidence to suggest that the situation in the region is so dire that this will be the case.
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.	**No.** The avoidance and mitigation measures proposed are considered sufficient to prevent any impacts to threatened migratory shorebirds as a result of increased visitation. In the unlikely event that increased visitation rates disturb migratory shorebirds, birds are expected to fly to Lee Point or other suitable roosting/feeding habitat nearby as they have already been observed to do (Lilleyman 2016).
Result in the invasive species that are harmful to the species becoming established in the species' habitat.	**No.** There are no invasive species that are considered a threat to migratory shorebirds, which may establish as a result of the project.
Introduce disease that may cause the species to decline.	**No.** There is no information to suggest that diseases could be introduced or would be detrimental to the species.
Interfere with the recovery of the species.	**No.** Appropriate measures will be taken to avoid impacts to threatened migratory shorebirds. Furthermore, the communication, education and monitoring program will assist with the species' recovery beyond the potential impacts of the project, and will encompass the entire Lee Point area.

Sawfish

Dwarf Sawfish and Green Sawfish have been recorded within Buffalo Creek. Freshwater Sawfish has not been recorded in the area, but has similar habitat requirements and so is likely to occur in Buffalo Creek. All three species are listed as Vulnerable under the EPBC Act, and if present would be considered to constitute important populations.

The main potential impact to these species associated with project activities is reduced water quality entering Buffalo Creek as a result of sedimentation, erosion and pollution during construction and from stormwater discharge.

The potential for the project to have a significant impact on threatened sawfish is assessed below (Table 50). It is concluded that it is unlikely that the project would have an impact on threatened sawfish. Buffalo Creek is already a highly polluted water-way as a result of industrial and other developments upstream, and effluent discharge from the Leanyer Sewerage Treatment Plant. Stormwater run-off from the project site would be treated through a series of retention basins, and the quality of water being discharged into Buffalo Creek from the project site would be of better quality then *in situ* conditions.

Table 50. Significant impact assessment for Dwarf Sawfish, Green Sawfish and Freshwater Sawfish

Action is likely to…	Response
Lead to a long-term decrease in the size of a population.	**No**. The only way in which project activities might lead to a long-term decrease in the size of a population is if water pollution rendered Buffalo Creek unsuitable habitat. Buffalo Creek already has compromised water quality due to other developments and industries. With the mitigation measures proposed including WSUD, there should not be any significant decrease in the water quality of Buffalo Creek, and therefore no long-term decrease in the size of any sawfish populations.
Reduce the area of occupancy of the species.	**No**. The only way in which project activities might reduce the area of occupancy of these species is if water pollution rendered Buffalo Creek unsuitable habitat. Buffalo Creek already has compromised water quality due to other developments and industries. With the mitigation measures proposed including WSUD, there should not be any significant decrease in the water quality of Buffalo Creek, and therefore no reduction in the area of sawfish occupancy
Fragment an existing population into two or more populations.	**No**. This consideration is of low relevance for marine species such as sawfish.
Adversely affect habitat critical to the survival of a species.	**No**. Buffalo Creek may be critical habitat during certain stages of a sawfish's lifecycle – particularly breeding. The only way in which project activities might adversely affect that habitat is if water pollution rendered Buffalo Creek unsuitable habitat. Buffalo Creek already has compromised water quality due to other developments and industries. With the mitigation measures proposed including WSUD, there should not be any significant decrease in the water quality of Buffalo Creek, and therefore no adverse effect to critical habitat or the breeding cycle.
Disrupt the breeding cycle of a population.	
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.	**No**. The only way in which project activities might affect the availability or quality of habitat to these species is if water pollution rendered Buffalo Creek unsuitable habitat. Buffalo Creek already has compromised water quality due to other developments and industries (Section XX). With the mitigation measures proposed in Section XX, there should not be any significant decrease in the water quality of Buffalo Creek, and therefore no reduction in the availability or quality of habitat to these species.
Result in the invasive species that are harmful to the species becoming established in the species' habitat.	**No**. Invasive species are not listed as a threatening process for these species. There is no literature on invasive species that could be introduced by the project and that would detrimentally affect these species.
Introduce disease that may cause the species to decline.	**No**. Disease is not listed as a threatening process for these species. There is no literature on diseases that could be introduced by the project and that would detrimentally affect these species.
Interfere with the recovery of the species.	**No**. Because there will not be any significant impact on the water quality of Buffalo Creek, sawfish species will not be affected and so the recovery of these species will not be interfered with.

7.4.1.3 *Migratory species*

As described in Section 7.2.4.3, a detailed and thorough assessment process led to the conclusion that areas directly adjoining the project site, namely Sandy Creek and Casuarina Beach, provides important habitat for migratory shorebirds. Buffalo Creek, which is located directly to the east of Muirhead North, is also considered important habitat for the Narrow Sawfish.

An assessment of whether project activities will have a significant impact on migratory shorebird species and on the Narrow Sawfish is undertaken below.

Migratory shorebirds

Twenty migratory shorebird species have been recorded roosting and feeding along Casuarina Beach (see Table 42).

The potential for the project to have a significant impact on migratory shorebirds has been assessed in accordance with *EPBC Act Policy Statement 3.21 – Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species* (DoE 2015). These guidelines consider significant impacts to important populations of migratory shorebirds of which the following four species have internationally or nationally important populations along Casuarina Beach:

- Great Knot
- Greater Sand Plover
- Red Knot
- Sanderling.

The significant impact guidelines have been applied to these four species (Table 51 below). It is concluded that it is unlikely the project will significantly impact upon migratory shorebirds.

Table 51. Significant impact assessment for migratory shorebirds with important populations recorded near Sandy Creek (Great Knot, Greater Sand Plover, Red Knot and Sanderling).

Significant impact	Response
Loss of habitat	**No.** There will not be any direct loss of habitat for migratory shorebirds due to this development.
Degradation of habitat leading to a *substantial reduction** in migratory shorebird numbers	**No.** Stormwater management and remediation of erosion gullies is expected to increase the quality of habitat near the mouth of Sandy Creek for migratory shorebirds.
Increased disturbance leading to a *substantial reduction** in migratory shorebird numbers	**No.** The project is expected to increase visitation to Casuarina Beach by approximately 2%, albeit most of the additional visits will be concentrated near Sandy Creek. The proposed mitigation measures which include locating the access path to the east of Sandy Creek and away from areas of sensitivity, increased signage, barrier fencing, community education and citizen science, will appropriately avoid and mitigate any potential disturbance to migratory shorebirds. If migratory shorebirds are disturbed, they would move temporarily up beach to Lee Point as they are already observed to do (Lilleyman 2016).

Significant impact	Response
Direct mortality of birds leading to a *substantial reduction** in migratory shorebird numbers	**No.** Project activities will not impact on migratory shorebird habitat. Traffic, noise and light pollution during construction and operation will be buffered by the Casuarina Coastal Reserve and unlikely to impact on migratory shorebirds. In terms of predation, although the development is likely to lead to an increase in the number of dogs that occur on Casuarina Beach, and possibly of cats in the surrounding area, predation of shorebirds by these species is not identified as a threat to migratory shorebirds. Furthermore, the areas adjoining Sandy Creek are already on dog-on-lead area, and increased signage will ensure this occurs.

* A 'substantial reduction' includes the number of migratory shorebirds using an area

7.4.1.4 Actions on Commonwealth Land or by Commonwealth Agencies

As the proposed development will be undertaken on Commonwealth land (2CRU) and by a Commonwealth agency, an assessment has been made as to whether the project has an impact on the 'environment as a whole' in accordance with Section 26-28 of the EPBC Act. The assessment has been made in accordance with the *EPBC Act 1.2 Actions on, or impacting upon, Commonwealth land or by a Commonwealth Agency* (DSEWPaC 2012).

The results of the significant impact assessment are provided in the sub-sections below. Based on these findings which account for the avoidance and mitigation measures described in Section 7.2.4.5, it is considered unlikely that the project will have a significant impact upon the environment.

Landscape and soils

The potential for project activities to significantly impact upon landscapes and soils is assessed in Table 52.

Table 52. Significant impact assessment on landscapes and soils

Is there a real chance or possibility that the action will...	Response
Substantially alter natural landscape features?	**No**. The project would result in the replacement of woodland habitat with a housing and commercial development, but this is not considered to be a substantial alteration given that native vegetation that will be removed is heavily degraded, not threatened or sensitive, and occurs in adjoining areas. The most important natural landscape features are considered to be 20.6 ha of Monsoon Vine-thicket in 2CRU which will be retained and annexed as part of the Casuarina Coastal Reserve (although 0.5 ha will be removed for the detention basin), and 0.9 ha of Monsoon Rainforest in Muirhead North that will be retained and incorporated into public open space.
Cause subsidence, instability or substantial erosion?	**No**. An ESCP will be prepared by an appropriately-qualified person in accordance with the International Erosion and Association Guidelines to manage erosion and sedimentation across the development site for each stage of construction . ESCP will be reviewed by Parks and Wildlife Commission and approved the Land Management Unit of DENR before commencement. Areas of high erosion risk, i.e. the escarpment area along the western boundary, will not be developed. In addition, the inclusion of open space buffers between developed areas and the escarpment, and the establishment of a formal access point (staircase) into the Casuarina Coastal Reserve, will

Is there a real chance or possibility that the action will…	Response
	further mitigate erosion risks. Furthermore, the erosion gullies in the south-west of 2CRU will be rehabilitated.
Involve medium or large-scale excavation of soil or minerals?	**No**. The proposed development does not involve medium or large-scale excavation of soils, as the levels required for construction can be achieved by re-contouring. Excavations for services will be shallow (typically within 3 m of the ground surface) and there is no identified requirement for importation of fill material.

Coastal landscapes and processes

The potential for project activities to significantly impact upon coastal landscapes and processes is assessed below (Table 53).

Table 53. Significant impact assessment on coastal landscapes and processes

Is there a real chance or possibility that the action will…	Response
Alter coastal processes, including wave action, sediment movement or accretion, or water circulation patterns?	**No**. The development is terrestrial and will not cause off-site physical impacts that would alter the coastal or estuarine environment. Erosion and sediment controls will ensure that there is no significant increase in sedimentation entering Sandy Creek and Buffalo Creek, and would likely result in a net improvement in the quality of Sandy Creek due to the existing erosion issues on this site. That will be treated.
Permanently alter tidal patterns, water flows or water quality in estuaries?	**No**. The development is terrestrial and will not cause off-site physical impacts that would alter the coastal or estuarine environment. The Stormwater Management Plans (Appendix E and Appendix F) shows a series of water-sensitive urban design treatment trains and retarding basins designed to reduce the amount of sediment leaving the site and assist in reducing nutrient load. The Stormwater Management Plans for the development area entails: - Maximising on site storage and recharge of surface run-off into existing aquifers - Limiting run-off to pre-development conditions by promoting filtration of run-off through enhanced natural vegetation and storage systems - Provide erosion and sediment control by incorporating measures during construction and permanent sediment basins at outlets to natural waterways.
Reduce biological diversity or change species composition in estuaries?	**No**. With the mitigation measures proposed there should not be any significant decrease in the water quality of Sandy Creek or Buffalo Creek that may impact on biological diversity. Nonetheless, water-quality monitoring is proposed in Sandy Creek due to the lack of existing data and the importance of the creek on supporting migratory shorebirds at the confluence with Casuarina Beach. Water monitoring will be undertaken in accordance with the Water Quality Monitoring Plan (see Appendix O) at Sandy Creek. Due to the poor quality of Buffalo Creek, monitoring within this water-body is not considered necessary.
Extract large volumes of sand or substantially destabilise sand dunes?	**No**. There will be no direct disturbance of beach, dune or intertidal areas.

Ocean forms, ocean processes and ocean life

The potential for project activities to significantly impact upon ocean forms, ocean processes and ocean life is assessed in Table 54.

Table 54. Significant impact assessment on ocean forms, ocean processes and ocean life

Is there a real chance or possibility that the action will…	Response
Reduce biological diversity or change species composition on reefs, seamounts or in other sensitive marine environments?	**No**. The project footprint does not include any sensitive marine environments.
Alter water circulation patterns by modification of existing landforms or the addition of artificial reefs or other large structures?	**No**. The development is on land and will not cause off-site physical impacts that would alter the coastal or estuarine environment.
Substantially damage or modify large areas of the seafloor or ocean habitat, such as sea grass?	**No**. The development is on land and will not cause off-site physical impacts that would alter the coastal or estuarine environment.
Release oil, fuel or other toxic substances into the marine environment in sufficient quantity to kill larger marine animals or alter ecosystem processes?	**No**. The development does not involve any significant quantities of toxic substances. A spill management plan will be in place during concentration, and pollutants from run-off will be treated as part of treatment train described in the Stormwater Management Plan (Appendix E and Appendix F).
Release large quantities of sewage or other waste into the marine environment?	**No**. Sewerage will be treated at the Leanyer Sewerage Treatment Plant. The sewerage network that will be constructed for the project has sufficient storage capacity for emergency situations and complies with PWC requirements (Section 6).

Water resources

The potential for project activities to significantly impact upon water resources is assessed in Table 55.

Table 55. Significant impact assessment on water resources

Is there a real chance or possibility that the action will…	Response
Measurably reduce the quantity, quality or availability of surface or ground water?	**No.** The Stormwater Management Plans shows that a treatment train of bioretention and detention basins will ensure the quality and quantity of water discharging into Sandy Creek and Buffalo Creek meets NT Guidelines. Furthermore, given the extent of erosion that has occurred on 2CRU, the Stormwater Management Plans along with remediation of the erosion gullies is likely to improve the quality of water discharging into Sandy Creek. The project is unlikely to have any interaction with ground water (see Section 4.3.2.1).
Channelise, divert or impound rivers or creeks or substantially alter drainage patterns?	**No.** The project will not involve any modifications to Sandy Creek or Buffalo Creek.
Measurably alter water table levels?	**No.** Increasing the area of impenetrable surface is likely to reduce the infiltration from rainfall and recharge of groundwater levels. However, the local groundwater system is unlikely to be measurably altered and recharge will occur in other parts of the catchment (see Section 4.3.2.1).

Pollutants, chemicals and toxic substances

The potential for project activities have a significant impact regarding pollutants, chemicals and toxic substances is assessed in Table 56.

Table 56. Significant impact assessment regarding pollutants, chemicals and toxic substances

Is there a real chance or possibility that the action will…	Response
Generate smoke, fumes, chemicals, nutrients, or other pollutants which will substantially reduce local air quality or water quality?	**No.** The CEMP will involve standard mitigation measures to ensure all equipment, plant and machinery are maintained and operated in suitable manner to ensure air quality and water quality is maintained in accordance with NT Guidelines.
Result in the release, leakage, spillage, or explosion of flammable, explosive, toxic, radioactive, carcinogenic, or mutagenic substances, through use, storage, transport, or disposal?	**No.** All chemicals will be used and stored in accordance with the MSDS. A spill management plan will be in place in the unlikely event a spill of toxic substances occurs.
Increase atmospheric concentrations of gases which will contribute to the greenhouse effect or ozone damage?	**No.** The quantity of greenhouse gases released from vegetation clearing or during construction would not have any impact on the global warming. The use of Chlorofluorocarbons will be in accordance with international guidelines.
Substantially disturb contaminated or acid-sulphate soils?	**No.** It is unlikely that acid-sulphate soils will be disturbed during the development (see Section 4.2.1).

Plants

The potential for project activities to significantly impact upon plants is assessed in Table 57.

Table 57. Significant impact assessment on plants

Is there a real chance or possibility that the action will…	Response
Involve medium or large-scale native vegetation clearance?	**No**. Approximately 110 hectares of degraded native vegetation that is common in the region will be cleared. All sensitive vegetation-types (i.e. Monsoon Vine-thicket and Monsoon Rainforest), which cover approximately 22.5 ha of the project site, will be retained, except for 0.5 hectares of Monsoon Vine-thicket to be removed for the detention basin. There will also be opportunities to retain native vegetation within the areas of public open space.
Involve any clearance of any vegetation containing a listed threatened species which is likely to result in a long-term decline in a population or which threatens the viability of the species?	**No**. There are no EPBC Act-listed threatened plant species or ecological communities within or surrounding the area proposed for development. One NT-listed threatened flora species – the Darwin Cycad– occurs in patches throughout the area proposed for development. However, the population of this species within the project footprint does not constitute an 'important population'. Moreover, where possible, individual plants will be retained *in situ* or relocated to public open spaces within the development. Sensitive Monsoon Vine-forest and Monsoon Rainforest that occurs on the project site will be protected (except for 0.5 hectares of Monsoon Vine-thicket to be removed for a detention basin on 2CRU).
Introduce potentially invasive species?	**No**. The site is heavily disturbed. It has been subjected to significant disturbance in the past and weeds are widespread along tracks and in

Is there a real chance or possibility that the action will…	Response
	previously cleared and disturbed areas. Grassy weeds make up the majority of the weed impact – particularly Gamba Grass and Mission Grass. An active program to control the extent of weeds on 2CRU, particularly Gamba Grass, commenced in 2015 and will continue through the construction phase of the project and be extended into Muirhead North. Post construction, areas of open space will be managed for weeds.
Involve the use of chemicals which substantially stunt the growth of native vegetation?	**No**. The development will not involve the use of chemicals which substantially stunt the growth of native vegetation.
Involve large-scale controlled burning or any controlled burning in sensitive areas, including areas which contain listed threatened species?	**No**. No control burning will occur as part of the project. The project area has previously been subjected to a damaging fire regime, to the detriment of ecological values. Once the site is developed and native vegetation cleared, the adjacent rainforest and vine thicket within the Casuarina Coastal Reserve will become better protected from fire.

Animals

The potential for project activities to significantly impact upon animals is assessed in Table 58.

Table 58. Significant impact assessment on animals

Is there a real chance or possibility that the action will…	Response
Cause a long-term decrease in, or threaten the viability of, a native animal population or populations, through death, injury or other harm to individuals?	**No**. Habitat clearing will lead to the loss of habitat for native animals. The potential for construction activities to cause death or injury to fauna will be mitigated through the use of fauna spotter-catchers during land clearing. Apart from the Black-footed Tree-rat, all the fauna species that occur within the areas to be cleared are common and abundant in analogous habitat within the greater Darwin region.
Displace or substantially limit the movement or dispersal of native animal populations?	**No**. The project will result in the loss of habitat for native fauna. However, the species affected are common and widespread across the northern suburbs of Darwin and should not be isolated as a result of the project.
Substantially reduce or fragment available habitat for native species?	**No**. The project will result in the loss of habitat for native fauna. However, the species affected are common and widespread across the northern suburbs of Northern Territory and should not be isolated as a result of the project. The project would result in the loss of approximately 23 ha of fragmented, Black-footed Tree-rat habitat including approximately 5.3 ha of habitat on 2CRU and 17.5 ha of habitat on Muirhead North. Habitat will also be diminished in a 7.5 ha of habitat along the boundary with 2CRU and the conservation area to comply with the Biting Insect Management plan. Given the availability of suitable quality elsewhere in Lee Point, including at the CDU campus and near the Buffalo Creek ramp where the species has been previously recorded, the loss of habitat within a local context is not considered to be substantial. The links between Black-footed Tree-rat habitat, 2CRU and Casuarina Coastal Reserve will be maintained by preserving and rehabilitating habitat in the south-west corner of 2CRU.
Reduce or fragment available habitat for listed threatened species which is likely to displace a population, result in a long-term	**No.** Black-footed Tree-rat was recorded during targeted surveys in Muirhead North and suitable habitat for the species occurs in Muirhead North and 2CRU. The project would result in a reduction of 23 ha of fragmented, Black-footed Tree-rat habitat including approximately 5.3 ha of habitat on 2CRU and

Is there a real chance or possibility that the action will…	Response
decline in a population, or threaten the viability of the species?	17.5 ha of habitat on Muirhead North. The links between Black-footed Tree-rat habitat, 2CRU and Casuarina Coastal Reserve will be maintained by preserving and rehabilitating habitat in the south-west corner of the 2CRU. The development of Muirhead North is unlikely to fragment populations on the eastern side of Lee Point Road as continuous habitat along the eastern boundary connecting areas to the north and south of Muirhead North will be sustained. In addition, the eastern section of Muirhead North will be developed as larger, rural lots, that could potentially support Black-footed Tree-rat dispersal. The number of Black-footed Tree-rats that are likely using the project site is expected to be low based on the results of the targeted surveys, and other information sources. There is considered to be sufficient habitat in the adjoining landscape to support any individuals displaced by the project.
Introduce exotic species which will substantially reduce habitat or resources for native species?	**No**. The site is adjacent to developed areas. It is already heavily infested with weeds and supports feral species such as cats and wild dogs. Weed control has already commenced on 2CRU and will be extended to Muirhead North throughout the construction phase of the project.
Undertake large-scale controlled burning or any controlled burning in areas containing listed threatened species?	**No**. No control burning will occur as part of the project. The project area has previously been subjected to a damaging fire regime, to the detriment of ecological values. Once the site is developed and native vegetation cleared, the adjacent rainforest and vine thicket within the Casuarina Coastal Reserve, and Monsoon Rainforest within Muirhead North, will become better protected from fire.

People and communities

The potential for project activities to significantly impact upon people and communities is assessed in Table 59.

Table 59. Significant impact assessment on people and communities

Is there a real chance or possibility that the action will…	Response
Substantially increase demand for, or reduce the availability of, community services or infrastructure which have direct or indirect impacts on the environment, including water supply, power supply, roads, waste disposal, and housing?	**No.** Water, power and sewerage services will be provided to satisfy the projected demands and meet NT and PWC requirements. The commercial precinct will provide a number of community services including health care, a primary school, child-care facilities, a sports oval and other community services to meet the demand for the northern suburbs of Darwin including for new residents at the project site.
Affect the health, safety, welfare or quality of life of the members of a community, through factors such as noise, odours, fumes, smoke, or other pollutants?	**No.** The project is unlikely to produce environmental pollution that may affect the health of the community. The CEMP includes measures to avoid and mitigate any potential impacts due to noise (machinery) or pollutants (chemical spills and water run-off). An odour assessment found that the project site is not within the odour footprint of the Leanyer Treatment Plant.
Cause physical dislocation of individuals or communities?	**No.** The site currently does not provide any housing or other forms of accommodation. No adjoining residents will have to relocate during construction. The project will provide affordable housing options for the local community.

Is there a real chance or possibility that the action will…	Response
Substantially change or diminish cultural identity, social organisation or community resources?	**No.** The site is not considered to be of cultural or social importance to the local community. The 2CRU site has been used for Defence purposes, and therefore has not been available to the community for social or recreational purposes. Muirhead North is vacant crown land.

Heritage

The potential for project activities to significantly impact upon heritage is assessed in Table 60. The proposed development will not impact on any sites listed on the NT Heritage Register, National Heritage List, World Heritage List or Commonwealth Heritage List. There are also no registered or recorded Aboriginal Sacred Sites protected under the NT *Aboriginal Sacred Sites Act* in the areas proposed for development.

Table 60. Significant impact assessment on heritage

Is there a real chance or possibility that the action will…	Response
Permanently destroy, remove or substantially alter the fabric (physical material including structural elements and other components, fixtures, contents, and objects) of a heritage place?	**No**. The Proponent proposes to retain the sites referred to as the 'Bunkers' located along Lee Point Road. There is no other heritage or cultural sites within the project area including known sacred sites. An Aboriginal Areas Protection Authority Certificate will be obtained by the Proponent prior to commencement of construction.
Involve extension, renovation, or substantial alteration of a heritage place in a manner which is inconsistent with the heritage values of the place?	
Involve the erection of buildings or other structures adjacent to, or within important sight lines of, a heritage place which are inconsistent with the heritage values of the place?	
Substantially diminish the heritage value of a heritage place for a community or group for which it is significant?	
Substantially alter the setting of a heritage place in a manner which is inconsistent with the heritage values of the place?	
Substantially restrict or inhibit the existing use of a heritage place as a cultural or ceremonial site?	

7.4.2 Northern Territory

7.4.2.1 *Territory Parks and Wildlife Conservation Act*

The *Territory Parks and Wildlife Conservation Act* makes provision for the establishment of Territory Parks, other Parks and Reserves, and the study, protection, conservation and sustainable utilisation of wildlife. A permit would be required to take or interfere with protected wildlife during habitat clearing, where protected wildlife includes all vertebrate animals that are indigenous to Australia.

7.4.2.2 Weed Management Act 2001

Certain plants are declared as weeds under the WM Act. Under the Act, landowners must take all reasonable measures to prevent their land being infested with a declared weed, and take all reasonable measures to prevent a declared weed on their land spreading to other land.

The following declared weeds have been found within the project site:

- Gamba Grass
- Mission Grass
- Hyptis
- Snakeweed.

Under the Act, Gamba Grass is classified as a Class A weed (to be eradicated), and the other species are classified as Class B weeds (to be controlled). In accordance with the Act, works will be undertaken to eradicate Gamba Grass from the site (which has already commenced on 2CRU), while actions are included in the CEMP to ensure Class B weeds will not be spread off-site.

7.4.2.3 *Heritage Act 2011*

The *Heritage Act 2011* provides for the conservation of cultural and natural heritage within the Northern Territory, where cultural heritage refers to places or objects that have been created or modified by humans. It includes a wide range of structures and places associated with European settlement, including maritime heritage. All Aboriginal and Macassan archaeological sites are protected under the Act.

The project will destroy a background scatter of stone artefacts recorded in the west of 2CRU (EcOz 2015). In accordance with Section 72 of the Act, DHA will apply for a works approval to carry out work on this scatter.

7.4.2.4 *Aboriginal Sacred Sites Act*

The *Northern Territory Aboriginal Sacred Sites Act* affords protected all Aboriginal Sacred Sites, whether they have been recorded or not. Under the Act, the Aboriginal Areas Protection Authority (AAPA) is responsible for the protection of all sites listed under the Act.

There are no registered sacred sites within the project site. The proponent will obtain an Authority Certificate from the AAPA prior to commencement of works.

7.5 Environmental Offsets

In accordance with the EPBC Act, an offset is required to compensate for any residual adverse impact to a matter of NES. Offsets are likely to be required for Black-footed Tree-rat as it was assessed that after considering the proposed mitigation and avoidance measures, a significant impact on the species is likely (Section 7.4.1.2).

The area of habitat that is likely to require offsetting is estimated to be 23 ha, consisting of one 5.53 ha patch in 2CRU and 17.5 ha across four patches in Muirhead North (see Section 7.2.4.3). In addition, habitat within a 7.5 ha patch along the boundary of the development with the conservation area in 2CRU will be modified to comply with the Biting Insect Management Plan. All other habitat is unlikely to be suitable for Black-footed Tree-rat due to a lack of large trees and food plants, and proliferation of Gamba Grass in the ground-layer (see Section 7.2.4.3).

Offsets would be obtained in a staged manner reflective of the staged development of the project, with offsets sought prior to each stage commencing (see Table 3). Offsets will be sought via a combination of on-site and off-site offsets as described below.

7.5.1 On-site offset

The protection of suitable habitat within the 21.95 ha conservation area would more than suitably offset the loss of habitat within 2CRU in accordance with the EPBC Act offset policy (DSEWPaC 2012). The conservation area supports Monsoon Vine-thicket and eucalypt woodland, and the study by Griffiths *et al.* (2002) not only recorded the species in this area but showed the species had a preference for nesting trees in the area of Monsoon Vine-thicket compared to other habitats in and around 2CRU.

The 21.95 ha conservation area, previously zoned as Commonwealth land was rezoned as 'Conservation' during the rezoning process in late 2015. The conservation area is currently managed by DHA and will be transferred to the NT Government.

The EPBC Act-offset policy (DSEWPaC 2012) was considered when assessing whether the conservation area would be suitable habitat for the loss of habitat for Black-footed Tree-rat at 2CRU (

Table 61). The data used to characterise the offset site is considered to be conservative. Nonetheless, the conservation area achieves more than 100% of the required offset for loss of Black-footed Tree-rat habitat at 2CRU (

Table 61).

As the rezoning of the conservation area was undertaken to facilitate the residential development of the project site, and was done voluntarily by the proponent, it is considered to meet the 'additionality' requirement of an offset site in accordance with the EPBC Act offset policy (DSEWPaC 2012). In addition, the rezoning process occurred in December 2015, and therefore conservation benefits have been delivered to Black-footed Tree-rat prior to the proposed impact occurring. As such, early rezoning of the conservation areas has increased the overall benefit of the offset site as outlined in the EPBC Act advanced offset policy (DoE 2016). These additional benefits have not been accounted for in the offset calculations below.

Management actions to be undertaken in the conservation area that will improve the overall quality of the offset site include:

- Rehabilitating informal access tracks
- Addressing erosion issues
- Planting Black-footed Tree-rats' preferred food plants in suitable locations
- Pest animal control
- Improved awareness of values of conservation area as part of broader signage programs for migratory shorebirds and threatened sawfish.

A suitably qualified environmental contractor will be appointed by DHA to implement these actions until the NT Government take responsibility for managing (and funding) the conservation zone. It has yet to be agreed when the NT Government will take ownership of the conservation area.

The management of the conservation area for offsets will be implemented in accordance with an approved offset management plan to be prepared in conjunction with Parks and Wildlife Service.

Table 61. Offset calculations for Black-footed Tree-rat habitat at 2CRU

	Factor	Value	Description
IMPACT CALCULATOR	Area (ha)	9.28	Loss of 5.53 ha patch adjoining Lee Point Road, as well as 50% of the area lost in the 7.5 ha (i.e. 3.75 ha) patch due to habitat modifications to comply with Biting Insect Management Plan.
	Quality (/10)	5	Averaged from components scores of: site condition (7/10), species stocking rate (4/10) and site context (4/10). Stocking rate is considered low given no animals were detected during survey in 2CRU. Site context is low as local population is considered to be isolated in Lee Point area and unlikely to be connected with other populations.
	Total quantum of impact	4.64	As per offset calculator
OFFSET CALCULATOR	Time over which loss is averted (years)	20	Maximum time allowed in accordance with the EPBC Act policy.
	Time until ecological benefit (years)	5	Rezoning, rehabilitation of informal tracks, replanting with food trees, fixing erosion problems, pest animal control are expected to deliver benefits to species within this time frame.
	Start area (ha)	21.95	Area of conservation area.
	Start quality (/10)	4	Conservative estimate for purposes of calculation. Species has previously been recorded in conservation area, and number of large trees present that would provide suitable denning resources. Dense areas of Monsoon Vine-thicket without large eucalypt or pandanus trees only marginal value.
	Future quality without offset (/10)	3	Conservative estimate for purposes of calculation. Illegal site access, ongoing pressure from existing users of Casuarina beach, plus erosion would contribute to decline in quality.
	Future quality with offset (/10)	6	Conservative estimate for purposes of calculation. Revegetation with preferred food plants, addressing erosion problems, formalising access tracks, would improve value of habitat.
	Risk of loss (%) without offset	20	Conservative estimate for purposes of calculation. Ongoing pressures from illegal site access, ongoing pressure from existing users of Casuarina Beach, pest animals and erosion threatens the viability of the proposed offset site.
	Risk of loss (%) with offset	5	Background rate of extinction.
	Confidence in result (%)	80	Conservative estimate for purposes of calculation. Rezoning process, managing impacts from beach users, formalising access tracks and revegetation are considered best-practice in or der to achieve intended ecological benefit.

The conservation area represents one of the few remaining, if not the remaining area of freehold land that is suitable habitat for Black-footed Tree-rat and can be used as an offset. An examination of the current land-uses and tenure of known Black-footed Tree-rat sites in the greater Darwin area identified all as either Crown land or Defence land that is therefore either already protected for conservation purposes or could not be realistically managed for conservation purposes (see Stokeld and Gillespie 2015 for further information).

7.5.2 Off-site offset

To offset the loss of Black-footed Tree-rat habitat in Muirhead North, it is proposed that a direct payment on a per hectare basis be made into a fund, or to a conservation group, that will be dedicated to undertaking management on crown land, that will provide direct benefits to Black-footed Tree-rat. Rangers from the Larrakia National Aboriginal Corporation have identified a suitable site at Cox's Peninsula. The area contains suitable habitat for Black-footed Tree-rat; however, is currently not being managed for conservation and is under threat from hire fire frequency, weeds (Gamba Grass) and pest animals (feral cat and pig). The proposed off-site offset will involve providing rangers from the Larrakia National Aboriginal Corporation with funding to implement a range of management actions to improve Black-footed Tree-rat habitat in accordance with an approved offset management plan. The offset management plan will be implemented over a ten-year period. The offset management plan will be developed prior to offset commencement and will directly address the key threats on site.

The location of the offset has not been finalised but will be approximately 100 hectares in size. The use of the EPBC Act calculator to determine the adequacy of the off-site offset proposal cannot be directly applied in this instance due to the land-tenure of the offset site. This is common for many offset proposals in the Northern Territory as the majority of land is lease-hold (although the project site is owned by DHA). Given the proposed on-site offset, which is 21.95 hectares in size, can address the loss of approximately one third of Black-footed Tree-rat habitat on site (Table 62), a 100 hectare off-site offset would adequately compensate for the loss of the remaining two-thirds of Black-footed Tree-rat habit.

Using the approval conditions for the Eastern Leases Project at Groote Eyland, Northern Territory (EPBC 2014/7228) as a precedent, a cash payment of $4,500 (exc GST) is proposed for every hectare of Black-footed Tree-rat habitat removed. Using the Eastern Leases Project as a precedent, a cash payment of $4,500 (exc GST). While the cash payment for the Eastern Leases Project was for all native vegetation removed (not just identified habitat), it was also to address impacts to two threatened species and the quality of native vegetation was much higher. Furthermore, no detailed habitat mapping for threatened species was undertaken for the Eastern Leases Project, whereas an accurate understanding of habitat for Black-footed Tree-rat has been provided for 2CRU and Muirhead North based on targeted camera trap surveys and detailed habitat assessments.

Payments will be made directly to the Larrakia Nation Aboriginal Corporation prior to each stage commencing, for an amount equivalent to the area of habitat to be removed.

The NT EPA and DoEE will be notified in writing prior to each stage commencing to confirm that payment has been made to the relevant management group.

The offset arrangement of paying compensatory fees will be finalised as part of the offset management plan.

7.5.3 Staging Strategy

Due to the staged nature of development, Black-footed Tree-rat habitat will be cleared progressively in accordance with the staging plan (Table 3). The area of Black-footed Tree-rat habitat that will be impacted by each stage has been calculated below (Table 62). The strategy for offsetting habitat is also shown. Removal of Black-footed Tree-rat will not commence until offsets are secured (i.e. for habitat loss in 2CRU), or

compensatory payments have been made in accordance with approved offset management plan (i.e. for habitat loss in Muirhead North).

Table 62. Alignment of Black-footed Tree-rat offset strategy with staging plan

Stage	Site	Estimated Start Date	Estimated Completion Date	Area of habitat (ha)	Offset Strategy
1A	2CRU	April 2019	November 2019	0.40	Onsite offset
1B	Muirhead North	April 2019	November 2019	5.10	Compensatory payments
2A	2CRU	March 2020	December 2020	0.47 (=0.93 x 0.5)	Onsite offset
2B	Muirhead North	March 2021	November 2021	12.37	Compensatory payments
3	2CRU	March 2022	October 2022	5.13	Onsite offset
4	2CRU	April 2023	November 2023	3.02 (=6.03 x 0.5)	Onsite offset
5	2CRU	March 2024	November 2024	0.26 (=0.52 x 0.5)	Onsite offset
Total				26.75	

8 SOCIAL ECONOMIC

8.1 Introduction

This chapter has been prepared to satisfy the socio-economic requirements of the ToR for the *Lee Point Master-Planned Urban Development* Environmental Impact Statement, and covers the required aspects from Sections 4, 5.6 and 5.7.8 of the ToR. The chapter has been prepared in accordance with the NT EPA's *Guidelines for the Preparation of an Economic and Social Impact Assessment* (NT EPA 2013).

The chapter is structured in the following manner:

- Background information on the relevant legislation, planning provisions, the Lee Point Master-planned Urban Development and key stakeholders that will be involved or impacted (positively or negatively) during the project (Sections 8.2 to 8.4).
- Description of the availability of community services, and workforce to support the project, any stresses the project is likely to project on to existing services, and the commercial and employment opportunities the project is expected to deliver (Section 8.5).
- A summary of the risks to social and economic factors and related mitigation measures, including stakeholder engagement and community strategy (Section 8.6).

Further information is provided in the CEMP about the proposed monitoring methods that will be undertaken to check that performance of the project meets the stated social and economic Key Performance Indicators.

8.2 Legislation

The following legislation and guidelines have been referenced in the preparation of this chapter:

- *Northern Territory Environmental Assessment Act*
- *Northern Territory Planning Act*
- *Northern Territory Environment Protection Authority Guidelines for the preparation of an Economic and Social Impact Assessment (May 2013)*
- *Queensland Department of Infrastructure and Planning Social Impact Assessment: Guideline to preparing a Social Impact Management Plan (September 2010)*
- *International Association for Public Participation Public Participation Spectrum (2014)*
- *Queensland Government Office of Urban Management (Department of Infrastructure) South East Queensland Regional Plan 2005-2026 – Implementation Guideline No. 5: Social Infrastructure Planning (June 2007)*
- *Parks and Wildlife Commission of the Northern Territory Casuarina Coastal Reserve Management Plan (April 2016)*
- *Parks and Wildlife Commission of the Northern Territory Casuarina Coastal Reserve Experience Development Plan (2015)*
- *Northern Territory Planning Scheme*
- *Northern Territory Department of Lands, Planning and the Environment Darwin Regional Land Use Plan 2015*

In addition to the above legislation and policy documents, a number of reports, studies and websites have been reviewed in the preparation of these reports, which are included in the reference list (Section 0).

8.3 Locality

The 2CRU and Muirhead North sites are situated in the area of Lee Point, between the existing and developing suburbs of Lyons and Muirhead (respectively), the Casuarina Coastal Reserve to the west of 2CRU and the Lee Point public recreation area at the northern end of Lee Point Road (comprising the northern extent of the Casuarina Coastal Reserve). Immediately north of Muirhead North is the Lee Point Village Resort, comprising a large caravan park including cabins and camp grounds, along with recently developed motel facilities concentrated in the northern portion of the site (adjacent to Buffalo Creek Road). Buffalo Creek Road, located opposite and slightly north of Muirhead North provides access to the mouth of Buffalo Creek, including boat ramp and trailer parking area.

To the south of the project site, the joint DHA/private residential suburbs of Lyons and Muirhead are located on the western and eastern sides of Lee Point Road respectively. Lyons comprises approximately 690 lots with Muirhead some 1,200 lots once completed. Stages 6 and 7 of Muirhead are currently under construction. A small local centre is identified for future development within Muirhead, located adjacent to the Lee Point Road frontage. Adjacent to the western boundary of Lyons is the Royal Darwin Hospital, Darwin Private Hospital and associated government and private health facilities. Further south are the suburbs of Tiwi, Wanguri and Leanyer.

Zoning within the greater locality comprises a mix of residential, accommodation, public, community and conservation zones. The project site is zoned FD (Future Development) per Clause 5.26 of the Northern Territory Planning Scheme. The FD Zone within the subject land links with the Lee Point Area Plan and Planning Principles within Clause 14.1.5 of the Scheme, which provide a framework for urban residential, commercial, tourism and community development within the project site, along with the protection of significant environmental and heritage qualities.

The Casuarina Coastal Reserve, which extends along the western boundary of 2CRU, is zoned CN (Conservation). To the south of 2CRU is the Royal Darwin Hospital, which is encompassed within Zone CP (Community Purpose). The suburb of Lyons is Zoned SD17 (Specific Use Darwin 17). Muirhead is zoned SD23 (Specific Use Darwin 23), with land adjacent to the eastern boundary zoned PS (Public Open Space). To the north of Muirhead North, land is zoned OR (Organised Recreation), reflective of current/future development as a golf course, with a small strip of PS land extending from Lee Point Road adjacent to part of the site's northern boundary. The Lee Point Village Resort is zoned CV (Caravan Park), with land further north comprising a combination of PS, CP and CN zones.

Commercial and recreation facilities within the broader locality include the Tracey Village Social and Sports Club, Casuarina shopping and commercial precinct, Hibiscus Shopping Centre and various small local shops.

Schools, early learning centres and childcare facilities in the greater locality include the Dripstone Middle School, Tiwi Early Learning Centre, Henbury School, Wanguri Preschool, Leanyer Primary School, St Andrew Lutheran School and the Holy Spirit Catholic Primary School. The majority, if not all, commercial and community facilities are outside of what would ordinarily be considered the immediate locality.

Both Muirhead North and 2CRU present to Lee Point Road as natural bushland with relatively minimal intrusion, and thus the amenity of the locality is moderate-high. The communications tower adjacent to the north-east corner of the project site is a prominent feature, with the southern portion of the Lee Point Village

Resort maintaining vegetation through established landscaping. Further north along Lee Point Road, the Resort is more sparsely vegetated due to the presence of hardstand areas and the recently developed motel facilities. Lee Point Road crests near the intersection with Buffalo Creek Road, and allows ocean views from this point onwards (to vehicles travelling north).

8.4 Lee Point Master Planned Urban Development

In late 2015, the Minister for Lands and Planning approved an amendment to the Northern Territory Planning Scheme to rezone the land to FD (Future Development) and introduce the Lee Point Area Plan into the Scheme. The amendment was proposed to facilitate the regulatory policy framework to allow the development of the area for the purpose of a new suburb, including residential, commercial, tourist accommodation, recreation, community, education and open space uses. Specifically, the amendment sought to:

- Introduce a land use/development zone under the NT Planning Scheme to the project site by zoning the land FD.
- Rezone lot 09370 from SD26 to FD (Future Development).
- Amend Part 8 of the Scheme to include the *Lee Point Area Plan and Planning Principles,* contained in Attachment B**,** in order to facilitate a master planned urban subdivision on the project site.

The Lee Point Area Plan will ultimately facilitate for the project site:

- Residential development at a range of densities and housing typologies to accommodate a mix of defence and private residents.
- The development of land for necessary and appropriate community services and facilities based on the existing and anticipated population within the subject land and surrounding areas.
- A mixed use 'neighbourhood centre' that will integrate tourism, commercial, community and residential development around a 'main street', whilst integrating with surrounding residential, community and open space development.
- A dedicated tourism precinct, including accommodation and tourism/community activities that integrate with the main street.
- Coastal view corridors and access to the Casuarina Coastal Reserve, whilst protecting the reserve from potential impacts arising from the development of the land.
- Development that responds to the characteristics and constraints of the site and surrounding land, including the coastal reserve, tourism and public space facilities, the Royal Darwin Hospital and existing residential areas.
- Due consideration to historically significant items within the subject land and the historic use and significance of defence operations.
- Integration with the surrounding road network, including safe, functional and efficient connections to Lee Point Road for all necessary forms of transport.
- A high quality open space network, including a high level of accessibility and connectivity for pedestrians and cyclists.
- Staging of development to align with population growth, the demand for housing and other facilities, and the provision of services and infrastructure.

The FD Zoning will enable the Lee Point Urban Development Master Plan to be finalised and an application for subdivision to reflect the final Master Plan to be lodged in accordance with the *Lee Point Area Plan and Planning Principles*. Upon the completion of the various stages of development within the site, the land will be rezoned in accordance with the relevant Planning Scheme Zone, likely to include (but not necessarily limited to):

- TC (Tourist Commercial) and C (Commercial).
- SD (Single Dwelling), MD (Multiple Dwelling), MR (Medium Density Residential) and HR (High Density Residential).
- CP (Community Purpose).
- PS (Public Open Space) and OR (Organised Recreation).
- CN (Conservation).

The draft planning principles seek to ensure the development of a distinctive neighbourhood environment that takes advantage of its coastal location, provides an integrated neighbourhood centre, includes tourism activities and accommodation, requires the appropriate provision of community services and ensures an emphasis on walking and cycling.

8.4.1 Residential Development

The majority of the Area Plan identifies land for residential development within the project site at General Urban and Suburban densities, in addition to residential development within the neighbourhood centre.

Nominal densities are provided based on net developable area (i.e. residential areas exclusive of open space, road infrastructure and community facilities), with the following density rates provided:

- *Urban Centre* – 60-80 dwellings per hectare, reflective of intended future development in the form of medium-high density housing as part of the mixed use neighbourhood centre.
- *General Urban* – 20-40 dwellings per hectare to facilitate a range of housing options including detached housing (single dwellings), duplex housing, units, townhouses, row dwellings and apartments at densities consistent with zones SD, MD and MR.
- *Sub-Urban* – 10-20 dwellings per hectare reflective of a more traditional sub-urban residential area, whilst retaining the ability to provide a range of housing options generally consistent with zones SD and MD. Small-lot housing (less than 400m^2), townhouse, unit and walk-up housing development to be concentrated in areas of high amenity and/or in close proximity to public open space.
- *Rural Residential* – Provision of housing development with minimum lot size of 4,000m^2 in accordance with Zone RR due to the need to retain the 1 kilometre biting insect buffer to urban development. Maximum dwelling densities of 5 dwellings per hectare is reflective of the ability for the development of *independent units* pursuant to Clause 7.10.4.

Based on the above density rates and servicing, it is anticipated that the project site will accommodate between 600 and 1,000 dwellings.

8.4.2 Community Purpose Land

The Area Plan identifies a *Primary School and Community Hub* at Muirhead North, comprising approximately 3.7 ha of land for community development, and an additional 2 ha as an *Active Recreation Reserve*. Fully-served lots to provide for the Primary School and Community Hub will be provided by DHA, while the NT Government will be responsible for construction of the buildings and other facilities.

The Lee Point Urban development is intended to facilitate the future provision of the following community and social infrastructure:

- Affordable housing, particularly for Defence personnel and key workers.
- Medical practitioner and/or allied health services.
- Two child care centres, each with 60 places with room for expansion.
- Integrated school/education facility comprising one primary school, integrated/collocated after school-hours care facilities, pre-school/long day-care/kindergarten.
- Community centre as a shared space with multiple rooms and flexible useability.
- Outdoor sports facilities including AFL/cricket oval, football (soccer) pitch, tennis and netball facilities.
- Local/neighbourhood parks and playgrounds.
- Neighbourhood shops.

The provision of a range of housing options, lot sizes and locations seeks to increase the affordability of housing in the northern suburbs of Darwin. Commercial space within the neighbourhood centre will be appropriately zoned to allow the development of land for convenience shopping needs and recreational retail (such as cafes and restaurants), as well as the development of a medical clinic, including general practice and allied health services.

It is anticipated this service would be provided by the private sector. Additional child care facilities outside of the community precinct could also be accommodated in the neighbourhood centre.

8.4.3 Commercial Development and Neighbourhood Centre

The Lee Point Area Plan proposes a main street neighbourhood centre expanding into the tourist accommodation and higher density residential areas. The main street is anticipated to accommodate a vibrant mix of retail servicing the local (and broader) community, along with occupants of accommodation facilities, with convenience shopping to complement the future Muirhead Centre. Retail areas within 2CRU are provided in close proximity to the community precinct, with appropriate urban design opportunities available to maximise accessibility and pedestrian traffic between the two.

In addition to accommodation, commercial and recreation-based retail development, the centre is expected to take advantage of the ability to combine residential and non-residential opportunities in accordance with Zone C (Commercial), including medium-high density residential uses above ground level. Varied building heights along the main street, from 4, to 8 to 12 storeys, along with the setback requirements for residential buildings within the Planning Scheme, will prevent overbearing built form and ensure the appropriate transition of scale to urban residential areas. Mixed use development incorporating residential areas will

extend the vibrancy and viability of the neighbourhood centre beyond daylight hours and outside of the peak tourist season, and increase opportunities for a range of housing options to be collocated with goods and services.

8.4.4 Street Network and Open Space

The Lee Point Area Plan establishes the intent for a primary road network that enables efficient access to and between all areas of the estate, with connections to Lyons, Muirhead and the primary connection to Lee Point Road. The intention for primary pedestrian and cycling routes are also demonstrated, including along Lee Point Road, and along the Coastal Esplanade. The coastal esplanade is intended to provide a shared route integrated with a lineal open space along the western side, providing a cleared separation between development areas and the coastal reserve. Beyond the esplanade and lineal open space, the existing coastal reserve boundaries will extend into 2CRU to align with the open space and drainage reserve (in the southern portion).

Road connections heading west from Lee Point Road are generally aligned perpendicular to the coast to allow the creation of focal points at the western extent of the site. The main street will provide an efficient connection to Lee Point Road to encourage vehicles into the neighbourhood centre, whilst retaining fluid vehicle movements for those visiting destinations further north, including the Lee Point Village Resort, Lee Point coastal area and the Buffalo Creek boat ramp. An open space area at the Lee Point Road entrance to the neighbourhood centre signifies the desire to establish an entry statement to the site.

Primary street connections into Muirhead North seek to reaffirm the community hub as the focal point east of Lee Point Road by indicating roads to the north and south from Lee Point Road. The importance of safe controlled intersections to Lee Point Road, with a particular emphasis on pedestrian and cycle movement, is identified in the area plan. Vital connections to Lyons and Muirhead have been identified to increase accessibility to existing residential areas, and to increase accessibility to future commercial and community land.

Discussions with the Public Transport Division within the Department of Transport have led to the development of a bus route that connects to the existing Lyons service through Damabila Drive, along the coastal esplanade and back along Lee Point Road, ensuring the provision of public transport services within 400 metres of the majority of residential areas, and direct public transport services to the centre and the community hub.

The majority of open space in the form of local and neighbourhood parks will be provided as part of a master plan/subdivision proposal in accordance with the requirements of the Planning Scheme. The Lee Point Area Plan identifies open space areas critical to the development of Lee Point due to their role:

- In the establishment of view corridors and areas of high amenity.
- As part of a broader community benefit (such as the coastal esplanade and additional coastal reserve area).
- Due to a critical design importance (neighbourhood centre entry statement).
- Broader community purpose role (active recreation space).

  OR

- Service/infrastructure role (drainage reserves).

Open space on the eastern side of the proposed coastal reserve boundary within 2CRU would be developed as formal, lineal open space. Land to the west of the boundary line would remain in its natural state, with the possible inclusion of a beach access trail, appropriately located, constructed and limited to preserve the integrity of the expanded coastal reserve.

8.4.5 Stakeholder Overview

8.4.5.1 Key Stakeholders

The project will proceed via an arrangement between the two primary stakeholders, being DHA and the Northern Territory Government, with DHA the landowner of 2CRU, and the Northern Territory Department of Infrastructure, Planning and Logistics (DIPL) the controlling agency of Muirhead North. Defence Housing Australia provide housing and related services to Defence members and families, including the acquisition and development of land, construction and house purchasing.

In addition to the primary stakeholders, there are a number of key agency stakeholders to which the proposal will provide infrastructure that will require ownership and management and/or has the potential to directly impact on land under the control of the relevant agency. These stakeholders include:

- Larrakia Development Corporation and Larrakia National Aboriginal Corporation, representatives of the Larrakia people who are the traditional owners of the project site.
- City of Darwin as the relevant local government body, including the responsible agency for local roads, stormwater systems and public open space.
- Northern Territory Parks and Wildlife Commission as the agency responsible for the Casuarina Coastal Reserve.
- PWC as the agency responsible for the ownership and maintenance of reticulated electricity, potable water and sewerage services within the Northern Territory.

In addition to the above, there are a number of agencies, commercial and community stakeholders who have an approval or regulatory role, may have a non-commercial or direct stakeholder interest in the site or may stand to benefit from additional development and/or population growth within the area, including:

- Larrakia people as traditional owners.
- Northern Territory Department of Health, including the Royal Darwin Hospital.
- Users of the Casuarina Coastal Reserve, including the Buffalo Creek Boat Ramp.
- Existing Darwin residents and landowners, particularly those within Lyons and Muirhead, including those residents in the northern section of Lyons, close to future development.
- Owners, staff and guests of the Lee Point Village Resort and Club Tropical Resorts.
- Northern Territory Department of Land Resource Management.
- Northern Territory Environment Protection Authority.

- Northern Territory Department of Transport.

8.4.6 Consultation

Defence Housing Australia and those engaged by DHA have undertaken a range of consultation activities with stakeholders to inform and seek input into the proposed development. Consultation has included:

- Stakeholder workshop (10 April 2014) with relevant government agencies and service authorities. Inform and involve ensuring input into the development master plan.
- Stakeholder workshop (30 July 2014) with relevant government agencies and service authorities. Presentation of draft concepts, inform and seek feedback as input into the advancement of the development master plan.
- Community workshop at the Lyons Community Centre. Inform and involve to ensure community concerns are adequately understood and considered in the planning process.
- Community infrastructure workshop with identified stakeholders to identify community and social infrastructure requirements (19 June 2014). Inform and involve relevant stakeholders to define required social and community infrastructure based on projected population growth.
- Consultation with representatives of the Larrakia people including the LDC and LNC (13 March 2018).
- Parks and Wildlife Commission (14 March 2018).

In addition to consultation undertaken by and on behalf of DHA, statutory consultation has also occurred as part of the submission to the Minister for Lands and Planning to amend the Northern Territory Planning Scheme, including:

- Public exhibition of proposed Planning Scheme Amendment, including all application documents, in accordance with Part 2 of the Northern Territory Planning Act, between 21 November and 19 December 2014. Exhibition included on-site yellow notification signs, NTNews and online advertisements and direct notification.
- Consideration of all matters raised in submissions received per the above exhibition. Detailed response to all issues raised, further environmental and servicing investigations in response to issues raised, and amendments to master plan, area plans and nature of proposed Planning Scheme Amendment in response to specific issues.
- Reporting Body Hearing, conducted by the Darwin Division of the Development Consent Authority, to obtain feedback, hear the applicant's response and provide a report to the Minister for Lands and Planning.

8.5 Existing Conditions and Project Impact

8.5.1 Community Structures and Vitality

8.5.1.1 Social Demographics and Development Impact

Demographic data was sourced from the Australian Bureau of Statistics (ABS) database, including population, employment and economic data from the 2011 census, as well as 2012, 2013 and 2014 where available.

The project site is located in the ABS division of Lyons, encompassing the residential suburbs of Lyons and Muirhead, the northern portion of the Casuarina Coastal Reserve, Lee Point and immediate surrounds. The greater Darwin Statistical Region is used for comparison. According to the ABS Region Profile, relevant demographic characteristics of the Lyons region include:

- A total population in 2014 of 2,933 persons, comprising 1,417 (48.3%) females and 1,516 (51.7%) males, with a median age of 29.2 years. The ratio of females to males within Lyons is generally consistent with greater Darwin, with 47.5% females and 52.5% males. Lyons accommodates a younger population than Greater Darwin, which has a median age of 33.1 years.
- Based on the population estimates between 2010 and 2014, population growth within the Lyons statistical division is well above the regional average, averaging approximately 12.65% growth per annum compared with 2.34% for Greater Darwin. This increase is likely due to the growth suburbs of Lyons and Muirhead, which comprise a significant portion of the statistical division.
- A population density of 416.6 persons per km^2 compared to 44.4 persons per km^2 for Greater Darwin. The lower figure reflects the range of suburb and locality types in Greater Darwin (i.e. non-residential areas, rural areas, etc.).
- In 2011 (limited by the availability of data), household types overwhelmingly consisted of family households, with approximately 12.36% of households consisting of lone person or group households. The average household size in 2011 was 3.1 persons compared to 2.7 persons for the Greater Darwin Region. The larger household size for Lyons is likely due to the predominance of low and medium density housing rather than low, medium and high density housing for Greater Darwin.
- At the 2011 census, Aboriginal and Torres Strait Islander people within Lyons as a proportion of the total population was well below that for Greater Darwin, at 3.2%, compared to 9.2%;

Based on the areas identified within the Lee Point Master Plan, and using the density rates within the Lee Point Area Plan in Clause 14.1.5 of the Northern Territory Planning Scheme, the Lee Point Master-planned Urban Development is likely to be developed with between 600 (low range) and 1,000 (high range) dwellings, comprising a mix of detached and attached housing. For the purpose of determining the likely population, a projected density at the high range is taken.

A range between the average household size for Greater Darwin and the Lyons statistical division is considered appropriate. The higher average household size for Lyons is reflected by the relative lack of apartments and medium-high density living, and is unlikely to accurately reflect population projections for the Lee Point Master-planned Urban Development. Accordingly, the projected development profile for the proposal comprises:

- Approximately 1,000 new dwellings comprising a range of low, medium and medium-high density housing.
- Dwelling typology comprising approximately 700 detached and semi-detached dwellings, 270 apartments and 30 low density rural residential allotments (Muirhead North only).
- A projected residential population between 2,700 and 3,100 persons.
- Projected population cross-section consistent with that existing in the Lyons statistical division, including approximately 16.9% of residents aged between 5 and 14 years (between 456 and 523 persons), with some 3.7% of residents over the age of 65 (between 100 and 115 persons), and a median age of 30.1 years.

8.5.1.2 Health and Social Well-being

Lee Point is located in the northern extent of Darwin's northern suburbs, with a range of health care services and facilities easily accessible by private motor vehicle and public transport. The Royal Darwin Hospital and Darwin Private Hospital are located a short distance south of the project site. The hospital campus includes specialty health services such as the Alan Walker Cancer Care Centre, as well as medical research facilities such as the Menzies School of Health Research.

In addition to the hospital campus, there are a number of community and private-sector based health services available to the northern suburbs, including the Casuarina Community Care Centre, health and medical services provided by CDU, and the Casuarina Health Services Centre. Services include general practitioners, community health-care, specialist services, medical imaging and day surgery facilities.

Associated health facilities and services within the locality include:

- Carpentaria disability services
- Somerville Community Services
- Centre for Youth and Community Music (CDU)
- Headspace Darwin
- Healthy Living NT
- Danila Dilba Health Services.

A review of the capacity, normative- and identified need for the Lee Point area identifies a requirement for the provision of a general practice and allied health facilities (such as physiotherapy or dental) to provide an immediate service to new development areas, whilst there's sufficient capacity in existing community health precincts, hubs, centres and hospitals to accommodate the increase in population.

8.5.1.3 Education and child care

Approximately 15 child care centres are situated within the broader locality, albeit concentrated within the areas south of Lyons and Muirhead. A future commercial development within the suburb of Muirhead will include a child care facility to alleviate demand from Lyons and Muirhead residents; however, existing centres

are at or near capacity, and the likely high proportion of future residents in the project between the ages of 0 and 4 is likely to demand childcare facilities within the development, in addition to that proposed in Muirhead.

A number of public and private primary, secondary and specialty education facilities are accessible from the Lee Point area within a regional locality (i.e. in Darwin's northern suburbs in the area east of Rapid Creek). Public Pre- and Primary Schools include Wanguri, Leanyer, Malak, Nakara, Wulagi, Jingili, Alawa, Moil and Anula. Public secondary education facilities include the Dripstone and Sanderson Middle Schools, and the Casuarina Senior College. Specialty education facilities include the Nemarluk School and Henbury School, adjacent the Dripstone Middle School. Private education facilities include the Holy Spirit Catholic Primary School, St Andrew Lutheran School, Holy Family Catholic Primary School, O'Loughlin Catholic College and Marrara Christian School and College.

The CDU Casuarina Campus provides undergraduate, post-graduate and vocational education including in the faculties of law, business, arts, education, health, science and technology. There are also a number of institutes of advanced studies, including the Menzies School of Health Research, School of Social and Policy Research, the Research School of Environmental Studies, and the Graduate School of Health Practice.

Existing education facilities (particularly Public Pre- and Primary schools) are concentrated in the areas south of Lyons and Muirhead; thus, are poorly situated to accommodate increased demand from further population growth in the Lee Point area, in additional to housing and population increase in Muirhead. Discussions with the Department of Education (GHD 2014) indicates existing pre-school/long day care/ kindergarten facilities are at capacity, and located such that accommodation of increased population in the Lee Point area is unlikely to be feasible or appropriate. There is limited capacity at some local primary schools, with some space at existing sites for expansion; however, the distance to primary schools coupled with additional population in Muirhead is likely to create a shortage of current services. Existing secondary school facilities are currently at or near capacity; however, expansion of existing facilities with space available is likely to accommodate increased demand. Increased mobility of secondary school students indicates a greater ability to rely on an expansion of current services.

8.5.1.4 Conservation Areas and Recreation/Sporting Facilities

The Casuarina Coastal Reserve is located immediately adjacent to the western boundary of 2CRU, with the development including a proposal to increase the size of the coastal reserve to encapsulate and protect the fragile Monsoon Vine-thicket area. The reserve extends along the coastline from Dripstone Cliffs to Buffalo Creek. In addition to conservation areas, the reverse includes visitor facilities, open space/recreation areas, vehicle access and car parking, a boat ramp and the Darwin Surf Club.

The Casuarina Coastal Reserve, managed by the Northern Territory Parks and Wildlife Commission, remains the most popular Northern Territory Conservation/National Park by annual visits (with the exception of the federally-managed Kakadu National Park). The Casuarina Coastal Reserve receives 935,000 annual visits, with the vast majority of users being local to the Greater Darwin Area (Parks and Wildlife Commission of the Northern Territory 2016).

Assuming 80% of visits consist of Greater Darwin locals and an average of 5.33 annual visits per resident (based on 2014 population estimate), an additional 3,100 residents in the Lee Point area as a result of the project is likely to contribute an additional 16,517 annual resident visits, while there is likely to be 1,632 annual tourist

visits from accommodation areas. This combines to a total of an additional 18,149 visits to the Casuarina Coastal Reserve, or an increase in 2%, as a result of the Lee Point Master-planned Urban Development.

Other areas of public open space generally comprise neighbourhood and local parks and reserves, tailored for local and neighbourhood open space and recreation needs. The Tracy Village Sporting Complex includes multi-sport fields, indoor and outdoor function and recreation areas and licensed premises. The Marrara Sports Complex comprises the primary regional sporting facility and includes TIO Stadium, Darwin Football Stadium, Marrara Indoor Stadium, the Darwin Netball Association, as well as smaller ovals and courts for other sports. Gsnell Park is occupied by the Casuarina Public Swimming Pool, including toddler pools and swimming/lifesaving training. The Leanyer Water Park on Trower Road provides a large-scale community recreation water park.

8.5.1.5 Shopping, Commerce and Governance

A range of convenience, weekly and specialty shopping services are accessible from the Lee Point area. Neighbourhood and district-level centres, all including full-line supermarkets, are available at Leanyer (Hibiscus), Karama, Casuarina Village and Casuarina Shopping Centre (Casuarina Square). Casuarina Shopping Centre includes a major internalised shopping facility with discount department stores, specialty shops, eateries and commerce services (banking, insurance and health care).

Neighbourhood and district centres are supplemented by local centres at Tiwi, Wanguri, Wagaman, Wulagi, Moil, Jingili, Alawa and Malak. Lot 11847 (15 Fuhrmann Street, Muirhead) is a 9,760m^2 site within the latter stages of Muirhead, adjacent to Lee Point Road, which will be developed as a local centre with childcare facilities, improving the availability of commercial and community services to residents of Lyons, Muirhead and the Lee Point area. An application to the Darwin Division of the Development Consent Authority (DCA) has been lodged for the development of a commercial centre comprising a mid-line supermarket, a childcare centre, medical clinics, gymnasium and specialty shops and restaurants.

Government and additional community services are available in the Scaturchio Street locality of Casuarina, including Centrelink, the Northern Territory office of Consumer Affairs, employment services and the Northern Territory Civil and Administrative Tribunal offices and hearing rooms. The Casuarina Library is located on Bradshaw Terrace. Higher order judicial services are available in the Darwin Central Business District, including the Darwin Magistrates Court and Northern Territory Supreme Court.

Given the anticipated development of a neighbourhood centre at Muirhead, commercial development within the main street centre (identified in the Lee Point Area Plan) will comprise a mix of retail servicing the local (and broader) community, along with accommodation facilities. Convenience shopping will be limited so as not to compromise the level of service offered by the Muirhead Centre.

8.5.1.6 Emergency Services

Access to emergency services includes the Casuarina Police Station (approximately 4.4 km by road) within the broader locality, with the Peter McAuley Centre (9.8 km) providing administrative police services. St John Ambulance services are located in Dripstone Road (4.8 km), in close proximity to the Casuarina Shopping Centre. Fire and rescue services are located in Marrara (5 km), Berrimah (13.5 km) and Darwin (16.5 km).

8.5.1.7 Access to Services

Lee Point Road is a City of Darwin-controlled sealed single lane road (each-way) which connects directly with the road network throughout the northern suburbs. Further south of Lee Point, through the suburb of Wanguri, Lee Point Road has been subject to significant upgrades to improve traffic flow and facilities for cyclists and pedestrians. The City of Darwin will require these upgrades to continue north as residential development expands, and have established a Developer Contribution Plan to facilitate developer funding for upgrade works.

Services and facilities throughout the northern suburbs are generally easily accessible from the Lee Point area for private motor vehicles. Informal and 'nature' walking trails are available within the Casuarina Coastal Reserve, with upgrades to Lee Point Road improving formal access arrangements for pedestrians and cyclists.

8.5.1.8 Housing

Residential development within the Darwin's northern suburbs comprises mostly detached dwellings at average densities (lot sizes approximately 800m^2), with areas of medium density development at townhouse and apartment densities generally concentrated near commercial areas, community facilities (such as schools), public open space and public transport routes. Housing in the newer suburbs of Lyons and Muirhead is generally at marginally higher densities, with average land size for detached dwellings between 600 and 700m^2, and a higher concentration of multiple dwellings (15-20% of all dwellings), generally at townhouse densities (i.e. 1 dwelling per 300m^2). Built form includes a range of post-cyclone housing types, both ground-level and elevated homes. Development in Lyons and Muirhead is typical of newer estate homes, with strict covenants in both suburbs controlling the layout and appearance of built form.

8.5.2 Community infrastructure needs analysis

GHD were engaged in early 2014 to analyse the Lee Point Area Plan along with the surrounding population, and through a workshop process with relevant stakeholders identify specific demands for the provision of community infrastructure within the Lee Point Area.

Relevant stakeholders include community service agencies such as the Department of Education, Department of Housing, Department of Lands, Planning and the Environment, Department of Health, Department of Sport and Recreation and the City of Darwin (Department names have been changed since the 2016 Northern Territory Elections).

The report identified a need for the following facilities within the Lee Point area:

- Affordable housing, particularly for Defence personnel and key workers.
- Medical practitioner and/or allied health services.
- 1-2 child care centres, each with 60 places with room for expansion.
- Integrated school/education facility comprising one primary school, integrated/collocated after school-hours care facilities, pre-school/long day care/kindergarten.
- Community centre as a shared space with multiple rooms and flexible useability.

- Outdoor sports facilities including AFL/cricket oval, football (soccer) pitch, tennis and netball facilities.
- Local/neighbourhood parks and playgrounds.
- Neighbourhood shops.

Additional community purpose infrastructure was considered and discounted within the project site for the following reasons:

- Aged care/residential aged care/aged housing – service dependant on provision by the private sector.
- Community health precincts, hubs, centres and services – capacity in existing services.
- Hospitals – capacity in existing services/inappropriate location.
- Ambulance, Police and Fire – capacity in existing services/inappropriate location.
- Library – capacity in existing services/inappropriate location.
- Youth Centre – reliance on general community infrastructure.
- Middle school/high school – existing facilities to be expanded as required.
- Aquatic centre and indoor recreation centre – not required for local needs.
- Outdoor youth recreation facility – can be accommodated in local parks.
- District park – not required for local needs.

The outcomes of the Community Infrastructure Requirements are provided in Table 63 below. The facility type is identified, including the number existing within the local and district areas, comparative rate (based on existing population), normative need for the Lee Point Master-planned Urban Development, any identified need and the development approach.

The increased provision of a range of housing options, lot sizes and locations will likely increase the affordability of housing in the northern suburbs. Commercial space within the neighbourhood centre will allow development of land for convenience shopping needs and recreational retail (such as cafes and restaurants), as well as the development of a medical clinic, including general practice and allied health services.

It is anticipated that the medical clinic would be provided by the private sector. Additional child care facilities outside of the community precinct could also be accommodated in the neighbourhood centre.

A community precinct of approximately 5.7 hectares is indicated in the master plan in Muirhead North, and comprises 3.7 hectares of land for combined community and education facilities, and 2 hectares for organised recreation.

The community purpose site at Muirhead North covers an area of 3.5 hectares for combined primary school, after school-hours care facilities, pre-school/long day-care/kindergarten and child care facilities, with the inclusion of school-specific play space and sports facilities (such as a soccer pitch). An additional 2,000m^2 will allow the development of a community centre. The recreation site provides approximately two hectares of land for the development of larger organised recreation facilities, such as an AFL/cricket oval, tennis and netball courts.

More passive areas of public open space, such as neighbourhood parks and lineal shared paths, will be required at the rate of no less than 10% of the total residential area, and located within 400 metres of the majority of residential development, as per Clause 11.2.2 of the Northern Territory Planning Scheme.

The location of the community site at Muirhead North, whilst somewhat separated from the northern boundary of Lyons and Muirhead, will allow the integration of facilities within close proximity of the neighbourhood village by acting as a natural extension of the 'main street' identified in the Lee Point Area Plan. An appropriate design outcome will need to ensure connectivity in accordance with the Planning Principles within the Area Plan. Given the intended concentration of foot traffic between the centre and the community hub, the integration maximises accessibility and walkability for students, residents and the community. This location also permits the provision of community facilities in close proximity to higher density residential areas, and thus a greater concentration of population.

Table 63. Community Infrastructure Requirements (project site and Muirhead North site)

Facility Type	Existing	Comparative Rate	Normative Need	Identified Need	Approach
Aged Care					
Aged Care	4 local, 1 district	1:10,000 persons	Low need. Low proportion of incoming residents aged over 65 years. Increasing proportion of older people in district area.	Department of Health indicated that there is a need for local aged care in the northern suburbs with currently several aged patients in Darwin Hospital unable to find suitable housing and care in the community. Potential services could include respite care, personal home care and social support at both home or in a facility.	Provision of land led by demand from public/private sector, but unlikely to be required for local needs.
Residential Aged Care/Aged Housing	1 local	1:54,000 persons	Moderate need. Low proportion of incoming residents aged over 65 years but significant proportion of older people in district catchment.	Some Departments have identified need for aged housing particularly for low income residents. Limited aged housing in Northern suburbs.	Provision of land led by demand from public/private sector, but unlikely to be required for local needs.
Housing					
Affordable housing	Not applicable	Not applicable	High need. Defence households will require access to housing which is affordable. Key workers require access to affordable housing in Northern suburbs.	Rent paid by Defence households in DHA homes are required to be affordable. For non-Defence households, some Departments have identified need for affordable housing particularly for key workers e.g. nurses, teachers, retail workers etc. There was an agreement amongst Departments that a change in the range of housing types to increase density would assist affordability.	Range of housing types and lot sizes within development.
Healthcare					
Medical practice and General Practitioner including allied health services such as physiotherapy or chiropractor	10 local, 3 district	1:4,500 persons	Some need. Due to the high proportion of incoming children aged 0-12 requiring higher frequency medical care and preventative health services.	Department of Health indicated that a General Practitioner would be needed to service this new population.	One medical practice that could include allied health services. This service would be provided by the private sector.

Facility Type	Existing	Comparative Rate	Normative Need	Identified Need	Approach
Community Health Precincts, Hubs, Centres and Services	3 local	1:18,000 persons	Some need. Due to the high proportion of incoming children aged 0-12 requiring higher frequency medical care.	No need identified given the proximity to existing community health precincts.	Capacity in existing services
Hospital	1 Local	1:54,000 persons	Some need. Due to the high proportion of incoming children aged 0-12 requiring hospital services.	No need identified	Capacity in existing services
Emergency Services					
Ambulance	1 Local/District	1:27,000	Low need. Serviced by facility at Casuarina.	No need identified, however improved access for Ambulances was identified.	Capacity in existing services
Police	1 Local/District	1:27,000	Low need. Serviced by facility at Casuarina.	No need identified	Capacity in existing services
Fire and Rescue	1 Local/District	1:27,000	Low need. Serviced by facility at Casuarina.	No need identified	Capacity in existing services
Childcare					
Child Care Centre	8 local, 13 district	1:3,000	High need due to high proportion of incoming children aged 1-4 years.	Need for additional childcare centres as existing centres are at capacity.	Commercial and community land at Muirhead North will allow the provision of 1-2 child care centres with 60 places with opportunity for expansion.
Out of School Hours Care	10 local, 9 district	1:3,000	High need due to high proportion of incoming children aged 5-12 years.	After school care is an issue as service is at capacity and will be in high demand as more people move into the Muirhead area. Generally attached to schools.	One located on primary school site at Muirhead North.
Community Facilities					
Community Centre	3 local, 1 district	1:18,000 persons	High need. Due to large number of new resident requiring facility for	Need for additional community centre space should be considered as the existing facility at Lyons is well utilised.	One Community

Facility Type	Existing	Comparative Rate	Normative Need	Identified Need	Approach
			community building and social integration.	Departments agreed that it should be a shared space that included multiple rooms and the provision of affordable office space. It could also have a service attached to it with a lead tenant.	Centre at Muirhead North site.
Library	1 local, 2 district	1:18,000 persons	Moderate need. Due to significant number of children expected but estate will have broadband access	Casuarina library is a district facility which will service new residents.	Capacity in existing services.
Youth Centre	Unknown local, 3 district	1:18,000 persons	Moderate need. Due to the significant number of incoming and future youth aged 13-18 years.	Provision of outdoor space suitable for youth activities/program identified by Council.	Service model is to use general community infrastructure.
Education					
Pre-School, Long Day Care, Kindergarten	4 local, 3 district	1:8,000 persons	High need. Due to the high proportion of incoming children aged 0-4 years and significant need of preschool/kindergarten by Defence families.	Existing services at capacity and need identified for long day care an/preschool focused on early childhood education.	One located on school site at Muirhead North.
Primary School	6 local, 11 district	1:3,500 persons	High need. Due to the high number of incoming children aged 5-12 years.	Limited capacity at local primary schools with some space for expansion on existing sites. Could be part of a 'community hub' which includes long day care/preschool/kindergarten.	One primary School at Muirhead North
Middle School	4 local, 2 district	1:9,000 persons	High need. Due to the significant number of incoming children aged 13-17 years.	Existing school servicing local catchment is at capacity.	Existing middle school to be expanded as required.
High School	3 local, 1 district	1:14,000 persons	High need. Due to the significant number of incoming children aged 13-17 years.	No need identified.	Existing facilities to be expanded as required.
Recreation and Open Space					
Sports Field / Sports Ground	5 local, 3 district	1:7,000 persons	High need. Due to predominance of young children and young parents. Likely to be high sports participation.	Strong demand for sports field with potential for joint use with public school facilities. A football (soccer) field with junior pitch and a shared AFL and cricket oval were identified by Council and could be located on the school site.	One full sized AFL/Cricket oval, one full sized football (soccer) pitch and one junior size football

Facility Type	Existing	Comparative Rate	Normative Need	Identified Need	Approach
					(soccer) pitch integrated within school and recreation area at Muirhead North
Aquatic Centre	1 local, 1 district	1:27,000 persons	Low need due to existing pool at Casuarina	No need identified at a local level; however, Council is currently assessing the future of Casuarina Pool and this may create demand for a future district leisure centre.	Not required for local needs.
Indoor Recreation Centre	2 district	1:11,000 persons	Low need	No need identified at a local level. Opportunity exists to develop covered playground areas and indoor spaces for recreation at community centre or other indoor spaces.	Not required for local needs.
Outdoor Sports Courts e.g. tennis, netball	1 local, 3 district	1:18:000 persons	High need. Due to predominance of young children and young parents. Likely to be high sports participation.	Opportunity for parks to provide more activities for youth e.g. half basketball court. Tennis and netball courts were identified and could be located on school site with community access.	One or two tennis courts. One or two netball courts.
Playground/Play space	2 local, 1 district	1:18,000 persons	High need. Due to the high proportion of incoming children aged 0-12 years.	Need identified by government agencies for local playgrounds Opportunity exists to develop covered playground areas and indoor spaces for recreation at community centre or other indoor spaces.	Provided in accordance with NT Planning Scheme
Local Park	5 local, 3 district	1:7,000 persons	High need. Due to the high proportion of incoming children aged 0-12 years.	Need identified from government agencies for local parks.	Provided in accordance with NT Planning Scheme
Neighbourhood Park	30 local, 20-30 district	1:2,000 persons	High need Due to predominance of young children and young parents. Likely to be active and require outdoor activities.	Need identified from government agencies for a range of open spaces of varying size.	Provided in accordance with NT Planning Scheme
District Park	5-10 local, 5-10 district	1:5,500 persons	Moderate need. Due to predominance of young children and young parents. Likely to be active and require outdoor activities. However close to other district parks and beach.	No need identified	Not required for local needs
Shopping					

Facility Type	Existing	Comparative Rate	Normative Need	Identified Need	Approach
Neighbourhood Shops			Moderate need. Large incoming population of 6,000. Residents with need for local shops but Casuarina centre and others located within driving distance.	There is agreement amongst agencies about the need for local shops particularly on major transport routes and within walking distance.	Appropriately zoned and serviced land for local supermarket, café and local speciality shops on the project site.

8.5.3 Economic and workforce considerations

8.5.3.1 Economic demographics

The 2014 release of the NT Population Projections for the Greater Darwin region (comprising Darwin City and the suburbs of Palmerston and Litchfield) identifies that the population of Greater Darwin is expected to increase to 172,271 persons by 2026. In 2011, the Census measured a total population of the Greater Darwin region of 129,106. The 2014 estimates increased this existing population to 140,386. In order to provide for this population, and based on current occupancy rates in the Greater Darwin region in 2011 of 2.7 persons per dwelling, an additional 1,066 dwellings will be required each year. The historic rate of population growth is strong in comparison to other cities and Australia as a whole, and future projections anticipate the rate of growth to average 2.1 percent per annum to 2016, before slowing to 1.8 percent per annum to 2026.

The requirement for an additional 1,066 dwellings per year aligns with the forecast short-term (i.e. 5 year) requirement for 5,700 dwellings per the Darwin Regional Land Use Plan (DRLUP). The difference is likely due to the DRLUP accounting for any existing shortfall as well as housing to accommodate growth. The DRLUP anticipates the location of these dwellings as per Table 64 below. Development of the project site is considered as part of the greenfield development in the Darwin Northern Suburbs.

Table 64. Darwin Regional Land Use Plan (2014)

GREENFIELD	DWELLINGS
Darwin Northern Suburbs	680
Palmerston and Litchfield	2,220
Sub-total	2,900
Infill	**Dwellings**
Darwin CBD	930
Darwin Inner Suburbs	800
Darwin Northern Suburbs	360
Palmerston and Litchfield	770
Sub-total	2,800
Total	**5,700**

Greenfield Development in Darwin's Northern Suburbs aligns with the remaining development in Muirhead and the first 3-4 stages of the development at the project site that is likely to occur within the short term. The above confirms the importance of residential development within the Lee Point area, in addition to infill areas (for example Berrimah Farm) and greenfield areas (including Palmerston East) to meet the projected short term housing demands.

The 2013-14 mid-year economic report by the NT Treasury states that in 2012-13, the NT economy grew by 5.6 percent, the highest level of economic growth of all States and Territories and well above the national economic growth rate of 2.6 percent.

The report states:

> *"The strengthening economy was mainly driven by business investment, reflecting construction work on major projects, robust household consumption growth and improvement in the Territory's goods trade surplus.*

The outlook for economic growth to remain buoyant at 5 percent in 2013-14, increasing to 7 percent in 2014-15, driven by higher levels of construction activity and household consumption that will more than offset the forecast contraction of public expenditure.

Economic growth is expected to slow in 2015-16 and 2016-17 as construction activity related to INPEX and Total joint venture Ichthys project passes its peak.

As the Ichthys project moves from the construction to the production phase, the export sector is forecast to underpin Territory economic growth from 2016-17… A strengthening in local economic conditions is expected to flow through to stronger growth in population and employment. The Territory's rising population is expected to be driven by increased direct workface requirements of major projects and indirectly due to increasing levels of economic activity. From 2015-16 onwards, employment is forecast to moderate reflecting the transition of the Ichthys project to the less labour-intensive production phase.7" (Northern Territory Government 2013, P2).

Although both population and economic projections are forecast to somewhat moderate following the completion of the construction periods of major projects in the region, overall population growth and housing demand is expected to continue. The recent focus on *Developing Northern Australia* (Commonwealth of Australia 2015) provides confidence of future investment and focus in utilising the strengths and advantages within the region, particularly the region's proximity to Asia for trade and defence purposes.

Domain (2016) reports that the median house price in Darwin in the 12 months to September 2016 is $587,000, identifying that despite an easing of property prices in the last 24 months, Darwin remains one of the most expensive cities to buy property. The proposed development of the project site is likely to improve housing affordability both through an increase in supply and the provision of alternative housing options in addition to more traditional options prevalent throughout the northern suburbs. Any improvement in housing availability must occur in a location with an appropriate level of access to existing community health facilities and regional centres, as well as the provision of neighbourhood-level community, commercial and open space facilities equal to the increased demands of the locality.

A search of real estate marketing websites identified 195 detached dwellings (realestate.com.au 2016) available for sale within the northern suburbs west of Rapid Creek, with 58 apartments/townhouses (realestate.com.au 2016) available for sale. Within the same area, a total of 114 detached dwellings were available to rent, with 70 apartments/townhouses available (realestate.com.au 2016). SQM Research (2016) identifies Darwin Vacancy rates at 3.1% in September 2016, slightly up from August 2016 (3.0%) and relatively steady (slight decrease) compared with the vacancy rate in September 2015 (3.3%). The Darwin vacancy rates are slightly higher than the national capital city average of 2.4% for the same period. The same report identifies a price reduction in rental asking prices in the last 12 months to September 2016, with a reduction of 4.8% for houses and 3.5% for units. The report concludes that *"rents remain under pressure in Darwin too as the mining downturn weighs on demand"*. Prior to June 2016, vacancy rates were recorded by SQM Research (2016) around 4%, indicating a tightening of vacancy rates and indicative of a cyclical event over the last three years (Australian Broadcasting Corporation 2016).

Labour force participation in Lyons was notably above that for Greater Darwin, at 76.6% compared with 68.7%. Likewise, full youth engagement in either work or study was well above the regional average, at 83.6% compared with 69.6% for Greater Darwin. Median income is $64,868 compared with $87,617 for Greater Darwin.

8.5.3.2 *Project Costs and Revenue*

Based on the anticipated development outcomes in Section 8.5.1.1, the Lee Point Master-planned Urban Development is anticipated to provide between 740 to 760 residential lots, apartment blocks and lots for community and commercial development. With an average subdivision construction cost equivalent to $125,000 per eventual dwelling, overall construction cost is likely to be in the region of $125 million. Of this, 10% ($12.5 million), is likely to consist of consultant and design fees, with the remainder comprising construction and works. In context, the development of the Zuccoli Aspire estate comprises 408 lots, whilst the Zuccoli Village is 830 lots. The Northcrest residential development at Berrimah Farm has just been granted development approval for stage 1 (144 lots), with 2,000 lots anticipated upon completion. With the exception of Northcrest, which is likely to attract significant headworks upgrades, construction costs for the comparable Palmerston East projects are likely to be comparable to those for the Lee Point Master-planned Urban Development project. The proposed Noonamah Ridge rural residential project anticipates more than 4,000 lots upon completion, albeit at rural densities.

In addition to design and construction costs applicable to the project, there will be costs associated with external infrastructure upgrades, headworks, application fees and capital work (Table 65). With an anticipated average lot sale price equivalent to $350,000 per eventual dwelling, the Lee Point Urban Development is expected to add approximately $350 million to the Northern Territory Economy.

Construction is expected to commence mid-2018, with completion in consistent staging over the course of 7-8 years, thus allowing for approximately 140-150 dwellings per year. Accordingly, the project is expected to contribute to the Northern Territory economy and provide employment benefits in the short to medium term.

Table 65. Capital expenditure costs associated with the Lee Point Master-planned Urban Development project

Trunk Water Main	
Environmental	$10,000
General Requirements	$125,000
Water main excavation and backfill	$780,000
Pressure main construction	$1,365,000
Total	$2,280,000
Upstream and Downstram Capital Works	
DCP COD cost Lee Point Rd	$1,543,000
DCP PWC pressure booster	$1,200,000
DCP PWC Sewer pump station	$300,000
PWC HV	$1,400,000
Total	$4,443,000
Headworks Cost – External	
DCP COD cost Lee Point Road/MHN	$1,236,175
DCP PWC sewer pump station MHN	$200,000
Total	$1,436,175
Local Authority Costs external – project site	
Planning application fees	$21,868
COD application fees	$462,915
PWC application fees	$43,155
Landscape application fees	$75,000
Total	$602,938

local authority costs external – muirhead north	
Planning application fees	$12,408
COD application fees	$370,852
PWC application fees	$39,450
Landscape application fees	$45,000
Total	$467,710
Other External Contributions	
DHA spend on Casuarina Coastal Reserve (in exchange for Muirhead North)	$1,250,000

8.5.3.3 Workforce

As a large subdivision project including housing, commercial, accommodation, community services and infrastructure construction, development of the project site is expected to provide significant employment benefits to the Darwin region. The employment benefits will be experienced both directly through the infrastructure and subdivision construction works (external to the developer in the form of building construction and development of on-sold allotments), and indirectly in the form of services and employment opportunities in the community, tourism and commercial areas. In addition, peripheral industries, such as building material and tool suppliers, furniture suppliers, landscaping and plant supplies are also likely to benefit from the project.

The Lee Point Master-planned Urban Development project is expected to provide a direct employment benefit through the creation of full-time positions for approximately 150 persons for the duration of construction works.

In addition, approximately 70 sub-contracts will be required, each of which is likely to require between 1 and 4 persons. In relation to external employment benefits, i.e. housing construction, the Housing Institute of Australia forecasts the commencement of 1,490 dwellings in 2017, 1,520 in 2018 and 1,780 in 2019 (Housing Industry Association 2016). Based on the annual dwelling construction identified in section 8.5.2, construction within the project site is likely to comprise between 8 and 10% of construction activity within the Darwin Region. In February 2016, the construction industry employed approximately 15,300 persons within the Northern Territory. Allocating an appropriate proportion to the Darwin Region (63%), the project is likely to provide a direct employment benefit to the construction industry of between 771 and 964 jobs (of which 60% is assumed to be derived from the project site).

Given the strong civil and building construction industry within the Darwin Region, and the nature of civil and construction development works consistent with other new urban estates within the Darwin Region, it is anticipated that there will be a sufficient skill set available within the Darwin region without the need for external recruitment. The commencement of the project, beyond the Inpex construction period and the completion of Muirhead, will ensure that appropriate resources are available.

Long-term, the Lee Point Urban Master-planned Urban Development project is likely to provide permanent indirect employment benefits to the following sectors:

- Electricity, Gas, Water and Waste Services

- Retail Trade
- Accommodation and Food Services
- Information Media and Telecommunications
- Financial and Insurance Services
- Rental, Hiring and Real Estate Services
- Education and Training
- Health Care and Social Assistance
- Arts and Recreation Services.

The largest indirect employment benefits are likely to be gained by the accommodation and food services sector (due to the proposed accommodation precinct), and the education and training sector (due to the proposed primary school).

The accommodation precinct within the project site will provide 1.3% of available short term accommodation within the Northern Territory, and 5.5% of short term accommodation within the Darwin Region (Tourism NT 2017). Based on the August 2016 accommodation and food services sector employment predictions (ABS 2016), the Lee Point Master-planned Urban Development project will provide 117 full and part time accommodation and food service positions. Education facilities are likely to contribute approximately 40 full and part time positions. In addition, there are expected to be smaller benefits within the project to permanent retail, landscape and maintenance, community service and trade employment.

In addition to direct and indirect employment benefits, both the construction process and establishment of the Lee Point Master-planned Urban Development project is likely to benefit education and training through the provision of additional apprenticeship, certificate and on-the-job training opportunities. Defence Housing Australia actively encourage local industry participation and include local input weighting in tender contracts, with specific requests made for local input and/or local emphasis. The project will also present new small business opportunities in the hospitality and retail sectors.

Defence Housing Australia has provided a number of education, training and employment benefits to Indigenous Australians, including the Breezes Muirhead Aboriginal Landscape Education Program (DHA 2016), along with required indigenous participation and training objectives for DHA tender invitation and expression of interest requests (for example, *Expression of Interest for Upgrades and Minor Works to Defence and DHA Homes* – DHA 2013*).* These initiatives will continue into the development of the project site, with corresponding benefit to indigenous participation, training, education and employment.

The Breezes Muirhead Aboriginal Landscape Education Program was developed with Greening Australia Northern Territory, and comprises an indigenous training program with a practical component based around the Muirhead development site as well as the Greening Australia Native Nursery. This program provides trainees a rare opportunity to gain hands on experience in a commercial setting, emphasizing the need for quality and efficiency in production and task performance. During the Muirhead development, the program saw over 49 entrants, 70% rate of progress to further employment/education, and 67% of participants achieving a Certificate 1 in Horticulture. The same initiative will be implemented during development of the

project site, with the LDC engaged to assist with seed collection, translocation of Darwin Cycads and revegetation works.

There will also be other employment opportunities for the Larrakia people to assist with implementing the management actions detailed in the biodiversity and heritage section (Chapter 7). Defence Housing Australia has committed to engaging the LDC to undertake heritage monitoring during clearing works and prepare interpretive signage, while rangers from LNAC will implement the off-site offset program.

8.5.3.4 Commercial Development

A retail analysis for the Lee Point Urban Development project and locality prepared by Deepend Services in July 2014, reviewed the likely demand and locational aspects of retail floor space within the new development, particularly in the context of the planned retail space adjacent to Lee Point Road in the Muirhead subdivision.

The report concluded that likely retail demand would be limited to convenience shopping facilities and services in the vicinity of 400m^2 combined convenience retail floor space, in order to complement the recently approved floor space of the Muirhead Centre. This floor space is in addition to more tourism or recreation-based retail, such as restaurants and cafes to be located within the project site.

Accordingly the main street is anticipated to accommodate a vibrant mix of retail servicing the local (and broader) community, along with occupants of accommodation facilities, with convenience shopping to complement the expanded (once development occurs) Muirhead Centre.

The location of the land set aside for the Muirhead Centre, more central to surrounding Lyons and Muirhead populations, will better facilitate larger convenience shopping facilities. As recommended, retail areas within the project site are provided in close proximity to the community precinct, with appropriate urban design opportunities available to maximise accessibility and pedestrian traffic between the two.

In addition to accommodation, commercial and recreation-based retail development, development of the project site is expected to take advantage of the ability to combine residential and non-residential opportunities in accordance with Zone C (Commercial) of the Northern Territory Planning Scheme, including medium-high density residential uses above ground level. Varied building heights along the main street, from 4, to 8 to 12 storeys, along with the setback requirements for residential buildings within the Northern Territory Planning Scheme, will prevent overbearing built form and ensure the appropriate transition of scale to urban residential areas. Mixed use development incorporating residential areas will extend the vibrancy and viability of the neighbourhood centre beyond daylight hours and outside of the peak tourist season, and increase opportunities for a range of housing options to be collocated with goods and services.

8.5.3.5 Tourism Development

In September 2013 the Northern Territory Government established targets for growth in the tourism sector, and identified a demand for an additional 1,660 accommodation rooms to 2020, with current trends suggesting a demand ratio for additional accommodation rooms in the CBD equal to 75% of total demand (Tourism NT 2013). Accordingly, it is anticipated the tourist commercial area will accommodate 150-200 accommodation rooms initially, increasing to 300 rooms over time. The Tourism NT Profile for the year ending

2015 indicates a total of 766,000 visitors to the Northern Territory during 2015, a small (less than 0.2%) growth from 2014. Visitors equated to a total of 6.693 million visitor nights during 2015.

Tourism NT also reports an average Darwin accommodation occupancy rate of 68% for year ending June 2016, a reduction from previous years due to the combination of a softening tourism market and increased accommodation supply. Adopting a conservative estimate for the purpose of determining likely visitor numbers as part of the social impact assessment, a higher rate approaching 2013 highs of roughly 80% occupancy has been taken in this instance. With up to 200 rooms initially, the tourism precinct within the project site could accommodate some 58,400 visitor nights per year, increasing to 87,600 over time (based on an anticipated provision of up to 300 rooms).

Members of the Larrakia people currently run cultural tours around Darwin including in the Lee Point area. The tourism precinct will provide opportunities for the Larrakia people to further market their tourism businesses and improve demand for their services.

8.5.3.6 Affordable Housing

Housing affordability has become a critical issue for Darwin accommodation. Although affordability issues have subsided with the easing of the Darwin housing market and a reduction in property prices and rents, a forecast steadying of the housing market and anticipated growth into 2017 and 2018 suggests that the provision of affordable housing options will continue to be critical in ensuring equitable accommodation levels across all sectors of the community.

The Lee Point Master-planned Urban Development project will provide a mix of 1/3rd Defence Housing rentals with the remaining properties released to the private owner/occupier and rental market. Defence Housing Australia provides significant rent subsidies to Defence personnel, with housing types provided based on intended occupant types (e.g. singles, couples or families).

The range of dwelling density rates identified in the Lee Point Area Plan will ensure a range of dwelling types and lot sizes are available at a range of prices, with apartments, townhouses and smaller residential lots more affordable than the larger SD and rural residential (>4,000m^2) lots. The inclusion of single dwelling lots (in accordance with NT Planning Scheme Zone SD), small lot residential development and townhouses (Zone MD), medium and medium-high density apartments (in accordance with Zones MR and HR) will ensure a range of detached, attached and apartment dwellings

8.5.3.7 Visual and Social Amenity

In addition to active social and community infrastructure, the project site will provide a number of passive social and amenity features available to residents and workers within the project, as well as benefitting the general public. Part 5 of the Northern Territory Planning Scheme provides minimum requirements for the provision of public open space within residential subdivisions, and includes design criteria regarding the form and useability of open space. The City of Darwin's *Subdivision and Development Guidelines* provide further detail on the internal design, servicing and provision of exercise and play equipment, as well as the provision of shared pedestrian and cycle paths and the achievement of full pedestrian connectivity throughout urban areas. The subdivision and development guidelines also cover the provision of street and open space lighting,

landscaping of verge areas and disabled access. The design of subdivision works in accordance with both the Planning Scheme and the Subdivision and Development Guidelines will ensure the appropriate provision of community infrastructure.

No formal access currently exists from Lee Point Road between the area immediately north of the project site and the walking cycling paths from Rocklands Drive. Whilst there are a number of informal walking and cycling paths to the rear and through the hospital, and from the northern section of Lyons, the development of the project site will include a new access to the Casuarina Coastal Reserve, coinciding with the western end of the main street precinct.

Access will be designed in a manner that minimises disturbance to the escarpment, sand dunes, and migratory shorebirds (see Section 7.3.1) and provides a benefit not only to residents and visitors to the Lee Point area, but also to residents of Lyons and Muirhead, and members of the public whose primary purpose in visiting the area is utilising other facilities (for example Lee Point, the Buffalo Creek Boat Ramp and the caravan park).

Residential development within the subject land will supplement the availability of housing within Darwin's northern suburbs, and increase housing options through innovative and varied dwelling design techniques. The provision of climatically appropriate and distinctive row housing, units, townhouses and apartments, along with alternative infrastructure and street connection opportunities, such as rear-lot vehicle access, will have a corresponding benefit on neighbourhood amenity. Defence Housing Australia's commitment to climate responsive design is evident by the design covenants in the Breezes Muirhead estate, with a focus on small lot housing with a corresponding reduction in energy consumption (Safarova 2016). This innovative approach to environmentally sensitive housing has been recognised by the industry with a number of awards, including:

- 2016 Urban Development Institute of Australia (UDIA) Northern Territory Award for Environmental Excellence
- 2016 UDIA Northern Territory Awards for Innovation in Design
- 2015 UDIA Northern Territory Award for Excellence in Masterplanned Development
- 2015 UDIA Northern Territory Award for Excellence for Environmentally Sustainable Development.

It is expected that a similar approach will be adopted for the Lee Point Master-planned Urban Development project.

Development of the project site comprises a large residential subdivision and urban development over a period of 7-8 years. As such, the existing landform will be altered due to the clearing of vegetation, earthworks and drainage works, construction works comprising the installation of and upgrade to service infrastructure, landscaping and built form construction. Landform alteration to the extent proposed will alter the nature and character of the locality, and has the potential to affect public amenity (i.e. visual, sound and traffic) during construction.

The extent of amenity impacts during the construction period will be subject to the management and phasing of construction activities, and the layout, design and implementation process.

Defence Housing Australia has identified the potential for critical amenity impacts and determined appropriate management responses. Specific measures incorporated into the design and construction process will minimise amenity impacts, both visual and otherwise, including:

- Adherance to the built form requirements of the Northern Territory Planning Scheme, including the Lee Point Area Plan, which seeks to limit densities adjacent to existing residential areas in the north of Lyons and Muirhead, with increasing density and building height towards the centre of the project site. The NT Planning Scheme includes design principles relating to urban and streetscape design, protection of heritage and conservation areas, landscaping and public open space.
- Monetary and land contribution to the Casuarina Coastal Reserve, securing a formal buffer between the existing coastal reserve and the extent of urban development.
- Construction Environment Management Plan to detail construction management, including erosion and sediment control, dust control, noise, hours of operation and construction traffic. The management plan will ensure all construction regulations provided by the Northern Territory EPA are adhered to, and amenity impacts from construction activities are minimised. The preparation, approval and adherence to a detailed CEMP will be required as a condition of the subdivision development permit issued by the Development Consent Authority, and must be approved and implemented prior to the commencement of any works on site.
- The determination of all traffic impacts and the capacity of the road network to accommodate increased vehicle movements through detailed traffic impact analysis. Provision of developer contributions to facilitate road upgrades as required.

8.6 Risk Assessment

8.6.1 Risk assessment summary

The identification of social and economic risks during the site preparation, construction and occupation phases of the project site are identified in the risk assessment (Appendix C). The risk assessment identifies parties responsible for potential risks as well as possible affected parties.

The table below presents a summary of the medium to high level risks that could potentially arise through the proposed development of the project site. It also includes the recommended management responses to ensure the project has no negative impact on the local and regional community either socially or economically. The full results of the risk assessment are provided in Appendix C which includes a list all risks identified, as well as a description of expected positive outcomes from the project.

Table 66. Risk assessment summary for the project site

Impact	Phase	Stakeholders	Type of potential impact (positive or negative)	Probability (high, medium or low)	Consequence (high, medium or low)	Management and/or mitigation strategies	Responsible Parties	Timeframe	KPI
Housing and Accommodation									
Oversupply of housing, impact on housing market	Residential stage completion and commencement of sales and marketing.	DHA Housing market vendors	Negative	Medium	High	Align staging and development with growth rates per Darwin Regional Land Use Plan (or updated policies and projections)	DHA	Duration of construction and initial sales (<10 years)	Maintenance and/or growth of pricing and consistency of sales.
Workforce									
Inadequate suitably trained persons within the Darwin Region to supply skills.	Construction	Construction Industry DHA.	Negative although solutions comprising additional training/ education opportunities potentially positive.	Low	Medium	Provision of appropriate training opportunities for local market. Importation of skills as a last resort.	DHA.	Duration of construction.	Minimum local input achievement.
Shortfall of skilled workers elsewhere due to construction	Construction	Construction Industry DHA.	Negative although solutions comprising additional	Low (primarily due to commencement of the project post-	Medium-high	Ensure staging and timing of construction aligns with anticipated	DHA (Responsible for management strategy in	Duration of construction.	No unreasonable effect on access to trades /

Impact	Phase	Stakeholders	Type of potential impact (positive or negative)	Probability (high, medium or low)	Consequence (high, medium or low)	Management and/or mitigation strategies	Responsible Parties	Timeframe	KPI
works at Lee Point			training / education opportunities potentially positive.	Inpex construction)		population and housing growth rates for the Darwin Region	previous column)		construction services.
Shortage of workers to provide services in community, commercial and accommodation facilities	Occupation and ongoing	Northern Territory Government Public and private education sector Private service providers and commercial operators DHA	Negative	Low (range of skilled, unskilled, vocational and training opportunities avoids a concentrated demand for specific skills)	Medium	Development in accordance with projected commercial, accommodation and social infrastructure demand based on population projections, to ensure service provision doesn't exceed demand created by population.	DHA Northern Territory Government	Design and Construction	Establishment and continued operation of non-residential services and facilities.
Social Infrastructure									
Increase use of Buffalo Creek Boat Ramp.	Occupation	Northern Territory Government.	Negative	Low	Medium	Ramp has recently been upgraded and access is limited by tidal movement. Continual monitoring required upon	Northern Territory Government.	Upon occupation of development and ongoing.	Ramp waiting times and congestion are within normal ranges.

Impact	Phase	Stakeholders	Type of potential impact (positive or negative)	Probability (high, medium or low)	Consequence (high, medium or low)	Management and/or mitigation strategies	Responsible Parties	Timeframe	KPI
						occupation to determine impact on use patterns.			
Increase visitation to Casuarina Coastal Reserve	Occupation	Northern Territory Parks and Wildlife DHA	Negative	High	High	Monetary and spatial (land) contributions by DHA to increase size and improve visitor facilities within the reserve.	DHA (contribution) Northern Territory Parks and Wildlife (monitoring)	Completion of Construction.	Achievement of appropriate access to facilities for all users. Achievement of relevant objectives of CCR Management Plan.
Shortfall of social services	Occupation	DHA Residents and general public	Negative	Medium	High	Ensure adequate serviced land is available for community and social infrastructure in accordance with needs analysis.	DHA (land) Northern Territory Government / Private Sector (infrastructure) .	Commencement of occupation and ongoing.	Achievement of Lead Practice Principles and Benchmarks per social needs analysis.
Increase traffic impacts – Lee point Road	Construction and occupation	DHA All road users.	Negative	High	Medium	Undertake road upgrades in accordance with Traffic Impact Assessment	DHA City of Darwin	Construction and ongoing	Road operates within capacity

Impact	Phase	Stakeholders	Type of potential impact (positive or negative)	Probability (high, medium or low)	Consequence (high, medium or low)	Management and/or mitigation strategies	Responsible Parties	Timeframe	KPI
Amenity and Safety									
Adverse amenity impacts during construction	Site preparation and construction	DHA Lyons / Muirhead Residents and General public Royal Darwin Hospital	Negative	Medium	High	All construction and development works in accordance with a detailed Construction Environment Management Plan (CEMP). Establishment of a complaints register to monitor and respond to complaints	DHA Subcontractors.	Construction	No complaints received. Any complaints are promptly resolved.
Adverse amenity impacts from modified landform / built form	Construction and occupation	DHA Lyons / Muirhead Residents and General public Royal Darwin Hospital	Negative	Low	Medium	Ensure appropriate compliance with design and layout requirements of NT Planning Scheme, including minimum lot sizes, setbacks, building heights, landscaping	DHA. DCA. City of Darwin	Construction and ongoing (maintenance)	Issue of Development Permit. Positive public reception of project.

Impact	Phase	Stakeholders	Type of potential impact (positive or negative)	Probability (high, medium or low)	Consequence (high, medium or low)	Management and/or mitigation strategies	Responsible Parties	Timeframe	KPI
						and open space, to ensure visual amenity is maximised.			
Economic / Business Development									
Low / slow take-up of commercial land by private sector	Marketing and occupation	DHA Retail and hospitality sector.	Negative	Low	Medium	Ensure the appropriate provision of serviced commercial land, designed and located to cater for end use. Provide commercial land in accordance with needs analysis (ie avoid over supply)	DHA	Design, construction and marketing	Consistent take-up of commercial land.
Impact on viability of nearby commercial areas by proposed centre facilities	Occupation	DHA Retail and hospitality sector.	Negative	Low-medium	Medium-high	Provide commercial land in accordance with needs analysis (ie avoid over supply), which considers the	DHA	Design, construction and ongoing	No discernible effect on nearby centres. Consistent take-up of commercial land within Lee Point

Impact	Phase	Stakeholders	Type of potential impact (positive or negative)	Probability (high, medium or low)	Consequence (high, medium or low)	Management and/or mitigation strategies	Responsible Parties	Timeframe	KPI
						current and future provision of commercial and centre-type facilities (including the planned Muirhead centre)			(suggesting strong demand)
Over-supply of commercial land	Occupation	DHA Retail and hospitality sector	Negative	Low-medium	Medium-high	Provide commercial land in accordance with needs analysis. Update needs analysis and consult with retail sector during subdivision design. Provide accommodation in accordance with tourist accommodation demand analysis.	DHA. Northern Territory Government (confirm demand for tourist accommodation land)	Design, construction and marketing	Consistent take-up of commercial land. Progression of development concepts to construction.
Commercial land remains	Completion of construction,	DHA	Negative	Medium	Medium	Contractual provisions regarding	DHA	Sales / Marketing and occupation	Commencement, progression and completion

Impact	Phase	Stakeholders	Type of potential impact (positive or negative)	Probability (high, medium or low)	Consequence (high, medium or low)	Management and/or mitigation strategies	Responsible Parties	Timeframe	KPI
vacant after sale	occupation and ongoing	Commercial land purchasers				commencement of construction (ie within specified time after settlement)			of lot development

8.6.2 Description of impacts and mitigation

Providing the following considerations are adopted, future residents and visitors will have appropriate access to social infrastructure, and the project will provide an appropriate economic and social benefit at both a local and regional scale:

- Provide a range of lot sizes and housing types to ensure availability of housing across different market sectors.
- Provide public open space which, at a minimum, achieves the minimum requirements of the Northern Territory Planning Scheme.
- Provide land for commercial development, appropriately integrated with recreation and tourism-focussed activities which, at a minimum, facilitates a convenience store and opportunity for the establishment of a general practice medical clinic, with provision to be led by the private sector.
- Ensure commercial development does not compromise the hierarchy of centres in the northern suburbs, and more specifically does not compromise the role and function of the commercial centre in Muirhead.

In addition, the social and economic impacts associated with developing the project site assume the provision of community services in the adjoining Muirhead North site as outlined in the Lee Point Master-planned Urban Development plan, including:

- Approximately 3.5 hectare site for the purpose of an integrated primary school, kindergarten and long day care facility.
- At least one childcare centre for approximately 60 children.
- Community centre (likely to be owned and operated by the City of Darwin).
- Integrated formal recreation complex, collocated with primary school site, comprising sport fields and courts.

The proposed development of the project site is also expected to have a number of positive social and economic impacts including:

- Housing affordability
- Integrated residential, community and commercial uses
- Employment opportunities
- Access to commercial services and facilities
- Access to Casuarina Coastal Reserve and Casuarina Beach
- Increased public open space and recreational facilities.

To ensure the social and economic benefits of the project are realised, and that the proposed mitigation and management strategies meet the community and Government's expectation, a stakeholder engagement

strategy will be implemented (Table 67). There will also be ongoing monitoring of the projects' performance against social and economic Key Performance Indicators (KPIs) as detailed in the CEMP (Appendix D).

Defence Housing Australia will adopt an existing organisational dispute resolution policy to outline an active response to community and stakeholder concerns regarding potential social impacts. As a general rule, all concerns, whether from a community group or member, or from a stakeholder/approval agency, will be addressed promptly and a written response provided thereto. A written record or all relevant complaints/issues, action taken and the response provided will be kept by DHA. Identified responses include (but are not limited to):

- Written response to all written submissions received as part of the statutory exhibition process for the development application.
- Transcription of all verbal/written concerns/complaints raised at community meetings, including contact details where provided, and written response thereto.
- Ensure written agreements follow any verbal agreements in relation to development undertakings, agreements and conditions, and continued engagement with relevant stakeholders regarding agreement conditions.
- Implementation of grievance procedure policy for receiving, actioning and responding to complaints/concerns during construction.

The dispute resolution policy will provide pathways and processes for handling grievances, outline procedural steps, measures for the keeping of grievance logs, data evidence of dialogue and communication processes, substantive outcomes achieved and measures for implementing outcomes into wider policy.

Table 67. Stakeholder Engagement Strategy

Key Stakeholders	Stakeholder Interest	Engagement Actions	Steps to ensure implementation	Review Mechanisms
City of Darwin	Agency responsible for local roads and associated infrastructure, stormwater drainage and associated infrastructure, public open space (at a local level) and some community facilities.	Pre-design and application meetings, including presentation to full Council. Legislative consultation during development application process. Formal application to Council for design approval.	Council to formally approval detail design.	Ongoing review during Council meetings and review of full Council decision.
Development Consent Authority	Consent authority for development approval.	Pre-application meetings and briefing to the DCA. Engagement through development application.	Development approval and conditions.	Adverse development application decision.
Northern Territory Parks and Wildlife Commission	Agency responsible for the administration, management and maintenance of the Casuarina Coastal Reserve.	Ongoing meetings and formal agreement with Parks regarding the provision of part of the site into the CCR. Engagement with Parks regarding CEMP.	Agreement to integrate part of the site into the CCR. Approval of CEMP.	Ongoing review during meetings.
Northern Territory Power and Water Corporation	Agency responsible for the reticulation of power, water and sewerage infrastructure within the Northern Territory.	Pre-design and application meetings. Legislative consultation during development application process. Formal application to PWC for design approval.	Detailed design approval of reticulated infrastructure and services.	Review on advice received in response to development application. Review need for further engagement based on detailed design feedback.
Northern Territory Department of Health	Royal Darwin Hospital and associated facilities. Provide advice regarding development potentially subject to impacts from mosquitoes and biting midges.	Pre-application meetings and advice on progress. Pre-application meetings with medical entomology unit to finalise land use restrictions on land affected by biting insects.	No objection from the Department of Health to Development application.	Ongoing review during design, approval and construction phase.

Key Stakeholders	Stakeholder Interest	Engagement Actions	Steps to ensure implementation	Review Mechanisms
General Public – Adjoining owners / occupants	Development on adjoining / nearby land.	Community consultation sessions pre-lodgement. Provision of design details pre-lodgement (Development application).	Design and construction undertakings in response to feedback to be enforced by way of development permit conditions.	Review based on initial feedback.
General Public – users of Casuarina Coastal Reserve	Development on nearby / adjoining land. Increased size and facilities within Casuarina Coastal Reserve.	Community information provided via general community media. DHA contact provided.	Design and construction undertakings (including agreed DHA upgrades / contributions to CCR) in response to feedback to be enforced by way of development permit conditions.	Review based on initial feedback.
Northern Territory Department of Education	Owner / operator of future education facility within 09370.	Pre-design and application meetings, including addressing design and servicing requirements of school site. Legislative consultation during development application process.		Review on advice received in response to development application. Review need for further engagement based on design feedback.
Northern Territory Department of Environment and Natural Resources	Agency responsible for reviewing erosion and sediment control measures, implementation and onsite management.	Pre-design and application meetings, including design input into erosion and sediment control measures. Legislative consultation during development application process.	No objection from the Department of Education to Development application. Development of school site by the Department of Education.	Review on advice received in response to development application. Review need for further engagement based on comments received on ESCP application.
Northern Territory Environment Protection Authority	Agency responsible for assessment and approval of the Environmental Impact Statement under the NT Environmental Assessment Act.	Ongoing consultation during EIS. Legislative consultation during development application process.	Approval of EIS. Acceptable implementation of EIS conditions.	Engagement to be reviewed subject to EIS feedback, decision and conditions.

Key Stakeholders	Stakeholder Interest	Engagement Actions	Steps to ensure implementation	Review Mechanisms
Commonwealth Department of the Environment and Energy	Department responsible for assessment and approval of the Environment Impact Statement under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*	Ongoing consultation during EIS (pre and post lodgement).	Approval of EIS. Acceptable implementation of EIS conditions.	Engagement to be reviewed subject to EIS feedback, decision and conditions.
General Public - Other	Community groups with a focus on environment and development. Members of the public with an interest in the Lee Point area and/or development generally.	Community information provided via general community media. DHA contact provided.	Design and construction undertakings in response to feedback to be enforced by way of development permit conditions.	Review based on initial feedback.

9 NOISE

9.1 Introduction

This chapter assesses the potential noise and vibration impacts of the project and addresses the following criteria of the EIS ToR:

- The Proponent should address the impact of noise resulting from construction stages of the Project on nearby residents.
- The potential sensitivity of receptors to noise and mitigation measures should be discussed.
- A Noise Management Plan should outline methods for communicating with, and reducing the impact on, residents within the vicinity of the Project who may be adversely affected by the Project.

The chapter is structured in the following manner:

- Description of the methods used to model the magnitude of noise and vibration disturbance emanating from the project site during the construction and operation phase, a description of benchmarks based in industry guidelines for the acceptable level of disturbance, and the likely impacts to sensitive receivers including adjoining residents, future residents and future receivers (i.e. proposed primary school at Muirhead North) (Section 9.2).
- A summary of the Identified risks to sensitive receivers and future residents and a list of practical and appropriate mitigation measures to avoid any unacceptable noise or vibration disturbance that may occur during the construction or operation phase of the project (see Section 9.3).

The full risk assessment is provided in Appendix C, while most of the findings presented in this chapter are based on the Noise Impact Assessment prepared by Cardno (2017a, b), which is provided in Appendix H for 2CRU and Appendix I for Muirhead North .

9.2 Existing conditions and impacts

9.2.1 Method of Assessment

The section describes the methods used to model the disturbance of noise and vibration during the construction and operation phase of the project. Modelling is based on industry and Australian Standards. As the type and number of plant and equipment to be utilised during construction has not been confirmed, assumptions were made based on experience with similar residential projects.

9.2.1.1 Construction Noise

To determine construction noise, a SoundPLAN noise model was prepared and noise levels of typical construction plant were input into the model. The type and number of plant and equipment was assumed based upon experience from similar projects and the plant noise data provided in Australian Standard AS 2436:2010, "Acoustics – "Guide to Noise & Vibration Control on Construction, Demolition & Maintenance Sites".

The different construction phases for the project have been assumed based on similar previous projects. The construction phases and assumed sound power levels are outlined below:

- Clearing of Vegetation & Site Establishment (L_{Aeq} = 121 dB(A) & L_{Amax} = 131 dB(A))
- Bulk Earthworks (L_{Aeq} = 123 dB(A) & L_{Amax} = 133 dB(A))
- Drainage Infrastructure (L_{Aeq} = 115 dB(A) & L_{Amax} = 116 dB(A))
- Road Surfacing Works (L_{Aeq} = 118 dB(A) & L_{Amax} = 130 dB(A))

9.2.1.2 Construction Vibration

Recommended minimum separation distances between sensitive structures and typical vibration generating plant to minimise the risk of cosmetic damage to structures were identified with reference to standard expected ground vibration curves for various equipment types and are likely construction areas and activities.

9.2.1.3 Operational Noise

Road traffic noise was predicted using the 3D noise modelling software SoundPLAN 7.4. SoundPLAN software applies the algorithm from the Calculation of Road Traffic Noise, UK Department of Transport, Welsh Office 1988 (CoRTN), which is commonly used for road traffic noise assessment throughout Australia. The modelling predicts expected road traffic noise impacts based on the following data inputs.

- Existing 3D topography of the site, surrounds and nearby road alignments.
- Proposed Site topography.
- Road traffic flows.
- Posted road traffic speeds, and % heavy vehicles.
- Pavement surface type

General Modelling Methodology

The traffic noise model was used to predict post-development road traffic noise impacts on the dwellings located within the proposed development in the year 2026. The predicted noise levels were compared to the relevant noise criteria and exceedances determined.

Recommendations relating to feasible and reasonable mitigation measures were then developed.

The CoRTN assessment methodology was adopted for this assessment. The CoRTN modelling methodology sets traffic sources at a height of 0.5 metres above the road.

Noise modelling was conducted with and without noise barriers along Lee Point Road for year 2026.

Application of Correction Factors

The following correction factors were applied to the modelling:

- Pavement surface corrections of 0 dB(A) for dense graded asphalt (DGAC)
- An AustRoads correction factor to convert standard CoRTN outputs to Australian Conditions of -1.7 dB(A) was applied to the modelling results for receivers associated with future buildings.
- The standard conversion (referenced from AS 3671) of $L_{A10,18hr} = L_{Aeq,\ day} + 3$ dB(A) was also applied.
- A conversion factor of $L_{Aeq,\ night} = L_{Aeq,\ day} - 3$ dB(A) was applied to determine night-time traffic noise levels.
- A façade correction factor of + 2.5 dB(A) was applied to modelled receivers to allow for façade correction once the buildings are located on each Lot.

Noise Modelling Inputs and Assumptions

Table 68 below details the modelling input asumptions used for the noise modelling.

Table 68: Modelling Assumptions

Modelling Element	Input/Assumption. Source Reference
Ground Elevation Geometry	Provided by Cardno
Proposed Elevation Geometry	Provided by Cardno
Road Alignment	Provided by Cardno
Site Traffic Flow Data	Provided by SMEC & DHA
Road Traffic Speed	Provided by Cardno
Road pavement surfaces	Assumed to be DGA with no pavement correction factors added.
Ground Absorption	50% over soft ground
Methodology	Calculation of Road Traffic Noise, UK Department of Transport, 1988
Weather conditions	Calm Conditions
Façade Reflection	+2.5 dB(A) – applied to traffic prediction models, for receivers associated with future buildings.
L_{A10} and L_{Aeq} conversions	$L_{Aeq,day} = L_{A10,18hr} - 3$ dB(A)
Day time to night-time conversion	$L_{Aeq,night} = L_{Aeq,day} - 3$ dB(A)

Modelling Element	Input/Assumption. Source Reference
AustRoads Correction to CoRTN for Façade Corrected Australian Conditions	-1.7 dB(A) CoRTN correction for Australian conditions (with reference to AustRoads.)
Receiver Height	Assumed to be 1.8 and 4.6 metres above ground level.

Traffic Volumes and Posted Speed

Projected traffic volumes for the year 2026 within the project site were obtained from the traffic impact assessment by SMEC (2015). The traffic impact assessment report projected traffic volumes for year 2025 for the finished development of the green field sites north of Lions and Muirhead Breezes Estate. For this assessment it is assumed that traffic volumes for year 2026 is identical to year 2025 as no further developments are likely to occur and that Lee Point Road is a dead end road north of the project site.

The percentage of heavy vehicles (HV) were stated by SMEC (2015) as 0.0%; however, a 5% HV should be used as a conservative assumption, which is in line with previous noise impact assessments carried out for residential developments. Projected traffic volumes and traffic speeds on Lee Point Road, for the noise modelling is presented in the Table 69 below.

It should be noted that traffic volumes at the southern part of the development are predicted to be significantly higher than at the northern end of the development as Lee Point Road is a dead end road with no significant area north of the development suitable for further development.

Table 69. Modelled Traffic Volumes & Speeds

Road Segment	Projected 18 Hour Traffic Volumes on Lee Point Road Between 6am and Midnight (94% of AADT)	% Heavy Vehicles	Proposed Speed
South	8580	5%	60 Km/h
Mid-South	7851	5%	60 Km/h
Mid	5131	5%	60 Km/h
Mid-North	1628	5%	60 Km/h
North	717	5%	60 Km/h

9.2.2 Adopted Noise & Vibration Criteria

9.2.2.1 Construction Noise

To mitigate the risk of excessive construction noise impacting on nearby existing sensitive receivers, noise management criteria has been adopted for the development referenced from the Northern Territory Environmental Protection Authority's Noise Guidelines for Development Sites in the Northern Territory, May 2014. (EPANGDS).

The EPANGDS outlines acceptable construction times and noise levels that should not be exceeded during those times.

The guideline states that construction activities should be restricted to:

a. between the hours of 7am and 7pm Monday to Saturday; and

b. between the hours of 9am and 6pm on a Sunday or public holiday.

The table below outlines the applicable construction noise limits for the project. Derivation of these noise limits is based on assumed background noise levels in each of these areas, and the methodology outlined in Appendix H and Appendix I.

Table 70. Adopted Construction Noise Limits for the Development

Noise Area	Construction Noise Limit, $L_{Aeq,15min}$		Sleep Disturbance from 10pm to 7am, L_{Amax} Externally
	Monday to Saturday from 7am to 7pm	Sunday and public holidays from 9am to 6pm	
Residential	50	50	65
Casuarina Coastal Reserve	50	50	65
Hospital	55	55	65

9.2.2.2 Construction Vibration

The following vibration criteria for human comfort apply to this project.

Table 71. Adopted Continuous Construction Vibration Limits for the Development – Sensitive Receivers

Building	Work Period	Resultant PPV mm/s	
		Lower Limit	Upper Limit
Dwellings (including hotels and motels)	Standard hours	1	2
	Non-Standard hours - evening	0.3	1
	Non-Standard hours - night-time		
Medical/health buildings (wards, surgeries, operating theatres, consulting rooms)	All	0.3	1
Educational facilities (rooms designated for teaching purposes)	While In Use		
Court of Law (Court rooms)			
Court of Law (Court reporting and transcript areas, Judges' chambers)			
Community buildings (Libraries, places of worship)	While In Use	1	2
Commercial (offices) and retail areas			

The minimum 'safe limits' for continuous construction vibration at low frequencies for commercial and industrial buildings for the project have been referenced from German Standard DIN 4150.3 as follows Table 72).

Table 72. Adopted Continuous Construction Vibration Limits for the Development – Commercial & Industrial Receivers

Type of Structure	Assessment Criteria, mm/s	Reference
Dwellings (including hotels and motels)	5 (rms) at 1-10Hz 5 to 15 (rms) at 10-50Hz 15 to 20 (rms) at 50-100Hz	German Standard DIN 4150
Sensitive structures (including heritage listed structures)	3 (rms) at 1-10Hz 3 (rms) to 8 at 10-50Hz 8 to 10 (rms) at 50-100Hz	German Standard DIN 4150

'Safe limits' are defined as levels where no visible or cosmetic damage is expected to occur.

The transient construction vibration 'limits' to avoid cosmetic damage at low frequencies for different types of buildings from BS 7385-2, have been adopted for this development as follows (Table 73).

Table 73: Adopted Transient Construction Vibration Limits for the Development – All Receivers

Type of Building	Resultant PPV in Frequency Range of Dominant Pulse, mm/s	
	4 to 15Hz	15Hz and above
Reinforced or framed structures. Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	-
Unreinforced or light framed structure. Residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

Additional noise management measures with respect to construction noise are detailed in Appendix H and Appendix I

9.2.2.3 Sleep Disturbance

In the absence of NT specific criteria for sleep disturbance, relevant guidelines from the World Health Organisation and the QLD EPA EcoAccess Planning for Noise Control Guideline have been applied.

As a rule in planning for short-term or transient noise events, for good sleep over eight hours, the indoor sound pressure level measured as a maximum instantaneous value should not exceed the noise levels outlined in

Table 74 within a bedroom.

Table 74. Adopted Sleep Disturbance Noise Limits

Internal Maximum Noise Level L_{Amax}	Maximum Number of Noise Events at Night
45 dB(A)	10 to 15

Internal Maximum Noise Level L_{Amax}	Maximum Number of Noise Events at Night
50 dB(A)	up to 3
65 dB(A)	1

9.2.2.4 Operational Noise

With regard to operational noise impacts the following risks apply to the development:

- Road traffic noise levels above the recommended noise limit for health and wellbeing.
- Road traffic noise levels above the recommended noise limit for sleep disturbance.
- Annoyance or awakening from siren of an emergency vehicle.

To manage these risks, potential impacts for operational noise sources associated with the development has been assessed against the appropriate NT regulations, and mitigation designed accordingly so that noise emissions and immissions associated with this development can be managed to acceptable levels.

The table below shows the applicable external road traffic noise limits as outlined in the Northern Territory Government's Road Traffic Noise on NT Government Controlled Roads.

Table 75. Adopted External Traffic Noise Limits for the Development – Sensitive Receivers

Receiver Description	Applicable Road Traffic Noise Limits	
	Noise descriptor	External noise level in dB(A)
Residential, Hotels and Tourist Precincts	$L_{10,18hr}$	63
School, Day Care, Library and Community Building	$L_{10,18hr}$	58
Outdoor Educational and Passive Recreational Areas	$L_{10,18hr}$	58
Hospital, Aged Care Facility and Nursing Home	$L_{10,18hr}$	58

Table 76 below shows the applicable internal noise limits as recommended in AS 2107 Recommended design sound levels and reverberation times for building interiors.

Table 76. Adopted Internal Traffic Noise Limits for the Development – Sensitive Receivers

Area	Recommended Internal Design Sound Objective, $L_{eq,(T)}$, dB(A)
Sleeping Areas (All bedrooms)	30
Living Areas (Lounge rooms within dwellings)	35
Work Areas	35
Apartment common areas	45

9.2.3 Impacts

9.2.3.1 Construction Vibration

The tables below outline the recommended minimum separation distances between sensitive structures and typical vibration generating plant for development at 2CRU (Table 77) and Muirhead North (Table 78), in order

to avoid cosmetic damage to structures. It is based on the expected plant and equipment to be used for construction, as the equipment to be used during construction is yet to be determined. The table indicates that cosmetic damage to buildings can be avoided by correct selection of plant when working near vibration sensitive structures.

Table 77. Recommended minimum separation distances – 2CRU

Receiver	Nearest Potential Construction Area	Distance to Nearest Sensitive Structure, metre	Maximum size of Vibratory Roller	Maximum size of Hydraulic Hammer
Darwin Hospital	Project site	175	> 300 kN > 18 tonnes	1600 kg – 18 to 34t excavator
Lee Point Village Resort	Lee Point Road Traffic Corridor	15	< 300 kN Typically 7-13 tonnes	900 kg – 12 to 18t excavator
Lyons Estate	Project site and Lee Point Road Traffic Corridor	1.5	< 50 kN Typically 1-2 tonnes	300 kg - 5 to 12t excavator
Current dwellings at Muirhead Breezes Estate (June 2016)	Lee Point Road Traffic Corridor	50	> 300 kN > 18 tonnes	1600 kg – 18 to 34t excavator
Potential future dwellings at Muirhead Breezes Estate	Lee Point Road Traffic Corridor	15	< 300 kN Typically 7-13 tonnes	900 kg – 12 to 18t excavator

Table 78. Recommended minimum separation distance - Muirhead North

Receiver	Nearest Potential Construction Area	Distance to Nearest Sensitive Structure, metre	Maximum size of Vibratory Roller	Maximum size of Hydraulic Hammer
The 2CRU Site	Muirhead North Site and Lee Point Road Traffic Corridor	1.5	< 50 kN Typically 1-2 tonnes	300 kg - 5 to 12t excavator
Lee Point Village Resort	Muirhead North Site	1.5	< 50 kN Typically 1-2 tonnes	300 kg - 5 to 12t excavator
Lyons Estate	Muirhead North Site and Lee Point Road Traffic Corridor	15	< 300 kN Typically 7-13 tonnes	900 kg – 12 to 18t excavator
Current dwellings at Muirhead Breezes Estate (June 2016)	Muirhead North Site and Lee Point Road Traffic Corridor	50	> 300 kN > 18 tonnes	1600 kg – 18 to 34t excavator
Potential future dwellings at Muirhead Breezes Estate	Muirhead North Site and Lee Point Road Traffic Corridor	1.5	< 50 kN Typically 1-2 tonnes	300 kg - 5 to 12t excavator

9.2.3.2 Predicted Noise Impacts

Construction Noise

Construction noise levels are unlikely to exceed the design benchmark noise limits except for the worst case scenarios, where work is conducted at the boundary of the development and during upgrade work of Lee Point

Road. The exceedances are due to limited separation distance between the site and neighbouring receivers and the high noise levels typically generated by construction plant. It is worth noting that work along the boundary of the development will occur for shorty durations only, as clearing of vegetation and general construction work will move around the development site as work progresses. Furthermore, the model exceedances assume that all the noisiest items of plant will be operating simultaneously which is unlikely to occur.

Sleep Disturbance

The most likely source of potential sleep disturbance from the night construction works will be from the use of pneumatic hammers or saw cutting during services relocation and/ or road pavement works or from truck movements on site, in particular the application of air brakes.

Maximum noise levels have been predicted to the nearest affected residential receivers to allow a review of the potential for sleep disturbance from construction activities at night. Noise levels have been calculated based on a worst case scenario when plant is located at the closest point to each receiver. On this basis, the predicted results (L_{Amax}) indicate that maximum construction noise levels at the nearest noise sensitive receivers are likely to exceed the sleep disturbance criteria, when construction works are located nearby. For this reason, activities with potentially high maximum levels such as the use of pneumatic tools and truck air-braking will be minimised or not operated at locations close to noise sensitive receivers during the night-time period. Furthermore, noise screening using temporary noise barriers will be used for stationary plant at night.

9.2.3.3 Operational Noise

2CRU

Road traffic noise emanating from Lee Point Road is predicted to exceed the 63 dB(A) criteria at 16 (4 ground floor and 12 first floor) of the nearest receivers without any external mitigation installed (such as noise barriers). The results also show that this number is reduced to 9 with the inclusion of 1.8 metre high noise barrier located along the site boundary with Lee Point Road, with all of these exceedances being first floor exceedances.

Based on these results, the location of noise sensitive uses, such as schools, childcare centres, retirement accommodation or hospitals, is not recommended immediately adjacent to Lee Point Road. The noise limit of 58 dB(A) for non-residential noise sensitive use is predicted to be exceeded at 70 receivers without the inclusion of noise barriers. This number is reduced to 29 with the inclusion of 1.8 metre high noise barriers located along the site boundary with Lee Point Road.

The noise impact from road traffic upon 2CRU is primarily occurring at the southern end of the development, due to the higher traffic volumes at this end of the development.

The results indicate that noise barriers aren't required between Lee Point Road and the northern part of the development to achieve compliance with the $L_{A10,\ 18hour}$ of 63 dB(A) for residential use.

Most of the lots will require building construction in accordance with either AS 3671 Category 1 or Category 2. Forty-eight receivers (26 lots) will require building construction in accordance with AS 3671 Category 3 without the provision of 1.8 metre high noise barriers. The number of receivers requiring building construction

in accordance with AS 3671 Category 3 reduces to 15 (all at first floor levels) with the provision of 1.8 metre high noise barriers.

Muirhead North

Road traffic noise from Lee Point Road is not predicted to exceed the 58 dB(A) criteria at any of the modelled outdoor receivers whether the noise barriers are included or not. As such the predicted noise levels at the proposed sportsgrounds and playgrounds do not indicate that noise barriers are required for the Muirhead North development.

Road traffic noise is not predicted to exceed the 63 dB(A) criteria at any of the receivers with or without the inclusion of noise barriers. As such the predicted noise levels at the proposed residential lots do not indicate that noise barriers are required for the Muirhead North development.

Road traffic noise at two of the proposed school buildings and the proposed community centre building is predicted to exceed the noise limit of 58 dB(A) for non-residential noise sensitive use. Without the provision of a 1.8 metre noise barrier between the school site and Lee Point Road 5 (2 ground floor and 3 first floor) exceedances are predicted. This number is reduced to 3 (1 ground floor and 2 first floor) with the inclusion of 1.8 metre high noise barriers located along the site boundary with Lee Point Road.

Noise modelling therefore indicates that the school buildings and the community centre building should be placed further away from Lee Point Road or that noise mitigation options, such as a noise barrier between the proposed school site and Lee Point Road, should be included in the design to allow compliance with the external noise limit of 58 dB(A) for non-residential noise sensitive use.

Noise levels of less than 58 dB(A) are predicted at distances in excess of approximately 50 metres from Lee Point Road without including noise amelioration. The inclusion of 1.8 metre high noise barriers provides a significant amount of noise reduction for ground floor levels. Therefore increased buffer distances between the proposed buildings and the road, or provision of a barrier, or both is recommended at this location.

The results indicate that all of the proposed residential lots will require building construction in accordance with either AS 3671 Category 1 or 2. The community centre building and the nearest school building will require building construction in accordance with AS 3671 Category 3 without the provision of a 1.8 metre high noise barrier. If a 1.8 metre high noise barrier is included along the site boundary, the Category 3 construction requirements are only applicable for the first floor levels of the two buildings.

9.3 Risk Assessment

9.3.1 Purpose

This section summarises the noise and/or vibration sources that may impact upon the nearest sensitive receivers, adopted assessment criteria and proposed mitigation measures where appropriate. Full details of the above are contained in Appendix C.

9.3.2 Description of impacts and mitigation measures

9.3.2.1 Recommended Noise Mitigation Measures

General

A summary of noise and vibration impacts that exceed the adopted assessment criteria details above is summarised in Table 79. Appropriate mitigation measures to reduce impacts to below threshold levels are provided.

Table 79. Summary of Recommended Mitigation Measures - General

Impact	Description	Considered Mitigation Measures
Operational Noise		
Sleep disturbance (operation)	Noise events during the night at levels able to cause awakenings	• Noise barriers or receiver façade upgrades
Health and wellbeing (operation)	Extended periods of traffic noise levels above recommended levels	• Noise barriers, low noise asphalt, reduced speed limits or façade upgrades
Annoyance (operation)	Unusual or unexpected noise events	• Noise barriers or façade upgrades
Construction Noise		
Sleep disturbance	Noise events during the night at levels able to cause awakenings	• Avoid construction at night, temporary noise barriers.
Health and wellbeing	Extended periods of construction noise	• Temporary noise barriers or provide respite periods
Annoyance	Continued perception of reversing beeping alarm	• Temporary noise barriers, provide respite periods, offer gifts (movie tickets for noisy periods)
Noise	Annoyance (construction)	• Mulchers should be located away from noise sensitive receivers • Reduce the number of plant operating at one time where works are required to be carried out outside of standard hours and close to existing sensitive receivers • Preference should be for electric powered plant over combustion engine powered plant

Impact	Description	Considered Mitigation Measures
		• Preference should be for hydraulic or electric powered plant over pneumatic powered plant • Avoid metal to metal contact on equipment to reduce impulsive or scraping noise consultation with residents • Provision of noise attenuating controls at the source, such as mufflers, acoustic screens • Keeping plant and equipment well maintained • Locating static sources of noise such as the generators as remotely as possible from noise sensitive receivers • Developing proposed hours of operation in consultation with the residents/occupants of the affected receivers, and NT EPA with a view to minimising potential impacts as far as is practically feasible • Allowing construction to occur only during approved construction hours, unless otherwise required due to climatic conditions or safety requirements • Conducting noise monitoring during operations for the purposes of assisting in noise mitigation and to verify the findings of this noise assessment, if complaints are received or proposed activities and number of plant exceed those assumed in this assessment
Noise	Annoyance (construction)	• Use of broadband reversing alarms, or “quackers”, on mobile equipment in accordance with the relevant health and safety regulations • Informing potentially affected receivers with adequate notice of the construction program and any planned activities that may exceed noise and vibration targets • Modification of work activities where noise or vibration is found to cause unacceptable impact • Implementing a procedure for dealing with complaints to ensure that all complaints are registered and dealt with appropriately • Ensure that managers effectively communicate acceptable and unacceptable work practices for the site, through staff site inductions, notice boards, and prestart meetings • Avoid the need for reversing in the construction area by creating a loop road or similar • Avoid dropping materials from height • Workers should avoid shouting, minimise talking loudly, and avoid slamming vehicle doors
Operational Vibration		
Vibration (operation)	Perception of heavy vehicles	• Road design and avoid speed bumps

Impact	Description	Considered Mitigation Measures
Construction Vibration		
Vibration (construction)	Perception of vibration or structural damage due to vibration intensive plant	• Select suitable plant when near vibration sensitive receivers
	Annoyance (construction)	• Avoid vibration intensive work at night to minimise the risk of sleep disturbance • Informing potentially affected receivers with adequate notice of the construction program and any planned activities that may exceed noise and vibration targets • Modification of work activities where noise or vibration is found to cause unacceptable impact • Implementing a procedure for dealing with complaints to ensure that all complaints are registered and dealt with appropriately • Ensure that managers effectively communicate acceptable and unacceptable work practices for the site, through staff site inductions, notice boards, and prestart meetings • Avoid dropping materials from height

Construction Noise

Construction noise is typically a problem outside designated working periods such as would be the case for work scheduled during the night time. However, predicted noise levels have been compared to the night time noise limits to determine if out of hours work can be undertaken while complying with the night-time noise limits and in particular the adopted sleep disturbance noise limit. General construction noise mitigation measures to minimise the impact upon sensitive receivers are outlined in Table 79, and include:

- Avoid night-time works.
- Temporary noise barriers
- Reducing the number of plant operating at anyone time.
- Preference for hydraulic electric powered plant over combustion engine or pneumatic powered plant.
- Noise attenuating controls at the source (e.g. mufflers).
- Keeping plant and equipment well maintained.

Construction Vibration

Vibration generated by large plant during the construction of infrastructure and buildings may be transmitted through the ground to such a degree that vibration can be felt at nearby receivers or in some cases at levels that can cause cosmetic damage. Mitigation of vibration is for most cases undertaken by using smaller plant that generates less vibration, however digging a trench between the source and the receiver is also an option

for mitigation of ground borne vibrations. General construction vibration mitigation measures to minimise the impact upon sensitive receivers are outlined in Table 79, and include:

- Select suitable plant when near vibration sensitive receivers.
- Avoid works at night.
- Notifying potentially affected receivers.

Operational Noise

Traffic noise primarily affects dwellings located close to busy roads. Some of the proposed residential dwellings to be developed in the project site are located adjacent to Lee Point Road. Noise mitigation of traffic noise would normally include provision of screening such as noise barriers, reduction of traffic speed, low noise asphalt or upgrade of building facades. General mitigation measures for operational noise impacts are recommended above in Table 79 and focus on the use of noise barriers and façade upgrades. Specific details on the recommended noise barriers and the required category constructions for dwellings for the development are detailed in Appendix H and Appendix I.

It should be noted that upgrade of building facades provides noise reduction internally in homes, but not externally, such as for parks and outdoor recreation areas.

10 CONCLUSION

This EIS has been prepared to address the assessment requirements under the EPBC Act and NT EA Act as set out in the Terms of Reference in Appendix A. Through undertaking detailed risk assessment, the magnitude of impacts to the following environmental components has been identified:

- Hydrology
- Air Quality
- Utilities and Infrastructure
- Biodiversity and Heritage
- Social Economic
- Noise

The major risks to the environment are considered to be increased disturbance of migratory shorebirds along Casuarina Beach and managing stormwater run-off to avoid impacts to Sandy Creek and contributing breeding habitat for biting insect breeding. Appropriate controls have been proposed that will adequately address these risks, which include:

- Locating access to Casuarina Beach north of Sandy Creek mouth.
- Increased signage and community events to improve knowledge of migratory shorebird habitat and their threats.
- A stormwater management plan that ensures no increase in the volume of water entering Sandy Creek from the site, and removing sediment and pollutants.
- Development of an Erosion and Sediment Control Plan.
- Water Quality Monitoring Program.

These and other control measures that have been proposed to ensure any environmental impacts is within an acceptable limit are provided in detail in a CEMP (Appendix D). In addition to the potential impacts of the project, the EIS also discusses the likely benefits of the project which include:

- Provision of affordable housing.
- Employment opportunities in construction during a down-turn in the mining and resources industry.
- Permanent employment in the retail, accommodation and hospitality industries.
- Reduction in sediment entering Sandy Creek through rehabilitation of erosion gullies.

Post approval of the EIS, the following management plans will be prepared or further developed prior to construction commencing:

- Construction Environmental Management Plan including sub-plans for biodiversity, water, heritage and noise based on the overarching CEMP prepared as part of the EIS (Appendix D).

- Water Quality Monitoring Plan based on the overarching WQMP prepared as part of the EIS (Appendix O).
- Erosion and Sediment Control Plan based on the overarching ESCP prepared as part of the EIS (Appendix D).
- Conservation and Offset Management Plan for the 21.95 ha Conservation Area.
- Offset Management Plan for Black-footed Tree-rat third-party offset site.

11 REFERENCES

ABC Radio Darwin. (June 2016). Darwin Rental Prices tipped to bottom out by Christmas [online]. http://www.abc.net.au/news/2016-06-30/darwin-rental-prices-may-bottom-out-by-christmas/7557500. [Accessed 12 October 2016].

Aplin KP, Braithwaite RW and Baverstock PR 2008, '*Pale Field-rat: Rattus tunneyi*', Van Dyck S and Strahan R (eds.), The Mammals of Australia, 3rd Edition, Reed New Holland, Sydney, NSW.

Armstrong and Price 2007, *Conservation Values of the Parks and Reserves of the Greater Darwin Area*, Biodiversity Conservation Division, Department of Natural Resources, Environment and the Arts, NT.

Aumann T and Baker-Gabb DJ 1991, *The ecology and status of the Red Goshawk in northern Australia*, Royal Australasian Ornithologists Union, Melbourne.

Australian Bureau of Statistics. (2012). Schools, Australia [online]. http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/4221.02011?OpenDocument. [Accessed 4 November 2016].

Australian Bureau of Statistics. (2016). Labour force, Australia, Detailed, Quarterly August 2016 [online]. http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/6291.0.55.003Aug%202016?OpenDocument. [Accessed 4 November 2016].

Australian Government. (2014). *Our North, Our Future: White Paper on Developing Northern Australia*. Licensed from the Commonwealth of Australia under Commons Attribution 3.0 Australia Licence.

Baker B, Price O, Woinarski J, Gold S, Conners G, Fisher A and Hempel C 2005, *Northern Territory Bioregions Assessment – assessment of key biodiversity values and threats*, a resource document that accompanies the Northern Territory Parks and Wildlife Conservation Masterplan.

Brock J 1995, *Remnant Vegetation Darwin Municipality (map only),* produced by Conservation Commission Northern Territory using information from various studies in the Darwin region.

Brocklehurst P 1991, *Casuarina Coastal Reserve Management Plan*, CCNT.

Brocklehurst P, Lewis D, Napier D and Lynch D 2007, *Northern Territory Guidelines and Field Methodology for Vegetation Survey and Mapping*, Technical Report No. 02/2007D, Department of Natural Resources, Environment and the Arts, Palmerston, Northern Territory.

Bureau of Meteorology (BOM), Groundwater Dependent Ecosystems Atlas, http://www.bom.gov.au/water/groundwater/gde/

Bureau of Meteorology (BOM), weather data

Cavanagh RD, Kyne PM, Fowler SL, Music JA and Bennett MB (eds) 2003, *The conservation status of Australia Chondrichthyans*, Report to the IUCN park specialist group Australia and Oceania Regional Red List workshop, University of Queensland, Brisbane.

Chatto R 1998, *A preliminary overview of the locations of marine turtle nesting in the Northern Territory*, In Marine turtle conservation and management in northern Australia (eds Kennett R, Webb G, Duff G, Guinea M and Hill G), pp. 33-40 Northern Territory University, Darwin.

Chatto R 2003, *The distribution and status of shorebirds around the coast and coastal wetlands of the Northern Territory*, Technical Report 73, Parks and Wildlife Commission of the Northern Territory, Darwin.

Chatto R and Baker B 2008, *The distribution and status of marine turtle nesting in the Northern Territory-Technical Report 77/2008*, Department of Natural Resources, Environment, the Arts and Sport, Parks and Wildlife Service, Palmerston.

Christian K 2004, *Varanus mertensi*, in Varanoid Lizards of the World, Pianka ER, King DR and King RA (eds), Indiana University Press, Bloomington, Indianapolis.

Churchill S 1998, *Australian Bats*, Reed New Holland, Sydney.

City of Darwin. (September 2005). *Subdivision and Development Guideline.* Technical Services Department, City of Darwin.

Cowie I and Westaway J 2012, *Threatened species of the Northern Territory - Typhonium praetermissum*, Department of Land Resource Management, Darwin, NT.

Debus S and Czechura G 1988, *Field identification of the Red Goshawk Erythrotriorchis radiates*, Australian Bird Watcher, vol. 12, pp. 154-159.

Deepend Services. (July 2014). *Muirhead North and 2CRU Review*. Deepend Services for Defence Housing Australia.

Defence Housing Australia, (2015). 2CRU Engineering Services Report. SMEC, 2015

Defence Housing Australia, (2016). 2CRU Development Water and Wastewater Assessment. Cardno, 2016

Defence Housing Australia. (August 2016). Industry partnership educates Indigenous youth in natural resource management [online]. https://www.dha.gov.au/about-us/news-and-events/news/news-article?news=f80000ff-f4c9-6b29-aef8-2e9bd7cbb03f. [Accessed 4 October 2016].

Defence Housing Australia. (February 2013). *Expression of Interest: Upgrades and Minor Works to Defence and DHA Homes*. Defence Housing Australia.

Department of Natural Resources, Environment, The Arts and Sport (NRETAS) 2010, *Land Clearing Guidelines*, Department of Natural Resources, Environment, The Arts and Sport, Darwin, Northern Territory.

Department of Natural Resources, Environment, the Arts and Sport (undated), *Sites of Conservation Significance*, <https://nt.gov.au/environment/environment-data-maps/important-biodiversity-conservation-sites/conservation-significance-list>

Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) 2011, *Survey guidelines for Australia's threatened fish*, EPBC Act survey guidelines 6.4.

Department of the Environment (DoE) 2014, *Draft Recovery Plan for Sawfish and River Sharks (Pristis pristis, Pristis zijsron, Pristis clavata, Glyphis glyphis and Glyphis garricki)*, Department of the Environment, Canberra.

Department of the Environment (DoE) 2015a, *Saccolaimus saccolaimus nudicluniatus in Species Profile and Threats Database*, Department of the Environment, Canberra.

Department of the Environment (DoE) 2015b, EPBC Act Policy Statement 3.21 – Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species (Commonwealth of Australia 2015), Commonwealth of Australia, Canberra ACT.

Department of the Environment 2013 (DoE), *Matters of National Environmental Significance - Significant impact guidelines 1.1*, Environment Protection and Biodiversity Conservation Act 1999, Commonwealth of Australia, Canberra ACT.

Department of the Environment (DoE) 2016, Policy Statement: Advanced Environmental Offsets under the *Environemnt Protection and Biodiversity Conserv ation Act 1999,* Department of the Environment, ACT.

Department of the Environment (DoE), NT Environment Protection Agency (NT EPA), 2016, Terms of reference for the preparation of a combined environmental impact statement/public environment report, Lee Point Master Planned Urban Development, Defence Housing Australia, May 2016

Department of the Environment, Water, Heritage and the Arts (DEWHA) 2010, *Survey Guidelines for Australia's Threatened Bats*, Department of the Environment, Water, Heritage and the Arts, ACT.

Department of Sustainability, Environment, Water, Population and Community (DSEWPaC), *EPBC Act Offset Policy,* Australian Government, Department of Sustainability, Environment, Water, Population and Community, ACT.

Domain Group. (2016). *Domain House Price Report – September Quarter 2016*. Fairfax Media.

Doody JS, Green B, Rhind D, Castellano C, Sims R and Robinson T 2009, *Population-level declines in Australian predators caused by an invasive species*, Animal Conservation, vol. 12, pp. 46-53.

Douglas Partner, Report of Geotechnical Assessment, Proposed residential subdivision, Lots 9737 & 9370, Lee Point Road, Muirhead, NT, 2009

Duncan A, Baker GB and Montgomery N (eds) 1999, *The Action Plan for Australian Bats*, Environment Australia, Canberra.

EcOz Environmental Consultants 2014, Ecological Assessment of Muirhead North and 2CRU, Darwin, NT.

EcOz Environmental Consultants 2016, *Black-footed Tree-rat Survey Report: Muirhead North EIS*, prepared by Brooke Rankmore.

EcOz Environmental Consultants, Ecological Assessment of Muirhead North and 2CRU, 2014

EcOz Environmental Consultants, EPBC Referral Lee Point Master-planned Urban Development Darwin, NT, 2015

Essential Economics. (March 2014). *Lee Point: Preliminary Market Assessment of Tourism Accommodation Options*. Essential Economics for the NT Department of Lands, Planning and the Environment.

Foo D. Yin, Northern Territory Government, Deportment of Infrastructure, Planning and Environment, Modelling of the McMinns / Howard East Groundwater System, 2004

Foo D. Yin, Water Resources Group, Goulburn Island Groundwater Resource Evaluation, 1987

Fortune J 2015, *Supplement to the 2014 Darwin Harbour Region Report Card*, Report No. 01/2015D, Aquatic Health Unit, Department of Land Resource Management, Palmerston, NT, viewed 12 June 2015, <http://www.lrm.nt.gov.au/water/water/darwin-harbour/regional-report-cards>.

Friend G and Braithwaite R 1986, Bat fauna of Kakadu National Park, Northern Territory, Australian Mammalogy, 9:43-52.

Friend GR 1985, *Ecological studies of a population of Antechinus bellus (Marsupialia: Dasyuridae) in tropical northern Australia*, Australian Wildlife Research 12: 151–162.

Friend GR 1987, *Population ecology of Mesembriomys gouldii (Rodentia: Muridae) in the wet-dry tropics of the Northern Territory*, Australian Wildlife Research 14, 293-303.

Friend GR and Calaby JH 1995, *Mesembriomys gouldii* in R Strahan (ed) The Mammals of Australia, pp564-566, Sydney: Reed Books.

Friend GR and Taylor JA 1985, *Habitat preferences of small mammals in tropical open-forest of the Northern Territory*, Australian Journal of Ecology 10: 173–185.

GHD 2010, *Report for Lee Point Road Defence Site – Environmental Site Assessment*.

GHD, Demolition Tender Specificications 2CRU – Contamination Review', Report prepared for Defence Housing Australia, December 2014.

GHD, Destructive Hazardous Building Materials Survey – 2CRU RAAF Transmission Facility, NT', Report prepared for Defence Housing Australia, November 2014.

GHD. (July 2014). *Lee Point Area Community Infrastructure Requirements*. GHD for Defence Housing Australia.

Gillespie GR, Brennan K, Gentles T, Hill B, Low Choy J, Mahney T, Stevens A and Stokeld D 2015, *A guide for the use of remote cameras for wildlife survey in northern Australia*, National Environmental Research Program, Northern Australia Hub, Charles Darwin University, Casuarina, NT.

Griffiths A, Koenig J, Carrol F and Price O 2002, Activity area and day-time tree use of the Black-footed Tree-rat *Mesembriomys gouldii, Australian Mammalogy* 23:181-183.

Hans F. Winterkorn and E. C. Chandrasekharan, Winterkorn Road Research Institute, Princeton, New Jersey, Laterite Soil and their Stabilisation, 1951

Harding SA, Wilson JR and Geering A 2007, Threats to shorebirds and conservation actions. In *Shorebirds of Australia* (Ed. Geering A, Agnew L, and Harding S) pp. 197-212. (CSIRO Publishing)

Harrison, L, McGuire, L, Ward, S, Fisher, A, Pavey, C, Fegan, M and Lynch, B, 2009, *An inventory of sites of international and national significance for biodiversity values in the Northern Territory*, Department of Natural Resources, Environment, The Arts and Sport, Darwin.

Higgins PJ (ed.) 1999, *Handbook of Australian, New Zealand and Antarctic Birds, Volume Four - Parrots to Dollarbird*, Oxford University Press, Melbourne, Victoria.

Higgins PJ and Davies SJJF (eds) 1996, *Handbook of Australian, New Zealand and Antarctic Birds, Volume Three - Snipe to Pigeons*, Oxford University Press, Melbourne, Victoria.

Higgins PJ, Peter JM and Cowling SJ (eds.) 2006, *Handbook of Australian, New Zealand and Antarctic Birds, Volume Seven - Boatbill to Starlings*, in Handbook of Australian, New Zealand and Antarctic Birds, Oxford University Press, Melbourne, Victoria.

Hill B 2012, Threatened Species of the Northern Territory – Black-footed Tree-rat Mesembriomys gouldii, Northern Territory Department of Land Resource Management, viewed 9 September 2015, <https://nt.gov.au/__data/assets/pdf_file/0018/205515/black-footed-tree-rat.pdf>.

Holmes J, Bisa D, Hill A and Crase B 2005, *A Guide to Threatened, Near Threatened and Data Deficient Plants in the Litchfield Shire of the Northern Territory*, WWF-Australia.

Housing Industry Association. (August 2016). HIA Housing Forecasts – August 2016 – Dwelling Starts by state and territory [online]. https://hia.com.au/~/media/HIA%20Website/Files/IndustryBusiness/Economic/forecasts/August%202016%20Forecasts.ashx. [Accessed on 4 October 2016].

IAP2 International. (2014). *Public Participation Spectrum*. IAP2 International Federation.

IUCN 2012, *IUCN Red List Categories and Criteria*: Version 3.1, Second edition, Gland, Switzerland and Cambridge, UK: IUCN.

Kerrigan R, Cowie I and Liddle D 2006, *Threatened Species of the Northern Territory – Cycas armstrongii*, Northern Territory Department of Land Resource Management, viewed 24 April 2015, <http://lrm.nt.gov.au/__data/assets/pdf_file/0005/10967/Cycas_armstrongii_VU.pdf>.

Liddle DT 2009, 'Management Program for Cycads in the Northern Territory of Australia 2009-2014', Northern Territory Department of Natural Resources, Environment, the Arts and Sport, Darwin.

Lilleyman A 2016, *Report on potential impacts from disturbance to migratory shorebirds in Darwin: Defence Housing Australia Lee Point Master-planned Urban Development*, prepared for EcOz Environmental Consultants.

MacKinnon J, Verkuil YI and Murray N 2012, IUCN situation analysis on East and Southeast Asian intertidal habitats, with particular reference to the Yellow Sea (including the Bohai Sea). Occasional Paper of the IUCN Species Survival Commission No. 47, Gland, Switzerland and Cambridge, UK.

Marchant S and Higgins PJ (eds) 1993, *Handbook of Australian, New Zealand and Antarctic Birds, Volume 2 – Raptors to Lapwings*, Oxford University Press, Melbourne, Victoria.

Meek P and Flemming P (eds.), 2014, *Camera Trapping: Wildlife Management and Research*, CSIRO Publishing.

Metropolitan Water Sewerage and Drainage Board – Sydney (now Sydney Water Board) Manual, (1979). Design of Separate Sewer Systems.

Milne DJ 2002, *Key to the bat calls of the Top End of the Northern Territory*, Parks and Wildlife Commission of the Northern Territory, Technical Report No. 71.

Milne DJ, Jackling FC, Sidhu M and Appleton B 2009, *Shedding new light on old species identifications: morphological and genetic evidence suggest a need for conservation status review of the critically endangered bat*, Saccolaimus saccolaimus, Wildlife Research, 36:495-508.

Moores N, Rogers DI, Rogers K and Hansbro PM 2016, Reclamation of tidal flats and shorebird declines in Saemangeum and elsewhere in the Republic of Korea. Emu 116(2), 136-146.

Morton CV 1992, *Diets of three species of tree-rat, Mesembriomys gouldii (Gray), M. macrurus (Peters) and Conilurus penicillatus (Gould) from the Mitchell Plateau, Western Australia*, B.Sc. (Hons.) thesis, University of Canberra, Canberra.

Murray NJ, Clemens RS, Phinn SR, Possingham HP and Fuller RA 2014, Tracking the rapid loss of tidal wetlands in the Yellow Sea. Frontiers in Ecology and the Environment 12(5), 267-272.

Northern Planning Consultants. (November 2014). *Planning Scheme Amendment: Lee Point Road Area Plan, Lots 04873 and 09370 Town of Nightcliff*. Northern Planning Consultants for Defence Housing Australia.

Northern Territory Department of Lands, Planning and the Environment. (2015). *Darwin Regional Land Use Plan.* Northern Territory Government.

Northern Territory Department of Treasury and Finance. (2014). *2013-14 Mid-Year Report*. Northern Territory Government.

Northern Territory Environment Protection Authority (NT EPA) 2014, *Noise guidelines for development sites in the Northern Territory*, May 2014, Darwin, NT.

Northern Territory Environment Protection Authority. (May 2013). *Guidelines for the Preparation of an Economic and Social Impact Assessment*. Ver 1.2. NT EPA.

Northern Territory Geological Survey, Darwin Geological Map, Australia 1:250 000 series, 1988

Northern Territory Water Data Portal, https://nt.gov.au/environment/water/water-data-portal

Parks and Wildlife Commission NT 2015, *Upgrades to Casuarina Coastal Reserve and Litchfield National Park*, viewed 22 June 2015, <http://www.parksandwildlife.nt.gov.au/manage/experience-development-plans#.VYdaNlI7PdV>.

Parks and Wildlife Commission of the Northern Territory. (2015). *Casuarina Coastal Reserve Experience Development Plan*. Parks and Wildlife Commission of the Northern Territory.

Parks and Wildlife Commission of the Northern Territory. (April 2016). *Casuarina Coastal Reserve Management Plan*. Parks and Wildlife Commission of the Northern Territory.

Peverell SC 2005, *Distribution of sawfishes (Pristidae) in the Queensland Gulf of Carpentaria, Australia, with notes on their ecology*, Environmental Biology of Fishes 73, 391-402.

Pittman GW 2003, *Occurrence and use of tree hollows by mammals in fragmented and continuous savanna woodlands in northern Australia*, B.Sc. (Hons.) thesis, Northern Territory University, Darwin.

Power and Water Corporation, (2010). Water Supply Code of Australia Northern Territory Supplement Part 1 (Supplement to Water Supply Code of Australia, 2011).

PowerWater, Guidelines for Developers and Consulting Engineers for the Provision of Water and Sewerage Infrastructure in Subdivisions

Price O, Rankmore B, Milne DJ, Brock C, Tynan C, Kean L, and Roger L 2005, *Regional patterns of mammal abundance and their relationships to landscape variables in eucalypt woodlands near Darwin, northern Australia*, Wildlife Research, vol. 32, pp. 435-446.

Queensland Government Office of Urban Management. (June 2007). *Implementation Guideline No. 5: Social Infrastructure Planning, South East Queensland Regional Plan*. Queensland Department of Urban Management.

Queensland Government. (September 2010). *Social Impact Assessment: Guideline to preparing a social impact management plan*. Queensland Department of Infrastructure and Planning.

Rankmore B 2006, *Impacts of habitat fragmentation on the vertebrate fauna of the tropical savannas of northern Australia; with special reference to medium-sized mammals*, Ph.D. thesis, Charles Darwin University, Darwin.

Rankmore BR 2003, *Species Profile: The Black-footed Tree-rat (Mesembriomys gouldii)*, Northern Territory Naturalist 17:56—57.

Rankmore BR and Friend GR 2008, *Black-footed tree-rat Mesembriomys gouldii*, In S. Van Dyck and R. Strahan, The mammals of Australia (pp.591-593), Sydney: Reed New Holland.

Realestate.com. (October 2016). Online Real Estate Search [online]. http://www.realestate.com.au/buy/property-house-in-karama%2c+nt+0812%3b+malak%2c+nt+0812%3b+wulagi%2c+nt+0812%3b+anula%2c+nt+0812%3b+leanyer%2c+nt+0812%3b+wagaman%2c+nt+0810%3b+moil%2c+nt+0810%3b+wanguri%2c+nt+0810%3b+casuarina%2c+nt+0810%3b+jingili%2c+nt+0810%3b+alawa%2c+nt+0810%3b+nakara%2c+nt+0810%3b+brinkin%2c+nt+0810%3b+tiwi%2c+nt+0810%3b+lyons%2c+nt+0810%3b+muirhead%2c+nt+0810%3b+marrara%2c+nt+0812%3b+northlakes%2c+nt+0812%3b+/list-1?includeSurrounding=false&source=location-search. [Accessed 11 October 2016]

Realestate.com. (October 2016). Online Real Estate Search [online]. http://www.realestate.com.au/buy/property-townhouse-unit+apartment-in-karama%2c+nt+0812%3b+malak%2c+nt+0812%3b+wulagi%2c+nt+0812%3b+anula%2c+nt+0812%3b+leanyer%2c+nt+0812%3b+wagaman%2c+nt+0810%3b+moil%2c+nt+0810%3b+wanguri%2c+nt+0810%3b+casuarina%2c+nt+0810%3b+jingili%2c+nt+0810%3b+alawa%2c+nt+0810%3b+nakara%2c+nt+0810%3b+brinkin%2c+nt+0810%3b+tiwi%2c+nt+0810%3b+lyons%2c+nt+0810%3b+muirhead%2c+nt+0810%3b+marrara%2c+nt+0812%3b+northlakes%2c+nt+0812/list-1?includeSurrounding=false&source=location-search. [Accessed 11 October 2016]

Realestate.com. (October 2016). Online Real Estate Search [online]. http://www.realestate.com.au/rent/property-house-in-karama%2c+nt+0812%3b+malak%2c+nt+0812%3b+wulagi%2c+nt+0812%3b+anula%2c+nt+0812%3b+leanyer%2c+nt+0812%3b+wagaman%2c+nt+0810%3b+moil%2c+nt+0810%3b+wanguri%2c+nt+0810%3b+casuarina%2c+nt+0810%3b+jingili%2c+nt+0810%3b+alawa%2c+nt+0810%3b+nakara%2c+nt+0810%3b+brinkin%2c+nt+0810%3b+tiwi%2c+nt+0810%3b+lyons%2c+nt+0810%3b+muirhead%2c+nt+0810%3b+marrara%2c+nt+0812%3b+northlakes%2c+nt+0812/list-1?includeSurrounding=false&source=location-search. [Accessed 11 October 2016]

Realestate.com. (October 2016). Online Real Estate Search [online]. http://www.realestate.com.au/rent/property-townhouse-unit+apartment-in-karama%2c+nt+0812%3b+malak%2c+nt+0812%3b+wulagi%2c+nt+0812%3b+anula%2c+nt+0812%3b+leanyer%2c+nt+0812%3b+wagaman%2c+nt+0810%3b+moil%2c+nt+0810%3b+wanguri%2c+nt+0810%3b+casuarina%2c+nt+0810%3b+jingili%2c+nt+0810%3b+alawa%2c+nt+0810%3b+nakara%2c+nt+0810%3b+brinkin%2c+nt+0810%3b+tiwi%2c+nt+0810%3b+lyons%2c+nt+0810%3b+muirhead%2c+nt+0810%3b+marrara%2c+nt+0812%3b+northlakes%2c+nt+0812/list-1?includeSurrounding=false&source=location-search. [Accessed 11 October 2016]

Reardon TB, Armstrong KN and Jackson SM 2015, *A current taxonomic list of Australian Chiroptera*, Australasian Bat Society, Inc. Version 2015-05-15, <http://ausbats.org.au/taxonomic-list/4589345107>.

Safarova, Shokhida. (2016). *Thermal performance of 6 star rated houses in the hot and humid tropical climate of Darwin.* Paper prepared for SBE16 International High-Performance Built Environment Conference. Centre for Renewable Energy, Research Institute for the Environment and Livelihoods, Charles Darwin University.

Schulz M and Thomson B 2007, *Recovery plan for the Bare-rumped Sheathtail Bat, Saccolaimus saccolaimus nudicluniatus 2007-2011*, Report to Department of the Environment and Heritage, Canberra. Brisbane: Queensland Parks and Wildlife Service.

SMEC 2014, *Preliminary Geotechnical Investigation and Assessment, Muirhead North*, Report prepared for Defence Housing Australia, SMEC 2014.

SMEC Urban. (July 2014). *2CRU Lee Point Road, Muirhead Darwin Rezoning Report*. Smec Urban for Defence Housing Australia.

SMEC, Preliminary Geotechnical Investigation and Assessment, Muirhead North Due Diligence, January 2015

Specialised Zoology 2015, *Bat call identification from Casuarina, Northern Territory*, prepared by Kyle Armstrong and Yuki Konishi.

Specialised Zoology 2016, *Bat call identification from near Darwin, Northern Territory*, prepared by Kyle Armstrong and Yuki Konishi.

SQM Research. (October 2016). *SQM Research Vacancy Rates and Asking Rents Media Release*. SQM Research.

Stokeld D and Gillespie G 2015, Assessment of Small Mammal Fauna of the Darwin Area, prepared by the Flora and Fauna Division (Department of Land Resource Management) and NERP Northern Australia Hub.

Thorburn DC, Peverell S, Stevens S, Last JD and Rowland AJ 2003, *Status of freshwater and estuarine elasmobranchs in Northern Australia*, Report to Natural Heritage Trust, Canberra.

Tidemann SC 1996, *Causes of the decline of the Gouldian Finch Erythrura gouldiae*, Biological Conservation International, vol. 6, pp. 49-61.

Tourism NT. (January 2017). Darwin Monthly Accommodation Report – January 2017 [online]. http://createsend.com/t/t-BF3EFDC5B76A2017. [Accessed 2 March 2017].

Tourism NT. (January 2017). *Tourism NT Regional Profile: Greater Darwin. Report Period Year Ending June 2016*. Tourism NT, Northern Territory Government.

Tourism NT. (September 2013). *Tourism Vision 2020: Northern Territory's Strategy for Growth*. Tourism NT, Northern Territory Government.

Van Dyck S, Gynther I and Baker A (eds.) 2013, *Field companion to the Mammals of Australia*, New Holland, London.

Vanden Broek P.H. Bureau of Mineral Resources, Geology and Geophysics, Engineering geology of Darwin East, NT, 1980

VDM-EcOz 2008, *Flora and Fauna Survey of the Proposed Muirhead Development Site*, prepared for Connell Wagner Pty Ltd.

VDM-EcOz 2008, *Flora and Fauna Survey of the proposed Muirhead Development Site*.

Water Services Association of Australia, (2011). Water Supply Code of Australia WSA 03-2011

Watson ML and Calaby JH 2008, *Fawn Antechinus: Antechinus bellus*, in The Mammals of Australia, 3rd Edition (eds. Van Dyck, S and Strahan, R), Reed New Holland, Sydney

Woinarski J and Ward S 2012, Threatened Species of the Northern Territory – Masked Owl (north Australian mainland subspecies), Tyto novaehollandiae kimberli. Northern Territory Department of Land Resource Management < https://nt.gov.au/__data/assets/pdf_file/0019/206362/masked-owl-kimberli.pdf>.

Woinarski J, Armstrong M, Brennan K, Fisher A, Griffiths AD, Milne D, Palmer C, Ward S, Watson S, Winderlich S and Young S 2010, *Monitoring indicates rapid and severe decline of native small mammals in Kakadu National Park, northern Australia*, Wildlife Research 37:116-126.

Woinarski JCZ 2006, Threatened Species of the Northern Territory – Partridge Pigeon (eastern subspecies) Geophaps smithii smithii, Northern Territory Department of Land Resource Management < https://nt.gov.au/__data/assets/pdf_file/0003/206355/partridge-pigeon.pdf>.

Woinarski JCZ, Milne DJ and Wanganeen G 2001, *Changes in mammal populations in relatively intact landscapes of Kakadu National Park, Northern Territory*, Australia, Austral Ecology 26, 360-370.

Ziembicki MR, Woinarski JCZ and Mackey B 2013, *Evaluating the status of species using Indigenous knowledge: novel evidence for major native mammal declines in northern Australia*, Biological Conservation 157, 78-92.

APPENDIX A

Terms of Reference

Table 8o. Breakdown of where ToR have been addressed in EIS

Terms of Reference Section		EIS Section
2.1	General Information	1
2.2	Project components	2 and 6
2.2.1	*Planning and development*	1
2.2.2	*Essential infrastructure*	8
2.2.3.	Workforce	8.5.1.1
2.3	Approvals, conditions and agreements	0
2.4	Environmental history	2.2
2.5	Alternatives	Last remaining site available for residential development in Darwin's northern suburbs.
3	Existing environment	
3.1	Climate	2.3
3.2	Topography and geology	4.2.1
3.3	Biodiversity	7.2.4
3.4	Surface water	4
3.5.	Groundwater	4.2.2.1
4.	Socio-economic aspects	8
5.	Risk assessment	
5.1	Approach	3 and Appendix C
5.2	Biodiversity	7.2.4.5 and Appendix D
5.2.1	*Environmental objectives*	
5.2.2	*Assessment of risk*	
5.2.3	*Mitigation and monitoring*	
5.3	Water	4.2.5and Appendix D
5.3.1	*Environmental objectives*	
5.3.2	*Assessment of risks*	
5.3.4	*Monitoring*	
5.4	Historical and cultural heritage	7.2.4.5 and Appendix D
5.4.1	*Environmental objective*	
5.4.2	*Assessment of risks*	

Terms of Reference Section		EIS Section
5.4.3	*Mitigation*	
5.5	Biting insects	4.2.5and Appendix D
5.5.1	*Environmental objectives*	
5.5.2	*Assessment of risks*	
5.5.3	*Mitigation*	
5.4.4	*Monitoring*	
5.6	Socio-economic	8.6 and Appendix D
5.6.1	*Environmental objectives*	
5.6.2	*Assessment of risk*	
5.6.3	*Mitigation and monitoring*	
5.7	Other risks	
5.7.1	*Noise*	9 and Appendix D
5.7.2	*Air*	0 and Appendix D
5.7.3	*Odour*	5.2.1 and Appendix D
5.7.4	*Acid Sulfate Soils*	4.2.1 and 4.3.2
5.7.5	*Waste Management*	Appendix D
5.7.6	*Policing, fire and emergencies*	6
5.7.7	*Transport*	6
5.7.8	*Visual Amenity*	8.6.2
5.8	Cumulative Impacts	7.3.1
6	Environmental offsets	7.5
7	Environmental management	Appendix D

APPENDIX B

Contributors

Name	Qualifications	Years' Experience	Role
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Ray Cook	I.Eng (UK)	30	Manager – Traffic and Transport Planning
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Asbjorn Hansen	Masters of Engineering in Acoustics	8	Acoustic Engineer
Brad Cunnington	Masters of Planning	12	Social Economic

APPENDIX C

Risk Assessment

Number	Component	Matter	Aspect	Potential Impacts	Consequence	Likelihood	Outcome	Management Control
1	Hydrology	Sandy Creek	Surface water quality	Increased nutrient load entering Sandy Creek	Moderate	Possible	Med	Bio-retention basins and pre/post construction monitoring of water quality in Sandy Creek
2	Hydrology	Sandy Creek	Surface water flow rates	Increased stormwater runoff to Sandy Creek	Moderate	Possible	Med	Stormwater detention basins to mitigate post-developed flows to pre-developed levels
3	Hydrology	Sandy Creek	Erosion	Increased erosion within receiving waters of Sandy Creek	Moderate	Possible	Med	Basin and Stormwater outlets to be designed to ensure velocities and bed shear stresses are not worsesned as a consequence of development
4	Hydrology	Sandy Creek	Flooding	Increased flood levels and volumes to Sandy Creek	Moderate	Possible	Med	Use of detention basins to mitigate post-developed flood levels to pre-developed conditions
5	Hydrology	Sandy creek	Groundwater depth	Decrease of groundwater recharge on 2CRU affecting water table levels and baseflow to Sandy Creek	Minimal	Remote	Negligible	Retention basins and pre/post allowing for recharge to groundwater. Groundwater baseflow contribution potentially limited. Groundwater is salty (i.e. naturally low environmental value)
6	Hydrology	Sandy creek	Groundwater contamination	Contamination of Sandy Creek through groundwater	Moderate	Remote	Very low	Incident control measures during construction, geographially further remote from activities
7	Hydrology	Casuarina Coasta	Groundwater depth	Decrease of groundwater recharge on 2CRU affecting water table levels and vegetation health on the reserve	Moderate	Possible	Very low	Groundwater found deeper in the top of the reserve at lower at the foothill. Reinfiltration of groundwater through unlines surface water retention ponds will compensate for any loss in groundwater recharge
8	Hydrology	Casuarina Coasta	Groundwater contamination	Contamination migrating off-site to Casuarina Coastal Reserve	Moderate	Unlikely	Low	Incident control measures during construction. No activities on the reserve itself. During site use, activities requiring chemical manage under licence.
9	Hydrology	2CRU	Groundwater depth	Decrease of groundwater recharge on 2CRU affecting water table levels and vegetation health on the reserve	Moderate	Unlikely	Low	Groundwater found deeper in the top of the reserve at lower at the foothill. Residential nature of the proposed development optimises the use of natural areas. Reinfiltration of groundwater through unlines surface water retention ponds will compensate for any loss in groundwater recharge
10	Hydrology	2CRU	Groundwater contamination	Groundwater contamination during construction and site use	Minor	Possible	Low	Incident control measures during construction. Rapid remediaton preventing further migration. Sewage connected to sewer main (i.e. no septic systems)
11	Hydrology	Muirhead North	Acid Sulphate Soils	Expose Acid-sulphate Soils during construction in south-eastern corner of Muirhead North	Moderate	Unlikely	Low	Acid Sulphate Soil testing to be done in south-eastern corner of Muirhead North. Acid Sulphate Soil Management Plan to be prepared if acid sulphate soils are detected.
12	Noise and	Noise	Traffic (operation)	Increase noise levels from traffic as a result of project	Moderate	Unlikely	Low	Speed limits, road design, noise barriers, low noise asphalt, façade upgrades and public transport options.
13	Noise and	Noise	Traffic (operation)	Noise levels could cause sleep disturbance	Minor	Unlikely	Very low	Screening such as noise barriers, façade upgrades to dwellings near Lee Point Road
14	Noise and	Vibration	Traffic (operation)	Perception of heavy vehicles	Minor	Unlikely	Very low	Road design, avoid speed bumps
15	Noise and	Noise	Plant (construction)	Could cause community complaints	Moderate	Possible	Medium	Communicate with impacted noise sensitive receivers and notify them in advance via letterbox drop and provide them with a contact number.
16	Noise and	Noise	Plant (construction)	Noise levels could cause sleep disturbance	Moderate	Possible	Medium	Avoid night time construction works, Install temporary noise barriers and provide respite periods
17	Noise and	Vibration	Plant (construction)	Could cause human discomfort	Minor	Possible	Low	Use smaller plant near sensitive receivers
18	Noise and	Vibration	Plant (construction)	Could cause structural damage	Moderate	Unlikely	Low	Use smaller plant near sensitive structures
19	Air Quality	Dust	Traffic (operation)	Impacts to adjoining residents health	Moderate	Possible	Medium	Watering on haul road surfaces, prevent material being deposited/spilled on haul roads, speed limits, trafficable areas clearly marked
20	Air Quality	Dust	Traffic (operation)	Impacts to workers health	Moderate	Possible	Medium	Watering on haul road surfaces, prevent material being deposited/spilled on haul roads, speed limits, trafficable areas clearly marked
21	Air Quality	Dust	Traffic (operation)	Vegetation smothering	Minor	Possible	Low	Watering on haul road surfaces, prevent material being deposited/spilled on haul roads, speed limits, trafficable areas clearly marked
22	Air Quality	Dust	Traffic (operation)	Sedimentation of waterways	Moderate	Possible	Medium	Watering on haul road surfaces, prevent material being deposited/spilled on haul roads, speed limits, trafficable areas clearly marked, WSUD
23	Air Quality	Dust	Plant (construction)	Impacts to adjoining residents health	Moderate	Possible	Medium	Application of dust suppression before construction, reducing double handling of material, minimise fall distance between the fall distance of materials during loading and unloading, relocate/reschedule works during dusty periods if practical, plant travel on defined roads
24	Air Quality	Dust	Plant (construction)	Impacts to workes health	Moderate	Possible	Medium	Application of dust suppression before construction, reducing double handling of material, minimise fall distance between the fall distance of materials during loading and unloading, relocate/reschedule works during dusty periods if practical, plant travel on defined roads
25	Air Quality	Dust	Plant (construction)	Vegetation smothering	Minor	Possible	Low	Application of dust suppression before construction, reducing double handling of material, minimise fall distance between the fall distance of materials during loading and unloading, relocate/reschedule works during dusty periods if practical, plant travel on defined roads
26	Air Quality	Dust	Plant (construction)	Sedimentation of waterways	Moderate	Possible	Medium	Application of dust suppression before construction, reducing double handling of material, minimise fall distance between the fall distance of materials during loading and unloading, relocate/reschedule works during dusty periods if practical, plant travel on defined roads
27	Air Quality	Dust	Vegetation clearing	Impacts to adjoining residents health	Moderate	Possible	Medium	Limit the amount of excavation required to clear native vegetation, Undertake vegetation clearing during wetter periods if practical, notify adjoining residents when work is to be undertaken, spray down affected vegetation, retain cleared native vegetation on surface,
28	Air Quality	Dust	Vegetation clearing	Impacts to workers health	Moderate	Possible	Medium	Limit the amount of excavation required to clear native vegetation, Undertake vegetation clearing during wetter periods if practical, notify adjoining residents when work is to be undertaken, spray down affected vegetation, retain cleared native vegetation on surface,
29	Air Quality	Dust	Vegetation clearing	Vegetation smothering	Minor	Possible	Low	Limit the amount of excavation required to clear native vegetation, Undertake vegetation clearing during wetter periods if practical, notify adjoining residents when work is to be undertaken, spray down affected vegetation, retain cleared native vegetation on surface,
30	Air Quality	Dust	Vegetation clearing	Sedimentation of waterways	Moderate	Possible	Medium	Limit the amount of excavation required to clear native vegetation, Undertake vegetation clearing during dry periods if practical to avoid monsoonal rains, notify adjoining residents when work is to be undertaken, spray down affected vegetation, retain cleared native vegetation on surface,
31	Air Quality	Dust	Exposed areas	Impacts to adjoining residents health	Moderate	Possible	Medium	Minimise the area of disturbance (staged development), rehabilitate areas as soon as possible, stabilise areas likely to remain extended periods, water exposed areas during watering runs
32	Air Quality	Dust	Exposed areas	Impacts to workers health	Moderate	Possible	Medium	Minimise the area of disturbance (staged development), rehabilitate areas as soon as possible, stabilise areas likely to remain extended periods, water exposed areas during watering runs
33	Air Quality	Dust	Exposed areas	Vegetation smothering	Minor	Possible	Low	Minimise the area of disturbance (staged development), rehabilitate areas as soon as possible, stabilise areas likely to remain extended periods, water exposed areas during watering runs
34	Air Quality	Dust	Exposed areas	Sedimentation of waterways	Moderate	Possible	Medium	Minimise the area of disturbance (staged development), rehabilitate areas as soon as possible, stabilise areas likely to remain extended periods, water exposed areas during watering runs
35	Utilities	Sewerage	Surface and Ground Water	Sewer overflows from development caused by extreme weather events, including first flush and wet season influences	Moderate	Unlikely	Low	Muirhead SPS - capacity upgrade, adequate emergency storage Lyons SPS - Capacity upgrade to buffer the inadequate emergency storage. Leanyer STP proposed augmentation by PWC in next 5 years has allowed for development load.
36	Utilities	Sewerage	Security	Disruption of existing sewerage service with the provision of sewerage to the development	Major	Unlikely	Low	Muirhead SPS - capacity upgrade, adequate emergency storage Lyons SPS - Capacity upgrade to buffer the inadequate emergency storage. Leanyer STP proposed augmentation by PWC in next 5 years has allowed for development load.
37	Utilities	Sewerage	Capacity	Inadequate capacity and/or treatment of wastewater treatment facilities	Minor	Unlikely	Low	PWC have advised that the Leanyer STP will be due for augmentation in the next 5 years. PWC future planning has accounted for projected loads from the development.
38	Utilities	Potable Water	Security of supply	Disruption of existing potable water supply with the provision of reticulated water to the development	Major	Remote	Low	Existing network - adequate. Ultimate network - proposed new break of head tank and booster pump station to service a small elevated area within the site.
39	Utilities	Potable Water	Source water availability	Inadequate source water capacity	Minor	Unlikely	Low	The proposed development is located within the Casuarina Water Supply Zone (WSZ), where water is supplied by the Marrara and Casuarina Reservoirs. Source water is obtained from the Darwin River Dam, which offers a secure water supply. There is low risk of inadequate supply from this catchment.
40	Utilities	Potable Water	Water quality	Groundwater seepage/contamination	Minor	Unlikely	Low	No dry weather overflows in sewerage network
41	Utilities	Potable Water	Capacity	Inadequate capacity and/or treatment of water treatment facilities	Minor	Unlikely	Low	PWC have not identified or advised of any deficiency in regard to the provision of treated water within the supply network.
42	Traffic	Transport	Future Road Capacity	Traffic growth over a long period of time may result in the road network being unable to accommodate with the traffic demand.	Moderate	Remote	Very Low	The traffic analysis shows that the road network is able to accommodate the traffic demand 10 years after the completion of the development. However if additional developments are to be proposed within the area a separate traffic assessment is required to determine its impacts.
43	Traffic	Transport	Road Safety	Increased frequency of road accidents.	Moderate	Unlikely	Low	Check that the design of roads and intersection follow the relevant standards and guidelines.
44	Traffic	Transport	Accessibility	Inconvenience for drivers.	Minor	Unlikely	Very Low	Multiple Site accesses are available and are conveniently located.
45	Traffic	Transport	Wayfinding	Poor wayfinding and longer travel times for drivers.	Minor	Possible	Low	Ensure appropriate wayfinding and signage strategies are implemented.
46	Traffic	Transport	Cyclist Safety	Increased risk of accidents and deters cyclists from riding due to perceived hazards.	Major	Unlikely	Medium	Dedicated cycling infrastructure has been proposed along Lee Point Road.
47	Traffic	Transport	Pedestrian Safety	Increased risk of accidents.	Major	Unlikely	Medium	Ensure that safe pedestrian infrastructure such as crossings and good quality paths are provided.
48	Traffic	Transport	Peak Period Traffic	Poor road network operation leading to increased congestion.	Moderate	Remote	Very Low	The traffic analysis shows that the road network is able to accommodate the peak period traffic without issues. If required, traffic management measures may also be implemented to reduce congestion at critical intersections and redistribute traffic into non-congested roads.
49	Traffic	Transport	Traffic Speeds	Higher speed increases the risk and severity of accidents.	Moderate	Possible	Medium	Check that the speed limit is suitable to the surrounding environment. This may require lowering the speed limit for residential access roads and areas where a school is located.
50	Traffic	Transport	Heavy Vehicles Access	Poor accessibility for HV and increased risk of collision with traffic and other objects.	Major	Unlikely	Medium	Ensure road and intersection geometry is capable of accommodate heavy vehicle turning movements.
51	Traffic	Transport	Public Transport	Over-reliance on vehicular transport.	Moderate	Unlikely	Low	Explore potential opportunities to extend bus service to the 2CRU Site.
52	Traffic	Transport	Construction	Road improvements on existing roads may lead to delays, congestion and overall inconvenience for drivers.	Moderate	Unlikely	Low	A construction traffic management plan should be implemented during upgrades of existing roads. This includes providing alternate routes or the construction of a temporary road to bypass the construction area.
53	Social and	Social	Social Infrastructure	Oversupply of housing, impact on housing market	Moderate	Possible	Medium	Align staging and development with growth rates per Darwin Regional Land Use Plan (or updated policies and projections)
54	Social and	Social	Social Infrastructure	Over-supply of tourist accommodation	Minor	Unlikely	Very Low	Staged delivery of tourist accommodation facilities to coincide with demand / take-up of initial stages. Provision of a range of accommodation to align with market expectations.
55	Social and	Social	Social Infrastructure	Low / slow occupation of accommodation facilities	Minor	Possible	Low	Staged delivery of tourist accommodation facilities to coincide with demand / take-up of initial stages. Provision of a range of accommodation to align with market expectations.
56	Social and	Social	Workforce	Inadequate suitably trained persons within the Darwin Region to supply skills.	Moderate	Unlikely	Low	Provision of appropriate training opportunities for local market. Importation of skills as a last resort.
57	Social and	Social	Workforce	Shortfall of skilled workers elsewhere due to construction works at Lee Point	Moderate	Unlikely	Low	Ensure staging and timing of construction aligns with anticipated population and housing growth rates for the Darwin Region
58	Social and	Social	Workforce	Shortage of workers to provide services in community, commercial and accommodation facilities	Moderate	Unlikely	Low	Development in accordance with projected commercial, accommodation and social infrastructure demand based on population projections, to ensure service provision doesn't exceed demand created by population.
59	Social and	Social	Social Infrastructure	Increase use of Buffalo Creek Boat Ramp.	Moderate	Unlikely	Low	Ramp has recently been upgraded and access is limited by tidal movement. Continual monitoring required upon occupation to determine impact on use patterns.
60	Social and	Social	Social Infrastructure	Increase visitation to Casuarina Coastal Reserve	Moderate	Almost Cert	Very High	Monetary and spatial (land) contributions by DHA to increase size and improve visitor facilities within the reserve.
61	Social and	Social	Social Infrastructure	Shortfall of social services	Major	Possible	High	Ensure adequate serviced land is available for community and social infrastructure in accordance with needs analysis.
62	Social and	Social	Social Infrastructure	Increase traffic impacts – Lee point Road	Moderate	Likely	High	Undertake road upgrades in accordance with Traffic Impact Assessment
63	Social and	Social	Amenity and Safety	Adverse amenity impacts during construction	Moderate	Possible	Medium	All construction and development works in accordance with a detailed Construction Environment Management Plan (CEMP). Establishment of a complaints register to monitor and respond to complaints
64	Social and	Social	Amenity and Safety	Adverse amenity impacts from modified landform / built form	Moderate	Unlikely	Low	Ensure appropriate compliance with design and layout requirements of NT Planning Scheme, including minimum lot sizes, setbacks, building heights, landscaping and open space, to ensure visual amenity is maximised.
65	Social and	Social	Amenity and Safety	Appearance of land	Minor	Possible	Low	Compliance with EMP regarding construction site appearance.
66	Social and	Social	Amenity and Safety	Prevention of unlawful access, use and dumping	Minor	Possible	Low	Removal of all unauthorised materials. On-site security to ensure no further illegal access, use or dumping.
67	Social and	Economic	Economic/Business Developme	Low / slow take-up of commercial land by private sector	Moderate	Unlikely	Low	Ensure the appropriate provision of serviced commercial land, designed and located to cater for end use. Provide commercial land in accordance with needs analysis (ie avoid over supply)
68	Social and	Economic	Economic/Business Developme	Impact on viability of nearby commercial areas by proposed centre facilities	Moderate	Unlikely	Low	Provide commercial land in accordance with needs analysis (ie avoid over supply), which considers the current and future provision of commercial and centre-type facilities (including the planned Muirhead centre)
69	Social and	Economic	Economic/Business Developme	Over-supply of commercial land	Moderate	Unlikely	Low	Provide commercial land in accordance with needs analysis. Update needs analysis and consult with retail sector during subdivision design. Provide accommodation in accordance with tourist accommodation demand analysis.
70	Social and	Economic	Economic/Business Developme	Commercial land remains vacant after sale	Moderate	Possible	Medium	Contractual provisions regarding commencement of construction (ie within specified time after settlement)
71	Biodiversi	Biodiversity	Vegetation clearance	Extinction of local Black-footed Tree-rat population due to a critical level of habitat loss.	Moderate	Possible	Low	Protect 21.8 ha area of Monsoon vine thicket and Low Eucalyptus Woodland and transfer to NT Parks and Wildlife Conservation (CN) as part of Casuarina Coastal Reserve.
72	Biodiversi	Biodiversity	Vegetation clearance	Loss of a sensitive vegetation type (monsoon rainforest and vine thicket).	Minor	Possible	Low	Survey and peg site boundaries prior to construction.
73	Biodiversi	Biodiversity	Vegetation clearance	Loss of habitat and flora species.	Minor	Likely	Medium	Salvage, and relocate Darwin Cycad plants for use in landscaping Open Space areas and parkland.
74	Biodiversi	Biodiversity	Direct Mortality	Loss of individual Darwin Cycads due to land-clearing activities.	Minor	Likely	Medium	Ongoing management of relocated Darwin Cycad plants.
75	Biodiversi	Biodiversity	Direct mortality		Moderate	Unlikely	Very Low	Ongoing management of relocated Darwin Cycad plants.
76	Biodiversi	Biodiversity	Direct mortality		Moderate	Unlikely	Very Low	Fence the boundary of adjoining Muirhead North site with mesh to prevent any Black-footed Tree-rats from entering the site.
77	Biodiversi	Biodiversity	Direct mortality	Loss of individual Black-footed Tree-rats due to land-clearing activities.	Moderate	Unlikely	Very Low	Remove habitat in a staged manner, working from Lee Point Road towards the Casuarina Coastal Reserve, to give fauna an opportunity to relocate at their own accord.
78	Biodiversi	Biodiversity	Habitat fragmentation		Minor	Possible	Low	Protect 21.8 ha area of Monsoon vine thicket and Low Eucalyptus Woodland and transfer to NT Parks and Wildlife Conservation (CN) as part of Casuarina Coastal Reserve.
79	Biodiversi	Biodiversity	Habitat fragmentation	Increased isolation of native vegetation adjoining the project site.	Minor	Possible	Low	Use native canopy species in landscaping where practical.
80	Biodiversi	Biodiversity	Edge effects	Reduced quality of a sensitive vegetation type (monsoon rainforest and vine thicket) due to increased exposure.	Minor	Likely	Medium	Protect 21.8 ha area of Monsoon vine thicket and Low Eucalyptus Woodland and transfer to NT Parks and Wildlife Conservation (CN) as part of Casuarina Coastal Reserve.
81	Biodiversi	Biodiversity	Water quality impacts	Reduced threatened and migratory shorebird roosting and feeding habitat quality due to reduced surface water quality in Sandy Creek from onsite contaminants.	Moderate	Unlikely	Low	Erosion and Sediment Control Plan (ESCP) will be implemented prevent erosion and remediate areas where erosion is an issue (Appendix D).
82	Biodiversi	Biodiversity	Water quality impacts		Moderate	Unlikely	Low	
83	Biodiversi	Biodiversity	Water quality impacts		Moderate	Unlikely	Low	Discharge flows into Sandy Creek will be maintained at pre-construction levels.
84	Biodiversi	Biodiversity	Water quality impacts	Reduced quality of riparian, wetland and aquatic habitat that receive water from the project area due to onsite contaminants.	Moderate	Unlikely	Low	Water Sensitive Urban Design (WSUD) initiatives that remove sediment, pollutants and contaminants from water run-off will be implemented (see Appendix E).
85	Biodiversi	Biodiversity	Groundwater	Impacts to groundwater dependent ecosystems (monsoon rainforest) due to reduced groundwater water quality from onsite contaminants.	Minor	Remote	Negligible	Construction spill management
86	Biodiversi	Biodiversity	Weed and pest invasion	Reduced quality of sensitive vegetation types (monsoon rainforest and vine thicket) due to weed infestation and/or proliferation.	Minor	Possible	Low	Weed infested areas will be removed during construction.
87	Biodiversi	Biodiversity	Weed and pest invasion		Minor	Unlikely	Very Low	Ensure all plant, equipment, vehicles and soil coming to and from site is treated for noxious weeds.
88	Biodiversi	Biodiversity	Weed and pest invasion		Minor	Unlikely	Very Low	Control Gamba Grass on site along the boundary that interfaces with the Casuarina Coastal Reserve.
89	Biodiversi	Biodiversity	Weed and pest invasion	Reduced habitat quality in surrounding areas due to the introduction and/or proliferation of weeds.	Minor	Unlikely	Very Low	Ongoing weed management within the expanded Casuarina Coastal Reserve will be the responsibility of the NT Government.
90	Biodiversi	Biodiversity	Human disturbance	Loss of shorebird roosting and feeding habitat due to disturbance by recreational beachgoers from increased use of Casuarina Beach.	Major	Unlikely	MEdium	Implement community awareness and engagement program involving pamphlets and public information sessions.
91	Biodiversi	Biodiversity	Human disturbance		Minor	Possible	Low	Construct well-defined access points to the beach located east of Sandy Creek to avoid disturbance to high tide roosting sites.
92	Biodiversi	Biodiversity	Human disturbance		Minor	Possible	Low	Provide one formal access point from the project site to Casuarina Beach, and rehabilitate all informal tracks between the project site and Casuarina Beach.
93	Biodiversi	Biodiversity	Human disturbance		Minor	Possible	Low	Install barrier fencing 100 metres on the western and eastern side of Sandy Creek.
94	Biodiversi	Biodiversity	Human disturbance	Reduced habitat quality in Casuarina Coastal Reserve due to increased human visitation.	Minor	Possible	Low	Install signage at beach access point from project site, as well as other access points off site, to inform beach users of the threat posed by human disturbance (walking, driving, motorbike riding) and dogs on roosting and feeding shorebirds.
95	Biodiversi	Biodiversity	Dust (during construction)	Reduced quality of sensitive vegetation types (monsoon rainforest and vine thicket), as well as vegetation in general, due smothering of vegetation.	Minor	Unlikely	Very Low	Dust control measures (e.g. water-trucks, protection of soil stock-piles) will be implemented during the dry season.
96	Biodiversi	Biodiversity	Domestic pets	Loss of shorebird roosting and feeding habitat due to disturbance by pet dogs from increased human use of Casuarina Beach.	Moderate	Possible	Low	Undertake an annual shorebird monitoring survey program lead by a local expert, supported by community volunteers.
97	Biodiversi	Heritage	Construction	Destruction of Aboriginal stone scatters.	Minor	Almost Cert	High	Apply for a work approval under Section 72 of the NT *Heritage Act* before carrying out any works within the area of the stone scatters
98	Biodiversi	Heritage	Post-construction		Minor	Unlikely	Very Low	Retain the Lee Point bunkers and Konfrontasi Cruciform.
99	Biodiversi	Heritage	Post-construction	Loss or degradation of Military history items	Minor	Possible	Low	Work with local NT Heritage Branch to develop signage and interpretation material of Lee Point Bunkers and Konfrontasi Cruciform.

APPENDIX D

Construction Environmental Management Plan

ecology & heritage partners

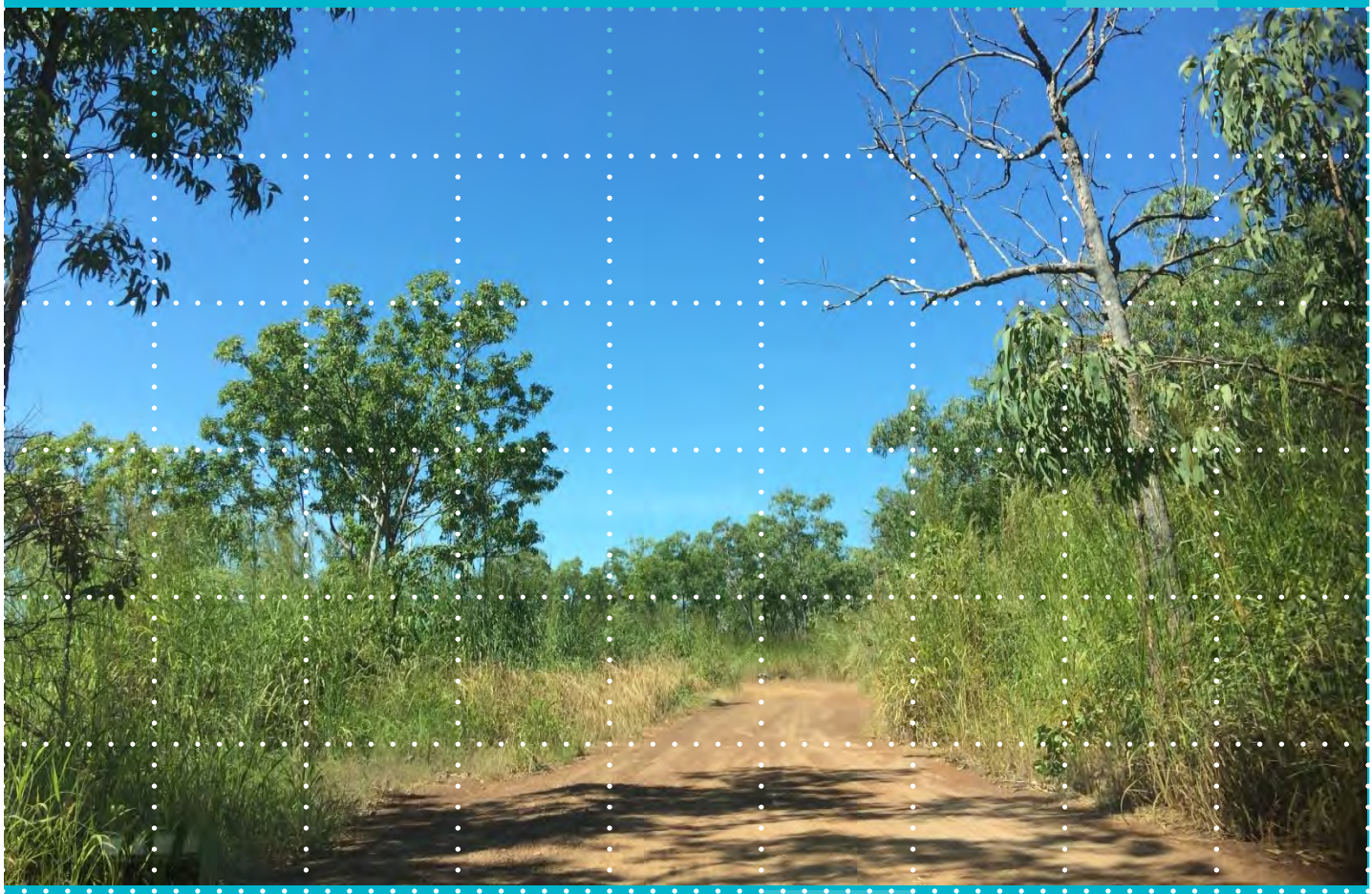
Final Report

Construction Environmental Management Plan (CEMP): Lee Point Master-planned Urban Development

Prepared for

Defence Housing Australia

July 2018



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Document Control

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Contents

1 INTRODUCTION 4
2 PROJECT OVERVIEW 5
3 ENVIRONMENTAL MANAGEMENT FRAMEWORK 7
4 BIODIVERSITY MANAGEMENT SUB-PLAN 10
5 WATER MANAGEMENT SUB-PLAN 17
6 EROSION AND SEDIMENT CONTROL PLAN 22
7 HERITAGE MANAGEMENT SUB-PLAN 28
8 SOCIAL AND ECONOMIC MANAGEMENT SUB-PLAN 30
9 NOISE MANAGEMENT SUB-PLAN 33
10 AIR QUALITY MANAGEMENT SUB-PLAN 37
11 SUPPORTING DOCUMENTS 39

1 Introduction

The purpose of this Construction Environmental Management Plan (CEMP) is to provide a framework for the management of environmental risks identified through the environmental impact assessment process for the Lee Point Master-planned Urban Development. The CEMP is a condition of assessment under the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) and Northern Territory *Environmental Assessment Act* (EA Act) and has been prepared with reference to the NT EPA's *Guidance for the Preparation of an Environmental Management Plan* (NT EPA 2015). It is to be assessed in conjunction with the overarching Environmental Impact Statement (EIS). The environmental risks identified for the project and addressed in this CEMP, were determined through a formal risk assessment process.

Implementation of the project in accordance with the CEMP will ensure that environmental risks are reduced to As Low As Reasonably Practicable (ALARP), and all environmental obligations are met including those contained in legislation, regulations and conditions of approvals, permits and licences issued to the project.

Due to the nature of the project, the CEMP focuses primarily on the construction phase of the project as there are unlikely to be many ongoing environmental issues once construction has been completed. The ongoing performance and maintenance of the stormwater management system; however, is of importance to the operational phase of the project along with the impacts on migratory shorebirds as a result of increased visitation rates to Casuarina Beach. These risks are also addressed in the CEMP.

The CEMP will be further refined and developed once the detailed construction plan has been finalised, and a head contractor has been awarded to construct the project. The management actions contained within this CEMP are considered to be the minimum commitment that Defence Housing Australia and their contractors will undertake to support approval of the project under relevant legislation and allow the project to proceed to construction phase.

1.1 Structure

This CEMP consists of a series of management sub-plans that relate to the key environmental themes that will be the focus of management. They include:

- Biodiversity
- Water
- Erosion and Sediment Control
- Heritage
- Social and Economic
- Noise
- Human Health and Safety
- Air Quality

Each sub-plan clearly articulates management objectives and performance criteria, and outlines the management measures to be applied to avoid and minimise environmental impacts during the relevant phases

of the project. Monitoring and reporting requirements, corrective actions and key responsibilities are also explained.

In addition to the sub-plans, stand-alone management plans have been prepared for Stormwater Management and Water Quality Monitoring, by specialist consultants.

2 Project Overview

The Lee Point Master-planned Urban Development will be developed in accordance with the Lee Point Area Plan and Planning Principle's as described in DHA's application to amend the NT Planning Scheme (PA2014/0922). It will accommodate approximately 700 ground-level dwellings, between 30 and 40 rural residential lots, and between 200 and 250 apartments.

The Lee Point Area Plan identifies a tourism and mixed use centre situated along a Main Street precinct in 2CRU running from Lee Point Road through the site in a north-westerly direction where it will terminate at a coastal esplanade. The area will provide most of the high density residence in 3-6 storey apartments. The coastal esplanade runs perpendicular to the Main Street precinct and parallel to the Casuarina Coastal Reserve. It will be an important area of public open space and provide bicycle and walking paths and other recreation facilities. There will also be a small area of open space in the north of the site as part of the preservation of local military history.

The Main Street precinct will provide a mixture of commercial, retail and community services. There are also four tourist sites to be established along the Main Street that will be transferred to the NT Government and will provide for hotel and apartment accommodation in buildings between 2-12 stories.

A Community Hub will be located in Muirhead North, and will include a primary school, child-care facility and sports facilities, covering approximately 3.7 ha. Immediately adjacent to the Community Hub will be an active recreation reserve including an AFL/cricket oval.

In addition to the coastal esplanade in 2CRU, other areas of public open space will include the preservation of 21 ha of Monsoon Vine-thicket and eucalypt woodland on the western side of 2CRU to conserve habitat for the endangered Black-footed Tree-rat and expand the area of the existing Casuarina Coastal Reserve. A further 1.6 ha within Muirhead North supporting sensitive Monsoon Rainforest vegetation will also be protected. The treatment train of bioretention and detention basins to manage stormwater will also be integrated into public open space, contributing an additional 10 ha (approximate). A series of parks and playground areas will be set-aside across the project site.

The current staging plan for the projects proposes a five staged development, with construction scheduled to commence in the south-east corner of 2CRU (Stage 1) in early 2018.

2.1.1 Construction

Stage 1 of the project is currently scheduled to commence in early 2018, while the final stage of the project (Stage 5) is expected to be completed by 2025 if demand for housing is as expected. The stage plan will be finalised closer to construction.

The construction footprint will involve the loss of approximately 100 ha of degraded eucalypt woodland. A 21.95 ha area of Monsoon Vine-thicket and Low Eucalypt Woodland along the western boundary of 2CRU will

be retained as a conservation reserve. A 1.5 ha patch of native vegetation in Muirhead North containing a 0.9 ha patch of the sensitive Monsoon Rainforest vegetation community will also be protected.

2.1.2 Operations

Operational aspects of the project relevant to the CEMP include the performance of detention and bioretention basins and impacts of increased visitors to Casuarina Beach on migratory shorebirds. All other ongoing maintenance activities after construction is completed, such as management of public open space, roads and utilities, is not considered under this CEMP.

…

3 Environmental Management Framework

Defence Housing Australia's Environmental Management System forms part of the projects Health, Safety, Environment and Quality (HSEQ) Strategy. The EMS provides a framework for identifying and managing environmental risks, and for compliance monitoring and reporting.

This CEMP provides overarching environmental management guidance for the project that will be implemented through the extant EMS processes and procedures of the head contractor. The CEMP establishes a framework of management plans and procedures to address key areas of environmental risk, and incorporates conditions of approval, commitments, and legal and other requirements.

3.1 Roles and Responsibilities for Environmental Management

Table 1 below provides information on the roles and responsibilities of the project's stakeholders in implementing the CEMP. Defence Housing Australia will be ultimately responsible for compliance with the CEMP, and will oversee the performance of the head contractor and sub-contractors in implementing the actions of the CEMP. The relevant environmental regulators are not statutorily required to undertake site audits, but can do at anytime. An independent auditor will review the performance of DHA's and it's contractors in complying with the CEMP on a five yearly basis.

Table 1. Roles and responsibilities

Organisation	Roles and responsibilities
Defence Housing Australia	Ensures head contractor is complying with CEMP, including implementing actions, monitoring and reporting. Site auditing on a discretionary and strategic basis. Respond to any complaints from the public. Approves corrective actions and notification of regulatory authorities when there is an exceedance, if necessary.
Head contractor	Implementation of all actions of the CEMP, including management actions, monitoring and reporting. Site auditing of sub-contractors on a discretionary and strategic basis. Environmental training. Complaints management. Notifies DHA of any non-compliance with CEMP.
Sub-contractor(s)	Implementation of all actions in relevant sub-plan of CEMP, including management actions, monitoring and reporting. Supervises the environmental performance of each task against the CEMP. Notifies head contractor of any non-compliance with CEMP.
Department of the Environment and Energy (Commonwealth)	Environmental regulator – undertake audits of project site if required, and assess compliance with CEMP in accordance with Commonwealth approvals. Review annual monitoring reports.
Environment Protection Authority (Northern Territory)	Environmental regulator – undertake audits of project site if required, and assess compliance with CEMP in accordance with Commonwealth approvals.

Organisation	Roles and responsibilities
	Review annual monitoring reports.
Independent auditor	Provide an independent audit of the projects' performance against the CEMP (every 5 years).

3.2 Training and Awareness

The head contractor will be responsible for training and awareness. Prior to commencing work, all staff including any contractors/sub-contractors must complete a site induction identifying them of the type and location of sensitive environmental areas and potential threats. The induction will include, as a minimum:

- Location of Casuarina Coastal Reserve, Sandy Creek and Buffalo Creek
- Description of Black-footed Tree-rat and where the species could potentially occur
- Migratory shorebird habitat
- Military heritage
- Area of Monsoon Vine-thicket and Monsoon Rainforest to be retained, and other areas of native vegetation to be retained in public open space.
- Adjoining residents and land-users and their exposure to the project
- The impacts of erosion, weed spread, habitat removal, human disturbance, dust and noise can have on these values.

3.3 Incidents and Complaints

An Incident and Complaints register will be established and maintained by the head contractor. Any incidents of non-compliance with the CEMP will be recorded and the DHA will be notified (and relevant environmental regulator if necessary) as soon as possible.

Any complaints received will be recorded in the same register. The head contractor will notify DHA of any complaints received as soon as possible, and DHA will be responsible for provide a response. The register will include a record of when the complaint was received, the nature of the complaint, when it was responded to, by whom and how.

3.4 Monitoring, auditing, and reporting

3.4.1 Monitoring responsibility

Monitoring will be undertaken to assess compliance with the CEMP and that the magnitude of impacts are within the approved limits.

There will be ongoing monitoring of the site by a representative of the head contractor who is aware of the prescriptions of the CEMP. The head contractor may also sub-contract aspects of monitoring including specific tasks such as water quality monitoring and migratory shorebird monitoring, if there is no available expertise within their organisation.

3.4.2 *Auditing*

Defence Housing Australia will undertake random audits periodically throughout the project, and during or after any major corrective actions or remediation works. They will also audit the head contractor to ensure the Incident and Complaint register is being maintained, training and awareness programs are being rolled out, and the monitoring is being undertaken as scheduled. The head-contractor will audit any sub-contractors on a periodic basis to check general environmental performance and compliance with relevant sub-plans of the CEMP.

Environmental regulators may undertake audits during construction phase.

An independent auditor will be engaged to review compliance with the CEMP, whether the CEMP is mitigating environmental impacts as intended, and whether any changes to the CEMP or its implementation are required.

3.4.3 *Reporting*

An annual CEMP report will be prepared and submitted to DoEE and NT EPA throughout the construction phase of the project. The report will include:

- List of actions from the CEMP that have been implemented including photographic evidence.
- Details of any non-compliance.
- Results of water quality and migratory shorebird monitoring.
- List of complaints received from adjoining residents.
- Number of staff that have completed environmental awareness training.
- Any unexpected impacts to the environment that was not adequately accounted for.
- Any corrective actions implemented (see Section 3.4.4 below).

The annual report will be prepared by DHA and submitted to DoEE and NT EPA prior to the end of the financial year.

3.4.4 *Adaptive Management*

Mitigation and avoidance measures have been developed as part of this CEMP that are intended to reduce the risk of the project impacting the environment. In the unlikely event that the monitoring shows that the impact has exceeded the performance indicator, the proposed management actions would need to be revised. Any changes to environmental management will be proposed as part of the annual CEMP report (see Section 3.4.3) and will be developed by DHA in conjunction with the head contractor, and in consultation with discipline experts from Government or the private sector as required. Changes to environmental management will only be proposed if the performance indicators outlined in the CEMP are exceeded within the twelve month reporting.

Any approved changes to environmental management will be incorporated into a revised CEMP.

4 Biodiversity Management Sub-plan

4.1 *Environmental values and risks*

The biodiversity values that occur within the project site, and potential impacts and risks to biodiversity associated with project activities were assessed as part of the EIS. A brief summary of the risks to biodiversity values is provided below.

- Increased access to Casuarina Beach causing disturbance to migratory shorebirds
- Impacts to sensitive vegetation including Monsoon Vine-thicket vegetation and Monsoon Rainforest.
- Loss of native vegetation fragmenting populations of species.
- Loss of habitat for the nationally significant Black-footed Tree-rat.
- Direct mortality of threatened species including Darwin Cycad and Black-footed Tree-rat.
- Dispersal of weeds and pathogens during construction.
- Further degradation of Casuarina Coastal Reserve.
- Increased numbers of recreational fishers causing higher mortality of threatened saw fish species.

In addition, the biodiversity management sub-plan also addresses the risk associated with native vegetation providing a corridor for biting insect movement between the Casuarina Coastal Reserve and 2CRU.

4.2 Management actions

A list of management actions to be undertaken to avoid and mitigate impacts to biodiversity is provided in the Biodiversity Management Sub-plan below (Table 2). Management actions specific to migratory shorebird habitat has been developed in conjunction with a local migratory shorebird expert (Amanda Lilleyman, Charles Darwin University).

Table 2. Biodiversity management sub-plan – management actions

Objective	Management Actions	Monitoring	Performance Indicators
Weed Management			
Reduce the extent of weeds in the project site, and minimise risk of spread into the Casuarina Coastal Reserve and other areas.	• Continuation of existing weed spraying regime. • Spray Gamba Grass and other environmental weeds on site prior to vegetation clearing. • Spray any residual weeds after clearing/excavation in unconstructed areas. • Use native species in landscaping where practical. • Treat any fill that may contain weed propagules, before bringing on site. • Wash-down bays for any plant or equipment working in infested areas that will be leaving site. • Spray environmental weeds along the boundary of Casuarina Coastal Reserve. • Retain 21.95 hectare patch of Monsoon Vine Thicket and Low Eucalypt Woodland to buffer any weed incursion into Casuarina Coastal Reserve.	Annual audit by head contractor in conjunction with appointed weed contractor and ecologist.	No increase in cover or type of environmental weeds on site or in adjoining areas of Casuarina Coastal Reserve
Vegetation Clearing			

Objective	Management Actions	Monitoring	Performance Indicators
Vegetation clearing is limited to the least amount of vegetation loss required for the project.	• Prior to commencing works, fence-off areas where native vegetation will be retained, i.e. 21.95 ha patch of Monsson Vine Thicket and Low Eucalypt Woodland (2CRU) and 1.5 ha patch containing 0.9 ha of Monsoon Rainforest (Muirhead North) and any other areas of native vegetation that will be retained in public open space, e.g. coastal esplanade. • Use native species in landscaping plans, if practical. • No machinery, equipment or laydown areas to be located within areas of native vegetation to be retained. • Prior to development of each stage, Darwin Cycads to be salvaged and relocated to area of public open space, or reinstated on other properties in Lee Point area.	Ongoing site monitoring and audit by head contractor	Area of native vegetation loss is no greater than what has been approved.
Native fauna			
No direct loss of native fauna	• Trained animal handler on site during habitat clearing of vegetation. Any captured animals to be released in nearest area of viable habitat. • Record the species, location, health, number of animals and date of capture, and details of where animals released. • Animal handler to have appropriate permits to handle fauna.	Animal handler site notes.	No injury, harm or death of native fauna.
Black-footed Tree-rat			
Compensate for the loss of Black-footed Tree-rat habitat	• Prior to the development of each stage, habitat this is likely to be suitable nesting or feeding habitat for Black-footed Tree-rat will be offset in accordance with the EPBC Act offset policy.	Head contractor including environmental sub-contractor ensure compliance prior to removal of habitat.	No net loss of Black-footed Tree-rat habitat.
Migratory Shorebirds			

Objective	Management Actions	Monitoring	Performance Indicators
Retain value of Casuarina Beach and mouth of Sandy Creek as migratory shorebird habitat..	• Beach access to be located at least 100 metres east of Sandy Creek mouth. • Barrier fencing to be established and maintained within 100 metres of Sandy Creek mouth • Liaise with NT Parks and Wildlife to ensure no-dog zone is being enforced near mouth of Sandy Creek. • Interpretative signs to be installed along boardwalk access from project site to beach. • Interpretative signs to be installed at locations outside of project site at access points to Casuarina Beach, informing the public of the significance of the site as migratory shorebird habitat, and the threat that human disturbance, dog-walking and motorbike riding can have. • Engage local community in migratory shorebird monitoring.	Migratory shorebird monitoring to be conducted for a period of five years, commencing once the access track to Casuarina Coastal Reserve is constructed. Survey will include: - One survey per month between September and April - Surveys to be conducted near mouth of Sandy Creek (impact) and at Lee Point (control) - Surveys to be conducted for two hours either side of high tide. - All migratory shorebirds to be counted and activity (e.g. foraging, roosting) recorded.	No detectable change in population of migratory shorebirds at Casuarina Beach that can be attributed to project.

Objective	Management Actions	Monitoring	Performance Indicators
		- All disturbances to migratory shorebirds to be recorded. - Surveys to be done at 100 m distance to avoid disturbance. - Monitoring data to be compared against thresholds (see 4.2 of the Migratory Shorebird bird) to determine impact and management response.	
Water			

Objective	Management Actions	Monitoring	Performance Indicators
No impact on biological diversity in Sandy Creek.	• Implement the Stormwater Management Plan to manage the flow of stormwater exiting the site, and treat stormwater for sediment, pollutants, hydrocarbons and heavy metals. • Rehabilitate erosion gullies in the south-west corner of the site in accordance with Erosion and Sediment Control Plan	Water Quality Monitoring Plan	Water quality to remain within limits of defined Water Quality Objectives (WQOs) which will be determined prior to construction commencing based on combination of pre-construction monitoring data and ANZECC Guidelines.
Biting Insects			
No connectivity between Casuarina Coastal Reserve and 2CRU for biting insects.	• A 50 metre open wind buffer to be established along the western perimeter of 2CRU. The tree canopy coverage will need to be reduced to 10%.	Head contractor in consultation with NT Department of Health (Medical Entomology) prior to site occupation.	Dimensions of buffer along western perimeter of 2CRU comply with Biting Insect Management Plan.
Threatened Sawfish			

Objective	Management Actions	Monitoring	Performance Indicators
No impact of increased recreational fishing in Sandy Creek and Buffalo Creek on Dwarf Sawfish and Green Sawfish	• Install signage at local popular fishing spots along Sandy Creek and Buffalo Creek informing public about threatened status of sawfish found in the creeks, identification guides, catch and release methods and contact details of NT G	Liaison between DHA and NT Government about reported threatened sawfish catches from Sandy Creek and Buffalo Creek.	No increased mortality rates of threatened sawfish due to increased fishing pressure along Sandy Creek and Buffalo Creek.

5 Water Management Sub-plan

5.1 Environmental values and risks

The hydrological values of the project site and adjoining areas that could potentially be impacted by the project include:

- Water quality of Sandy Creek, and potentially downstream receptors such as Casuarina Beach and Beagle Gulf.
- Groundwater that could potentially support a patch of Monsoon Vine-thicket along the western boundary of 2CRU, and vegetation in the eastern section of Muirhead North.
- Monsoon Rainforest patch in the adjoining Muirhead North site, which receives sheetflows from the eastern half of the project site via a culvert beneath Lee Point Road.
- Exposure of acid-sulphate soils in Stage 2B.

Stormwater management also needs to consider the potential for breeding habitat for mosquito habitat. It is unlikely that that project will have an impact on the quality of Buffalo Creek, consider Buffalo Creek is highly degraded and considered the most polluted waterway entering Darwin Harbour.

5.2 Management actions

A description of the management actions to mitigate impacts to hydrological values is provided below in Table 3. These actions are derived from the Stormwater Management Plans. The management actions contained within the ESCP (Section 6) will also contribute to achieving the objectives of the Water Management sub-plan.

Table 3. Water Management Sub-plan – management actions

Objective	Management Actions	Monitoring	Performance Indicators
Sandy Creek and Buffalo Creek			
Health and condition of three locations receiving discharge and down-stream receptors is maintained or improved if possible.	• As detailed in the Stormwater Management Plans, the following management actions will be undertaken as part of a treatment train of bioretention and detention basins, and vegetated swales: o Maintain the existing flow-rates of run-off from the project site. o Remove 80% of Total Suspended Solids (TSS), 30% of Total Nitrogen (TN), 35% of Total Phosphorous (TP) and 93% of Gross Pollutants (GP). • The following commitments are addressed in the Erosion and Sediment Control Plan o Erosion gullies in south-west corner of site will be filled and revegtated in a staged manner, starting at the head of the gullies and working down the face of the escarpment. o Sediment traps located around the boundaries of the property. o Avoid works in the wet season. o Clearly defined access points and haul roads. o Stockpiles to be located upstream of any sediment control and secured with cover or binding agent if necessary.	Water Quality Monitoring Plan.	Water quality does not exceed thresholds of Water Quality Objectives defined in Water Quality Monitoring Plan.
Groundwater			
Maintain the quantity and quality of groundwater	• Retain the 21.95 ha patch of Monsoon Vine-thicket and Low Eucalypt Woodland along the western boundary of the site. • Retain a 0.9 ha patch of Monsoon Rainforest in Muirhead North (within a larger 1.5 ha patch of native vegeation). • Maintain the proposed area of permeable surfaces that would ensure recharge of groundwater.	Monitoring of health of potential Groundwater Dependent Ecosystems as defined in Section 7.3.2.10 of the EIS for a ten year	Less than 10% change in any monitored parameter based on baseline conditions or control site.

Objective	Management Actions	Monitoring	Performance Indicators
	• Ensure all chemicals are stored and handled in accordance with the Materials Safety Data Sheet (MSDS). • Any chemical spill is treated immediately. • Excavate and remediate any potential contamination of groundwater. • Review Stormwater Management Plan if Monsoon Rain-forest or Monsoon Vine-thicket patch deteriorates by more than 10% based on 'monitoring' or 'performance indicators'.	period twice yearly, which includes for Monsoon Vine-thicket in 2CRU: - Two transects running from top to bottom of slope. - At one meter intervals along transect record percentage cover and live/dead cover for ground layer, shrub layer and overstorey layer. For Monsoon Rainforest-patch, monitor: - At five locations through patch esteablish photo-monitoring points. - Map the boundary of patch. - Estimate canopy cover	

Objective	Management Actions	Monitoring	Performance Indicators
		of overstorey species. - Identify all species presence and allocate a CAB rating. Monitoring will be completed by an independent ecologist. Reporting will be done annually and submitted to NT EPA and DoEE.	
Monsoon Rainforest Patch (Muirhead North)			
Maintain the flow of stormwater to Monsoon Rainforest Patch.	• The Stormwater Management Plan for 2CRU provides for: o Upgrades to the culverts beneath Lee Point Road o Managing the rate and volume of flow between 2CRU and the Muirhead North patch.	Ongoing site monitoring and auditing by head contractor.	Pre-construction flow rates and volumes to Monsoon Rainforest patch are sustained.
Biting insects			
Retain amenity for users by preventing habitat for biting insect habitat from establishing.	• Treatment train to be developed as part of Stormwater Management Plans to comply with recommendations of the Biting Insect Report.	Resident complaints, site auditing, liaison with entomologists	Compliance with Biting Insect Plan.
Acid-sulphate Soils			

Objective	Management Actions	Monitoring	Performance Indicators
Avoid exposing acid-sulphate soils during construction	• Test pits to be established throughout Stage 2B, before construction commences for this Stage. • If acid-sulphate soils are encountered, an acid-sulphate soils management plan will be developed.	Test pits to be established prior to construction commencing in Stage 2B.	Any acid-sulphate soils encountered to be managed in accordance with approved acid-sulphate management plan.

6 Erosion and Sediment Control Plan

6.1 Environmental values and risks

6.1.1 Erosion and sediment control

Land clearing and earthworks are likely to cause erosion in some areas if surface water flows associated with construction works are not appropriately controlled and managed. As part of the CEMP, an Erosion and Sediment Control Plan (ESCP) will be prepared to manage erosion and sedimentation across the development site for each stage of construction. The ESCP will be prepared by a suitably qualified person in accordance with the International Erosion and Association Guidelines. The ESCP will be submitted for each stage of the development for review and approval by the Department of Infrastructure, Planning and Natural Resources (DIPNR) as part of future Development Applications, and in accordance with approval processes established under the NT Planning Act the development will not be given approval to proceed without an approved ESCP.

The key objective of undertaking erosion and sediment control measures is '*to take all reasonable and practicable measures to minimise short and long-term soil erosion and the adverse effects of sediment transport.*' (IECA Best Practice Erosion & Sediment Control). The intended outcomes of sediment and erosion control is to prevent or at least minimise environmental harm caused by the project.

The following key principles as outlined in the IECA Guidelines are to be adhered to during the construction phase of the project:

1. Appropriately integrate the development into the site.
2. Integrate Erosion and Sediment Control (ESC) issues into the site and construction planning.
3. Develop effective and flexible Erosion and Sediment Control Plans (ESCP) based on anticipated soil, weather and construction conditions.
4. Minimise the extent and duration of soil disturbance.
5. Control water movement through the site.
6. Minimise soil erosion.
7. Promptly stabilise disturbed areas.
8. Maximise sediment retention on the site
9. Maintain all ESC measures in proper working order at all times.
10. Monitor the site and adjust ESC practices to maintain the required performance standard.

The NT tropics consist of a wet and dry season. These seasons have a significant impact on ESC issues and appropriate measures need to be considered. During the dry season the key focus is on dust control and the displacement of sediment by the wind. During the wet season the key focus is on the control of water movement and the displacement of sediment through erosion. It is common for the construction phase to stretch across both the seasons and the ESCP must be designed to accommodate this.

The ESCP will require approval of the Parks and Wildlife Commission and the Land Management Unit.

6.1.2 Rehabilitation of gully erosion (2CRU)

There are a number of severely eroded gullies in the south-west corner of the 2CRU as can be seen in the aerial photo with contour overlay overleaf. These gullies are eroded up to 4 m deep in places and

approximately 3 – 10 m across. It is likely that the area generally had sheet flows without any concentrated water flows previously. The gullies are likely to have formed from an initial concentration arising from vehicle tracks in the area followed by localised erosion along vehicle tracks and eventually gully erosion commencing from the lower slopes.

The gullies are dangerous and the excessive sediments being moved are causing localised flooding and siltation within and adjacent to Sandy Creek. Advice from Medical Entomology at Royal Darwin Hospital indicates that this also poses a public safety risk from biting insects.

Water flows down the gullies are intermittent and only occur during and immediately after storm events. Minor seepage is evident in a couple of the lowest points of the gullies.

The rehabilitation works will require significant intervention including major earthworks. The total area affected is approximately 5,000 m²

The key objectives of undertaking rehabilitation of the gullies are:

1 reduce public safety risks associated with falls

2 resolve erosion and sedimentation issues

3 control potential biting insect breeding sites arising from erosion and sedimentation.

In determining the best approach to the rehabilitation works, it is understood that this area will in time be handed over to Parks and Wildlife and be an extension of the Casuarina Coastal Reserve. Currently there are a number of Mountain Bike Tracks throughout the area, and the terrain is well suited for this sport with appropriate planning and design of the tracks.

The final rehabilitated area is expected to be a combination of:

- restored native vegetation
- combination of grassed and shaded parkland and shared tracks
- water flows being a combination of sheet flow (where areas are fully stabilised and velocities/ flows are low) and naturalised flow paths (vegetated creek lines with rock drop structures and other energy dissipation methods)
- MTB tracks integrated with other uses

The final design, extent and character of these works would be subject to detailed discussions and agreement with Parks and Wildlife.

The works will likely be undertaken across a couple of dry seasons. In works of this nature, it is important to ensure the water flows are effectively dealt with at the top of the catchment prior progressing down the slope. In addition, sufficient time and suitable techniques need to be employed that will ensure all stabilisation works are complete prior to the onset of the wet season. The following stages and sequences of work summarises the current intent:

6.2 Management actions

The proposed management actions for the ESCP are detailed below in Table 4, and are separated according to dry season actions, wet season actions, dry and wet season actions, and actions to be undertaken to rehabilitate the erosion gullies in the south-west of 2CRU. The timing and sequencing is critical in the success

of ESC. While every stage of the project will be slightly different generally the sequence of events should follow something along the lines of below:

1. No works to start until prior approval of the ESCP has been attained by DIPNR.
2. All ESC measures are to be in place prior to clearing and bulk earthworks.
3. The sequencing of the control measures are broadly outlined in the following;
    a. Install nominated site access point and wash down measures
    b. Install extent of clearing bunting fence
    c. Commence clearing and place mulch in nominated stockpile area
    d. Commence topsoil stripping and place in nominated stockpile area
    e. Commence earthworks.
    f. Excavate and install stormwater pipes and pits
    g. Implement inlet protection measures for stormwater pits
    h. Progressively stabilise (grass / mulch / soil binder / landscaping) batters and cleared areas on completion of earthworks as early as practicable
    i. Maintain and monitor all ESC measures as directed.

The ESCP will overlap with management actions implemented as part of the Air Quality Management and Water Management Sub-plans contained in this CEMP.

Table 4. Erosion and Sediment Control Plan - management actions

Objective	Management Actions	Monitoring	Performance Indicators
Dry season			
Limit impacts of dust pollution on human health and vegetation	• Ensure exposed soil surfaces are kept in a moist condition. Alternatively dust suppressants such as soil binders can be used. • Traffic movements on exposed surfaces shall be minimised. • Areas of soil disturbance at any given time shall be minimised and controlled to an immediate area. • Areas where works are completed shall be promptly stabilised through measures such as landscaping, mulching, soil binders or grassing.	Ongoing site monitoring and audit by head contractor. Dust complaints from adjoining residents, workers. WQMP for Sandy Creek.	No increase in sedimentation. No impacts on human health.
Wet season			
Minimise erosion and pollution of water-ways	• Construct sediment catchment devices, typically a temporary basin. • Install sediment control devices such as silt fencing, berms and swales. • Construct plant wash down bay and entry/exit shaker to ensure no mud attached to vehicles leaves the site. • Divert upstream storm water runoff away from disturbed areas of the site and into existing intact native vegetation, sediment control devices or existing drainage systems.	Ongoing site monitoring and audit by head contractor. Implementation of Stormwater Management Plans. WQMP for Sandy Creek.	No increase in pollution of waterways. Bioretention and detention basins working to specification.
Wet and dry season			

Objective	Management Actions	Monitoring	Performance Indicators
Minimise erosion and pollution of water-ways, and limit impacts of dust pollution on human health and vegetation	• Control all traffic into and out of the site including movement of traffic within the site. • No additional clearing or disturbance beyond the limit of works of a particular stage. • Maintenance and monitoring of the ESC measures are to be undertaken for the life of the project. • Stripped topsoil for re-use is to be stockpiled appropriately and protected from wind / runoff erosion and weed infestation. • Revegetation / stabilisation works are to occur as early as practicable on cleared / disturbed areas. • Staff working on the site need to be trained and informed of the importance of maintaining good ESC procedures.	Ongoing site monitoring and audit by head contractor. Implementation of Stormwater Management Plans. WQMP for Sandy Creek. Dust complaints from adjoining residents, workers.	No increase in pollution of waterways. Bioretention and detention basins working to specification. No increase in sedimentation. No impacts on human health.
Gully erosion rehabilitation (2CRU)			
Stabilise erosion gullies to prevent further erosion, sedimentation of Sandy Creek, breeding of biting insects and human safety risks.	• Undertake detailed survey of the entire site, including all areas of the upstream catchment • Preliminary design of the residential subdivision to identify which parts of the catchment may be cut off from this flow path and how it will be drained. • Subject to timing of the residential development, undertake necessary upper catchment stormwater diversion and control works. • Consult with Parks and Wildlife and agree overall end point condition and intended public use of the area. • Undertake Stage 1 rehabilitation works on minor gullies and upper reach of major gully. Works to comprise: o filling and compaction of the gullies o construction of diversion banks, spreader banks, silt fences and minor drop structures o establishment of vegetation (type of vegetation subject to agreed treatments, irrigated grass likely to be dominant as part of overall visitor use intention) o construct drop structures/energy dissipaters at lower end of the Stage 1 works	WQMP for Sandy Creek. Regular visits of work site by head contractor and sub-contractor responsible for rehabilitation works. Consultation with Medical Entomology regarding breeding habitat for biting insects.	Return of land-form to natural topography. Improvement in water quality at discharge point into Sandy Creek. Increase in suitable habitat for native fauna including Black-footed Tree-rat.

Objective	Management Actions	Monitoring	Performance Indicators
	• Monitor and repair works during first wet season, maintain and ensure full establishment of stable vegetation cover. • Undertake Stage 2 rehabilitation on lower end of major gully. Works to comprise: o filling and compaction of the gullies o construction of diversion banks, spreader banks, silt fences and minor drop structures o establishment of vegetation (type of vegetation subject to agreed treatments, irrigated grass likely to be dominant as part of overall visitor use intention) o construct drop structures/energy dissipaters and possible sedimentation basin at lower end of the Stage 2 works immediately adjacent to existing coastal reserve track; where there are concentrated flows o construction of piped outfall to suitable location within the tidal zone of sandy creek. • Key considerations in completion of the Stage 2 works will be elimination of any low flows or ponding of stormwater at or above the high tide mark. • Monitor and repair works during second wet season, maintain and ensure full establishment of stable vegetation cover. • Prepare and implement long term monitoring and maintenance program prior to removing all temporary erosion control structures.		

7 Heritage Management Sub-plan

7.1 Environmental values and risks

The historic and cultural heritage values that occur within the project site and potential impacts and risks to historic and cultural heritage values associated with project activities are described in Chapter 7 of the EIS. The historic and cultural heritage values include:

- Military heritage such as the Lee Point Bunkers and Konfrontasi Cruciform
- Background scatter of Aboriginal stone artefacts.

The site does not support any items listed on the Commonwealth or Northern Territory cultural heritage lists.

It also does not support any Aboriginal Sacred Sites registered under the *Northern Territory Aboriginal Sacred Sites Act.* However, there are registered sites along Casuarina Beach in close proximity to the project site.

7.2 Management actions

The management actions that support the Heritage Management Sub-plan are provided below in Table 5.

Table 5. Heritage Management Sub-plan – management actions

Objective	Management Actions	Monitoring	Performance Indicators
Military heritage			
Preserve important heritage items that reflect the site's military history, where possible.	• Retain the Lee Point bunkers and Konfrontasi Cruciform. • Work with local NT Heritage Branch to develop signage and interpretation material of Lee Point Bunkers and Konfrontasi Cruciform.	Not applicable	Residents have an understanding of the military history of the site.
Stone scatters			
Destruction of stone scatters is in accordance with heritage regulations.	• Apply for a work approval under Section 72 of the NT *Heritage Act* before carrying out any works within the area of the stone scatters. • Larrakia Development Corporation to undertake heritage monitoring during clearing works to detect any other Aboriginal artefacts not detected during original survey.	Not applicable	Compliance with NT *Heritage Act*
Aboriginal sacred sites			
There are no listed sacred sites within the project site; however, there are sacred sites in close proximity along Casuarina Beach. An Authority Certificate will be obtained from the AAPA before commencing works.	• Obtain Authority Certificate from AAPA before commencing works. • AAPA will consult with custodians of sacred sites along Casuarina Beach, with any recommendations to protect sacred sites included as a condition of the Authority Certificate.	Not applicable	Compliance with NT *Aboriginal Sacred Sites Act.*

8 Social and Economic Management Sub-plan

8.1 Socio-economic values and risks

The social economic values and risks of the project are described in Chapter 8 of the EIS. The project will have a number of positive impacts including supply of affordable housing, demand for construction services during a period of downturn in the mining and resources sector, and ongoing employment in the education and hospitality sectors

Some of the potential negative impacts of the project could include:

- Oversupply of housing and commercial land
- Lack of skilled workforce
- Draw labour and skills away from other projects
- High demand on local amenity including Casuarina Coastal Reserve and Buffalo Creek Boat Ramp
- Shortfall of social services
- Adverse amenity impacts
- Impact on the viability of nearby commercial areas.

8.2 Management actions

Management actions that will be undertaken as part of the Social Economic Management Sub-plan are described below in Table 6.

Table 6. Social and Economic Management Sub-plan – management actions

Objective	Management Actions	Monitoring	Performance Indicators
Oversupply of Housing and Commercial land			
Provide housing and commercial land that meets the demand of the local community.	• Align staging and development with growth rates per Darwin Regional Land Use Plan (or updated policies and projections) • Provide commercial land in accordance with needs analysis (ie avoid over supply), which considers the current and future provision of commercial and centre-type facilities (including the planned Muirhead centre)	Monitor local and regional land values and demand.	Maintenance and/or growth of pricing and consistency of sales.
Workforce			
A suitably qualified workforce can service the project without any impacts on other projects, including permanent positions in hospitality and retail that will be generated.	• Development in accordance with projected commercial, accommodation and social infrastructure demand based on population projections, to ensure service provision doesn't exceed demand created by population. • Provision of appropriate training opportunities for local market. Importation of skills as a last resort. • Ensure staging and timing of construction aligns with anticipated population and housing growth rates for the Darwin Region	Monitor local job advertisements and employment statistics.	Majority of workforce sourced locally. No unreasonable effect on access to trades/constructions services/retail and hospitality workforce.
Amenity			
No imposition to existing users of local amenity, such as Casuarina Coastal Reserve and Buffalo Creek Boat Ramp	• Buffalo Creek Boat Ramp has recently been upgraded and access is limited by tidal movement. Continual monitoring required upon occupation to determine impact on use patterns. • Contribute 21.95 ha of Monsoon Vine-thicket and Low Eucalypt Woodland to Casuarina Coastal Reserve, and 1.5 ha patch of native vegetation containing 0.9 ha of Monsoon Rainforest in Muirhead North to public open space. • Provide access to Casuarina Beach from project site, to reduce pressure at other access points.	DHA and NT Government to monitor use of facilities	Appropriate access to all facilities.
Social Services			

Objective	Management Actions	Monitoring	Performance Indicators
Achievement of Lead Practice Principles and Benchmarks per social needs analysis.	• Ensure adequate serviced land is available for community and social infrastructure in accordance with needs analysis.	Ongoing liaison with NT Government.	Adequate availability of social services for local residents.

9 Noise Management Sub-plan

9.1 Environmental values and risks

The potential impacts and risks associated with noise is described in Chapter 9 of the EIS. They include the effects of noise and vibration on:

- Health
- Sleep
- Annoyance
- Structural forms.

9.2 Management actions

The management actions proposed as part of the Noise Management Sub-plan is provided below in Table 7.

Table 7. Noise Management Sub-plan – management actions

Objective	Management Actions	Monitoring	Performance Indicators
Operational Noise			
Preserve workers and adjoining residents' health, and adjoining residents sleep.	• Noise barriers or receiver façade upgrades • Low noise asphalt, reduced speed limits	Complaints, deterioration in workers' health	No deterioration in workers' health or adjoining residents, no complaints from residents.
Construction Noise			
Preserve workers and adjoining residents' health, and adjoining residents sleep.	• Construction activities should be restricted between the hours of 7 am and 7 pm (Monday to Saturday); and 9 am and 6 pm on Sunday or a public holiday • Construction noise levels should not exceed: o Ambient noise plus 5 dB(A) in residential use areas o 60 db(A) in mixed commercial/residential use areas • Avoid construction at night, temporary noise barriers • Temporary noise barriers or provide respite periods • Offer gifts (movie tickets for noisy periods) to adjoining residents. • Mulchers should be located away from noise sensitive receivers • Reduce the number of plant operating at one time where works are required to be carried out outside of standard hours and close to existing sensitive receivers • Preference should be for electric powered plant over combustion engine powered plant • Preference should be for hydraulic or electric powered plant over pneumatic powered plant • Avoid metal to metal contact on equipment to reduce impulsive or scraping noise consultation with residents • Provision of noise attenuating controls at the source, such as mufflers, acoustic screens • Keeping plant and equipment well maintained	Complaints, deterioration in workers' health	No deterioration in workers' health or adjoining residents, no complaints from residents.

Objective	Management Actions	Monitoring	Performance Indicators
	• Locating static sources of noise such as the generators as remotely as possible from noise sensitive receivers • Use of broadband reversing alarms, or "quackers", on mobile equipment in accordance with the relevant health and safety regulations • Informing potentially affected receivers with adequate notice of the construction program and any planned activities that may exceed noise and vibration targets • Modification of work activities where noise or vibration is found to cause unacceptable impact • Implementing a procedure for dealing with complaints to ensure that all complaints are registered and dealt with appropriately • Ensure that managers effectively communicate acceptable and unacceptable work practices for the site, through staff site inductions, notice boards, and prestart meetings • Avoid the need for reversing in the construction area by creating a loop road or similar • Avoid dropping materials from height • Workers should avoid shouting, minimise talking loudly, and avoid slamming vehicle doors		
Operational Vibration			
Preserve building integrity, workers and adjoining residents' health, and adjoining residents sleep.	• Road design and avoid speed bumps	Complaints, deterioration in workers' health	No deterioration in workers' health or adjoining residents, no complaints from residents.
Construction Vibration			
Preserve building integrity, workers and adjoining residents' health, and adjoining residents sleep.	• Select suitable plant when near vibration sensitive receivers • Avoid vibration intensive work at night to minimise the risk of sleep disturbance	Complaints, deterioration in workers' health	No deterioration in workers' health or adjoining residents, no complaints from residents.

Objective	Management Actions	Monitoring	Performance Indicators
	• Informing potentially affected receivers with adequate notice of the construction program and any planned activities that may exceed noise and vibration targets • Modification of work activities where noise or vibration is found to cause unacceptable impact • Implementing a procedure for dealing with complaints to ensure that all complaints are registered and dealt with appropriately • Ensure that managers effectively communicate acceptable and unacceptable work practices for the site, through staff site inductions, notice boards, and prestart meetings • Avoid dropping materials from height		

10 Air Quality Management Sub-plan

10.1 Environmental values and risks

The potential impacts and risks to air associated with project activities are described in Chapter 5 of this EIS. An Odour Impact Assessment was undertaken and the project site was found to be over one kilometre away from the plume extent from the Leanyer Sanderson Water Treatment Plant.

The potential risks to air quality associated with the project relates to dust and asbestos contamination from removal of two 450 metre long parallel asbestos pipes. There may also be residual fragments of asbestos containing materials on the surface at 2CRU.

10.2 Management actions

A list of the management actions to be undertaken as part of the Air Quality Management Sub-plan is provided below in Table 8.

Table 8. Air Quality Management Sub-plan – management actions

Objective	Management Actions	Monitoring	Performance Indicators
Avoid contamination of air with asbestos	• Emu bob-grid walk across 2CRU in accordance with Western Australian Asbestos Guidelines (WA DoH 2009) to detect any residual asbestos containing materials. Inspections to be completed on a monthly basis until no further asbestos containing material is detected. • Removal of two 450 metre long parallel asbestos pipes in 2CRU to be undertaken by trained and certified removal company. • Remove all rubbish from Conservation Area. • Site audit report for Conservation Area	Certification of responsible contractor	No asbestos containing material detected on surface. No impact of asbestos on human health due to removal of pipes or other asbestos containing materials.
Maintain the respiratory health of workers and adjoining residents, and no adverse impacts on vegetation.	• Notify adjoining residents prior to works commencing • Vegetation cleared in a staged manner • Limit the amount of excavation required to cleari vegetation • Watering on haul roads, and exposed areas • Vehicles obey speed limits and stick to formed road • Trafficable areas clearly marked • Stabilise long exposed areas • Rehabilitate as soon as possible.	Complaints by adjoining residents	No decline in respiratory health of staff/adjoining residents, or decline in vegetation health, that can be attributed to the project. sf

11 Supporting Documents

The following documents support the actions proposed in this CEMP and can be found in the appendices of the CEMP. A list of guidelines that have been referenced in preparing this document are also provided.

11.1 Technical Studies and Reports

NT Department of Health 2016. Muirhead North and 2CRU Biting Insect Report. Final report prepared for Defence Housing Australia. Medical Entomology Centre for Disease Control, NT Department of Health, Darwin.

The Odour Unit Pty Ltd 2017. Odour Impact Assessment - field odour inspection of Leanyer-Sanderson WWTP, Darwin NT, Final Report prepared for Defence Housing Authority. The Odour Unity Pty Ltd, Perth, WA.

Lilleyman A 2017. Report on potential impacts from disturbance to migratory shorebirds in Darwin: Defence Housing Authority – Lee Point Master-planned Urban Development. Report prepared for EcOz Environmental Consultants, January 2017.

Cardno 2016a. Noise Impact Assessment. Darwin 2CRU Development. Final Report Prepared for Defence Housing Authority, December 2016.

Cardno 2016b. Noise Impact Assessment. Darwin Muirhead North Development. Final Report Prepared for Defence Housing Authority, December 2016.

11.2 Stand-alone Management Plans

Cardno 2017a. Stormwater Management Plan. 2CRU – Lee Point Road, Lee Point. Final Report Prepared for Defence Housing Authority, October 2017.

Cardno 2017b. Stormwater Management Plan. 2CRU – Lee Point Road, Lee Point. Final Report Prepared for Defence Housing Authority, October 2017.

Ecology and Heritage Partners Pty Ltd 2017. Lee Point Master-planned Urban Development – Water Quality Monitoring Plan. Draft report prepared for Defence Housing Australia, October 2017.

11.3 Guidelines

NT EPA 2015. Guidance for the Preparation of an Environmental Management Plan. Northern Territory Environment Protection Authority, Darwin, NT.

NT EPA 2013. Guidelines for the Preparation of a Social Economic Impact Assessment. Northern Territory Environment Protection Authority, Darwin, NT.

IECA 2016. Best Practice Erosion and Sediment Control Guidelines. International Erosion Control Association Australian Chapter, Picton, NSW.

Appendix A – CEMP Inspection Checklist

Date:	Inspected by/company:	Stage(s) of development:
Biodiversity		
Weed spraying completed. If yes, what dates where and by whom?		
Any evidence of increased weed spread or potential introduction of weed seed to site?		
Have wash-down bays been made available and in use?		
All areas of native vegetation to be retained have been appropriately fenced off prior to works commencing?		
Any disturbance in areas of native vegetation to be retained that could be attributed to project, i.e. vehicles, machinery or equipment?		
No. of Darwin Cycads salvaged, and location where Darwin Cycads have been relocated.		
Has an animal handler been present prior to any vegetation removal?		
Has Black-footed Tree-rat offsets been obtained prior to the removal of any Black-footed Tree-rat habitat?		
Are residents and visitors to the project site, using the provided access track to access Casuarina Beach?		
Has vegetation monitoring of Monsoon Rainforest and Monsoon Vine-thicket been completed or scheduled?		
Has migratory shorebird monitoring been completed for this month?		
Water		
Water quality monitoring of Sandy Creek been completed?		
Bioretention and detention basins inspected and working to specifications?		
No interactions with groundwater during clearance work or excavations?		
No contamination spills that may polluted groundwater?		
Any pooling of water observed which may be suitable habitat for biting insects?		
Erosion and Sediment Control		
Any complaints from surrounding residents or workers about dust?		

Water or soil binders applied to exposed soil?
Traffic movements confined to dedicated roads?
Sediment catching devices in places, e.g. silt fencing, berms or swales?
Stormwater diverted away from disturbed areas?
Revegetation of exposed areas completed?
Stage 1 gully erosion rehabilitation works commenced? What works have been completed?
Stage 2 gully erosion works rehabilitation commenced? What works have been completed?
Heritage
No damage or destruction of military heritage sites to be conserved?
Social and Economic
Has uptake of housing and commercial sites kept up with supply?
Is there enough suitably qualified people to resources the current development phase?
Has the project contributed to the inability for people to access facilities in the Lee Point area, e.g. Buffalo Creek Boat Ramp or Casuarina Beach, due to population increase or impediments to access?
What community space has been made available?
Noise
Has any construction work occurred at night? If so when, and what type of work?
Have any noise barriers been used?
Has there been any complaints received by adjoining residents or landowners?
Has there been any modifications to standard work procedures to compensate for noise impacts?
Has adjoining residents/landowners been informed of potential noise disturbance?
Air Quality
Have haul roads been watered?
Are trafficable areas cleared marked?

Any complaints from adjoining land-owners or residents? **Further comments including any communication with referral/regulatory authorities about potential breaches of CEMP?**

APPENDIX E

Stormwater Management Plan – 2CRU

2CRU - Lee Point Road, Lee Point

Stormwater Management Plan

DC1603/R1/V3

Prepared for
Defence Housing Australia

11 October 2017

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Shaping the Future

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Table of Contents

1 Introduction **1**

2 Site Description **2**

2.1 Existing Conditions 2

2.2 Proposed Development 3

3 Stormwater Quantity Assessment **4**

3.1 Available Information and Data 4

3.2 Rational Method 4

3.3 XPRAFTS Modelling 5

3.3.1 Pre-development Scenario 5

3.3.2 Post-development Scenario 6

3.3.3 XPRAFTS Results 7

3.3.4 Mitigated Scenario 7

4 Stormwater Quality Assessment **10**

4.1 Construction Phase Water Quality 10

4.2 Post-Construction Phase Water Quality 10

4.2.1 Water Quality Objectives 10

4.2.2 Stormwater Management Practices 11

4.2.3 Proposed Stormwater Quality Treatment Train 11

4.2.4 Design and Performance of Treatment Measures 12

4.2.5 Catchment Areas 12

5 Flooding **14**

6 Conclusions **15**

7 Qualifications **16**

Appendices

Appendix A Reference Drawings

Tables

Table 3-1 Rational Method Details 5

Table 3-2 XPRAFTS Sub-catchment Details – Pre-development 5

Table 3-3 Pre-development 100 Year ARI Peak Flow Rational Method Comparison 6

Table 3-4 Impervious Percentage Adopted For Various Land uses Proposed 6

Table 3-5 XPRAFTS Sub-catchment Details – Post-development 6

Table 3-6 Impact on 100 Year ARI Peak Flows 7

Table 3-7 Detention Basin Details 8

Table 3-8 Proposed Detention Basin Stage-Storage Relationships 8

Table 3-9 100 and 50 Year ARI Peak Discharge (m^3/s) 8

Table 3-10 20 and 10 Year ARI Peak Discharge (m^3/s) 9

Table 3-11 5 and 2 Year ARI Peak Discharge (m^3/s) 9

Table 3-12 Time Taken for Detention Basins to Drain 9

Table 4-1 Bioretention Details 11
Table 4-2 Stormwater Water Quality Parameters for MUSIC Source Nodes 12
Table 4-3 Catchment Areas 12
Table 4-4 Predicted Pollutant Load Reductions 13
Table 5-1 Total Storm Tide Levels (mAHD) at Lee Point 14

Figures

Figure 1 Site Location
Figure 2 Catchment Characteristics
Figure 3 XPRAFTS Pre-Development Model Layout
Figure 4 XPRAFTS Post-Developed Model Layout
Figure 5 MUSIC Model Layout

1 Introduction

This Stormwater Management Plan has been prepared by Cardno in order to support a Development Application (DA) for the 2CRU development located on Lee Point Road, Lee Point, Darwin, Northern Territory. The site location is shown in Figure 1.

The 2CRU site is to be developed by Defence Housing Australia (DHA) and consist predominantly of residential lots with smaller sections dedicated to commercial purposes and the potential for tourism / hotel development.

This report details the specific stormwater management requirements for the development and has been prepared in accordance with the following relevant policies and guidelines:

> Subdivision and Development Guidelines, Darwin City Council [COD, 2005];

> Queensland Urban Drainage Manual (QUDM) [Provisional, DEWS, 2013];

> Australian Rainfall and Runoff - A Guide to Flood Estimation, Volume 1 [IEAust, 2003];

> Australian Rainfall and Runoff - A Guide to Flood Estimation, Volume 2 [IEAust, 1987];

> Water Sensitive Urban Design - Modelling Guide, Northern Territory Department of Planning and Infrastructure [NTDPI1, 2009];

> Water Sensitive Urban Design - Technical Design Guideline, Northern Territory Department of Planning and Infrastructure [NTDPI2, 2009];

> Water Sensitive Urban Design - Vegetation Selection Guide, Northern Territory Department of Planning and Infrastructure [NTDPI3, 2009];

> Water Sensitive Urban Design - Operation and Maintenance Guidelines, Northern Territory Department of Planning and Infrastructure [NTDPI4, 2009];

> Water Sensitive Urban Design - Water Quality Monitoring Strategy, Northern Territory Department of Planning and Infrastructure [NTDPI5, 2009]; and

> Water Sensitive Urban Design - Construction, Asset Handover, Maintenance Guideline, Northern Territory Department of Planning and Infrastructure [NTDPI6, 2009].

> Water Quality Objectives for the Darwin Harbour Region,[Department of Natural Resources, Environment, The Arts and Sport, 2010]

2 Site Description

2.1 Existing Conditions

The 2CRU site is located to the west of Lee Point Road. The site is currently unoccupied but previously was used for a Royal Australian Air Force (RAAF) transmission facility situated in the northern half of the site. This facility previously included buildings, sealed roads and car parking together with cleared unsealed areas. The buildings and car parking areas have since been removed with only some sealed roads remaining. A number of unsealed tracks also traverse the site. The vegetation on the 2CRU site is predominantly casuarina forest and open woodland with densities increasing along the western boundary where the land drops off sharply towards Sandy Creek and Beagle Gulf. The existing catchment characteristics are shown on Figure 2.

Topography across the site ranges from approximately 33mAHD, at the highest point of the ridge which traverses the middle of the site in a roughly south to north alignment, down to the lowest point of 4.5mAHD in the south west corner. The lowest point along the Lee Point Road eastern frontage is approximately 22.5mAHD located 200m to the south of the Lee Point Resort southern boundary. Gradients across the site are generally less than 3% with steeper slopes adjacent to the western boundary within the proposed conservation area and within the south western corner where runoff from the local site catchment conveys flows to Sandy Creek.

While the majority of surface runoff across the site is conveyed as relatively shallow sheet flow and surface flow, there are some minor gullies where surface runoff is concentrated in defined gullies and excavated drains. These include natural gullies within the south west corner and also open drains located along the sealed road entrance to the former RAAF facility. The drain along the former RAAF facility entry road conveys flows to Lee Point Road via twin box culverts and a lined opened drain as shown in Plate 1 below courtesy of NearMap 2016.

Plate 1: Former RAAF Facility Entry Road (Ref: Nearmap 2016)

Flows are conveyed across Lee Point Road via 2 x 1200W x 450H RCBCs into an unlined drain that runs along the Lee Point Resort southern boundary before discharging into a large rural dam. A second culvert crossing of Lee Point Road is located 115m further south and consists of 5 x 750 RCPs that conveys flows collected within the road side drain to the east. The second culvert crossing is shown in Plate 2.

Plate 2: Culvert Crossing of Lee Point Road 115m South of the Lee Point Resort (Ref: Nearmap 2016)

The local catchment conveying flows to the south west corner via local gullies discharges into Sandy Creek which runs parallel to the coast in a north-easterly direction before joining the Beagle Gulf. There is also a relatively small catchment in the northwest corner of the site which conveys local runoff via the Casuarina Coastal Reserve and beach frontage to Beagle Gulf. It appears that this flow is conveyed as relatively shallow sheet flow down the escarpment.

There is no identifiable external catchments contributing to flows through the site with the Royal Darwin Hospital and Lyons Estate, adjacent to the southern boundary, effectively forming a catchment divide with flows from the site being conveyed via open drains along this boundary to both Sandy Creek and Lee Point Road.

The overall catchment delineation and general direction of runoff across the 2CRU site and surrounding areas are shown on Figure 2.

2.2 Proposed Development

DHA propose to develop the 2CRU site for residential and mixed-use land uses including commercial areas and the potential for tourism / hotel development. While the majority of the development will comprise standard residential lots, the balance will include superlots for commercial, low rise apartments and tourism accommodation.

3 Stormwater Quantity Assessment

The intensified development of the site has the potential to increase local site runoff due to the increase in impervious areas associated with the development. This potential increase in local peak flows can ultimately result in increased peak discharges within the adjacent waterways that can result in increased flood levels, erosion of the waterway and affect bank stability.

To limit the adverse impacts external to the developed site, it is required to limit post-development flows from the site to less than pre-development levels using appropriate mitigation measures where possible.

To mitigate the potential increase in flows discharging from the 2CRU development, it is proposed to include end-of-line detention basins at the site's major outlets, as shown on Figure 4.

The preliminary sizing of the detention basins has been undertaken using the XPRAFTS hydrology model with pre-development flows validated to the Rational Method as described herein.

3.1 Available Information and Data

To assist in the delineation of the local catchments and provide current land uses, the following information and data has been sourced:

> Site survey undertaken by Bennett & Bennett;

> ALS data of the site and immediate surrounding catchment was sourced from the Department of Lands, Planning and the Environment (DLPE) to derive contours; and

> Current aerial images from NearMap and Google Earth.

3.2 Rational Method

The Rational Method was used to calculate the existing 100 year peak Average Recurrence Interval (ARI) discharges for each local sub-catchment to the various points of discharge from the development sites.

The XPRAFTS catchments impacted by the proposed development areas are shown on Figures 3 and 4.

The time of concentration for each catchment to the point of discharge was determined using an initial overland flow time together with typical channel velocities based on the average slopes.

The coefficient of runoff (C_{10}) for the each local catchment was based on the current land uses as determined by a review of the areas aerial photography and the respective values recommended in Queensland Urban Drainage Manual (QUDM).

Design rainfall intensities for the area were calculated using AusIFD Version 2.0, and adopting the following parameters for the area as prescribed by *Australian Rainfall and Runoff, 2001*:

> 2 year, 1 hour rainfall intensity = 62.64 mm/h

> 2 year, 12 hour rainfall intensity = 9.78 mm/h

> 2 year, 72 hour rainfall intensity = 3.02 mm/h

> 50 year, 1 hour rainfall intensity = 100.0 mm/h

> 50 year, 12 hour rainfall intensity = 16.13 mm/h

> 50 year, 72 hour rainfall intensity = 6.04 mm/h

> Skew (G) = 0.37

> Geographical Factor (F2) = 4.39

> Geographical Factor (F50) = 18.50

The resultant 100 year ARI peak flows as determined by the Rational Method for the local catchment areas are shown in Table 3-1 and compared to the existing XPRAFTS peak discharges in Table 3-3. In addition to the three main outlets from the site, the sub catchments to both the rainforest patch to be retained and the existing rural dam have also been included for comparison purposes.

Table 3-1 Rational Method Details

Catchment Outlet (XPRAFTS Node)	Total Area to Outlet (ha)	Time of Concentration t_c (min)	Coefficient of Discharge C_{10}	100 Year ARI Peak Flow (m^3/s)
RP01 – North	8.43	33	0.70	3.19
RP04 – South West	27.02	33	0.70	10.22
RP05 – To Rainforest Patch	60.67	48	0.70	18.70
RP06 – To Rural Dam	9.43	20	0.70	4.58

3.3 XPRAFTS Modelling

XPRAFTS is an event based hydrologic model that calculates flood hydrographs from storm rainfall hyetographs. It can be used for modelling natural, part urban and fully urban catchments. For urban catchments, it calculates runoff from pervious and impervious surfaces and routes it through the major system of open watercourses. XPRAFTS does not model the details of piped drainage systems.

3.3.1 Pre-development Scenario

The following XPRAFTS parameters were adopted to obtain peak flow estimates similar to those obtained by the Rational Method.

The fraction impervious value for each sub-catchment is included in Table 3-2 below and is based on aerial photography of the area representing the pre-development conditions of each catchment.

Table 3-2 XPRAFTS Sub-catchment Details – Pre-development

Sub-catchment ID	Area (ha)	Fraction Impervious (%)
WA	1.73	0
WB	6.70	0
WC	3.48	0
WD	4.37	0
WE	1.31	0
WF	1.16	0
WG	14.47	0
WH	2.22	0
EA	9.43	0
EB	12.26	0
EC	9.37	0

An initial loss of 0 mm and a continuing loss rate of 0 mm/h were used for all storm events as *the City of Darwin Subdivision and Development Guidelines (2005)* recommends that all catchments are to be considered to be saturated.

The XPRAFTS model was run for a number of durations ranging from the 15 to 180 minute storm events with the 60 minute duration event producing the existing 100 year ARI peak flow for all catchment outlets.

The resultant XPRAFTS peak flows are shown in Table 3-3 and confirm that the parameters adopted provide a reasonable comparison to the Rational Method result for the existing site conditions and therefore, the XPRAFTS model is considered suitable for assessing the impact of the development on peak flows. Reporting Points are shown on Figures 3 and 4.

Table 3-3 Pre-development 100 Year ARI Peak Flow Rational Method Comparison

Sub-catchment Outlet ID	Rational Method Peak Flow (m^3/s)	XPRAFTS Peak Flow (m^3/s)	Impact (m^3/s)	Impact (%)
RP01 – North	3.19	2.51	-0.68	-21
RP04 – South West	10.22	9.46	-0.76	-7
RP05 – To Rainforest Patch	18.70	19.50	0.80	4
RP06 – To Rural Dam	4.58	3.92	-0.66	-14

3.3.2 Post-development Scenario

To model the impact of the development on peak flows downstream of the site, the sub-catchments that included the proposed development areas were modified taking into consideration the increase in percentage impervious and ultimate internal drainage catchments as shown in Figure 4. It is assumed that the post-development catchments will change to align with the development layout and internal drainage network. The post development hydraulic model developed considers the impact of the proposed diversion.

The fraction impervious for each developed sub-catchment was increased using an equivalent fraction impervious based on the proposed land uses for each catchment. The fraction impervious applied to each land use is detailed in Table 3-4 below with the catchment areas and adopted fraction impervious detailed in Table 3-5 for the post-developed scenario.

Table 3-4 Impervious Percentage Adopted For Various Land uses Proposed

Land use	Fraction Impervious (%)
Residential Medium Density	60
Rural Residential	20
Open Space/Park	0
Tourism/High Density Residential/Commercial	90

Table 3-5 XPRAFTS Sub-catchment Details – Post-development

Sub-catchment	Area (ha)	Fraction Impervious (%)
WA	1.73	23
WB	6.70	55
WC	3.48	51
WD	4.37	31
WE	1.31	0
WF	1.16	0
WG	14.47	45
WH	2.22	0
EA	9.43	67
EB	12.26	51
EC	9.37	60

The post-development schematic in XPRAFTS was updated to reflect the changes to the flow of the Eastern portion of the 2CRU site, as shown in Figure 3 and further detailed in Section 3.3.4 of this report. Diversion links were utilised to model the assumed 2 year ARI environmental flow diversion from the 2CRU site to the existing rural dam and rainforest area, with discharges greater than the 2 year ARI directed to the western outlet and Basin 3.

3.3.3 XPRAFTS Results

The resultant impact on the 100 year peak flows is shown in Table 3-6.

Table 3-6 Impact on 100 Year ARI Peak Flows

Reporting Point	Pre-development Peak Flow (m^3/s)	Post-development (Unmitigated, with diversions) Peak Flow (m^3/s)	Impact (m^3/s)	Impact (%)
RP01 – North West	2.51	4.50	1.99	79
RP04 – South West	9.46	19.26	9.80	104
RP05 – To Rainforest Patch	7.44	3.46	-3.98	-53
RP06 – To Rural Dam	3.92	1.86	-2.06	-53

The proposed development of the site has been shown to result in increases for the 100 year ARI peak flows at each outlet by up to 104%.

When considering the impact of the development on both the rainforest patch and rural dam, it is anticipated that the volume of the more frequent runoff events would be the critical hydrologic factor in maintaining the health and demand for the respective receiving environments. Given that the antecedent catchment condition is considered the same in both the pre and post-development scenarios, there should ultimately be no impact on runoff volume to the respective receiving locations if the contributing catchment area is maintained.

It should be noted that for the rainforest patch, during detailed design the depth and length of inundation, and velocities will need to be assessed to ensure they remain tolerable for the health of the vegetation during these infrequent storm events. If unacceptable impacts on the rainforest patch are determined, it will be necessary to provide a detention basin or diversion upstream to mitigate the peak flows whilst still maintaining runoff volume reaching the area.

3.3.4 Mitigated Scenario

To mitigate the increases in flows discharging from the site, it is typically required to provide detention basins to attenuate the local stormwater runoff from each developed catchment.

To ensure the rural dam supply is maintained by regular runoff from the upstream catchment, it is proposed to divert all flows up to the 2 year ARI event ($1.86m^3/s$ and $3.46m^3/s$) to the existing drains that conveys flows to the rural dam and rainforest patch respectively. The 2 year ARI peak flow was selected based on the existing cross drainage culvert of Lee Point Road expected to have a minimum 2 year ARI capacity and preliminary estimates of the capacity of the drain. The balance flows from the developed catchment will be diverted to link with the main drainage path to the south.

Preliminary design of the detention basins has been undertaken assuming the following criteria:

> 1 in 6 batters to facilitate maintenance of the batters, assumed to be turfed;

> Basins initially assumed to be trapezoidal with a width:length ratio of 1:2;

> Maximum depth within each basin to be 1.2m for the 20 year ARI event for public safety. Deeper basins may be possible with appropriate signage and fencing and approval from the City of Darwin; and

> Post-development peak flows to be mitigated to pre-development peak flows for all events from the 2 to 100 year ARI.

For the catchment discharging to the south-west corner of the 2CRU site, two individual detention basins have been designed to maintain existing peak flows in the two defined gullies immediately downstream rather than a single outlet which would potentially result in additional erosion in a single gully.

For the catchment discharging to the north of the 2CRU site, a detention basin has been designed to maintain existing peak flows.

The detention basin outlets are detailed in Table 1-1 with the stage-storage relationships shown in Table 3-8.

Table 3-7 Detention Basin Details

Basin ID	Outlet Pipes	High Flow Weir Width at 100 Year Level (m)	20 Year Depth in Basin (m)	100 Year Depth in Basin (m)	Surface Area at 100 Year Level (m^2)	Volume at 100 Year Level (m^3)
Basin 1	1 / 1200 x 600 RCBC	1.80	1.07	1.33	3,300	3,600
Basin 2	1 /1200 x 600 RCBC	1.80	1.04	1.25	3,200	3,350
Basin 3	2 / 1200 x 600 RCBC	1.80	1.04	1.45	15,950	22,050

Table 3-8 Proposed Detention Basin Stage-Storage Relationships

Stage (m)	Basin 1 Storage (m^3)	Basin 2 Storage (m^3)	Basin 3 Storage (m^3)
0.00	0	0	0
0.20	511	511	3,451
0.40	1,021	1,021	6,696
0.60	1,526	1,526	9,702
0.80	2,018	2,018	12,422
1.00	2,551	2,551	15,194
1.20	3,149	3,149	18,177
1.40	3,799	3,799	21,277
1.60	4,508	4,508	24,500

The resulting mitigated peak flows at each reporting point for all design events are presented in Tables 3-9 – Table 3-11 and demonstrate that there will be no increase in peak flows as a consequence of developing the 2CRU site.

Table 3-9 100 and 50 Year ARI Peak Discharge (m^3/s)

Reporting Point	100 Year ARI			50 Year ARI		
	Pre-developed	Mitigated Post-developed	Impact	Pre-developed	Mitigated Post-developed	Impact
RP01	2.51	2.05	-0.46	2.21	1.88	-0.33
RP02	2.91	2.27	-0.64	2.58	2.09	-0.49
RP03	6.38	4.70	-1.67	5.67	4.15	-1.53
RP04	9.46	6.90	-2.56	8.44	6.17	-2.27
RP05	7.44	3.46	-3.98	6.58	3.46	-3.12
RP06	3.92	1.86	-2.06	3.48	1.86	-1.62

Table 3-10 20 and 10 Year ARI Peak Discharge (m^3/s)

Reporting Point	20 Year ARI			10 Year ARI		
	Pre-developed	Mitigated Post-developed	Impact	Pre-developed	Mitigated Post-developed	Impact
RP01	1.85	1.66	-0.19	1.56	1.46	-0.10
RP02	2.25	1.89	-0.36	1.94	1.67	-0.28
RP03	4.83	3.44	-1.39	4.09	2.66	-1.43
RP04	7.27	5.24	-2.03	6.22	4.22	-2.00
RP05	5.64	3.46	-2.18	4.84	3.46	-1.38
RP06	3.02	1.86	-1.16	2.59	1.86	-0.73

Table 3-11 5 and 2 Year ARI Peak Discharge (m^3/s)

Reporting Point	5 Year ARI			2 Year ARI		
	Pre-developed	Mitigated Post-developed	Impact	Pre-developed	Mitigated Post-developed	Impact
RP01	1.41	1.32	-0.09	1.11	1.05	-0.06
RP02	1.76	1.51	-0.24	1.44	1.21	-0.23
RP03	3.66	2.01	-1.66	2.97	0.75	-2.23
RP04	5.60	3.39	-2.21	4.54	2.05	-2.49
RP05	4.33	3.46	-0.87	3.46	3.46	0.00
RP06	2.32	1.86	-0.46	1.86	1.86	0.00

The above results indicate peak flow rates from the 2CRU site increase as a consequence of development and the associated increase in impervious areas. The proposed detention basins are capable of attenuating this increase in discharge to post-developed levels.

It is noted that in some scenarios some over attenuation of flows is reported. The above designs are preliminary and may be subject to change and thus some conservatism into the required storage is proposed to ensure adequate footprint is provided. During detailed design of the site some variation to the overall size of the basin may occur, however the intent of the basins is to be maintained. Any redesign will necessitate reanalysis of the system to ensure that the peak flow rates discharging from the site are equal to or less than the pre development condition.

Table 3-12 below shows the time taken for each of the detention basins to drain. The times shown are adopted from the peak storm duration for each ARI.

Table 3-12 Time Taken for Detention Basins to Drain

Basin ID	Time (hrs)					
	2 Year ARI	5 Year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI
Basin 1	3.5	4	4.5	5	5	5.5
Basin 2	3	4	4.5	5	5	5.5
Basin 3	5	6	6.5	7	7.5	8

4 Stormwater Quality Assessment

Development of the site may have the potential to:

> Release sediment and potential contaminants into receiving waters as a result of vegetation clearing and / or excavation;

> Adversely impact fish and other aquatic species due to increased turbidity and / or release of contaminants during construction, or increased pollutant loads from road runoff during operation; and

> Contaminate water in the event of fuel or oil spills during construction and operation.

The majority of potential water quality related impacts can be adequately managed with effective implementation of the additional mitigation measures outlined in the following section to meet specific Water Quality Objective's (WQO's). These measures include the use of bioretention systems, vegetated swales/buffers and proprietary devices.

4.1 Construction Phase Water Quality

During the construction phase, the potential exists for increases in the amount of pollutants, particularly sediment, exported from the site. During this period, an Erosion and Sediment Control Plan will be required as part of the overall Environmental Management Plan prepared for the construction phase.

It is considered that the completion of construction activities in accordance with an Erosion and Sediment Control Plan developed using latest version of the following guidelines will minimise the nature of any adverse impacts during the construction phase and allow the design objectives to be achieved.

> IECA.2008, Best Practice Erosion and Sediment Control - Engineering Guidelines for Queensland Construction Sites.

> Institution of Engineers Australia.1996, Soil Erosion and Sediment Control, Engineering Guidelines for Queensland Construction Sites. June.

4.2 Post-Construction Phase Water Quality

4.2.1 Water Quality Objectives

Water quality objectives exist for Darwin Harbour (*Water Quality Objectives for the Darwin Harbour Region*, *Department of Natural Resources, Environment, The Arts and Sport*, 2010). These objectives are concentration based outcomes. In some cases, the algorithms used in the current industry standard water quality modelling package (MUSIC) make it impossible to comply with concentration-based water quality objectives regardless of the type or size of device installed.

In order to enable the development of a suitable treatment train, pollution reduction targets adopted from QLD guidelines detailed in *Department of State Development, Infrastructure and Planning 'State Planning Policy'* (April 2016) have been utilised. These targets provide a method of quantifying reductions within a computer model. The intent of this analysis is to develop a system which is likely to result in sufficient pollutant reductions to conform with the WQO's set out for the Darwin Harbour Region. Water quality monitoring, proposed for the site post development will confirm or highlight the treatment systems effectiveness.

Therefore, to be consistent with current best practice with respect to water quality, load based water quality objectives were adopted for the consideration of water quality issues. The following water quality objectives were adopted:

- an 80 % reduction in Suspended Solids;
- a 60 % reduction in Total Phosphorus;
- a 45 % reduction in Total Nitrogen; and,
- a 90 % reduction in gross pollutants.

4.2.2 Stormwater Management Practices

The formulation and implementation of the water quality management plan for the development is based on the following key principles:

> Adoption of Water Sensitive Urban Design (WSUD) principles where feasible; and

> Management and control of water quality both during and after construction. A detailed Erosion and Sedimentation Control Plan will need to be developed in accordance with recognised standards during the detailed design phase and implemented on site during the subdivision construction process.

4.2.3 Proposed Stormwater Quality Treatment Train

The treatment measures to be adopted for the majority of the development include the use of Ecosol Net Guards, bioretention basins and vegetated swales/buffers. High density areas within the development such as the tourism/commercial precinct may also incorporate proprietary treatment devices such as the Stormwater360 treatment system. The preliminary locations for the proposed treatment measures are shown in Figure 5.

The opportunity to develop small scale water sensitive urban design (WSUD) system has this stage not been considered. This document aims to provide suitable bioretention areas to treat the runoff from the site. It is acknowledged that treatment close to the source of runoff is desirable as this more closely mimics the surface/groundwater interaction of the pre development catchment.

During the detailed design phase of the project if opportunities to utilise small scale bio retention systems (such as tree pits and raingardens) exist they will be considered. It is noted that not all WSUD measures will be suitable for the Darwin Harbour region due to the variable climate experienced. Review of previously successful implementation of WSUD within the Darwin Harbour region will guide the final bioretention basin design approach.

To minimise the size of the bioretention areas, it is proposed to incorporate the proprietary treatment product by Ecosol being the Net Guard as pre-treatment to the bioretention basins. The Net Guard will primarily treat the Total Suspended Solids (TSS) and Gross Pollutants (GP) with some additional pollutant removal of Total Nitrogen (TN) and Total Phosphorus (TP). The recommended pollutant removal efficiencies have been provided by the manufacturer and listed below:

> TSS – 40% removal

> TN – 30% removal

> TP – 35%

> GP – 93%

The preliminary details of the bioretention basins are detailed in Table 4-1 with the locations of the bioretention basins are shown on Figure 5.

Table 4-1 Bioretention Details

Parameter	Bio-Basin A	Bio-Basin B	Bio-Basin C	Bio-Basin D	Bio-Basin E
Extended Detention Depth (m)	0.3	0.3	0.3	0.3	0.3
Surface Area (m^2)	900	700	700	900	650
Filter Media Surface Area (m^2)	900	700	700	900	650
Saturated Hydraulic Conductivity (mm/hr)	200	200	200	200	200
Filter Depth (m)	0.6	0.6	0.6	0.6	0.6
TN Content (mg/kg)	400	400	400	400	400
Orthophosphate Content (mg/kg)	30	30	30	30	30

It should be noted that the maximum bioretention area is recommended to be 800m^2 for both ease of maintenance and to aid the survival of bioretention vegetation during extended dry periods. The limiting pollutant in sizing most of the bioretention areas is Total Suspended Solids, with the use of proprietary pre-

treatment devices such as Ecosol's Net Guard product, the overall size of the bio-retention basins could be reduced.

Based on discussions with City of Darwin it was highlighted that the Net Guard product was a preferred solution. As the system, once installed will be serviced and maintained by City of Darwin their preferred product has been recommended.

It is noted that the use of rainwater tanks for re-use of rainwater could also potentially reduce the pollutant loads discharging from the site while also reducing demand on town water supply. However, imposing this requirement on potential property buyers is not easily enforced and has therefore not been included as part of the treatment train.

4.2.4 Design and Performance of Treatment Measures

In order to determine the effectiveness of the adopted treatment train in meeting the WQOs, a stormwater quality analysis was performed using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) Version 6.2

The model requires the user to specify meteorological data (rainfall and evaporation), soil properties and pollutant loads for each catchment. Suitable parameters for the MUSIC model have been adopted in accordance with the recommendations within the Water Sensitive Urban Design Stormwater Quality Modelling Guide, May 2009 prepared by the Northern Territory Department of Planning and Infrastructure.

The Urban Residential source node has been adopted within the MUSIC modelling. Further, the development has been divided into roof areas, road areas and general urban based on the applicable Source Node land use. The pollutant export parameters adopted are shown in Table 4-2.

Table 4-2 Stormwater Water Quality Parameters for MUSIC Source Nodes

Source Node		TSS (log_{10} values)		TP (log_{10} values)		TN (log_{10} values)	
		Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Baseflow	Roof	1.10	0.17	-0.82	0.19	0.32	0.12
	Roads	1.10	0.17	-0.82	0.19	0.32	0.12
	General Urban	1.10	0.17	-0.82	0.19	0.32	0.12
Stormflow	Roof	1.55	0.39	-0.92	0.29	0.42	0.19
	Roads	2.38	0.40	-0.60	0.50	0.42	0.19
	General Urban	2.20	0.32	-0.45	0.25	0.42	0.19

The rainfall data applied to the MUSIC model was for the Darwin Airport rainfall station for the period 1987-1996. A 6 minute time step was considered for the analysis.

4.2.5 Catchment Areas

Catchment areas and percentage impervious values were determined from the preliminary Master Plan provided by Bennett & Bennett. The adopted catchment characteristics are given in Table 4-3.

Table 4-3 Catchment Areas

Catchment	Total Area (ha)	% Impervious
A	14.33	42
B	11.91	49
C	9.43	67
D	12.26	67
E	9.37	60

The results of the MUSIC modelling, shown as total annual loads, are presented in Table 4-4.

Table 4-4 Predicted Pollutant Load Reductions

Parameter	Generated Load (kg/yr)	Mitigated Post-development Load (kg/yr)	Reduction Achieved (%)	Target Reduction (%)
TSS	123,000	24,200	80.3	80
TP	256	71.3	72.1	60
TN	1,850	791	57.1	45
Gross Pollutants	14,100	1.24	99.9	90

The results presented in Table 4-4 demonstrate that the proposed stormwater treatment measures for the development will satisfy the adopted pollution reduction targets for all pollutants modelled in MUSIC. Stormwater Quality and therefore the COD criteria for water quality have been appropriately addressed.

Reduction targets were adopted from QLD guidelines detailed in *Department of State Development, Infrastructure and Planning 'State Planning Policy'* (April 2016).

Water quality objectives exist for Darwin Harbour (*Water Quality Objectives for the Darwin Harbour Region*, *Department of Natural Resources, Environment, The Arts and Sport*, 2010). These objectives are concentration based outcomes. In some cases, the algorithms used in the current industry standard water quality modelling package (MUSIC) make it impossible to comply with concentration-based water quality objectives regardless of the type or size of device installed.

In order to enable the development of a suitable treatment train, pollution reduction targets adopted from QLD guidelines detailed in *Department of State Development, Infrastructure and Planning 'State Planning Policy'* (April 2016) have been utilised.

As part of the ongoing water quality monitoring proposed for the site, the effectiveness of the proposed treatment systems relative to the Darwin Harbour water quality objectives will be assessed. This assessment should be undertaken utilising the risk based approach set out within the document. If during this process the site runoff is found to be posing a high risk to the ecosystem, management intervention to mitigate this risk will be required.

5 Flooding

Notwithstanding inundation across the 2CRU site from local catchment runoff resulting in shallow sheet flow and concentrated gully flows that is not quantified in this report, other potential sources of inundation could occur due to storm tide inundation given the proximity of the site to Beagle Gulf.

Reference to the '*High Resolution Storm Tide and Climate Change Impacts Study – 2010'* prepared by System Engineering Australia for the Northern Territory Department of Lands and Planning identifies the following storm tide levels for Lee Point detailed in Table 5-1.

Table 5-1 Total Storm Tide Levels (mAHD) at Lee Point

Year	Estimated Return Period of Total Storm Tide Level				
	50y	100y	500y	1,000y	10,000y
2010	4.5	4.7	5.2	5.4	5.8
2050	4.9	5.1	5.6	5.8	7.1
2100	5.4	5.6	6.1	6.5	7.4

The above levels for 2100 have been mapped by GHD, 2014 based on the latest topographic information (2009 and 2011) as part of the Northern Territory Storm Surge Mapping with the area containing the site extracted below in Plate 3.

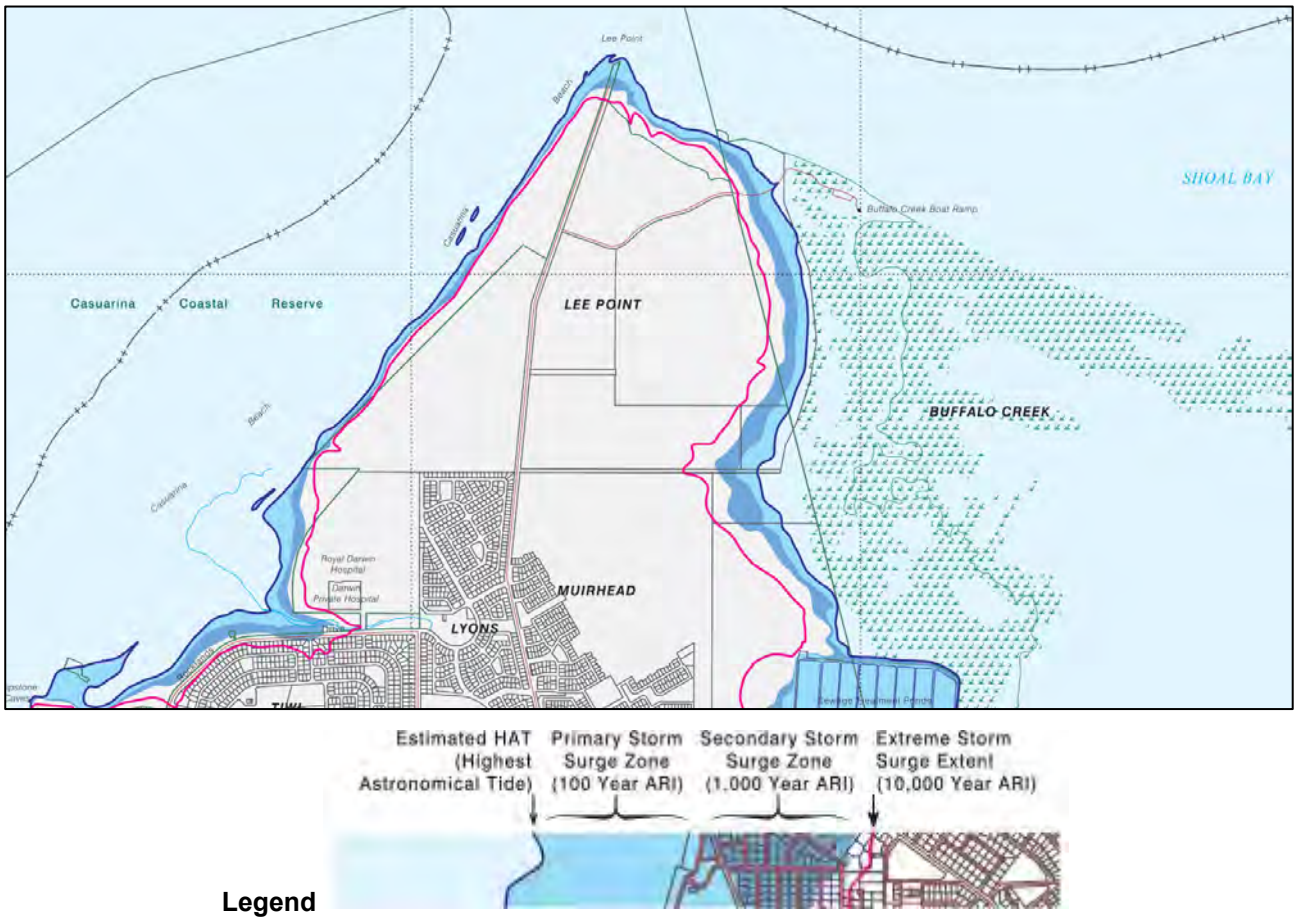

Plate 3: Darwin Area Storm Surge Inundation for 2100 Extract (Copyright: Northern Territory Government, GHD and SEA)

Based on the above, the majority of the 2CRU site is above both the 100 year and 1,000 year Average Recurrence Interval (ARI) storm tide level for 2100.

6 Conclusions

This Stormwater Management Plan has been prepared by Cardno Pty Ltd, specialist hydrologic, hydraulic and water quality consultants to support the preliminary application for the proposed 2CRU development. This report has investigated the water quantity and quality and flood management for the site and provides conceptual evidence the applicable development codes can be adhered to.

In preparation of this Stormwater Management Plan the following assessments were completed:

> A hydrologic assessment to determine the impact on the peak flows from the site catchments, to provide details of necessary mitigation requirements to ensure no increase in peak flows discharging from the site; and

> A pollutant export assessment to determine the stormwater quality management requirements for the site to ensure discharges meet the required load based reduction targets.

Local hydrologic modelling indicates no adverse offsite discharge, achieved using detention basins and 2 year ARI diversions to attenuate post-developed discharges to that of pre-developed levels.

Water quality modelling indicates that prescribed pollutant reduction targets can be achieved incorporating the proposed proprietary devices and bio-retention basins.

7 Qualifications

This report has been prepared by Cardno for Defence Housing Australia (DHA) and specifically to provide advice on the stormwater management for the development of the 2CRU, located in Lee Point, Darwin, Northern Territory. Our analysis and overall approach has been catered to the specific requirements of DHA, and may not be applicable beyond this scope. For this reason any other third parties other than Council are not authorised to utilise this report without further input and advice from Cardno.

Cardno has relied on the following information provided by others:

> Site survey undertaken by Bennett & Bennett;

> ALS data of the site and immediate surrounding catchment was sourced from the Department of Lands, Planning and the Environment (DLPE) to derive contours; and

> Aerial imagery, sourced from Nearmap and Google Earth; and

> Rainfall data supplied by the Bureau of Meteorology.

The accuracy of the report is dependent upon the accuracy of this information.

While Cardno's report accurately assesses peak flows from design storms, it is an ungauged catchment and consequently future observed flows may vary from that predicted.

Stormwater Management Plan

FIGURES

Figure 1 Site Location

Figure 2 Catchment Characteristics

Figure 3 XPRAFTS Pre-Development Model Layout

Figure 4 XPRAFTS Post-Developed Model Layout

Figure 5 MUSIC Model Layout

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NORTH

Legend

Site Boundary

CAD FILE: O:\DC1603_2CRU\RAFTS\Figures\Figures_R1V1.dwg
XREFs:

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Date	Scale	Size
February 2017	1:20,000	A3
DC1603	0 200 400 600 800m	1
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FIGURE 1

Site Location

2CRU - Lee Point Road, Lee Point
Stormwater Management Strategy
Defence Housing Australia

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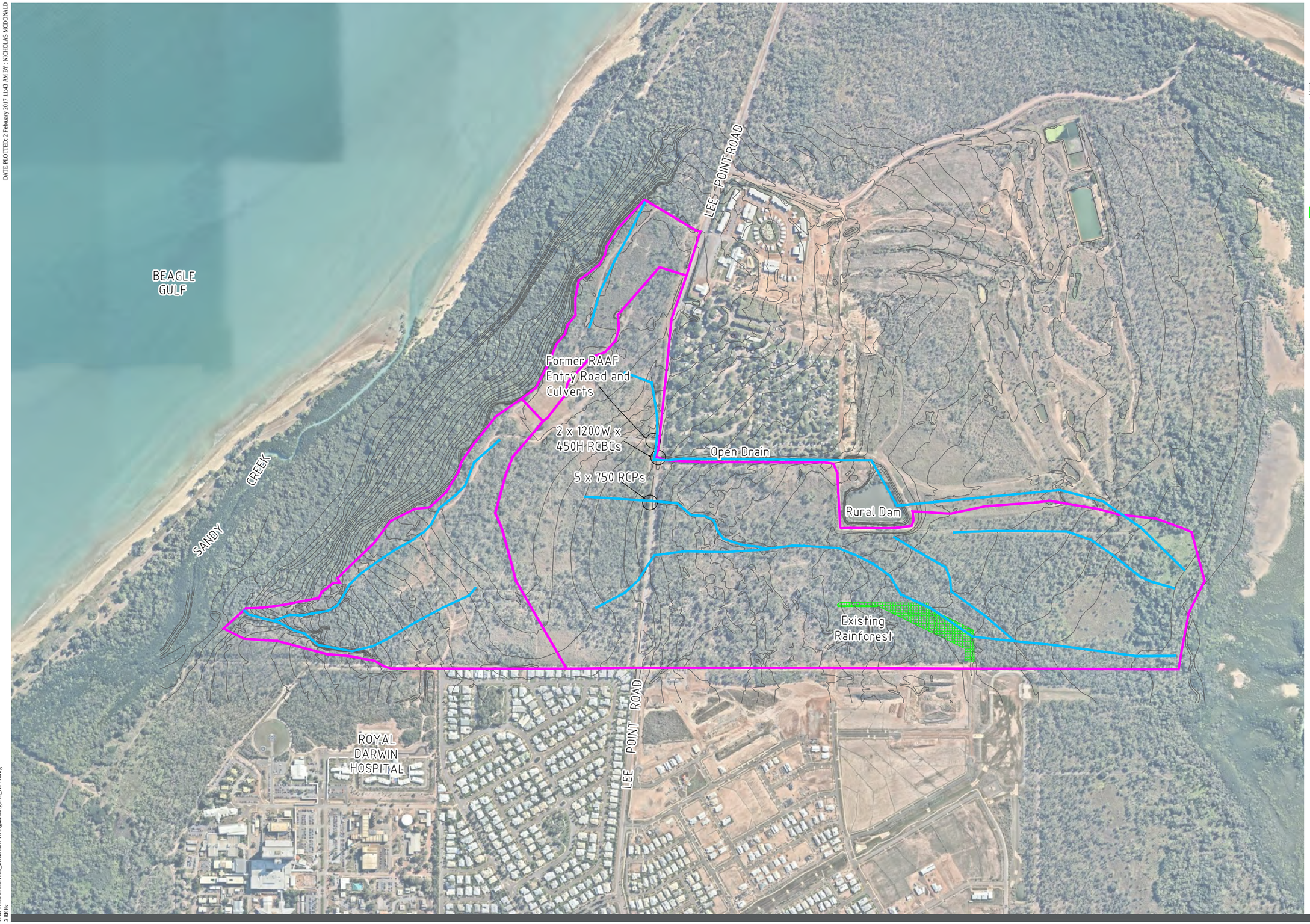

Legend

- Catchment Extents
- Flow Path
- Culvert Location
- Rainforest Patch

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FIGURE 2

Catchment Characteristics

2CRU - Lee Point Road, Lee Point
Stormwater Management Strategy
Defence Housing Australia

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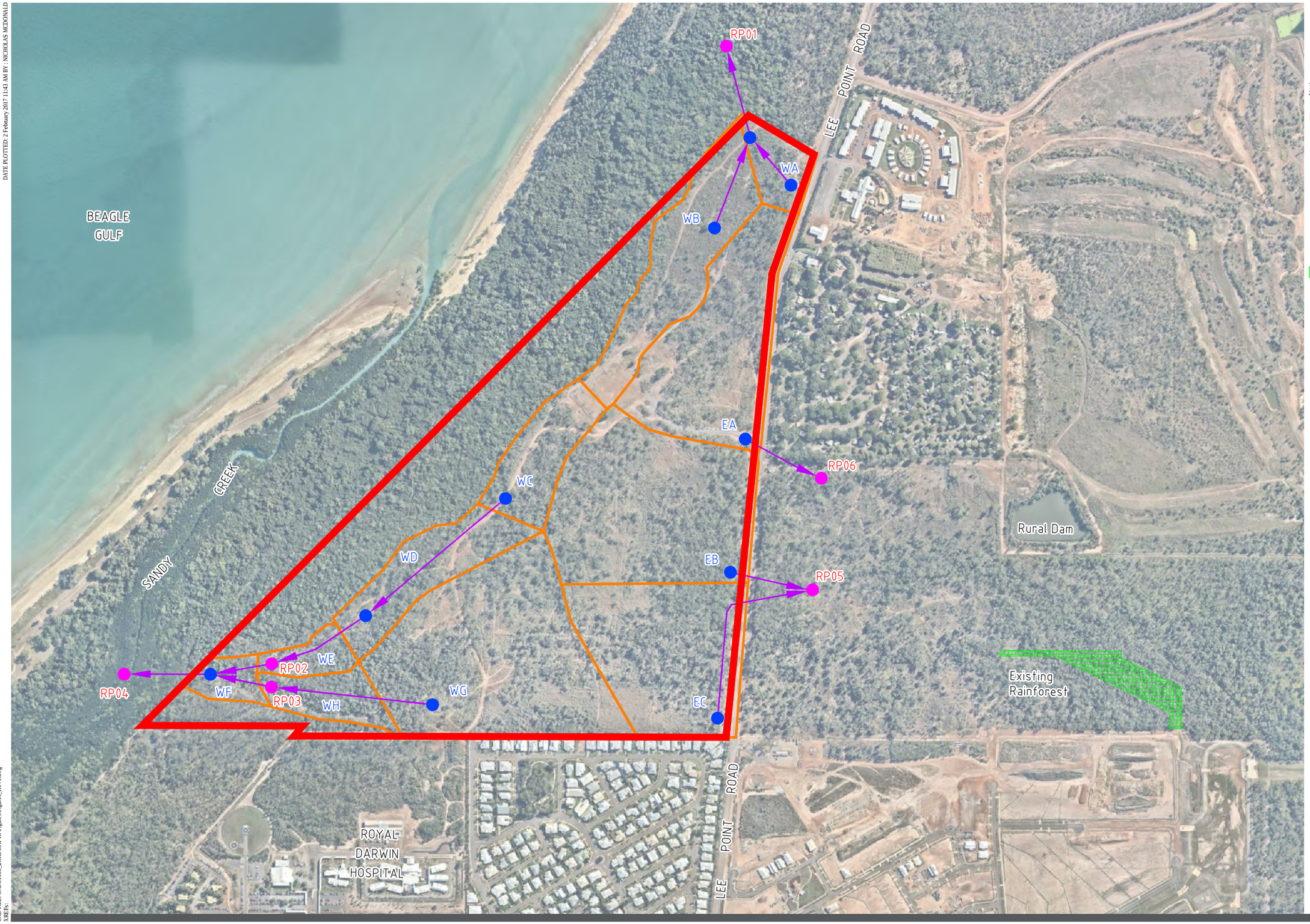

NORTH

Legend

- Site Boundary
- XPRAFTS Catchment
- XPRAFTS Catchment Link
- WA — XPRAFTS Catchment Node
- RP01 — Reporting Point
- Rainforest Patch

CAD FILE: O:\DC1603_2CRU\RAFTS\Figures\Figures_R1V1.dwg
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FIGURE 3

XPRAFTS Pre-Developed Model Layout (EX03)

2CRU - Lee Point Road, Lee Point
Stormwater Management Strategy
Defence Housing Australia

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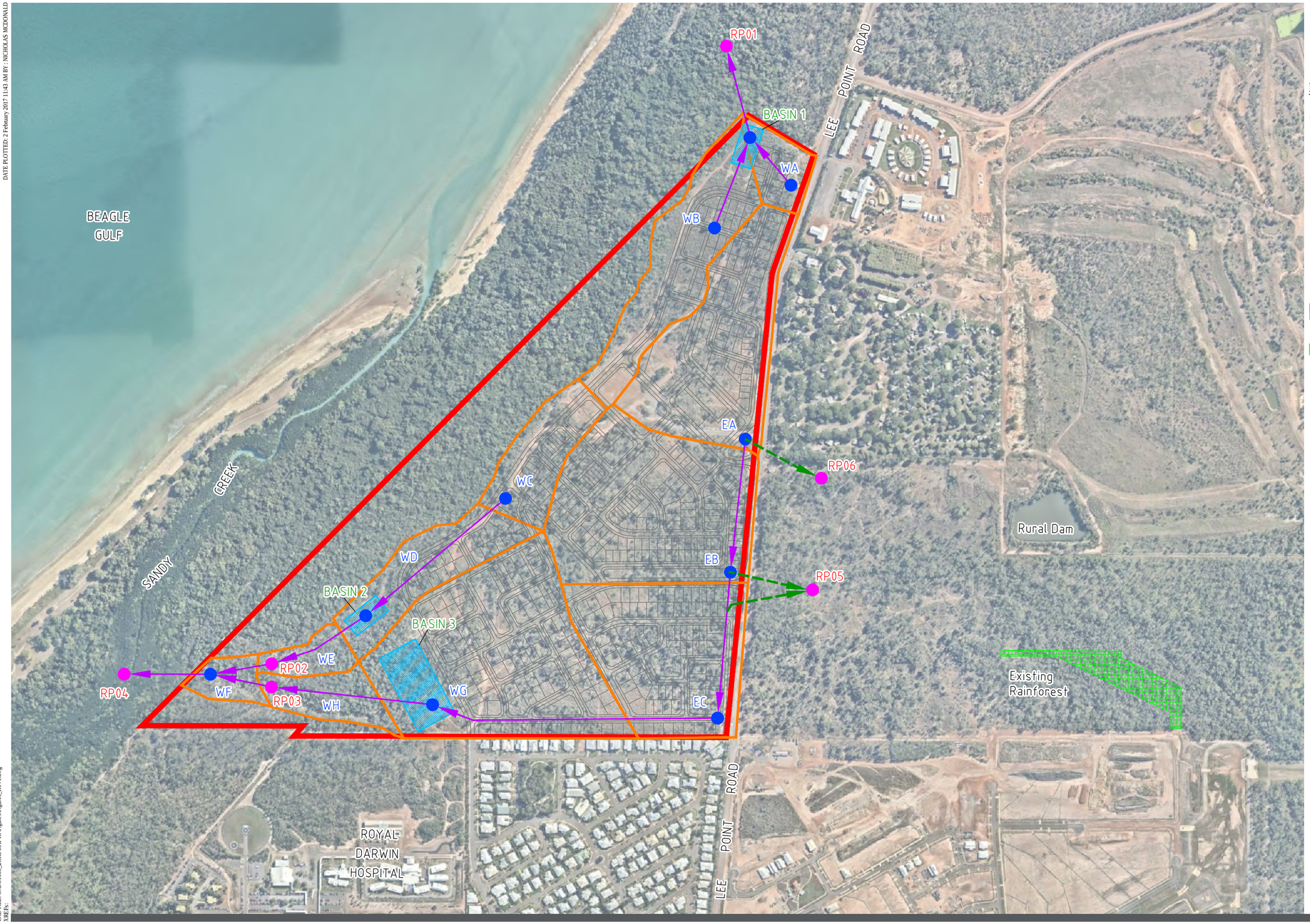

Legend

- Site Boundary
- XPRAFTS Catchment
- XPRAFTS Catchment Link
- XPRAFTS Q2 Diversion
- XPRAFTS Catchment Node (WA)
- Reporting Point (RP01)
- Detention Basin (Indicative size and location)
- Rainforest Patch

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FIGURE 4

XPRAFTS Post-Developed Model Layout (M13)

2CRU - Lee Point Road, Lee Point
Stormwater Management Strategy
Defence Housing Australia

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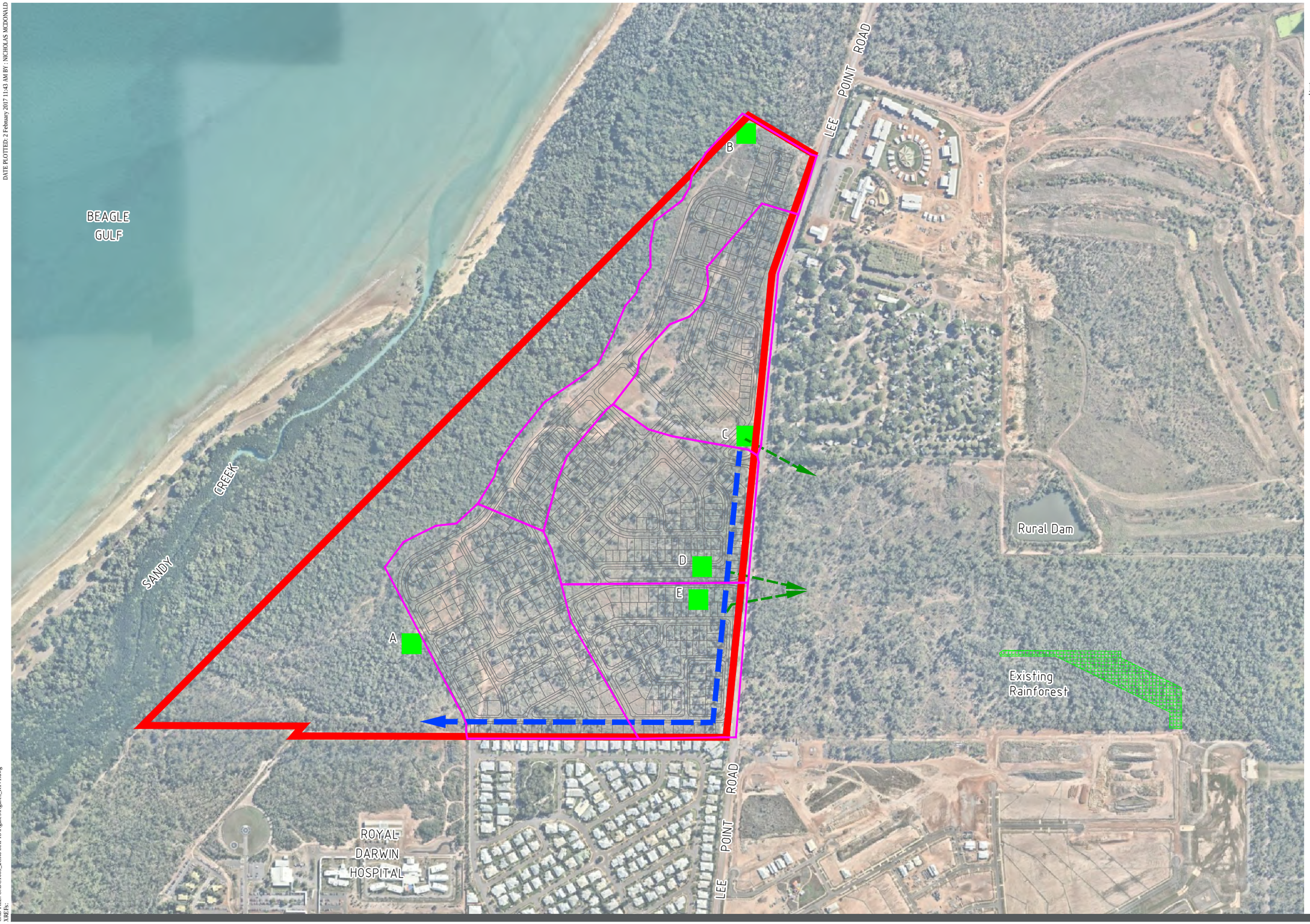

Legend

- Site Boundary
- Q2 Diversion
- Proposed Stormwater Drain
- MUSIC Catchment
- A — Bio-retention basin

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FIGURE 5

MUSIC Model Layout (M07)

2CRU - Lee Point Road, Lee Point
Stormwater Management Strategy
Defence Housing Australia

Stormwater Management Plan

REFERENCE DRAWINGS

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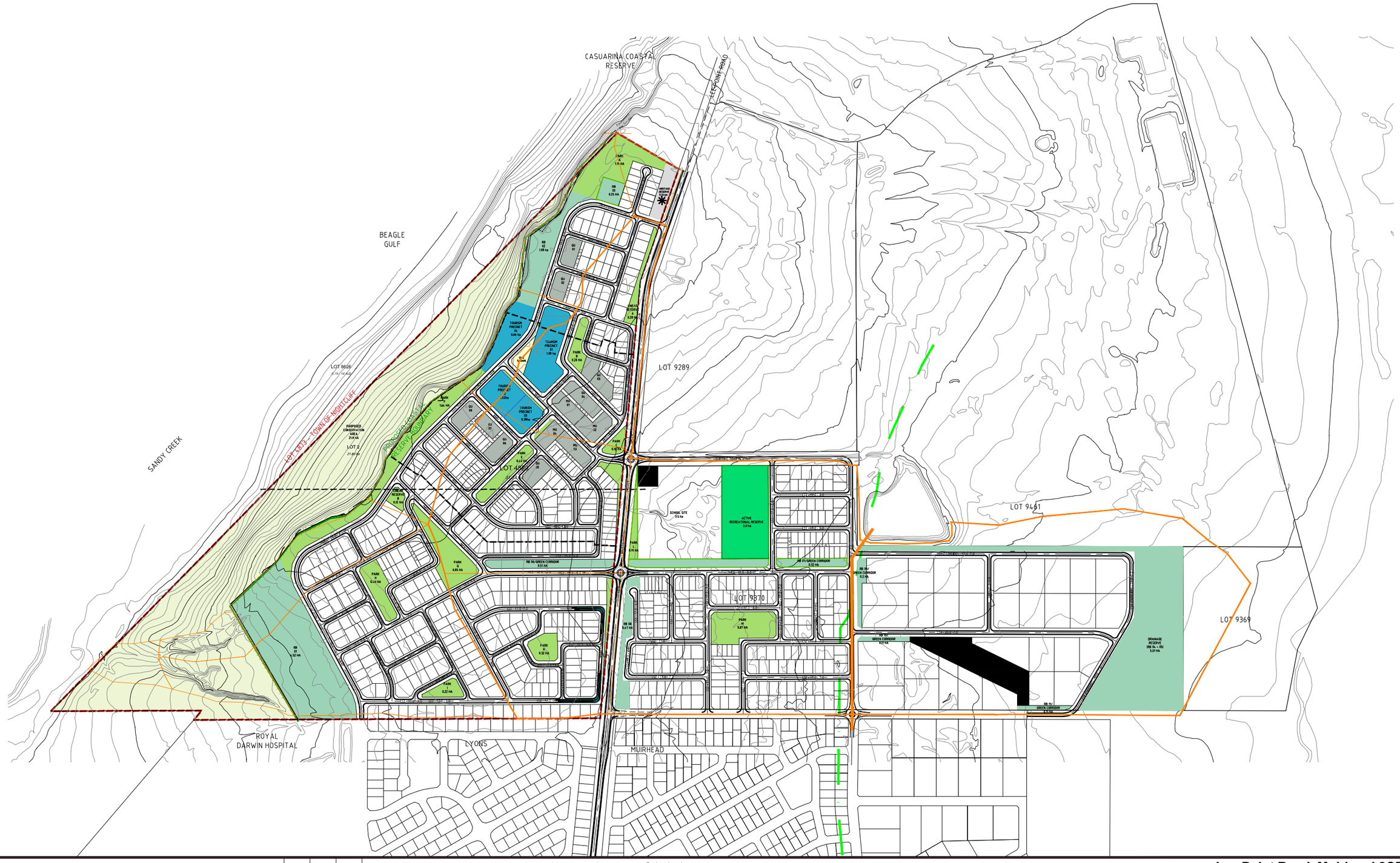

REVISION	DATE	DES/DFT	APP'D
- -	-	-	-

Principal
Defence Housing Authority

Project Leader
TFR
Designed
CH
Drawn
CH
Checked
DB
Authorised
TFR
Date
April 2016

NORTH

Scale @ A1
1:1000

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Lee Point Road, Muirhead 2CRU

Master Planning - Stages
City of Darwin
Roadworks Layout Plan

Sheet 1 of 2
Drawing No. -
Rev -
Dev. App. No. -
Sheet No. - of -

Issued For Review

CASUARINA COASTAL RESERVE

LEE POINT ROAD

BEAGLE GULF

LOT 8626
S 75/14 A.O.

LOT 9289

LOT 9461

LOT 9370

LOT 9369

LOT 4873
67.33 ha
S 2019/107

LOT 2
21.80 ha

LOT 6574 - TOWN OF NIGHTCLIFF

PROPOSED CONSERVATION AREA / 21.8 HA

PRESERVE BOUNDARY

SANDY CREEK

ROYAL DARWIN HOSPITAL

LYONS

MUIRHEAD

PARK A 1.19 HA

RB 03 0.25 HA

HERITAGE RESERVE A

RB 02 1.08 ha

GU 01

GU 02

LINEAR RESERVE A 0.39 ha

TOURISM PRECINCT 04 0.66 ha

TOURISM PRECINCT 01 1.08 ha

CIVIC SQUARE

PARK F 0.28 HA

GU 03

GU 04

MU 01

MU 02

TOURISM PRECINCT 02 0.52ha

TOURISM PRECINCT 03 0.38ha

PARK J 1.44 HA

GU 06

GU 07

GU 05

MU 04

MU 03

PARK C 0.58 HA

PARK G 0.48 HA

LINEAR RESERVE B 0.12 HA

PARK G 0.85 HA

PARK H 1.34 HA

RB 01 1.52 HA

PARK K 0.32 HA

PARK D 0.22 HA

RB 06/GREEN CORRIDOR 0.51 HA

EXISTING ROAD RESERVE

COMMUNITY CENTRE 0.2 ha

SCHOOL SITE 3.5 ha

ACTIVE RECREATIONAL RESERVE 2.0 ha

PARK L 1.19 HA

RB 07/GREEN CORRIDOR 0.32 HA

RB 08 0.47 HA

PARK M 0.87 HA

RB 09/ GREEN CORRIDOR 0.2 HA

RB 07/ GREEN CORRIDOR 0.11 HA

RB 11/ GREEN CORRIDOR 0.11 HA

DRAINAGE RESERVE (RB 04 + DS) 5.51 HA

LS1 – 15.0-6.0

LS2 – 17.0 – 7.2

LS3 – 17.0 – 8.0

LS4 (PARKSIDE) – 17.0 -7.0

LS4 – 20.0-7.0

NC1 – 18.5 – 8.0 LP

NC2 – 19.5 – 8.0 LP

LS2 – 17.5 – 6.0 LP

LS2 – 17.5 – 6.0 LP

LS1 – 6.5 - 5.5

LS2 – 17.0 – 6.0

LS3 – 17.0 – 8.0

LS4 (PARKSIDE) – 17.0 -7.0

LS4 – 20.0-7.0

LS5 – 20.0-7.0

LS4 (PARKSIDE) – 17.0 -7.0

DEPENDANCE – 17.0 -7.0

EXISTING ROAD RESERVE

LEE POINT ROAD

LOT 9289

LOT 9461

LOT 9370

LOT 9369

DRAINAGE RESERVE (RB 04 + DS) 5.51 HA

APPENDIX F

Stormwater Management Plan – Muirhead North

Muirhead North - Lee Point Road, Lee Point

Stormwater Management Plan

DC1603/R1/V2

Prepared for
Defence Housing Australia

11 October 2017

Cardno
Shaping the Future

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Table of Contents

1 Introduction **1**

2 Site Description **2**

2.1 Existing Conditions 2

2.2 Proposed Development 2

3 Stormwater Quantity Assessment **3**

3.1 Setup 3

3.2 Results 4

3.3 Mitigation 4

4 Stormwater Quality Assessment **6**

4.1 Construction Phase 6

4.2 Operational Phase 6

4.2.1 Water Quality Objectives 6

4.2.2 Proposed Treatment Train 6

4.2.3 Pollutant Impact Assessment 7

5 Regional Flood Assessment **9**

6 Conclusions **10**

7 Qualifications **11**

8 References **12**

Appendices

Appendix A Reference Drawings

Tables

Table 3-1 Adopted Impervious Fraction 3

Table 3-2 XPRAFTS Sub-catchment Details – Pre-development 3

Table 3-3 100 Year ARI Peak Flows 4

Table 3-4 Detention Basin Details 4

Table 3-5 Proposed Detention Basin Stage-Storage Relationships 5

Table 3-6 Peak Discharge at Outlet (RP5) 5

Table 3-7 Time Taken for Detention Basin to Drain 5

Table 4-1 Bioretention Details 7

Table 4-2 MUSIC Pollutant Generation Parameters 7

Table 4-3 Catchment Areas 8

Table 4-4 Predicted Pollutant Loads 8

Table 5-1 Total Storm Tide Levels (mAHD) at Lee Point 9

Figures

Figure 1 Site Location

Figure 2 Catchment Characteristics
Figure 3 XPRAFTS Pre-Development Model Layout
Figure 4 XPRAFTS Post-Developed Model Layout
Figure 5 MUSIC Model Layout

1 Introduction

This Stormwater Management Plan (SMP) has been prepared by Cardno in order to support a Development Application (DA) for Muirhead North. The site is located on Lee Point Road, Lee Point, as shown in Figure 1.

The Muirhead North site is to be developed by Defence Housing Australia (DHA) and consist predominantly of residential lots with smaller sections dedicated to commercial purposes, and a school. The site has the potential to be developed in conjunction with '2CRU', a development to the west of the site, as described in the Cardno report *2CRU – Lee Point Road, Lee Point – Stormwater Management Plan'* dated 25 May 2017 (ref: DC1603/R1/V2).

This report details the preliminary stormwater management requirements for the development and has been prepared in accordance with the following relevant policies and guidelines:

> Subdivision and Development Guidelines, Darwin City Council [COD, 2005];

> Queensland Urban Drainage Manual (QUDM) [Provisional, DEWS, 2013];

> Australian Rainfall and Runoff - A Guide to Flood Estimation, Volume 1 [IEAust, 2003];

> Australian Rainfall and Runoff - A Guide to Flood Estimation, Volume 2 [IEAust, 1987];

> Water Sensitive Urban Design - Modelling Guide, Northern Territory Department of Planning and Infrastructure [NTDPI1, 2009];

> Water Sensitive Urban Design - Technical Design Guideline, Northern Territory Department of Planning and Infrastructure [NTDPI2, 2009];

> Water Sensitive Urban Design - Vegetation Selection Guide, Northern Territory Department of Planning and Infrastructure [NTDPI3, 2009];

> Water Sensitive Urban Design - Operation and Maintenance Guidelines, Northern Territory Department of Planning and Infrastructure [NTDPI4, 2009];

> Water Sensitive Urban Design - Water Quality Monitoring Strategy, Northern Territory Department of Planning and Infrastructure [NTDPI5, 2009]; and

> Water Sensitive Urban Design - Construction, Asset Handover, Maintenance Guideline, Northern Territory Department of Planning and Infrastructure [NTDPI6, 2009].

> Water Quality Objectives for the Darwin Harbour Region,[Department of Natural Resources, Environment, The Arts and Sport, 2010]

2 Site Description

2.1 Existing Conditions

The site is currently undeveloped, predominately consisting of casuarina forest and open woodland. However an environmentally significant rainforest area exists within the centre of the site, as shown on Figure 2. A number of unsealed tracks traverse the site, and a rural dam exists immediately to the north.

Topography across the site ranges from approximately 5 to 25mAHD, generally grading from west to east before discharging into Buffalo Creek. Surface runoff from the site is relatively shallow, and is mainly conveyed via sheet flow and surface flow, in some areas runoff is concentrated in defined gullies. These include naturally occurring gullies within the centre of the site.

A proportion of the 2CRU catchment drains through the subject site, via 3 culverts as illustrated in Figure 2.

2.2 Proposed Development

DHA propose to develop the Muirhead North site for residential and mixed-use land uses including commercial areas and potential tourism / hotel development. While the majority of the development will comprise standard residential lots, the balance will include lots for commercial, low rise apartments and tourism accommodation.

As detailed in the Cardno (2017) report, a proportion of the external catchments will be redirected as part of the 2CRU development. The impact on site flows is detailed in the following sections.

3 Stormwater Quantity Assessment

The development of the site has the potential to increase local site runoff due to the increase in impervious areas. This potential increase in site runoff can result in downstream increases of peak flood levels, waterway erosion and affect bank stability. To ensure no adverse impacts external to the site, appropriate mitigation measures are required to limit post-developed runoff to the pre-developed conditions. The following section details this assessment.

In addition to the consideration of no downstream adverse impacts, the impact of the development on the existing rainforest area must be considered. At this stage the analysis undertaken focuses on ensuring the quantity of flow discharging from the site does not exceed the pre development condition. No quantity control measures (with the exception of the diversion upstream of Lee Point Road) are proposed upstream of the rainforest area at this stage.

The primary risk to the rainforest area is the reduction in low (base) flows from the upstream catchment. This hydrologic scheme is likely to be influenced more by the quality measures proposed. Further discussion on this is provided in Section 4.

3.1 Setup

Modelling has been conducted using XPRAFTS (Version 2013 SP1) and based on the models setup as part of the Cardno (2017) report. XPRAFTS is an event based hydrologic model that calculates flood hydrographs from storm rainfall hyetographs. It also has the ability to model basic hydraulic structures such as detention basins.

Delineation of the sub-catchments illustrated on Figure 3 were based on site ground survey and Aerial Laser Survey (ALS) of the area. For the purposes of this preliminary assessment, the post-developed scenario adopts the pre-developed sub-catchments, expected to change as part of the future detailed design stages of the project. However the fraction impervious values were modified in-line with the proposed development and based on the land use values within Table 3-1, with the resulting sub-catchment properties are detailed in Table 3-2 below.

Table 3-1 Adopted Impervious Fraction

Land use	Fraction Impervious (%)
Residential Medium Density	60
Rural Residential	20
Open Space/Park	0
Tourism/High Density Residential/Commercial	90

Table 3-2 XPRAFTS Sub-catchment Details – Pre-development

Sub-catchment ID	Area (ha)	Pre-Developed Impervious (%) (EX03)	Post-Developed Impervious (%) (M18)
ED	12.09	0	50
EE	16.24	0	57
EF	10.70	0	17
EG	7.00	0	20
EH	4.36	0	0
EI	5.96	0	12
EJ	12.48	0	0

An initial loss of 0 mm and a continuing loss rate of 0 mm/h were used for all storm events as per *Subdivision and Development Guidelines* (COD, 2005) recommends that all catchments are to be considered to be saturated.

Design rainfall intensities for the area were calculated using AusIFD Version 2.0, and adopting the following parameters for the area as prescribed by *ARR* (IEAust, 1987):

> 2 year, 1 hour rainfall intensity = 62.64 mm/h
> 2 year, 12 hour rainfall intensity = 9.78 mm/h
> 2 year, 72 hour rainfall intensity = 3.02 mm/h
> 50 year, 1 hour rainfall intensity = 100.0 mm/h
> 50 year, 12 hour rainfall intensity = 16.13 mm/h
> 50 year, 72 hour rainfall intensity = 6.04 mm/h
> Skew (G) = 0.37
> Geographical Factor (F2) = 4.39
> Geographical Factor (F50) = 18.50

The model was run for all standard design storm Average Recurrence Intervals (ARI) and durations from 15 to 180 minutes. Model results were validated to the Rational Method as detailed in the Cardno (2017) report.

3.2 Results

The resultant peak 100 year ARI flood discharge for both scenarios is shown in Table 3-3 below.

Table 3-3 100 Year ARI Peak Flows

Outlet ID	Pre-development Peak Flow (m^3/s)	Post-development (Unmitigated, with diversions) Peak Flow (m^3/s)	Impact (m^3/s)	Impact (%)
RP5	27.07	31.23	4.16	15.4

The proposed development is predicted to increase peak discharges at the site outlet. Therefore mitigation of these increases is required and detailed below.

3.3 Mitigation

It is proposed to mitigate the above increases in flows via a detention basin at the downstream extent of the site, as shown on Figure 4. The post development hydraulic model developed considers the impact of the proposed diversion of high flows along Lee Point Road. This preliminary design assumes the following criteria:

> 1 in 6 batters to facilitate maintenance of turfed batters;
> Trapezoidal with a width:length ratio of 1:2; and
> Maximum depth of 1.2m for the 20 year ARI event for public safety. It is noted this may be increased in the future with appropriate signage, fencing and approval from Council.

The basin outlet arrangement and stage-storage is detailed in Tables 3-4 and 3-6 respectively.

Table 3-4 Detention Basin Details

Outlet Arrangement (m)	Peak 20 Year ARI Depth (m)	Peak 100 Year ARI Depth (m)	Surface Area at Peak 100 Year ARI Level (m^2)	Volume at Peak 100 Year ARI Level (m^3)
7 / 1.5 x 0.9 RCBC	1.18	1.26	12,800	15,714

Table 3-5 Proposed Detention Basin Stage-Storage Relationships

Stage (m)	Storage (m^3)
0.00	0
0.20	3,451
0.40	6,696
0.60	9,702
0.80	12,422
1.00	15,194
1.20	18,177
1.40	21,277

The resulting mitigated peak flows at the downstream catchment extent for all design events are presented in Table 3-8 below.

Table 3-6 Peak Discharge at Outlet (RP5)

ARI (year)	Peak Flow (m^3/s)		Difference (m^3/s)
	Pre-developed (E03)	Mitigated Post-developed (M18)	
100	27.07	24.13	-2.94
50	24.01	21.83	-2.18
20	20.59	18.89	-1.70
10	17.72	16.26	-1.46
5	15.78	14.40	-1.38
2	12.68	11.84	-0.85

The above results demonstrate peak flood flow reductions occurring downstream of the site as a result of the proposed mitigated development. Table 3-9 below shows the time taken for the detention basin to drain. The times shown are adopted from the peak storm duration for each ARI.

It is noted that in some scenarios some over attenuation of flows is reported. The above design is preliminary and may be subject to change and thus some conservatism into the required storage is proposed to ensure adequate footprint is provided. During detailed design of the site some variation to the overall size of the basin may occur, however the intent of the basin is to be maintained. Any redesign will necessitate reanalysis of the system to ensure that the peak flow rates discharging from the site are equal to or less than the pre development condition.

Table 3-7 Time Taken for Detention Basin to Drain

ARI (year)	2	5	10	20	50	100
Time (hrs)	4.5	5	5.5	6	6	6.5

4 Stormwater Quality Assessment

Development of the site may have the potential to adversely impact the downstream environment due to increased turbidity, pollutant loads and / or release of contaminants during construction and operation.

These potential water quality impacts can be adequately managed with effective implementation of the measures outlined in the following section to meet specific Water Quality Objectives (WQOs). In the absence of local guidelines, WQOs have adopted from Queensland *Department of State Development, Infrastructure and Planning 'State Planning Policy'* (April 2016).

4.1 Construction Phase

During the construction phase, the potential exists for increases in the amount of pollutants, particularly sediment, exported from the site. During this period, a suitable Erosion and Sediment Control (ESC) plan will be required as part of the construction phase Environmental Management Plan (EMP). This ESC plan will limit construction phase water quality impacts to a minimum, if it is developed and operated in accordance to current best practice guidelines.

4.2 Operational Phase

4.2.1 Water Quality Objectives

Water quality objectives exist for Darwin Harbour (*Water Quality Objectives for the Darwin Harbour Region*, *Department of Natural Resources, Environment, The Arts and Sport*, 2010). These objectives are concentration based outcomes. In some cases, the algorithms used in the current industry standard water quality modelling package (MUSIC) make it impossible to comply with concentration-based water quality objectives regardless of the type or size of device installed.

In order to enable the development of a suitable treatment train, pollution reduction targets adopted from QLD guidelines detailed in *Department of State Development, Infrastructure and Planning 'State Planning Policy'* (April 2016) have been utilised. These targets provide a method of quantifying reductions within a computer model. The intent of this analysis is to develop a system which is likely to result in sufficient pollutant reductions to conform with the WQO's set out for the Darwin Harbour Region. Water quality monitoring, proposed for the site post development will confirm or highlight the treatment systems effectiveness.

Therefore, to be consistent with current best practice with respect to water quality, load based water quality objectives were adopted for the consideration of water quality issues. The following water quality objectives were adopted:

- an 80 % reduction in Suspended Solids;
- a 60 % reduction in Total Phosphorus;
- a 45 % reduction in Total Nitrogen; and,
- a 90 % reduction in gross pollutants.

4.2.2 Proposed Treatment Train

The treatment measures proposed for the development include Ecosol 'Net Guards' (or similar), and bioretention basins. The preliminary locations for the proposed treatment measures are shown in Figure 5.

The opportunity to develop small scale water sensitive urban design (WSUD) system has this stage not been considered. This document aims to provide suitable bioretention areas to treat the runoff from the site. It is acknowledged that treatment close to the source of runoff is desirable as this more closely mimics the surface/groundwater interaction of the pre development catchment. With the rainforest area downstream of the development it will be necessary to ensure that whatever system is employed ensures adequate flow (both via surface and groundwater) is directed to the area to maintain ecosystem health.

During the detailed design phase of the project if opportunities to utilise small scale bio retention systems (such as tree pits and raingardens) exist they will be considered. It is noted that not all WSUD measures will be suitable for the Darwin Harbour region due to the variable climate experienced. Review of previously

successful implementation of WSUD within the Darwin Harbour region will guide the final bioretention basin design approach.

To minimise the size of the bioretention areas, it is proposed to incorporate pre-treatment devices such as Ecosol 'Net Guards' (or similar). The recommended pollutant removal efficiencies have been provided by the manufacturer and listed below:

> Total Suspended Solids (TSS) – 40% removal;
> Total Nitrogen (TN) – 30% removal;
> Total Phosphorus (TP) – 35% removal; and
> Gross Pollutants (GP) – 93% removal.

The preliminary details of the bioretention basins are detailed in Table 4-1 below.

Table 4-1 Bioretention Details

Parameter	Bio-Basin F	Bio-Basin G	Bio-Basin H	Bio-Basin I
Extended Detention Depth (m)	0.3	0.3	0.3	0.3
Surface Area (m^2)	750	1050	600	600
Filter Media Surface Area (m^2)	750	1050	600	600
Saturated Hydraulic Conductivity (mm/hr)	200	200	200	200
Filter Depth (m)	0.6	0.6	0.6	0.6
TN Content (mg/kg)	400	400	400	400
Orthophosphate Content (mg/kg)	30	30	30	30

The limiting pollutant to achieve the required WQOs is TSS, with the use of proprietary pre-treatment devices such as Ecosol's Net Guard product, the overall size of the bio-retention basins could be reduced.

Based on discussions with City of Darwin it was highlighted that the Net Guard product was a preferred solution. As the system, once installed will be serviced and maintained by City of Darwin their preferred product has been recommended.

It is noted that the use of rainwater tanks for re-use of rainwater could also potentially reduce the pollutant loads discharging from the site while also reducing demand on town water supply. However, imposing this requirement on potential property buyers cannot be enforced and has therefore not been included as part of the treatment train.

4.2.3 Pollutant Impact Assessment

In order to determine the effectiveness of the adopted treatment train in meeting the WQOs, a stormwater quality analysis was performed using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) Version 6.2. MUSIC model parameters have been adopted in accordance with the appropriate guidelines (DPI, 2009)

A 'split node' urban residential source has been adopted with the pollutant export parameters shown in Table 4-2 below.

Table 4-2 MUSIC Pollutant Generation Parameters

Source Node		TSS (log_{10} values)		TP (log_{10} values)		TN (log_{10} values)	
		Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Baseflow	Roof	1.10	0.17	-0.82	0.19	0.32	0.12
	Roads	1.10	0.17	-0.82	0.19	0.32	0.12
	General Urban	1.10	0.17	-0.82	0.19	0.32	0.12
Stormflow	Roof	1.55	0.39	-0.92	0.29	0.42	0.19
	Roads	2.38	0.40	-0.60	0.50	0.42	0.19
	General Urban	2.20	0.32	-0.45	0.25	0.42	0.19

The rainfall data applied to the MUSIC model was for the Darwin Airport rainfall station for the period 1987-1996. A 6 minute time step was considered for the analysis.

Catchment areas and percentage impervious values were determined from the preliminary master plan provided by Bennett & Bennett. The adopted catchment characteristics are given in Table 4-3.

Table 4-3 Catchment Areas

Catchment	Total Area (ha)	% Impervious
F	12.20	50
G	16.24	57
H	10.70	16
I	9.81	17

The results of the MUSIC modelling, shown as total annual loads, are presented in Table 4-4.

Table 4-4 Predicted Pollutant Loads

Parameter	Post-Developed Load (kg/yr)	Mitigated Load (kg/yr)	Reduction Achieved (%)	WQO (%)
TSS	83000	16100	80.6	80
TP	177	48.1	72.8	60
TN	1300	545	58	45
Gross Pollutants	9460	0	100	90

The results presented in Table 4-4 demonstrate that the proposed stormwater treatment measures for the development meet the QLD guidelines pollution reduction targets.

Water quality objectives exist for Darwin Harbour (*Water Quality Objectives for the Darwin Harbour Region*, *Department of Natural Resources, Environment, The Arts and Sport*, 2010). These objectives are concentration based outcomes. In some cases, the algorithms used in the current industry standard water quality modelling package (MUSIC) make it impossible to comply with concentration-based water quality objectives regardless of the type or size of device installed.

In order to enable the development of a suitable treatment train, pollution reduction targets adopted from QLD guidelines detailed in *Department of State Development, Infrastructure and Planning 'State Planning Policy'* (April 2016) have been utilised.

As part of the ongoing water quality monitoring proposed for the site, the effectiveness of the proposed treatment systems relative to the Darwin Harbour water quality objectives will be assessed. This assessment should be undertaken utilising the risk based approach set out within the document. If during this process the site runoff is found to be posing a high risk to the ecosystem, management intervention to mitigate this risk will be required. Intervention may consist of the addition of additional water quality treatment devices or a review of the design and effectiveness of the treatment measures present onsite.

Based on our understanding of the site, the primary ecosystem at risk is the existing rainforest area. While the downstream receiving waters are also important it is noted that discharge from the Leanver Sanderson Water Treatment Facility, combined within the tidal nature of the channel is likely to control the water quality within this channel. Ecosystem monitoring at the rainforest area is proposed, with water quality monitoring proposed at the downstream channel

The primary risk to the rainforest area is the reduction in low (base) flows from the upstream catchment. During the detailed design stage the stormwater system will be designed to ensure the existing hydrologic regime is maintained as much as feasible. If during the monitoring phase it is identified the area is suffering due to the development, re-evaluation of the water quality treatment measures upstream may be required. If it is identified the bioretention systems result in too much (or too little) base flows entering rainforest area, redesign may be required.

5 Regional Flood Assessment

Notwithstanding inundation across the site from local catchment runoff resulting in shallow sheet flow and concentrated gully flows that is not quantified in this report, other potential sources of inundation could occur due to storm tide inundation given the proximity of the site to Beagle Gulf. *High Resolution Storm Tide and Climate Change Impacts Study – 2010* (SEA, 2010) identifies the following storm tide levels for Lee Point detailed in Table 5-1.

Table 5-1 Total Storm Tide Levels (mAHD) at Lee Point

Year	Estimated Return Period of Total Storm Tide Level (year)				
	50	100	500	1,000	10,000
2010	4.5	4.7	5.2	5.4	5.8
2050	4.9	5.1	5.6	5.8	7.1
2100	5.4	5.6	6.1	6.5	7.4

The above levels for 2100 have been mapped as part of the *Northern Territory Storm Surge Mapping* (GHD, 2014) with the area containing the site extracted below in Plate 1.

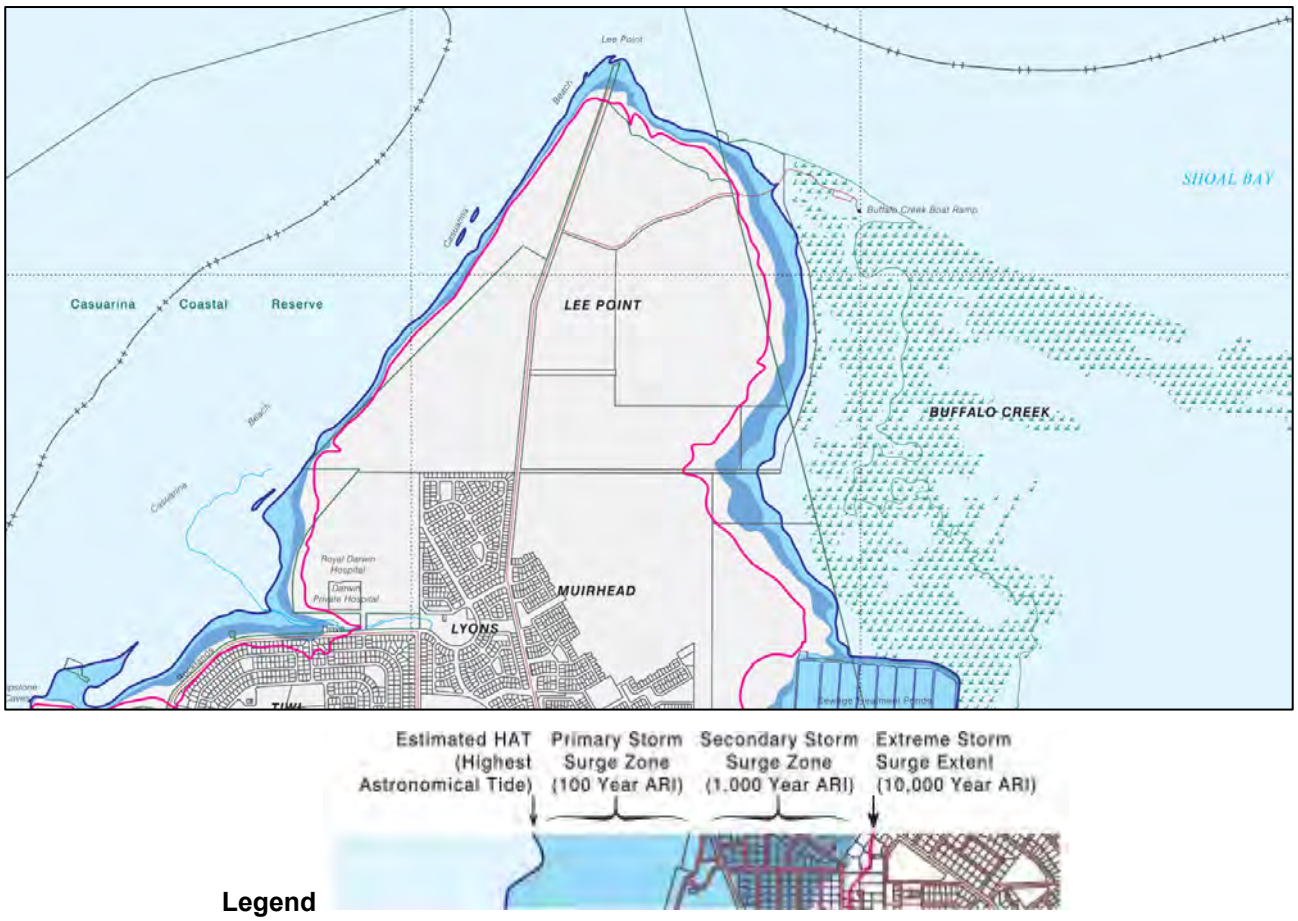

Plate 1: Darwin Area Storm Surge Inundation for 2100 Extract (GHD, 2014)

Based on the above, the majority of the site is above both the 100 year and 1,000 year ARI storm tide level for 2100.

6 Conclusions

This SMP has been prepared by Cardno to support the preliminary application for the proposed Muirhead North development. This report has investigated the water quantity and quality for the site and provides conceptual evidence the applicable development codes can be adhered to.

In preparation of this report the following assessments were completed:

> A hydrologic assessment to determine the impact on the peak flows from the site catchments, to provide details of necessary mitigation requirements to ensure no increase in peak flows discharging from the site; and

> A pollutant export assessment to determine the stormwater quality management requirements for the site to ensure discharges meet the required load based reduction targets.

Local hydrologic modelling indicates no adverse offsite discharge, achieved using detention basins and 2 year ARI diversions to attenuate post-developed discharges to that of pre-developed levels.

Water quality modelling indicates that prescribed WQOs can be achieved incorporating the proposed treatment train.

It should be noted that for the environmentally significant rainforest area, an impact assessment of the local flood conditions should be conducted to ensure no adverse impact to the vegetation health. This is outside the scope of the conceptual SMP and should be completed during the detailed design phase of the DA.

7 Qualifications

This report has been prepared by Cardno for Defence Housing Australia (DHA) and specifically to provide stormwater management advice for the Muirhead North development. Our analysis and overall approach has been catered to the specific requirements of DHA, and may not be applicable beyond this scope. For this reason any other third parties other than Council are not authorised to utilise this report without further input and advice.

Cardno has relied on the following information provided by others:

> Site survey undertaken by Bennett & Bennett;

> ALS data of the site and immediate surrounding catchment was sourced from the Department of Lands, Planning and the Environment (DLPE) to derive contours; and

> Aerial imagery, sourced from Nearmap and Google Earth; and

> Rainfall data supplied by the Bureau of Meteorology.

The accuracy of the report is dependent upon the accuracy of this information.

While Cardno's report accurately assesses peak flows from design storms, it is an ungauged catchment and consequently future observed flows may vary from that predicted.

8 References

> City of Darwin (Council) - Subdivision and Development Guidelines, [COD, 2005];

> Queensland Urban Drainage Manual (QUDM) [DEWS, 2013];

> Australian Rainfall and Runoff (ARR) [IEAust, 1987];

> Water Sensitive Urban Design (WSUD) [DPI, 2009]; and

> Cardno report 2CRU – Lee Point Road, Lee Point – Stormwater Management Plan' dated 25 May 2017 (ref: DC1603/R1/V2).

FIGURES

Figure 1 Site Location

Figure 2 Catchment Characteristics

Figure 3 XPRAFTS Pre-Development Model Layout

Figure 4 XPRAFTS Post-Developed Model Layout

Figure 5 MUSIC Model Layout

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NORTH

Legend

Site Boundary

CAD FILE: O:\DC1603_2CRU\RAFTS\Figures\Figures_R3V1.dwg
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FK

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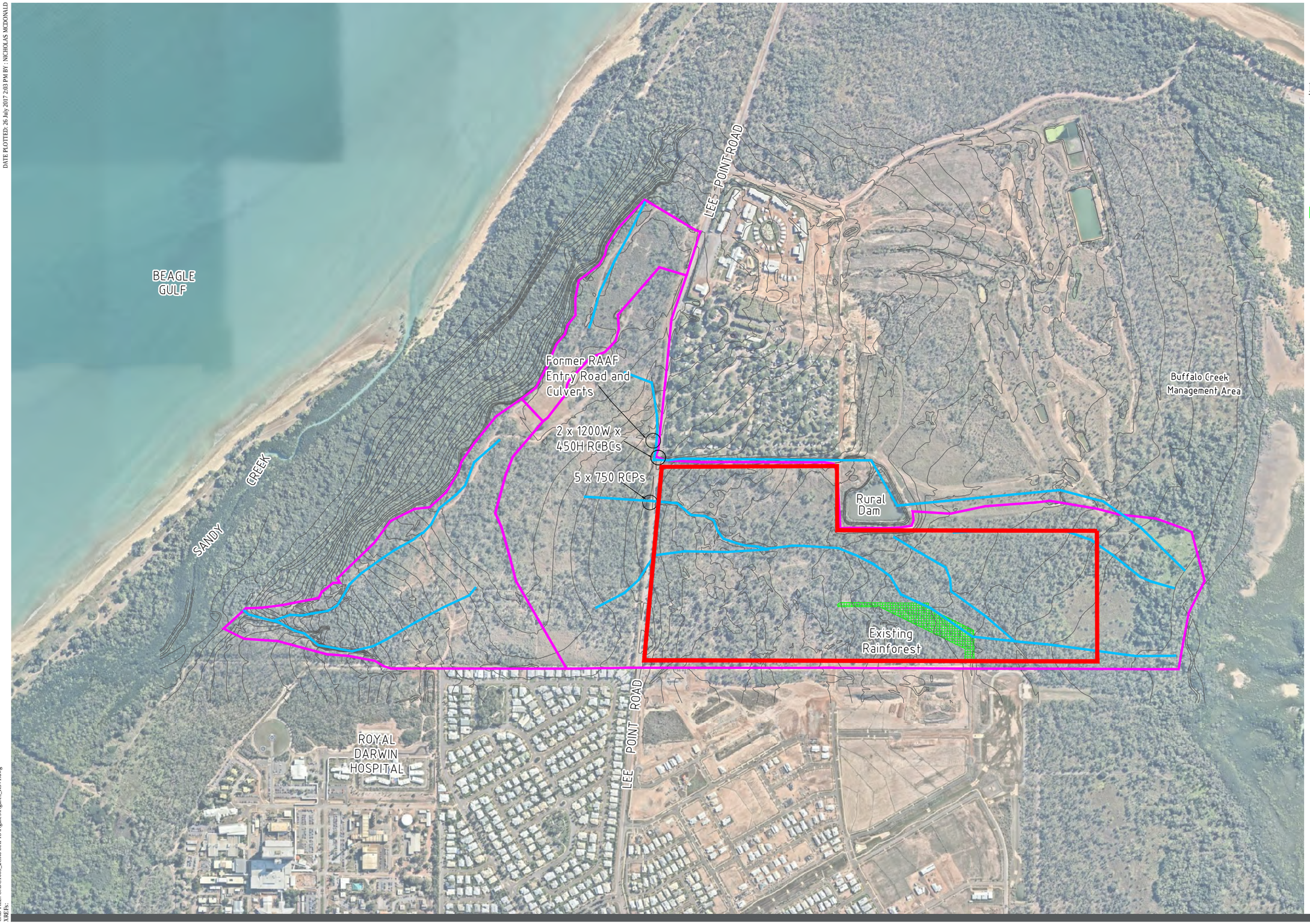
Date	Scale	Size
2017	1:20,000	A3
DC1603 Project Reference	0 200 400 600 800m	1 Revision

FIGURE 1

Site Location

Muirhead North - Lee Point Road, Lee Point
Stormwater Management Strategy
Defence Housing Australia

DATE PLOTTED: 26 July 2017 2:03 PM BY : NICHOLAS MCDONALD



Legend

- Catchment Extents
- Flow Path
- Culvert Location
- Rainforest Patch

CAD FILE: O:\DC1603_2CRU\RAFTS\Figures\Figures_R3V1.dwg
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Date	Scale	Size
2017	1:10,000	A3
DC1603	0 100 200 300 400m	1
Project Reference		Revision

FIGURE 2

Catchment Characteristics

Muirhead North - Lee Point Road, Lee Point
Stormwater Management Strategy
Defence Housing Australia

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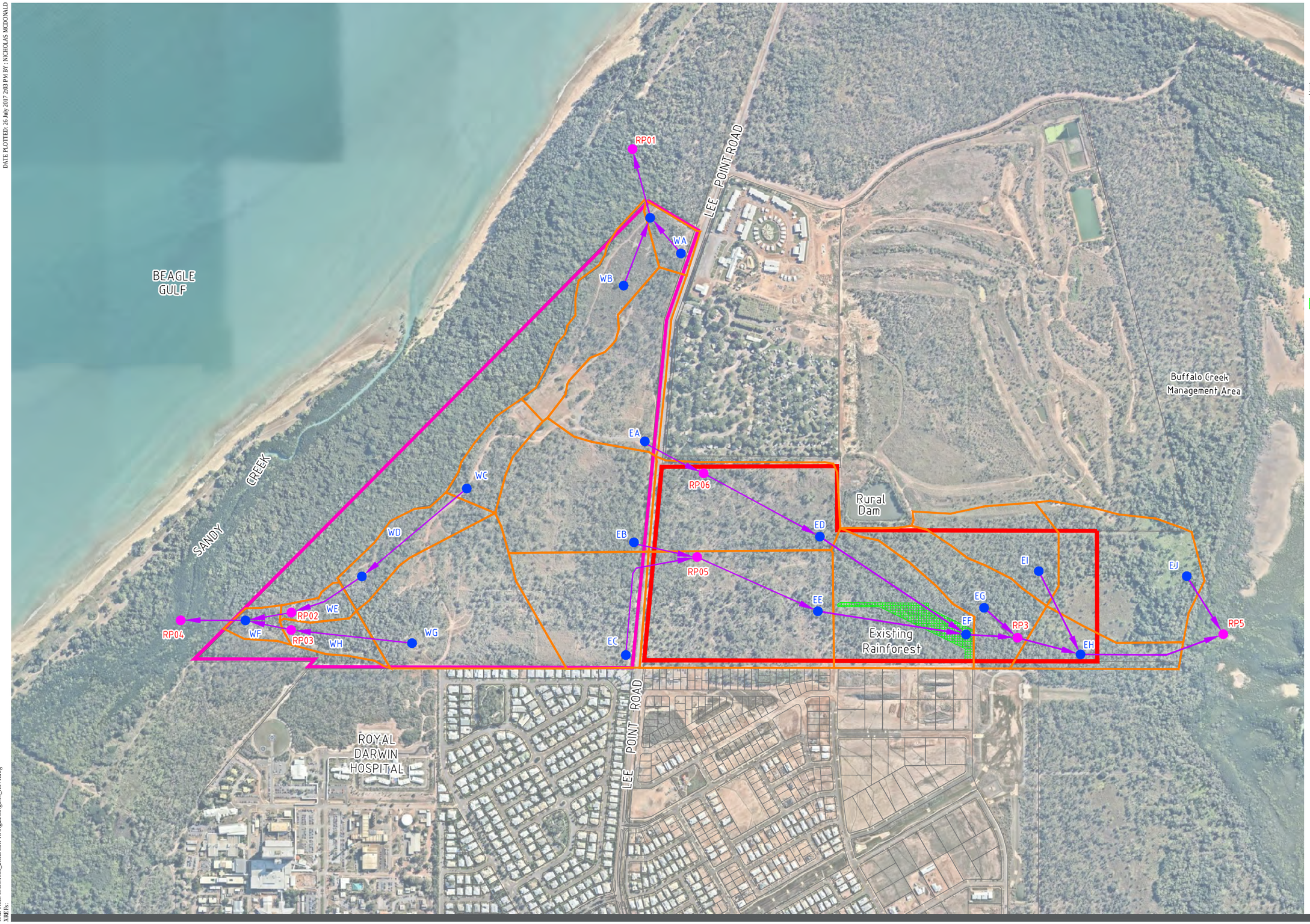

Legend

- Site Boundary
- "2CRU" Site Boundary
- XPRAFTS Catchment
- XPRAFTS Catchment Link
- XPRAFTS Catchment Node (EE)
- Reporting Point (RP1)
- Rainforest Patch

NORTH

CAD FILE: O:\DC1603_2CRU\RAFTS\Figures\Figures_R3V1.dwg
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0 100 200 300 400m

Size: A3

DC1603
Project Reference

1
Revision

FIGURE 3

XP-RAFTS Pre-Developed Model Layout (EX03)

Muirhead North - Lee Point Road, Lee Point
Stormwater Management Strategy
Defence Housing Australia

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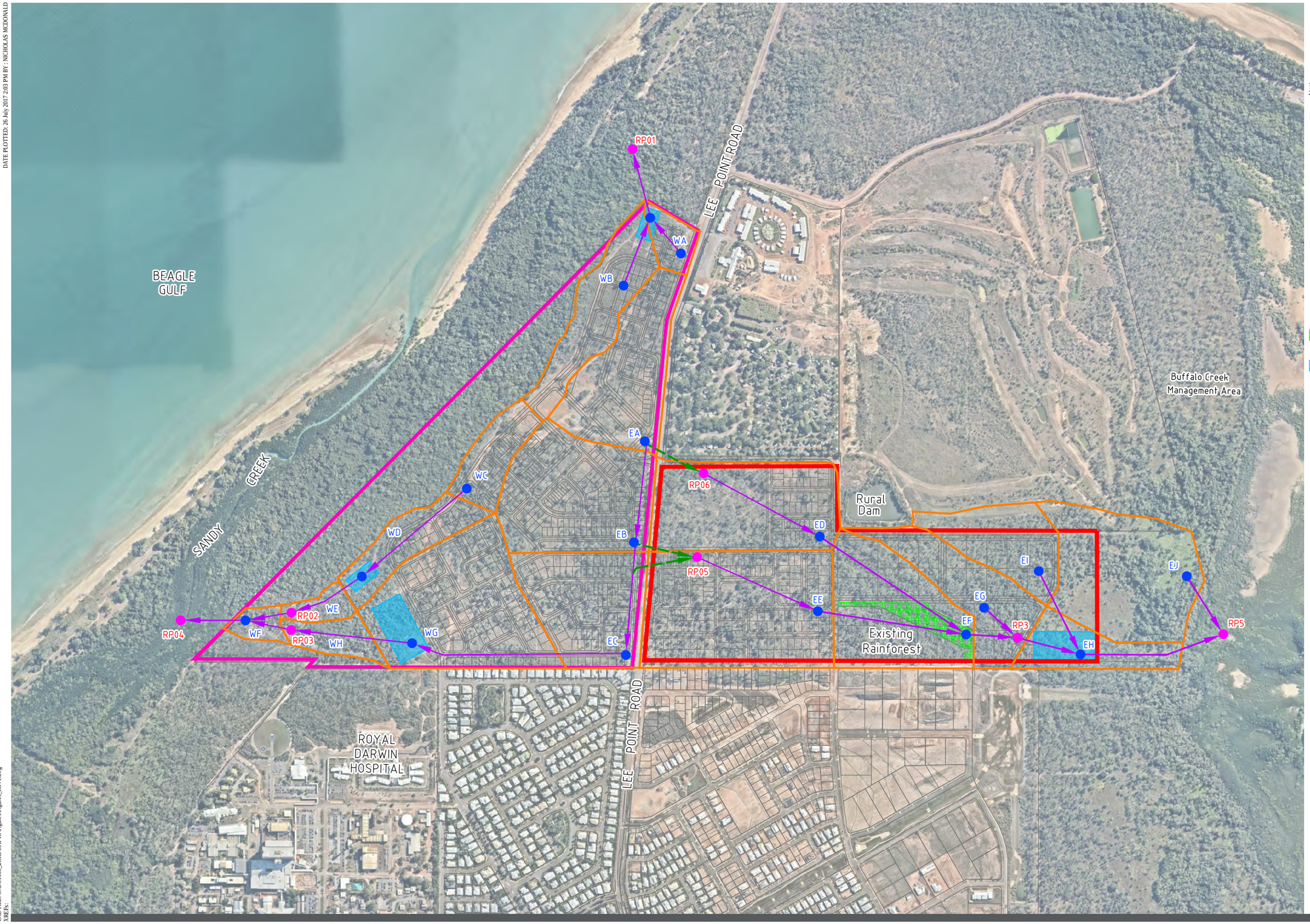

NORTH

Legend

- Site Boundary
- "2CRU" Site Boundary
- XPRAFTS Catchment
- XPRAFTS Catchment Link
- Q2 Diversion
- EF — XPRAFTS Catchment Node
- RP1 — Reporting Point
- Rainforest Patch
- Detention Basin

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Size: A3

DC1603
Project Reference

1
Revision

FIGURE 4
XP-RAFTS Post-Developed Model Layout (M18)
Muirhead North - Lee Point Road, Lee Point
Stormwater Management Strategy
Defence Housing Australia

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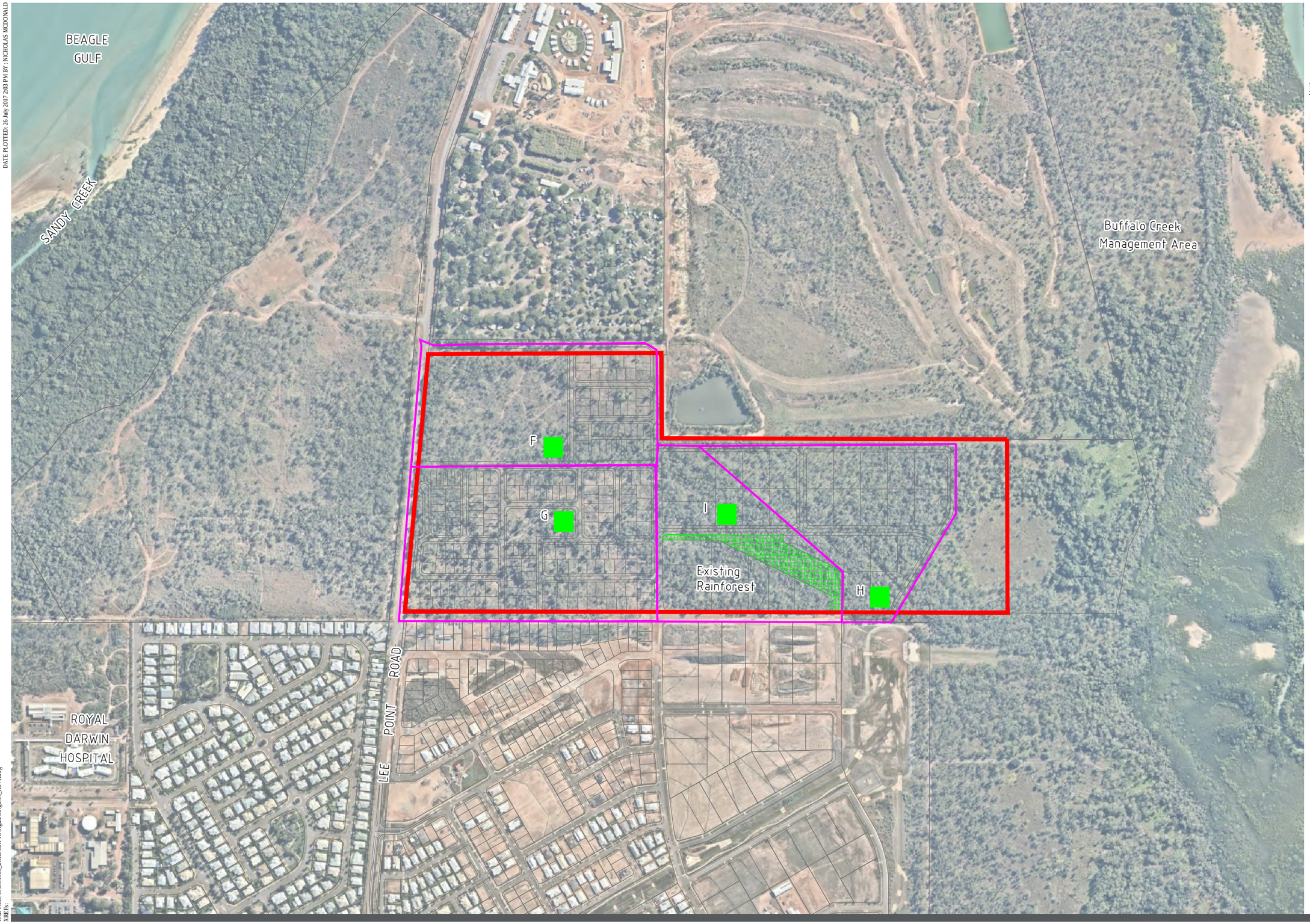

NORTH

Legend

- Site Boundary
- MUSIC Catchment
- A — Bio-retention Basin

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DC1603	0 75 150 225 300m	1
Project Reference		Revision

FIGURE 5

MUSIC Model Layout (M09)

Muirhead North - Lee Point Road, Lee Point
Stormwater Management Strategy
Defence Housing Australia

Stormwater Management Plan

REFERENCE DRAWINGS

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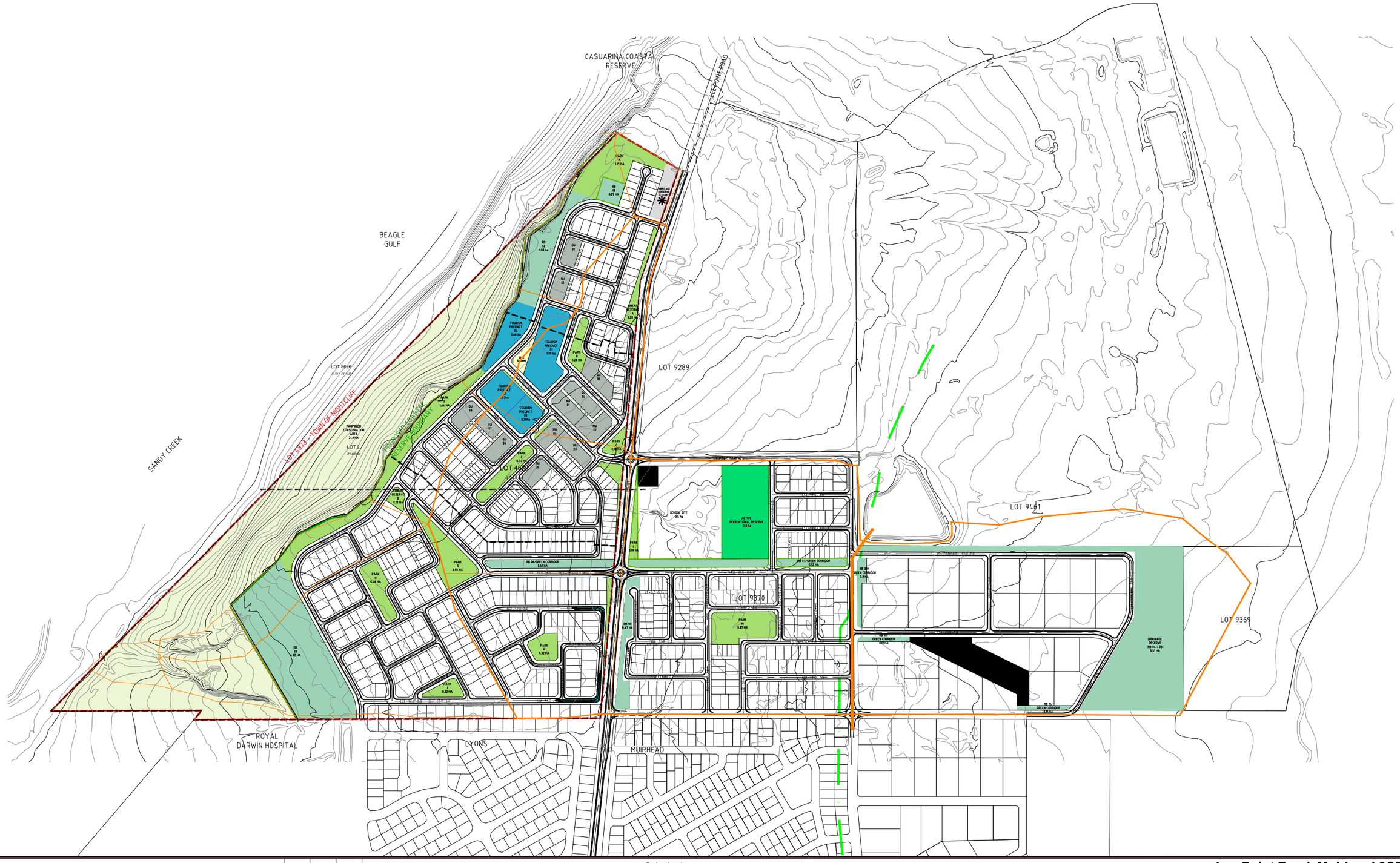

REVISION	DATE	DES/DFT	APP'D
- -	-	-	-

Principal
Defence Housing Authority

Project Leader
TFR
Designed
CH
Drawn
CH
Checked
DB
Authorised
TFR
Date
April 2016

NORTH

Scale @ A1
1:1000

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Lee Point Road, Muirhead 2CRU

Master Planning - Stages
City of Darwin
Roadworks Layout Plan

Sheet 1 of 2
Drawing No. -
Rev -
Dev. App. No. -
Sheet No. - of -

Issued For Review

CASUARINA COASTAL RESERVE

LEE POINT ROAD

BEAGLE GULF

LOT 8626
S 75/14 A.O.

LOT 9289

LOT 9461

LOT 9370

LOT 9369

LOT 4873
67.33 ha
S 2019/107

LOT 2
21.80 ha

LOT 6574 - TOWN OF NIGHTCLIFF

PROPOSED CONSERVATION AREA / 21.8 HA

PRESERVE BOUNDARY

SANDY CREEK

ROYAL DARWIN HOSPITAL

LYONS

MUIRHEAD

PARK A 1.19 HA

RB 03 0.25 HA

HERITAGE RESERVE A

RB 02 1.08 ha

GU 01

GU 02

LINEAR RESERVE A 0.39 ha

TOURISM PRECINCT 04 0.66 ha

TOURISM PRECINCT 01 1.08 ha

CIVIC SQUARE

PARK F 0.28 HA

GU 03

GU 04

MU 01

MU 02

TOURISM PRECINCT 02 0.52ha

TOURISM PRECINCT 03 0.38ha

PARK J 1.44 HA

GU 06

GU 07

GU 05

MU 04

MU 03

PARK C 0.58 HA

PARK G 0.48 HA

LINEAR RESERVE B 0.12 HA

PARK G 0.85 HA

PARK H 1.34 HA

RB 01 1.52 HA

PARK K 0.32 HA

PARK D 0.22 HA

RB 06/GREEN CORRIDOR 0.51 HA

EXISTING ROAD RESERVE

COMMUNITY CENTRE 0.2 ha

SCHOOL SITE 3.5 ha

ACTIVE RECREATIONAL RESERVE 2.0 ha

PARK L 1.19 HA

RB 07/GREEN CORRIDOR 0.32 HA

RB 08 0.47 HA

PARK M 0.87 HA

RB 09/ GREEN CORRIDOR 0.2 HA

RB 07/ GREEN CORRIDOR 0.11 HA

RB 11/ GREEN CORRIDOR 0.11 HA

DRAINAGE RESERVE (RB 04 + DS) 5.51 HA

LS1 – 15.0-6.0

LS2 – 17.0 – 7.2

LS3 – 17.0 – 8.0

LS4 (PARKSIDE) – 17.0 -7.0

LS4 – 20.0-7.0

NC1 – 18.5 – 8.0 LP

NC2 – 19.5 – 8.0 LP

LS2 – 17.5 – 6.0 LP

LS2 – 17.5 – 6.0 LP

LS1 – 6.5 - 5.5

LS2 – 17.0 – 6.0

LS3 – 17.0 – 8.0

LS4 (PARKSIDE) – 17.0 -7.0

LS4 – 20.0-7.0

LS5 – 20.0-7.0

LS4 (PARKSIDE) – 17.0 -7.0

DEPENDANCE – 17.0 -7.0

EXISTING ROAD RESERVE

LEE POINT ROAD

LOT 9289

LOT 9461

LOT 9370

LOT 9369

DRAINAGE RESERVE (RB 04 + DS) 5.51 HA

APPENDIX G

Biting Insect report

NORTHERN TERRITORY GOVERNMENT

DEPARTMENT OF HEALTH

Muirhead North and 2CRU Biting Insect Report

Final report September 2016.
Report written and prepared for Defence Housing Australia

Medical Entomology
Centre for Disease Control
NT Department of Health
September 2016

Muirhead North and 2CRU Biting Insect Report

Final report September 2016.
Report written and prepared for Defence Housing Australia

Allan Warchot
Medical Entomology
Centre for Disease Control
NT Department of Health
September 2016

Contents

CONTENTS **3**

LIST OF FIGURES **5**

LIST OF TABLES **5**

LIST OF APPENDICES **5**

1. INTRODUCTION **7**

2. METHODS **7**

3. RESULTS **7**

3.1 MUIRHEAD BITING MIDGE TRAPPING 2006-07 7
3.1.1 Species present *7*
3.1.2 Seasonal abundance *8*
3.1.3 Spatial abundance and dispersal *8*
3.1.4 Potential breeding sites *9*
3.2 MUIRHEAD MOSQUITO TRAPPING 2006-07 10
3.2.1 Species present *10*
3.2.2 Seasonal abundance *10*
3.2.3 Spatial abundance and dispersal *10*
3.2.4 Potential breeding sites *11*
3.3 FURTHER INFORMATION SINCE THE MUIRHEAD BASELINE INVESTIGATION 12
3.4 DARWIN ADULT MOSQUITO MONITORING RESULTS 2015-16 13

4. DISCUSSION **14**

4.1 MOSQUITOES 14
4.1.1 Species present *14*
4.1.2 Spatial abundance *14*
4.1.3 Seasonal abundance *14*
4.1.4 Mosquito breeding sites *15*
4.1.5 Mosquito pest problems *16*
4.1.6 Mosquito borne disease *17*
4.2 MOSQUITO BREEDING AND DEVELOPMENT ASPECTS 17
4.2.1 Stormwater drainage *17*
4.2.2 Stormwater treatment systems *18*
4.2.3 Biting Insect buffers *18*
4.2.4 Building design *19*
4.2.5 Construction phase *20*
4.3 MOSQUITO BREEDING SITE RECTIFICATION 20
4.4 INSECTICIDE MOSQUITO CONTROL 20
4.5 PERSONAL PROTECTION 21
4.6 BITING MIDGES 21
4.6.1 Species present *21*
4.6.2 Spatial abundance and dispersal *21*

4.6.3 Seasonal abundance *22*
4.6.4 Pest problems *22*
4.6.5 Biting midges and development aspects *23*
4.6.6 Personal protection *23*
4.6.7 Biting midge control *23*

5. CONCLUSIONS **24**

5.1 MOSQUITOES 24
5.2 BITING MIDGES 26

6. RECOMMENDATIONS **27**

6.1 MOSQUITOES 27
6.2 BITING MIDGES 28

8. BIBLIOGRAPHY **29**

FIGURES **34**

TABLES **35**

APPENDIX 1 – GUIDELINES FOR PREVENTING BITING INSECT PROBLEMS FOR NEW URBAN RESIDENTIAL DEVELOPMENTS OR SUBDIVISIONS IN THE TOP END OF THE NT. **36**

APPENDIX 2 – LEE POINT AREA PLANS 1 AND 2 (FROM PA2014/0992) **37**

APPENDIX 3 – PERSONAL PROTECTION FROM MOSQUITOES AND BITING MIDGES IN THE NT **38**

APPENDIX 4 – FIELD EVALUATION OF BISTAR 80SC AS AN EFFECTIVE INSECTICIDE HARBOURAGE TREATMENT FOR BITING MIDGES (CULICOIDES) AND MOSQUITOES INFESTING PERIDOMESTIC SITUATIONS IN AN URBAN ENVIRONMENT. **39**

APPENDIX 5 – SALT MARSH MOSQUITO *(AEDES VIGILAX)* PEST CALENDAR 2016. ..... **40**

APPENDIX 6 – BITING MIDGE (*CULICOIDES ORNATUS*) PEST CALENDAR 2016. ..... **41**

List of Figures

Figure 1 – General Location of Muirhead North and 2CRU and relevant adult biting insect trap sites.

Figure 2 – Muirhead biting insect assessment. Potential *Culicoides ornatus* breeding sites and full moon results.

Figure 3 – Muirhead biting insect assessment. Full moon *Culicoides species near subimmaculatus* results.

Figure 4 - Casuarina Coastal Reserve, Buffalo Creek Management area and western margin of Buffalo Creek mosquito breeding sites.

Figure 5 – Tidal swamps in the Darwin Northern Suburbs, and peak season *Aedes vigilax* trapping November 2006.

Figure 6 – Peak season *Aedes vigilax* trapping Darwin Northern Suburbs 29th-30th October 2012.

Figure 7 – Total numbers of adult *Aedes vigilax* and *Culex annulirostris* collected at the Leanyer Gate, Casuarina and Buffalo Creek road weekly CO2 baited trap sites July 2015 to June 2016.

List of Tables

Table 1 – Muirhead biting insect assessment. Total number of adult female biting midges collected during trapping in November and December 2007, and April, May, August and September 2007 at all 14 sites.

Table 2 - Muirhead biting insect assessment. Total number of female biting midges collected at all 14 trap sites during trapping in November and December 2007, and April, May, August and September 2007.

Table 3 - Muirhead biting insect assessment. Total number of female *Culicoides ornatus* collected during trapping at all sites on all dates.

Table 4 - Muirhead biting insect assessment. Total number of adult female mosquitoes collected at all 14 trap sites during trapping in November and December 2007, and April, May, August and September 2007.

Table 5 - Muirhead biting insect assessment. Total number of adult female mosquitoes collected during trapping in November and December 2007, and April, May, August and September 2007 at all 14 sites.

Table 6 - Muirhead biting insect assessment. Total number of female *Aedes vigilax* collected during trapping at all sites on all dates.

List of Appendices

Appendix 1 – Guidelines for preventing biting insect problems for new urban residential developments or subdivisions in the Top End of the NT.

Appendix 2 – Lee Point Area Plans 1 and 2 (from PA2014/0992).

Appendix 3 – Personal protection from mosquitoes and biting midges in the NT.

Appendix 4 - Field evaluation of Bistar 80SC as an effective insecticide harbourage treatment for biting midges (Culicoides) and mosquitoes infesting peridomestic situations in an urban environment.

Appendix 5 - Salt marsh mosquito *(Aedes vigilax*) pest calendar 2016.

Appendix 6 - Biting midge (*Culicoides ornatus*) pest calendar 2016.

1. Introduction

Muirhead North and 2CRU is intended to be a master planned urban residential subdivision, and is located on Lots 04873 & 09370 Town of Nightcliff, Lee Point (Proposal to Amend NT Planning Scheme PA2014/0922). The master planned subdivision was assessed as requiring an Environmental Impact Statement, which included the requirement for the proponent to assess the actual and potential biting insect problems at the development site, to determine the potential for workers and future residents to be affected by pest and potential mosquito borne disease problems, and pest biting midges.

Mosquitoes are usually the most common and widespread biting insect in the NT, and some species are also capable of transmitting mosquito borne diseases. Biting midges can cause significant pest problems in areas nearby to tidal mangrove creeks, with the bites capable of causing intense itching and potential secondary infection resulting from scratching. Development can also inadvertently create new mosquito breeding sites, particularly with regards to the discharge of stormwater into downstream areas, and the creation of water holding structures to treat/retain stormwater.

The Lee Point area is known to experience seasonal biting insect problems, with baseline trapping carried out in 2006-2007 for the Muirhead Subdivision revealing seasonally high to very high mosquito and biting midge abundance. Further ad-hoc trapping in the Lee Point area since the Muirhead baseline trapping has confirmed the presence of seasonally very high mosquito numbers. Therefore, the aims of this report are to provide a background as to what biting insect problems are expected to affect Muirhead North and 2CRU, provide mitigation measure to reduce the impact of biting insects on future residents, and provide advice on stormwater drainage to ensure that development does not create new mosquito breeding sites.

2. Methods

Information from the Muirhead Biting Insect Assessment 2008 report (Warchot & Whelan 2008) was used to form the basis of much of this report, as most of the trap sites used during this study were relevant to the Muirhead North and 2CRU areas, with some traps either inside or directly adjacent to the proposed subdivision. The 2008 investigation was carried out for GHD Pty Ltd on behalf of Defence Housing Australia for the Muirhead development. The adult biting insect traps used for this study were CO2 baited EVS traps, the same as those used for weekly adult biting insect trapping around Darwin since the early 1980's.

In addition, information from routine mosquito surveillance carried out by Medical Entomology in Casuarina Coastal Reserve and the Buffalo Creek area was included for analysis and discussion. This included both EVS trap results, as well as information regarding the location of mosquito breeding sites.

3. Results

3.1 Muirhead biting midge trapping 2006-07

The biting midge results from the Muirhead baseline biting insect trapping in 2006-07 are discussed below, with the results shown in Tables 1 to 3. The trap sites are shown in Figure 1.

3.1.1 Species present

The mangrove biting midge *Culicoides ornatus* was the most abundant biting midge species collected during baseline trapping, accounting for 49.41% of all biting midges collected at Muirhead at an average of 392.34 adult females per trap per trap night (Table 1). The next most abundant biting midge species was *Culicoides species near subimmaculatus (northern form)*, accounting for 47.11% of all biting midges trapped with an average of 374.09 per trap per trap night (Table 1). All other biting midge species were collected in very low numbers. In total there were 16 biting midge species collected during the Muirhead biting insect trapping program (Tables 1 & 2).

3.1.2 Seasonal abundance

Trapping was conducted for biting midges in November and December 2006, and in April, May, August and September 2007. For the months of December 2006 and August 2007, traps were set over two consecutive nights around the full moon. The most productive trap night for biting midges was the 29th of August, when 47.10% of total biting midges were collected, accounting for a total of 43,384 adult females and an average per trap of 3,337.23 (Table 1). Traps were set on the night of the full moon and collected the morning after the full moon. This was also the night of highest abundance for *C. ornatus* and *C. sp nr subimmaculatus (northern form)*, with a total of 23,965 adult female *C. ornatus* and 17,788 adult female *C.* sp *nr subimmaculatus (northern form)* collected (Table 1).

The second highest biting midge numbers were collected on the 28th of August (set one night before the full moon), with 22.74% of total biting midges collected for a total of 20,942 adult females with an average per trap of 1,745.17 (Table 1). This night collected the second highest numbers of *C. ornatus* and *C. sp nr subimmaculatus (northern form)*.

The trap results from the 5th of December and 6th of December were similar, with 5.93% and 5.12% of total biting midges collected respectively, accounting for a total of 5,462 adult females at an average per trap of 455.17 on the 5th of December, and 4,716 adult females at an average per trap of 362.77 on the 6th of December (Table 1). The 19th of December recorded 5.87% of total biting midges, accounting for a total of 5,405 adult females at an average per trap of 450.42 (Table 1). The 4th of April recorded 5.3% of total biting midges, accounting for a total of 4,887 adult females and an average per trap of 349.07 (Table 1). September recorded relatively low numbers of biting midges, with only 3.13% of all biting midges collected, accounting for a total of 2,886 adult females at an average per trap of 206.14 (Table 1).

When comparing the seasonal abundance of *C. ornatus* during full moon trapping, as discussed above, August was the month of highest abundance, with 52.66% of all *C. ornatus* collected on the 29th of August (full moon), accounting for a total of 23,965 adult females and average per trap of 1,843.46 (Table 3). A total of 16.27% of *C. ornatus* was collected on the 28th of August (1 night before full moon), accounting for a total of 7,404 adult females and average per trap of 617 (Table 3). April was the next most abundant month, with 9.55% (total of 4,347 adult females, average per trap of 310.5) collected on the 4th of April (Table 3). This was followed by December, with 6.03% of *C. ornatus* collected on the 6th December, for total of 2,746 adult females with an average per trap of 211.23, and 4.43% collected on the 5th of December, for total of 2,017 adult females with an average per trap of 168.08 (Table 3). The 28th of September recorded 4.31% of *C. ornatus* for a total of 1,961 adult females and an average per trap of 140.07, while the 3rd of May recorded 1.99% of *C. ornatus* for a total of 907 adult females and an average per trap of 82.45 (Table 3). Full moon *C. ornatus* trap results are also displayed in Figure 2.

Culicoides sp. nr subimmaculatus (northern form) was most abundant during the late dry season and early wet season months. Highest numbers were collected during the August 2007 trapping, followed by late December, early December and November (Table 1). The 29th of August (full moon) recorded a total of 17,778 adult females from 13 traps, while the 28th of August recorded a total of 12,762 adult females from 12 traps. The 19th of December recorded a total of 3,833 adult females from 12 traps, and the 5th of December recorded a total of 3,390 adult females from 12 traps, while the 18th of November recorded a total of 2,527 adult females from 13 traps (Table 1).

3.1.3 Spatial abundance and dispersal

Trap Site 6 was the most productive trap site for biting midges, with 26.82% of all biting midges collected at this site with an average per trap night of 3,529.19 (Table 2). This was followed by Trap site 3 (16.67% and average per trap night of 1,706.33), Trap Site 4 (10.67% and average per trap night of 1,228.38), Trap Site 11 (10.28% and average per trap night of 1,183) and Trap Site 12 (9.19% and average per trap night of 1,057.63) (Table 2). Other trap sites recorded between 0.99% - 6.4% of total numbers (Table 2).

Culicoides ornatus was most abundant at Trap Site 6, with a total of 10,618 adult females collected at an average of 1,516.86 per trap, accounting for 23.33% of all *C. ornatus* (Table 3). Other trap sites of high *C. ornatus* abundance were Trap Site 3 (7,540 at an average of 837.78 per trap and 16.57% of total), Trap Site 12 (5,461 at an average of 682.63 per trap & 12% of total), Trap Site 4 (5,123 at an average of 640.38 per trap & 11.26% of total) and Trap Site 11 (4,233 at an average 529.13 per trap & 9.3% of total) (Table 3). The spatial abundance of *C. ornatus* from full moon trapping at Muirhead is displayed in Figure 2.

For the 29th of August, when *C. ornatus* numbers were at their peak, the highest numbers were collected at Trap Site 6 (6,400 adult females), followed by Trap Site 3 (4,400), Trap Site 8 (2,980), Trap Site 12 (2,880) and Trap Site 11 (2,016) (Table 3, Figure 2).

Culicoides sp. nr subimmaculatus (northern form) was most abundant at Trap Site 6 (13,371 adult females), followed by Trap Site 3 (7,763), Trap Site 4 (4,619), Trap Site 11 (4,499) and Trap Site 13 (3,832) (Table 2). For the 29th of August (full moon), when *C. sp. nr subimmaculatus (northern form)* numbers were at their peak, by far the highest numbers were recorded at Trap Site 6, with elevated abundance at Trap Sites 11, 4, 3, 12 & 8 (see Figure 3 for the spatial abundance of this biting midge).

3.1.4 Potential breeding sites

Confirmed breeding sites for *Culicoides ornatus* near Muirhead were not determined during baseline biting insect investigations, or during any future biting insect surveys in the Lee Point area. Confirming mangrove biting midge breeding sites is arduous, and not warranted due to no method of larval control aside from modifying their tidal breeding sites. However, actual breeding sites and their characteristics have been located during extensive surveying of tidal mangrove areas in other areas of Darwin (Shivas 1999). Three distinct breeding sites for *C. ornatus* were discovered by Shivas (1999); two were associated with the upper reaches of small mangrove tidal tributaries, while the third larval habitat was at the seaward mangrove foreshore (*Sonneratia* zone) (Shivas 1999). These breeding site characteristics are applicable to other tidal mangrove areas in the Northern Territory, and other similar tidal mangrove areas in other parts of the Northern Australia.

The Muirhead baseline biting midge trap results indicated Buffalo Creek contains significant *C. ornatus* breeding habitat. The highest numbers of *C. ornatus* were collected in the trap sites near the edge of Muirhead North, with high numbers also collected in the traps towards the mouth of Buffalo Creek (Tables 2 & 3, Figure 2). The trap results, together with an examination of aerial photography indicates the major *C. ornatus* breeding sites are located around the middle reaches of Buffalo Creek, where there are numerous upper tidal tributaries (Figure 2). The tidal tributaries of Buffalo Creek near the Leanyer sewage ponds do not appear to be significant potential *C. ornatus* breeding sites. There also does not appear to be any significant *Sonneratia* foreshore mangrove areas associated with Buffalo Creek, because of the open and dynamic nature of the foreshore mangrove margin in this area.

Culicoides sp. nr. subimmaculatus is a new pest biting midge affecting urban areas in the Darwin Region, due to urban encroachment on its breeding areas. Whilst the preferred breeding sites in the Darwin area is not known, this midge is known to breed in sandy tidal estuarine areas (Whelan 2004, Bishop & Dyce 1988), with trap catches from the baseline trapping suggesting the sandy Buffalo Creek system is the main breeding site for this midge in the Lee Point area, with Sandy Creek a probable moderately productive breeding site.

The baseline trapping suggested that Muirhead North would generally be much more affected by pest biting midges than 2CRU.

3.2 Muirhead mosquito trapping 2006-07

The mosquito results from the Muirhead baseline biting insect trapping in 2006-07 are discussed below, with the results shown as Tables 4 to 6. The trap sites are shown in Figure 1, with the same traps used to collect biting midges also used to collect mosquitoes.

3.2.1 Species present

There were a total of 29 adult mosquito species collected at Muirhead, accounting for a total of 23,353 adult females (Tables 4 & 5). The most abundant species was the northern salt marsh mosquito *Aedes vigilax,* which accounted for 76.08% of all adult mosquitoes collected at an average per trap per trap night of 149.3 (Table 4). The next most abundant species was the common banded mosquito *Culex annulirostris,* which accounted for 18.37% of all mosquitoes at an average per trap per trap night of 36.06 (Tables 4 & 5). All other mosquitoes were collected in relatively low numbers (Tables 4 & 5).

3.2.2 Seasonal abundance

Aedes vigilax was most abundant in the month of November, with a total of 6,750 adult females collected during the November 2006 trapping, accounting for 37.99% of all *Ae. vigilax* at an average of 482.14 per trap (Table 6). May recorded the second highest numbers of *Ae. vigilax,* with a total of 4,267 females on the 3rd of May 2007 (24.02%), at an average of 387.91 per trap. The single trap fail reset at Trap Site 12 on the 4th of May recorded 547 *Ae. vigilax*. Trapping in late December recorded the third highest numbers, with 20.52% of total numbers collected on the 19th of December for an average of 280.46 per trap, with the single trap fail reset on the 20th of December recording 979 *Ae. vigilax* (Table 6).

Culex annulirostris was most abundant during May, with 1,911 females collected on the 3rd of May 2007 from 11 traps (Table 5). April was the next most abundant month, with 841 females collected on the 4th April 2007 from 14 traps, followed by August, with 431 females on the 29th of August from 13 traps (Table 5).

Anopheles farauti s.l. was most common during May 2007, with a total of 136 females collected from 11 traps during the 3rd of May trapping (Table 5). April was the next most abundant month for *An. farauti s.l.,* with a total of 68 females collected during the April trapping from 14 traps (Table 5). Other months recorded very low levels. The average per trap per trap night for *An, farauti s.l.* was 1.79 adult females.

Anopheles bancroftii was also most common in April and May 2007, with highest numbers recorded during trapping in April 2007 (152 females from 14 traps), and second highest numbers during the May 2007 trapping (92 females on the 3rd of May from 11 sites) (Table 5).

The golden mosquito *Coquillettidia xanthogaster* was most common in April 2007, with 96 females collected from all sites (Table 5). The receptacle mosquito *Aedes notoscriptus* was most common during the wet season months of November, December and April, with April the most abundant months with a total of 35 females (Table 5).

3.2.3 Spatial abundance and dispersal

Trap Site 12, located in a low lying forest area adjacent to the Buffalo Creek landward mangrove margin, was the most productive trap site for *Ae. vigilax,* with a total of 2,759 adult females (15.53%) of all *Ae. vigilax* collected at this site, at an average of 306.56 per trap night (Table 6). The next most productive trap site for *Ae. vigilax* was Trap Site 8, located on the west side of the Leanyer Sewage Ponds boundary fence, with a total of 1,987 adult females (11.18%) and average of 248.38 per trap night. Other trap sites of relatively high abundance were Trap Site 9, near Lee Point Rd (9.6% and average of 189.44 per trap night), Trap Site 4, close to Buffalo Creek Rd (8.16% and average of 181.13 per trap night), Trap Site 3, close to Buffalo Creek Rd (8.16% and average of 161.11 per trap night), Trap Site 5, near the Lee Point Caravan Park (7.88% and average of 175 per trap night) and

Trap Site 1 at Lee Point (7.37% and average of 145.44 per trap night), with moderate abundance at all other trap sites (Table 6).

Figure 4 shows peak season *Aedes vigilax* trapping in November 2006. Traps were set at the Shoal Bay Receiving Station and Muirhead on the 17th of November 2006 and collected the following morning on the 18th of November 2006, 11 days after the November monthly high tide of 7.8m. Traps were set at Karama and Casuarina on the 21st of November 2006 and collected the following morning, 15 days after the November monthly high tide. The highest numbers of *Aedes vigilax* were collected on the east side of the Shoal Bay Receiving Station (6,990 females), facing the uncontrolled upper tidal areas of King Creek and Howard River, while the lowest numbers were collected at the furthest site from the Shoal Bay Swamps, at Casuarina Coastal Reserve near Rocklands Dve (196 females).

These results indicate that some *Aedes vigilax* affecting Muirhead and other Darwin Northern Suburbs may be originating from swamps associated with King Creek and Howard River, although the majority of *Ae. vigilax* affecting Muirhead are likely to be originating from breeding sites in the western landward mangrove margin of Buffalo Creek, and in the Leanyer and Holmes Jungle Swamps.

Culex annulirostris was most abundant at Trap Site 8, with a total of 616 females collected during all trap nights (Table 4). This was followed by Trap Site 7 at the NE boundary of Muirhead (596), Trap Site 1 (489), Trap Site 9 (427) and Trap Site 13 in Casuarina Coastal Reserve (395).

Anopheles farauti s.l. was most common at Trap Site 9 (50), with minor numbers at most other trap sites (Table 4). *Anopheles bancroftii* was also most abundant at Trap Site 9 (87), with minor numbers at most other trap sites (Table 4). *Aedes notoscriptus* was most abundant at Trap Site 14, near the corner of Fitzmaurice Dve and Lee Point Rd, with 24 adult females collected at this site (Table 4). *Coquillettidia xanthogaster* was relatively evenly distributed at most trap sites, with highest numbers (35) at Trap Site 7 (Table 4).

3.2.4 Potential breeding sites

There is extensive information available on potential breeding sites that are likely to seasonally affect Muirhead North and 2CRU. The major potential mosquito breeding areas are shown in Figures 4 & 5, which were derived from many years of surveying by ME. The adjacent Leanyer Swamp is a major breeding site for *Aedes vigilax* and *Culex annulirostris*, and stretches from the east mangrove margin of Buffalo Creek to the Shoal Bay Dump and west margin of Micket Creek. The main species targeted for aerial mosquito control in the Leanyer Swamp is *Ae. vigilax*, with *Cx. annulirostris* breeding also controlled when numbers reach significant levels or when disease risk is high. The Holmes Jungle Reed Swamp, Holmes Jungle upper tidal mangrove areas and Micket Creek Swamps are also major breeding sites for *Ae. vigilax* and *Cx. annulirostris.* These areas are also targeted for aerial control, and are major potential sources of *Ae. vigilax* and *Cx. annulirostris* to Muirhead North and 2CRU.

Due to the very long flight range of *Ae. vigilax*, coastal swamps around King Creek and the Howard River, which are not controlled for *Ae. vigilax* breeding, are likely to be smaller sources of *Ae. vigilax* to Muirhead North and 2CRU.

Culex annulirostris affecting Muirhead North and 2CRU are likely to originate from areas closer to the development, such as areas of the Leanyer Swamp within 2-3km of the development, and localised smaller breeding sites located in CCR, BCMA and along the western mangrove margin of Buffalo Creek. The Leanyer sewage ponds and the caravan park sewage ponds could be potential *Cx. annulirostris* breeding sites, although respective management plans for the ponds should limit/prevent their effect on future residents.

Low lying seasonally flooded areas, such as to the west of the Leanyer Sewage Ponds and near the mangrove margin adjacent to the eastern corner of Muirhead North, are potential breeding sites for *Culex annulirostris, Anopheles species* and *Coquillettidia xanthogaster*. The dam near the boundary of Muirhead North is regarded as a potential minor breeding site only, due to predominantly steep sides

and minimal semi-aquatic vegetation. Two difficult to reach incised creeklines near the eastern edge of Muirhead North were identified in November 2007 as significant localised *Aedes vigilax* and *Verrallina funerea* breeding sites, and potential breeding sites for *An. farauti s.l.* and *Culex annulirostris.*

Casuarina Coastal Reserve from the mouth of Rapid Creek to the eastern side of Lee Point, and the Buffalo Creek Management Area around the mouth of Buffalo Creek contains many productive mosquito breeding sites for *Aedes vigilax*, both after monthly high tides and particularly after heavy rain. Depressions in upper tidal mangrove creeks and interdunal depressions are the main two breeding habitats for this mosquito in CCR and BCMA, with the interdunal depressions generally being the most productive and the most widespread habitat. Sunlit and partially sunlit depressions are usually preferred by this mosquito. Medical Entomology controls the breeding sites on behalf of the Parks and Wildlife Commission of the NT (PWNCT), although due to the physical nature of some breeding sites, larval mosquito control operations can sometimes not successfully target all mosquito breeding sites in the required time, and it is also difficult to successfully control all breeding at some difficult to access sites. Therefore, *Ae. vigilax* breeding in CCR and BCMA is likely to periodically affect 2CRU and Muirhead North. In addition, a new very large tide and rain *Ae. vigilax* breeding site formed on Lee Point beach in 2015 (Warchot et al 2015), further adding to the potential mosquito problem affecting 2CRU and Muirhead North.

Culex annulirostris also breeds in CCR and BCMA, in low lying grassy areas, and also in some grassy interdunal depressions that hold water for more than a week. The breeding sites for this species are usually targeted for control on occasions when adult numbers reach or are predicted to reach significant levels, although presently this species is usually only controlled in the breeding sites located closer to the hospital and Tiwi. Recent problems with stormwater drain discharge have increased the *Cx. annulirostris* problem in low lying grassy areas of Sandy Creek near the hospital.

Verrallina funerea breeds in wet season depressions and creeklines throughout CCR and BCMA, and can be found in very high numbers during the wet season. It is commonly found breeding in association with *Ae. vigilax*, as well as partially shaded/completely shaded areas such as jungle creeklines, beach hibiscus depressions and monsoon forest depressions. The breeding sites for this mosquito in CCR and BCMA are productive and widespread. The monsoon forest in Muirhead North is also likely to be a productive breeding site for this mosquito.

3.3 Further information since the Muirhead baseline investigation

In October 2012, a series of additional traps were set in Casuarina Coastal Reserve in conjunction with the eleven weekly routine mosquito monitoring traps set by Medical Entomology around Darwin. This was due to the incessantly high seasonal numbers of *Ae. vigilax* in the Lee Point area during the build up, despite having limited late dry-early wet season breeding sites. The trap results are displayed in Figure 6. The trap results confirmed that the undeveloped Lee Point area, including Muirhead North and much of the 2CRU site, can seasonally experience the highest *Ae. vigilax* abundance compared to other areas of Darwin. However, as this was a once off trapping event, the results may not reflect what occurs throughout the peak *Ae. vigilax* season. The general thoughts are that the high numbers in the monsoon forest areas of Lee Point is due to favourable harbourage, and that once developed, the urban areas of Muirhead North and 2CRU would eventually experience similar seasonal *Ae. vigilax* levels to Muirhead and Leanyer. However, due to the presence of mid and late wet season (January to April) *Ae. vigilax* breeding sites in CCR and BCMA, compared to Leanyer Swamp which finishes breeding *Ae. vigilax* by early January, the *Ae. vigilax* season affecting Muirhead North and 2CRU is expected to be longer than the other northern fringe suburbs of Darwin.

As discussed above, a new *Ae. vigilax* breeding site formed on Lee Point Beach in 2015. At present, the breeding area is about 11,000m^2, which makes it the largest tide mosquito breeding site in the Lee Point area. Controlling this site has added significant strain to the Medical Entomology larval

mosquito control program, and added to the cost of controlling mosquito breeding in CCR, which is borne by PWCNT.

3.4 Darwin adult mosquito monitoring results 2015-16

Medical Entomology sets routine weekly adult mosquito monitoring traps nearby to Muirhead North and 2CRU. The sites are Casuarina, Leanyer Gate, and more recently, a trap set in the monsoon forest near the mouth of Buffalo Creek was added to the weekly trapping program in January 2016. The results of last financial years trapping for the long dispersing species *Ae. vigilax* and *Cx. annulirostris* from the three sites are displayed in Figure 7. Trap locations are shown in Figure 1. The two mosquitoes species were chosen, despite the traps collecting over 20 different mosquito species, due to their long flight range and therefore potential to disperse to Muirhead North and 2CRU from the breeding sites nearby to the traps.

Figure 7 indicates that the main *Ae. vigilax* season lasts from September to December at Leanyer Gate and Casuarina, with August and January being months of elevated abundance, as well as June. The Buffalo Creek trap did not commence until January, however *Ae. vigilax* was common during all months from January to June, and was most likely also common from August to December. The Buffalo Creek trap results suggest the nearby presence of mid wet to early dry season breeding sites, which do not affect the Casuarina and Leanyer Gate traps, and thus may be localised breeding sites in interdunal and upper tidal areas somewhere in the vicinity of the mouth of Buffalo Creek.

The *Culex annulirostris* season was similar at all three sites, with January to March being the peak months. Buffalo Creek also recorded slightly elevated abundance from April to June, while Casuarina also recorded elevated abundance in September and October, and Leanyer Gate recorded elevated abundance in late December. The January to March peak abundance at all three sites is a reflection of breeding in ground pools after wet season flooding. The late dry season and early wet season abundance at Casuarina is a reflection of dry season mosquito breeding caused by dry season stormwater discharge into low lying areas near the upper Sandy Creek mangroves near the hospital. The late wet and early dry season *Cx. annulirostris* abundance at Buffalo Creek may have been due to dispersal from residual wet season flooding in nearby depressions, dispersal from Leanyer Swamp, and potentially dispersal from the nearby sewage ponds if vegetation and scum was present in the ponds.

4. Discussion

4.1 Mosquitoes

4.1.1 Species present

The most important and common mosquitoes likely to affect Muirhead North and 2CRU would be the northern salt marsh mosquito *Aedes vigilax*, and the common banded mosquito *Culex annulirostris*. To a localised extent, the black jungle mosquito *Verrallina funerea* could affect the western fringes of 2CRU, and potentially the residential areas of Muirhead North adjacent to the rainforest patch.

Occasionally, the golden mosquito *Coquillettidia xanthogaster* and various *Anopheles* species mosquitoes may affect Muirhead North and 2CRU, although these species were collected in much lower numbers compared to *Ae. vigilax* and *Cx. annulirostris.*

4.1.2 Spatial abundance

Aedes vigilax will affect all residents in Muirhead North and 2CRU on a seasonal basis. This mosquito is most common within 5km of its breeding sites, but can disperse in significant numbers up to 50km from very large breeding sites (Whelan 1997). Therefore, like the neighbouring northern suburbs, pest problems will extend throughout the proposed urban area during the peak season months.

Culex annulirostris is also likely to seasonally affect most residents in Muirhead North and 2CRU. *Culex annulirostris* can disperse up to 10km from extensive breeding sites, although is most common within 4km of breeding sites (Whelan 1997a), and there is usually a significant drop in *Cx. annulirostris* numbers up to 2km away from significant breeding sites (Whelan 2004a). In general, it is expected that the fringing residents facing the breeding sites would experience the higher problems, when they occur.

Verrallina funerea has a short flight range, and does not disperse far from its shaded breeding sites (Whelan 1997). Therefore, the western fringe of 2CRU could be impacted by this mosquito, with residential areas near the rainforest in Muirhead North also likely to be affected.

Other mosquito species such as *Cq. xanthogaster* and *Anopheles* species, when present, would probably mainly affect the outer residents due to the lower seasonal abundance of these species, and thus any problems would most likely be more localised rather than widespread.

4.1.3 Seasonal abundance

Aedes vigilax would be most abundant throughout 2CRU and Muirhead North from September to January. Smaller peaks are also likely to occur in both areas in August and during the early dry season. Due to the closeness of 2CRU to numerous interdunal and monsoon forest breeding sites in CCR, it is likely that at least the western portion of 2CRU could also experience elevated abundance from February to April. The Buffalo Creek trap recorded unseasonal abundance of *Ae. vigilax* during the mid and late wet season, suggesting that elevated *Ae. vigilax* abundance could also affect the northern edges of Muirhead North and 2CRU during February to April. Further trapping is required to delineate the seasonal abundance of *Ae. vigilax* arising from seasonally flooded areas near the mouth of Buffalo Creek.

Culex annulirostris would primarily be a mid to late wet season issue at 2CRU and Muirhead North, unless the nearby dam and sewage ponds become breeding sites for mosquitoes, which could then create a dry season problem. If stormwater infrastructure and drain discharge points are not designed to prevent mosquito breeding, then dry season *Cx. annulirostris* issues could be created by the development.

Verrallina funerea would be most abundant during the wet season, while *Cq. xanthogaster* and *Anopheles* species abundance would be highest in the late wet and early dry season.

4.1.4 Mosquito breeding sites

Northern salt marsh mosquito Aedes vigilax

The northern salt marsh mosquito breeds in tidal and brackish water in coastal areas, tidal rivers or other salt affected areas such as salt marshes, brackish water reed swamps, the upper reaches of tidal creeks, or salt lake/saline habitats (Whelan 1997a).

Breeding sites for *Ae. vigilax* near the Northern Suburbs of Darwin have been deduced by ME over many years of surveying and controlling the Leanyer and Holmes Jungle Swamps and Casuarina Coastal Reserve. Major breeding sites are indicated in Figures 4 & 5. Major breeding sites in the Leanyer, Holmes Jungle and Mickett Creek Swamps are mainly extensive poorly draining salt marsh habitat and brackish reed swamps, and poorly draining mangrove areas, generally above the 7.4m ACD tide level. Breeding also occurs in drains in the Leanyer Swamp from around 7.0m ACD level and above. Extensive breeding in these areas also occurs after rainfall of over 25mm in the months of September to January inclusive and in April and May.

Breeding sites on the west side of Buffalo Creek are found near the landward mangrove margin from the mouth of Buffalo Creek to near the Leanyer Sewage Ponds. Two creeklines and associated scoured/sediment affected upper mangrove areas adjacent to the north-east corner of Muirhead are significant breeding sites for *Ae. vigilax* and *Ve. funerea* in this area. These creeklines and associated mangrove ponding have been difficult to control due to access issues.

Breeding sites in Casuarina Coastal Reserve include a relatively large upper tidal mangrove area in upper Sandy Creek near the hospital, as well as many poorly draining interdunal areas, particularly from the mouth of Sandy Creek to the mouth of Buffalo Creek (Figure 5). Breeding sites in the interdunal depressions are usually very productive, with densities of over several thousand larvae per square metre common. Most breeding sites are controlled by ground operations, with the exception of the very large depression in the monsoon forest that runs almost parallel with the length of the western boundary of 2CRU (Figure 5), which is controlled by helicopter. The upper tidal reaches of Sandy Creek is an *Ae. vigilax* breeding site after tides over 7.4m or heavy rainfall from August to December inclusive. Interdunal depressions at Casuarina Coastal Reserve are generally only breeding sites after heavy rainfall and high tides in the mid to late wet season, when the high water table allows residual ponding in the depressions. The exception, as of 2016, is the very large beach depression that occurs between Lee Point and Buffalo Creek, which breeds during the dry season and early wet season after tides over 7.4m, or after heavy rain during this period.

Due to the long flight range of *Ae. vigilax*, with dispersal of up to 50km in pest numbers, the uncontrolled tidal swamps associated with King Creek and the Howard River are also likely breeding sites for *Ae. vigilax* which can affect Muirhead North and 2CRU, although these would not be as significant as closer breeding sites in the Leanyer and Holmes Jungle swamps, and CCR and BCMA.

The common banded mosquito Culex annulirostris

Culex annulirostris generally breeds in temporary and permanent freshwater and brackish water swamps and pools with emergent vegetation such as semi-aquatic reeds, temporary flooded grasslands, polluted stormwater drains, vegetated effluent ponds, and vegetated margins of creeklines and floodways (Whelan 1997a, Appendix 4).

Actual breeding sites for *Cx. annulirostris* likely to affect the development include Leanyer Swamp and Holmes Jungle reed swamp during the wet season and immediate post wet season, and some interdunal areas of CCR and BCMA during the wet season. *Culex annulirostris* breeding usually only commences once significant rainwater flooding occurs, usually in late December/early January for

Leanyer Swamp, and early to mid January for CCR, BCMA and seepage areas along the western fringe of the Buffalo Creek mangroves.

The low lying seasonally flooded grassy/weedy areas adjacent to the upper mangrove margin of Sandy Creek near the hospital are also major wet season breeding sites, with areas affected by dry season stormwater flows also breeding sites throughout the dry season. These breeding areas could affect the southern edge of 2CRU.

The Leanyer sewage ponds and caravan park Sewage ponds could be occasional breeding sites for *Cx. annulirostris,* when vegetation and flotsam occurs in the ponds, however these ponds are covered by management plans. The seasonally flooded low lying area to the west of the Leanyer sewage ponds is also a potential breeding site. Nearby breeding sites for *Cx. annulirostris* at Muirhead North include the low lying area adjacent to the Buffalo Creek mangrove margin near the east boundary of Muirhead North. The caravan park dam has so far not been found breeding mosquitoes, but could be a *Cx. annulirostris* breeding site if grass encroaches into the water, and dense semi-aquatic vegetation grows.

Other mosquito species
Verrallina funerea breeds in similar areas to *Ae. vigilax*, as well as numerous shaded pools and flowlines spread throughout the monsoon forest of CCR and BCMA.

Anopheles species mosquitoes are likely to breed in both freshwater and brackish water habitat utilised by *Cx. annulirostris* and *Ae. vigilax,* particularly in the Sandy Creek area of CCR, as well as poorly draining areas along the landward mangrove margin of Buffalo Creek and Leanyer Swamp. However, the low numbers of *Anopheles* species mosquitoes in the Lee Point area indicates a lack of nearby extensive/productive breeding habitat for these mosquitoes.

The golden mosquito *Coquillettidia xanthogaster* is likely to utilise similar mosquito breeding habitat as *Cx. annulirostris,* particularly paperbark depressions and depressions with semi-aquatic reeds. However, the low numbers in the Lee Point area indicates a lack of extensive/productive breeding habitat for this mosquito.

4.1.5 Mosquito pest problems

The most significant pest mosquito affecting Muirhead North and 2CRU will be the northern salt marsh mosquito *Ae. vigilax.* This mosquito is the cause of most mosquito complaints received by Medical Entomology from urban areas of Darwin and Palmerston. *Aedes vigilax* is an aggressive mosquito, which bites during the daytime in shaded areas and during the night. The trap results indicate that seasonally high to very high pest problems would affect Muirhead North and 2CRU from September to January, with low to moderate pest problems during August, May and June. Mid to late wet season pest problems could also affect the western portion of 2CRU, and the northern edges of Muirhead North and 2CRU. The general indicative pest threshold for this mosquito is 50 per trap/per night, with this level greatly exceeded during trapping at numerous sites over the years adjacent to Muirhead North and 2CRU. Pest problems would not occur continuously throughout these months, with this mosquito usually occurring in waves that last around one to two weeks.

Culex annulirostris was recorded below the indicative pest threshold for this species during baseline trapping, which is considered to be 600 per trap/per night. This mosquito only bites at night, as is more timid in the presence of lights and personal protection compared to *Ae. vigilax.* Therefore, the past Medical Entomology trap results from areas adjacent to Muirhead North and 2CRU indicate that this mosquito would rarely be responsible for appreciable pest problems. However, it could still cause occasional nuisance problems, most likely in the fringe areas facing seasonally flooded areas.

Verrallina funerea is generally not responsible for mosquito complaints in urban areas, as their breeding sites have usually been separated from urban areas by some type of buffer. Within the monsoon forests of CCR and BCMA during the wet season, pest problems can be extreme. However,

with careful planning, pest problems should be completely avoided in urban areas of 2CRU and Muirhead North. The monsoon forest in Muirhead North appears to be located in the rural area, which is satisfactory due to the limited amount of residents that would be affected by any breeding sites in this area.

Other mosquitoes that can cause pest problems in the Darwin area, such as *Cq. xanthogaster* and *Anopheles* species, are not expected to cause pest problems in Muirhead North and 2CRU, due to the absence of nearby large shallow reed swamps such as the Holmes Jungle Reed Swamp.

4.1.6 Mosquito borne disease

Aedes vigilax is a vector of Ross River virus (RRV) and Barmah Forest virus (BFV), and is likely to pose a high risk of disease transmission when numbers of this species are high, particularly in December to March when the longevity of this species is extended due to high humidity. The longer the mosquito lives, the greater the chances it will obtain a virus from an animal host and pass it onto a human. The main host animals of RRV are considered to be macropods, which are probably present in nearby areas. Ross River virus cases have been recorded in nearby suburbs such as Lyons and Leanyer, indicating the potential risk in the fringe northern suburbs. The main risk season for RRV in the Top End of NT is December to June, and the main risk period for BFV in the Top End is October to July (Whelan 1997b).

Culex annulirostris is also a vector of RRV and BFV, the potentially fatal Murray Valley encephalitis virus (MVEV), and Kunjin virus (KUNV). This mosquito is likely to pose an elevated disease risk during the wet season at Muirhead North and 2CRU. Water birds, particularly herons and egrets, are the host of MVEV and KUNV. Sentinel chickens have identified MVEV and Kunjin virus activity along the urban fringe of Leanyer in some years, suggesting there is a possible risk. However in general, MVEV and KUNV disease cases are rare, averaging about one case per year in the NT.

Aedes notoscriptus, the container breeding mosquito, is a potential vector of RRV and BFV, and is usually most common in urban areas of the NT during the wet season, when rainfall fills its receptacle breeding sites such as pot plant drip traps, buckets, unscreened rainwater tanks etc. It is likely to eventually colonise urban residential yards and pose a potential pest and disease risk.

Malaria was declared eradicated from Australia in 1982, with the last cases in the NT occurring in the 1960's (Whelan 1995). However, *Anopheles* species mosquitoes are potential vectors of malaria, and are prevalent in the NT. Several *Anopheles* species mosquitoes are seasonally recorded in Medical Entomology monitoring traps around Darwin, including nearby to 2CRU and Muirhead North. Past drainage issues in the nearby Sandy Creek were considered to create a potential malaria risk to the hospital and Casuarina Reserve, however the issue was fixed through the installation of a dry season low flow diversion pipe in Sandy Creek (Whelan 1988). Presently however, the low flow drainage pipe is impaired, and it is therefore likely that *Anopheles* species numbers would increase unless the pipe is repaired/desilted. In general, at the present time the potential malaria risk at Muirhead North and 2CRU is considered to be no greater than existing neighbouring suburbs.

4.2 Mosquito breeding and development aspects

4.2.1 Stormwater drainage

Stormwater drainage has been the creator of much of the historical mosquito breeding problems in Darwin, including at Sandy Creek within CCR, as briefly discussed in Section 4.1.5, and in Leanyer Swamp, in which a dry season swamp was created by dry season urban drain flows (Jacups et. al 2012). Other mosquito breeding swamps and associated disease risks caused by stormwater discharge were created in Coconut Grove in Kulaluk Reserve, and in Ludmilla Creek adjacent to Richardson Park.

In all of the above cases, the mosquito breeding has occurred at the constructed drain end point. The Leanyer Swamp problem and Ludmilla Creek problem was rectified by the construction of an open channel through the tidal area, to direct stormwater to a daily flushed (ie below 7m ACD/3m AHD) incised tidal creekline. Whilst the Leanyer drains are still functional due to regular maintenance, the Ludmilla Creek tidal drain became overgrown with mangroves, and the mosquito problems returned.

Mosquito breeding has also been associated with dry season ponding within open unlined drains in Darwin, and in water sensitive urban design structures in Palmerston. In general, the mosquito problems have usually been caused by dry season low flows, which seem to occur in almost all trunk drains around Darwin and Palmerton.

With regards to the proposed urban subdivision, stormwater discharge from both 2CRU and Muirhead North is regarded as having a high potential for creating new mosquito breeding sites, as stormwater will flow towards existing mosquito breeding areas. Therefore, there is a potential for mosquito breeding to be exacerbated via increased ponding, and there is a potential for dry season flows to create new dry season breeding sites. Stormwater discharge drains from both development sites would therefore need to be extended to the daily flushed tidal area of Sandy Creek and Buffalo Creek. The suggested design for an outfall drain to a daily flushed tidal area would be an open drain with a low flow concrete invert and appropriate erosion prevention structures. The entire length of any discharge drain should also be excised as an appropriately zoned separate lot (eg. Utilities), and handed over to local council or a relevant maintenance authority. Creating a drain on Conservation zoned land can make it difficult for routine maintenance to be expediently carried out in the future. Medical Entomology and the relevant authorities (PWCNT, DLPE) should be involved during the design phase for the stormwater drainage outfalls.

Internal stormwater drainage should follow the City of Darwin requirements, as they are the handover authority. In general, CoD requirements usually match the requirements of Medical Entomology with regards to ensuring drains are designed to be completely free draining, and easy to maintain. General stormwater recommendations can be found in Appendix 1.

4.2.2 Stormwater treatment systems

There have been measures implemented to improve water quality or prevent increasing downstream peak flows in the more recent urban subdivisions in Darwin and Palmerston. In terms of mosquito breeding prevention, detention basins that hold water for only a few hours have worked well in Lyons and Muirhead, while lake systems have worked well in Palmerston and Darwin. In general, any proposed treatment system would first need approval by City of Darwin, with Medical Entomology available to provide advice on design and management if required.

Rainwater tanks have been used as a means to reduce roof runoff in other states. However, the mandatory use of rainwater tanks in the tropical north is not supported by Medical Entomology, due to the potential issues with lack of maintenance and subsequent mosquito breeding and neighbourhood complaints. There is also and the potential for unmaintained rainwater tanks to act as major dengue and zika mosquito breeding sites, if an incursion of the exotic dengue mosquito occurs in Darwin. Presently, the dengue and zika vector mosquitoes (*Aedes aegypti* and *Aedes albopictus*) are usually detected at Darwin International Airport and East Arm Port on several occasions each year, however, so far the establishment of the mosquitoes in urban Darwin has been prevented.

4.2.3 Biting Insect buffers

Biting insect buffers can be implemented in various forms, such as a separation from the main flight range of the biting insect from its breeding habitat, a break in the harbourage/dispersal habitat to allow wind disruption (open wind buffer), and using low density rural/industrial lots that provide a break in the habitat and a distraction (e.g. animals, lights) to inland biting insect dispersal. The effect of open wind buffers can be seen at Trap Site 10 from the Muirhead baseline trapping program (Figure 2), with this trap site recording much lower biting midge numbers compared to trap sites located near

uncleared bushland. The open wind buffer was less effective against strong dispersing mosquitoes such as *Ae. vigilax* and *Cx. annulirostris* (Table 4), however Trap Site 10 was still the second least productive mosquito site during the Muirhead baseline trapping, suggesting some reducing effect by wind disruption or lack of suitable harbourage.

The Lee Point Area Plan 1 from PA2014/0992 shows the 2CRU site (Appendix 2). The plan does not formally indicate a biting insect buffer from the monsoon forest in CCR. However, the road along the western boundary would act as a small break in the mosquito habitat, and should be combined with other open space (eg footpaths, linear open park) to create an open buffer of at least 50m, similar to the Rocklands Dve and Lakeside Dve open buffers, the recently constructed Muirhead open wind buffer. The recommended mature tree canopy coverage in the open buffer should be about 10% (ie. when viewed by aerial photography, the predicted mature tree canopy coverage should cover no more that about 10% of the site, with the rest being mown grassland, roads, footpaths etc). As this has implications for maintenance, the suggested open buffer should be discussed with the future handover authority very early in the planning process.

The Lee Point Area Plan 2 for Muirhead North (Appendix 2) indicates rural residential buffer (Minimum 4000m2 lots), and a drainage reserve of about 100-150m, similar to what has been constructed for Muirhead. The drainage reserve should follow the principles of the Muirhead drainage reserve, which is an open mown grass area with mature tree coverage of no more than 10%. As discussed above, as this has implications for maintenance, the open drainage buffer should be discussed with the future handover authority very early in the planning process. Overall, the buffer indicated in the area plan is considered a suitable buffer to the urban residential component of Muirhead North.

In addition, it is expected that the nearby unfinished golf course would disrupt some dispersal to Muirhead North from the mosquito and midge breeding sites around the mouth of Buffalo Creek. The golf course, when finished, would contain large open areas with short grass, and thus allow some wind disruption of biting insects.

In general, whilst the biting insect buffers will offer some protection, particularly during the smaller breeding events, during peak season breeding events for salt marsh mosquitoes and mangrove biting midges, it is expected that the urban lots in both suburbs would still experience high seasonal mosquito problems, while most urban lots in Muirhead North would also experience high peak season biting midge problems. The open buffers however, should completely remove the potential for *Ve. funerea* problems.

With regards to the general layout of the subdivision, it is recommended that larger urban lots are located along the fringes of the suburb, graduating to smaller lots closer to the urban centres or Lee Point Rd. This would reduce the density of people located closest to the biting insect breeding areas, and for Muirhead North, also provide a better transition between the rural and urban area.

4.2.4 Building design

Building design and orientation can reduce the resident's exposure to biting insects. For example 'traditional' elevated Darwin houses, which have elevated verandas facing the seabreeze, anecdotally experience less biting insect problems than ground level houses which have breezes blocked by vegetation or other houses. Unfortunately, elevated houses appear to be unpopular, possibly due to cost. However, they should still be recommended, particularly for residents in Muirhead North, who are likely to experience appreciable mosquito and biting midge problems, and the western fringe residents of 2CRU directly opposite the monsoon forest. The use of high powered fans in verandas can also disrupt mosquito activity, and should be recommended.

Insect screens are standard in modern Darwin, which would prevent the indoor entry of mosquitoes. However, they do not prevent biting midge entry, and there have been several reports from Bayview residents experiencing indoor biting midge problems. It appears that locking all the doors and

windows around sunset and sunrise is how the indoor biting midge problem is usually prevented. There is the option of midge screening, however due to the ultra-fine mesh and effect on wind flow, it appears that midge mesh is not popular and may just be akin to closing the doors and windows.

There are other options with regards to building design that could minimise residents and businesses exposure to mosquitoes. Outward opening doors can reduce mosquito entry into a building. Businesses could benefit from installing air curtains for entrance doors. Other more costly options would be to follow the Florida, US example, where houses have completely screened verandas, front porches and outdoor pools.

Further information regarding building design can be found in the personal protection from mosquitoes handout, provided as Appendix 3.

4.2.5 Construction phase

During the construction phase, workers are likely to be affected by biting insect problems, particularly early morning and late evening workers. Therefore, all new workers should be advised of the likelihood of experiencing biting insect problems, and appropriate measures to prevent being bitten (see Appendix 3).

Construction also has the potential to create temporary mosquito breeding, in wheel ruts, shallow sediment ponds and bunded areas. The construction site should be maintained free from mosquito breeding, either by preventing shallow ponding, or in areas where shallow ponding is unavoidable, by treating the shallow ponding with a residual mosquito larvicide (e.g. methoprene 30 day pellets) until the shallow ponding has been rectified/developed.

4.3 Mosquito breeding site rectification

The amount and productivity of mosquito breeding sites in CCR and BCMA makes mosquito control fundamental to reducing the loss of amenity for adjacent urban residents and visitors to the park. However, it is difficult to achieve effective larval mosquito control throughout the year, particularly after very large rain events. CCR and BCMA also contains numerous inaccessible/partially inaccessible mosquito breeding sites, which makes ground control difficult to achieve, and post control surveys after aerial control difficult to carry out. Therefore, mosquito breeding sites in CCR and BCMA should be targeted for rectification, particularly those caused by past disturbance and those that are easy to rectify, and access should be improved to the impenetrable mosquito breeding sites.

Rectification could involve utilising any spare fill generated by development to fill mosquito breeding sites in CCR and BCMA, if the fill is deemed to be of suitable quality. Alternatively, sand could be sourced from lower tidal areas to fill the sand dune mosquito breeding sites. The construction of shallow surface drains could also be carried to improve drainage and reduce mosquito breeding at some sites. The rectification program should involve all interested groups, such as the Developer, PWCNT, Medical Entomology, traditional owners and local environmental groups.

4.4 Insecticide mosquito control

Medical Entomology currently carries out larval mosquito control in CCR and BCMA on behalf of PWCNT, with the cost borne by PWCNT. Most of the control is carried out by ground operations, with helicopter control carried out in two large, inaccessible sites. Due to the increasing number of residents living nearby to the mosquito breeding sites, it is likely that the larval mosquito control program would need to be intensified, adding to the cost of the program, and placing additional strain on Medical Entomology staff who also have to cover the nearby Leanyer, Holmes Jungle and Micket Creek tidal and brackish water swamps, and localised swamps, drains and depressions around Darwin Urban. Therefore at the present time, it is not possible for the larval mosquito program to be expanded. However, if some mosquito breeding sites in CCR and BCMA are rectified, and improved access to breeding sites created, this would allow Medical Entomology to more effectively control the other mosquito breeding sites in CCR and BCMA.

The helicopter control program may also be impacted by urban development. Civil Aviation Regulations designate a 300m buffer between the helicopter and buildings, with parts of the northwest portion of 2CRU located within this zone. Medical Entomology is so far unclear of what may be required to permit spraying within the 300m buffer, whether it is a note on the titles of affected residents and businesses, or some other formal means of notifying the landholders.

On an individual lot scale, affected property owners can utilise a residual barrier insecticide spray to control adult mosquitoes when pest problems are high. The insecticide can be applied to outside walls, screens and shrub vegetation where mosquitoes are likely to harbour, and provide protection for up to 4-6 weeks. However, any treatment should be applied by a licensed pest controller, and should only be sparingly used to prevent the potential for mosquito resistance, and due to the fact that barrier insecticide sprays will also kill other insects that land on the treated surface. Further information on barrier sprays can be found in Appendix 4.

4.5 Personal protection

As with other mosquito affected suburbs like Leanyer, Karama and Muirhead, residents would need to practice personal protection and avoidance when mosquito numbers are high. Further information can be found in the Medical Entomology personal protection handout, which has been provided in Appendix 3 Medical Entomology also produces pest calendars for salt marsh mosquitoes (*Aedes vigilax*), which residents can use to predict problem periods. The salt marsh mosquito pest calendar for 2016 has been provided as Appendix 5.

4.6 Biting Midges

4.6.1 Species present

There were two species of biting midges collected that can be significant pests of man, *Culicoides ornatus* and *Culicoides species near subimmaculatus (northern form). Culicoides ornatus* is the most common pest biting midge in areas of Darwin nearby to mangroves, while *C. species near subimmaculatus (northern form)* appears only to occur in significant numbers in Darwin in the Lee Point area.

4.6.2 Spatial abundance and dispersal

Culicoides ornatus actively disperses inland from its mangrove breeding sites (Shivas 1999, Shivas & Whelan 2001), which is a characteristic that makes this species a significant pest of humans. Mass movement of adults can occur to 0.5 to 1.5 km from the mangrove margin of their major breeding sites, with minor numbers up to 3km from the nearest mangrove margin (Whelan 2003). Greatest midge abundance is usually found at the top of the leading edge of escarpments within 1.5km of the mangrove margin (Shivas & Whelan 2001). One distance study has found *C. ornatus* numbers to be greatest at the 1km mark from the mangrove margin, when trapping was conducted at 400m or 500m intervals, from the mangrove margin to 2400m from the mangrove margin (Whelan et al 1988).

Wet season dispersal and mid dry season dispersal is lower that early and late dry season dispersal, with lower mid dry season dispersal associated with lower temperature, while the reasons for low inland dispersal in the wet season are unknown (Shivas & Whelan 2001), but may be associated with blood meal host availability, dense vegetation growth or rain and humidity effects. However, areas within about 500m of the mangrove margin of productive breeding areas can expect substantial levels of midges for most of the year (Shivas & Whelan 2001). Distance trapping by Shivas & Whelan (2001) also indicated significant mid dry season dispersal up to 750m from the mangrove margin.

Culicoides sp near subimmaculatus (northern form) is listed as being most common within 0.5km of their breeding sites (Whelan 2004), while in Queensland *Culicoides sp near subimmaculatus (northern form)* is listed as having a pest range of around 400m (Qld Health 2002), but can extend to 1.6km from abnormally large breeding areas.

Culicoides ornatus and *C. species near subimmaculatus (northern form)* were both more common in the area between Lee Point Rd and Buffalo Creek during the 2006-07 baseline trapping, indicating Buffalo Creek is the most important source of pest biting midges in the Lee Point area. The traps within 1km of the landward mangrove margin of Buffalo Creek were generally a lot more productive, although appreciable abundance of both species was still recorded at the southwest corner of Muirhead North near Lee Point Rd. The most productive trap for both species was Trap Site 6, which was set along the dam wall near the northern edge of Muirhead North. Both species of biting midges were also recorded in 2CRU, particularly *C. species near subimmaculatus (northern form)* which was recorded in relatively high numbers. Overall however, 2CRU recorded lower biting midge numbers compared to areas east of Lee Point Rd.

4.6.3 Seasonal abundance

Culicoides ornatus is most common in the Darwin area from August to November, when widespread inland dispersal occurs. However, areas within about 500m of the mangrove margin of productive breeding areas can expect substantial levels of midges for most of the year (Shivas & Whelan 2001). As urban areas in Muirhead North are located further than 1km from the mangrove margin of Buffalo Creek, August to November would be the main months of abundance.

The 2CRU site is located within 500m of the Sandy Creek mangroves, suggesting a longer biting midge season compared to Muirhead North. However, midge numbers at 2CRU were much lower than Muirhead North, suggesting smaller breeding sites in Sandy Creek, and lower potential for major widespread inland dispersal.

Culicoides sp near subimmaculatus (northern form) generally has a peak in abundance during the latter part of the dry season (August –September) with numbers tapering to the late dry/early wet season (Whelan 2004). During baseline trapping, there was a major August peak, with December being the next most productive month. This suggests that the *C. species near subimmaculatus (northern form)* peak season is likely to be August to December.

4.6.4 Pest problems

Culicoides species bites can be a significant nuisance problem and can cause associated health problems. The bites are painful and large numbers of bites can cause a generalised reaction in non-immune people. Many people, particularly newly arrived or newly exposed people, suffer from bite reactions that can lead to intense itching, scratching, skin lesions, secondary infection and scarring. As there is no specific larval control method for mangrove biting midges, due to breeding sites being in impenetrable mangrove areas, affected residents will have to rely on personal protection measures, or treatment of individual properties with a suitable residual barrier insecticide.

Peak biting times for *C. ornatus* are in the two hours either side of sunset and sunrise (Whelan 2003). This species also bites in low levels throughout the night (Logan et al 1991). *Culicoides sp near subimmaculatus (northern form)* is also likely to be crepuscular (sunset and sunrise) in biting activity (Whelan 2004b), with man biting studies indicating this species bites from at least one hour before sundown to sundown, and probably to at least one hour after sundown. Potential pest problems from this species are therefore likely to occur in the two hours either side of sunset, and most likely also in the two hours either side of sunrise.

The highest numbers per trap of 6,400 *C. ornatus* at Site 6 in August 2007, which is adjacent to Muirhead North, represents approximately 3 times the numbers experienced in the eastern side of Stuart Park in Darwin, which has a seasonally high pest problem, and is similar (but slightly lower) to the western edge of Durack in Palmerston. These numbers represent a potentially very high pest problem for Muirhead North. The peak season numbers of *Culicoides sp near subimmaculatus (northern form)* collected at Site 6 in August 2007 were even higher than *C. ornatus*, with 9,280

collected during the overnight trapping. This also represents a potentially very high pest problem for Muirhead North.

At the southwest corner of Muirhead North, a peak of 2,016 *C. ornatus* was collected at Site 11 during August 2007, which represents levels similar to the seaward eastern edge of Stuart Park. *Culicoides sp near subimmaculatus (northern form)* was also collected in high numbers at Site 11 in August 2007 (2,240). This indicates that in peak season months, Muirhead North residents could experience high to very high pest biting midge problems throughout the suburb.

Although both biting midge species were recorded in much lower numbers in 2CRU, moderate to relatively high numbers were still recorded, indicating the likelihood of moderate to relatively high pest biting midge problems in 2CRU during the peak season months of August to November/December.

4.6.5 Biting midges and development aspects

The only effective way to prevent pest biting midge breeding would be to alter or fill their tidal breeding sites. This is unlikely to ever occur in Buffalo Creek and Sandy Creek. Therefore, it can be expected that biting midge problems will always affect Muirhead North and 2CRU. However, the same buffers used for mosquitoes would also reduce biting midge dispersal to some extent. Once the suburb has been developed, pest problems are also likely to be diluted to some extent, however probably not to an extent that prevents what would be perceived to be a seasonally moderate to high pest problem for many residents. Building design, as discussed in Section 4.2.4 for mosquitoes, can also be implemented to reduce pest biting midge problems. Elevated houses in particular are known to experience less biting midge problems, as pest biting midges have a general preference to bite near the ground. High powered outdoor fans can also be used to disrupt midges in verandas.

4.6.6 Personal protection

In general, as with other biting midge affected suburbs such as Durack and Stuart Park, people would need to practice personal protection and avoidance when midges are present in appreciable numbers. The same personal protection measures used for mosquitoes would also work for biting midges. As with the salt marsh mosquito, Medical Entomology has produced a pest calendar for *C. ornatus*, which should also cover the *C. sp near subimmaculatus (northern form)* pest season. The biting midge pest calendar for 2016 has been provided as Appendix 6. Workers should be advised of the potential seasonally high pest biting midges problems affecting the area.

4.6.7 Biting midge control

As insecticide control of the pest biting midge breeding sites affecting Muirhead North and 2CRU is not possible, the only method to control biting midges would be to utilise a residual barrier insecticide spray on individual lots. Refer to Section 4.4.

5. Conclusions

The major findings of the biting insect assessment of Muirhead North and 2CRU are provided below:

5.1 Mosquitoes

- *Aedes vigilax* will be present in seasonally high to very high numbers in both Muirhead North and 2CRU, and is likely to be the most abundant mosquito affecting the subdivision. Once the area has been developed, and provided with appropriate buffers similar to other nearby suburbs, it is expected that peak season numbers would be similar to other mosquito affected suburbs such as Muirhead, Leanyer and Karama.

  The peak season is expected to be September to January, when periodic waves of this mosquito would occur after high tides and large rainfall events. Elevated abundance is also expected to occur during the early dry season months of May and June. Elevated abundance is also expected to occur from February to April, particularly in 2CRU and the northern part of Muirhead North, due to interdunal breeding sites in Casuarina Coastal Reserve and the Buffalo Creek Management Area. This indicates the proposed suburb is likely to experience a longer *Ae. vigilax* season compared to existing suburbs of Darwin.

  Aedes vigilax is an aggressive mosquito which inflicts a painful bite, and bites during the daytime in shaded areas and during the night. Pest problems could be periodically high to very high during the peak season, and periodically low to moderate during the February to June period. This mosquito is a potential vector of Ross River virus and Barmah Forest virus, and would pose a risk of virus transmission whenever present, with the peak RRV and BFV virus period being December to March.

  The breeding sites for this mosquito affecting the subdivision are extensive, including the vast Leanyer, Holmes Jungle and Micket Creek Swamps, the numerous and large interdunal and upper tidal mangrove breeding sites in CCR and BCMA, and upper tidal mangrove breeding sites associated with the western margin of Buffalo Creek.

- *Culex annulirostris* is likely to be present in seasonally low to moderate numbers in both Muirhead North and 2CRU, with Muirhead North likely to be more affected by this mosquito, as it is closer to Leanyer Swamp. This mosquito bites at night, and is more timid in the presence of lights and personal protection compared to *Ae. vigilax*. However, this mosquito is the major vector of mosquito borne disease in the NT, capable of transmitting RRV, BFV, as well as the potentially fatal Murray Valley encephalitis virus and serious Kunjin virus. The peak season is likely to be January to March, with elevated abundance likely to occur in December and also during the early dry season. Due to drainage issues in and adjacent to the upper tidal mangrove area of Sandy Creek, this mosquito could also occur in elevated numbers around the southern edge of 2CRU throughout the dry season.

  Breeding sites for this mosquito, in addition to the Sandy Creek stormwater drainage area receiving urban stormwater, would be any temporary flooded grassy ground pool, grassy interdunal depressions, the Leanyer Swamp floodplains and seepage areas along the western mangrove margin of Buffalo Creek. Sewage ponds can be productive breeding sites, if grass and scum is allowed to accumulate around the edges of the ponds, although the sewage ponds adjacent to the subdivision have management plans to prevent mosquito breeding. The large dam adjacent to Muirhead North has so far not been found breeding mosquitoes, although water impoundments can become mosquito breeding sites if grass encroaches into the water, and semi-aquatic vegetation growth occurs.

- Other important mosquitoes such as *Anopheles* species mosquitoes and the golden mosquito *Coquillettidia xanthogaster* would be present in seasonally low numbers in 2CRU and Muirhead North. Breeding sites are likely be similar to those utilised by *Cx. annulirostris. Anopheles* species mosquitoes are important due to their potential to transmit malaria, while *Cq. xanthogaster* can be a significant pest mosquito. The low abundance suggests these mosquitoes would have a low impact on residents.

- Stormwater drainage discharged into the upper tidal mangrove area of Sandy Creek in CCR has previously created a major dry season mosquito problem, which was rectified via the construction of a low flow pipe. However, the low flow pipe is currently obstructed, and the dry season mosquito problems are returning and could impact the southern edge of 2CRU.

- Stormwater drainage from the proposed subdivision has the potential to replicate the issues caused by past stormwater discharge in CCR and other fringe areas of Darwin. The greatest potential for mosquito breeding creation would occur if inadequate drain discharge points are chosen, and if shallow water ponding occurs within drains and other stormwater structures.

- Medical Entomology currently carries out mosquito control in CCR and BCMA on behalf of the Parks and Wildlife Commission of the NT, and carries out helicopter control in the Leanyer, Holmes Jungle and Micket Creek swamps. Whilst these control programs greatly reduce mosquito abundance, routine trap results indicate salt marsh mosquitoes still seasonally affect the Darwin Northern Suburbs in numbers significant enough to cause high to very high pest problems to exposed people. The breeding sites in CCR and BCMA also provide an extended breeding season for salt marsh mosquitoes compared to other problem suburbs such as Leanyer. In general, the rectification of mosquito breeding sites would be the best form of mosquito control to protect future residents.

- Mosquito problems can be reduced to some extent by providing buffers that allow wind disruption and a break in the harbourage habitat. The proposed rural lots and 100-150m drainage buffer for Muirhead North, which is similar to the existing Muirhead, should provide some disruption to dispersing mosquitoes. There does not appear to be any buffer designed for 2CRU, although there is potential to combine roads, footpaths and perhaps a linear park to create a buffer for future 2CRU residents from the edge of the monsoon forest.

- Building design can reduce the impact of mosquitoes. Insect screens and outward opening doors can reduce the potential for mosquitoes to enter houses. Elevated houses with verandas facing the prevailing breezes can experience lower mosquito problems compared to ground level houses due to wind disruption. High powered outdoor fans can also disrupt mosquitoes.

- Residual barrier insecticides could be utilised by landowners to reduce adult mosquito problems around the house, when required. However, there is the potential for mosquito resistance to develop with long term widespread use, and the insecticides will also kill other insects that land on the treated surface.

- Personal protection, such as use of repellents, suitable clothing, or staying indoors during mosquito problem periods, will be seasonally required of residents in 2CRU and Muirhead North.

- Construction activities could create temporary mosquito breeding sites, for example via wheel ruts, sediment ponds and bunding. Any mosquito breeding could impact on existing residents near the development area.

5.2 Biting midges

- There were two species of pest biting midges recorded in Muirhead North and 2CRU during baseline trapping in 2006-07, *Culicoides ornatus* and *Culicoides species near subimmaculatus (northern form).* Both species were recorded in seasonally high to very high numbers adjacent to Muirhead North, and low to relatively high numbers in the northern portion of 2CRU. The peak season would be August to November/December. Buffalo Creek, particular the lower to middle reaches opposite Muirhead North and the Caravan Park, appears to be the largest source of both midges, with Sandy Creek a potentially moderate source of *Culicoides species near subimmaculatus (northern form)* and low source of *C. ornatus.* The levels of biting midges recorded indicate a high to very high seasonal pest problem is expected to affect Muirhead North during the peak season months, while a moderate to relatively high pest problem is expected to affect 2CRU during the peak season months.

- Biting midges are not known to transmit human disease in Australia. However, the bites can cause intense itching, and lead to secondary effects such as infection and scarring. High and continual pest problems can also lead to a loss of sense of wellbeing.

- Biting midge problems can be reduced to some extent by providing buffers that allow wind disruption and a break in the harbourage habitat. The proposed rural lots and 100-150m drainage buffer for Muirhead North, which is similar to the existing Muirhead, should provide some disruption to dispersing midges. There does not appear to be any buffer designed for 2CRU, although there is potential to combine roads, footpaths and perhaps a linear park to create a buffer for future 2CRU residents from the edge of the monsoon forest.

- Biting midges can be disrupted by wind. Elevated houses with verandas facing the prevailing breezes can experience lower biting midge problems compared to ground level houses. High powered outdoor fans can also disrupt biting midges.

- There is no known larval insecticide treatment for *C. ornatus*, while the breeding sites for *C. species near subimmaculatus (northern form)* are currently unknown. Therefore unlike mosquitoes, which can be controlled for breeding, there is no method of controlling the pest biting midge breeding sites affecting Muirhead North and 2CRU. The only effective way to control their breeding sites would be to alter or fill their tidal breeding sites in Buffalo Creek and Sandy Creek, which would be an unlikely scenario.

- Personal protection, such as use of repellents, suitable clothing, or staying indoors during periods of biting midge problems, will be seasonally required of residents in 2CRU and Muirhead North. Further information can be found in Appendix 3.

- Residual barrier insecticides could be utilised by landowners to reduce adult biting midge problems around the house, when required. However, there is the potential for biting midge resistance to develop with long term widespread use, and the insecticides will also kill other insects that land on the treated surface.

6. Recommendations

6.1 Mosquitoes

- A mosquito breeding rectification program should be initiated in Casuarina Coastal Reserve and the Buffalo Creek Management Area, targeting mosquito breeding sites that are deemed suitable to rectify via low impact measures such as sand filling or shallow drainage.

- The Sandy Creek low flow pipe system and associated drainage channels should be rectified as soon as possible, to prevent the current mosquito problems from the impacted Sandy Creek area affecting the southern edge of 2CRU.

- An open wind buffer of at least 50m in width should be provided along the western boundary of 2CRU, to provide a break in the mosquito harbourage and breeding habitat in the monsoon forest. The 50m open wind buffer can include roads, footpaths, drains, mown grass etc, and should have a mature tree canopy coverage of no more than 10%, similar to the Rocklands Dve open wind buffer. The potential handover authority should be determined early in the planning process, due to the maintenance requirements for such an area.

- The 1km urban residential exclusion zone, combined with an open wind/drainage buffer and rural lots indicated for Muirhead North in the Lee Point Area Plan 2 is considered an appropriate buffer. The wide drainage area should have a mature tree canopy coverage of no more than 10%, similar to the Muirhead open wind/drainage buffer. The potential handover authority should be determined early in the planning process, due to the maintenance requirements for such an area.

- All stormwater discharge drains from the subdivision would need to discharge to a free draining tidal channel or daily flushed area, which is likely to be below the 3m AHD (7m ACD) level in the receiving tidal area. Discharge drains should have concrete low flow inverts and appropriate erosion prevention measures, and should be excised as separate lots for appropriate zoning (eg Utilities) and handed over to the relevant authority for maintenance. Stormwater outfall drain design and the final end points should be discussed with Medical Entomology, PWCNT and DLPE. Where possible, the number of discharge drains from the subdivision should be minimised, to minimise disturbance to downstream areas.

- Appropriate building design should be recommended to prospective buyers, including having outward opening screen doors, insect screening around the house, elevated houses with verandas facing the prevailing breezes, and high powered outdoor fans in verandas and patios. Businesses should also consider using air curtains on front entrance doors to keep out flying insects.

- A mosquito warning note should be provided on the titles of the proposed rural lots in Muirhead North.

- Construction workers should be advised of the mosquito problem periods and appropriate personal protection measures. Salt marsh mosquito problem periods for 2016 are outlined in Appendix 5, and can be downloaded from the Medical Entomology website for subsequent years. http://www.health.nt.gov.au/medical_entomology/. Personal protection measures can be found in Appendix 3.

- Construction activities should avoid creating new mosquito breeding sites. If shallow ponding occurs on site, it should be treated with a suitable residual insecticide (methoprene 30 day pellets) until the ponding area has been rectified/developed.

6.2 Biting midges

- The 1km urban residential exclusion zone, combined with an open wind/drainage buffer and rural lots indicated for Muirhead North in the Lee Point Area Plan 2 is considered an appropriate buffer. The wide drainage area should have a mature tree canopy coverage of no more than 10%, similar to the Muirhead open wind/drainage buffer. The potential handover authority should be determined early in the planning process, due to the maintenance requirements for such an area.

- An open wind buffer of at least 50m in width should be provided along the western boundary of 2CRU, to provide a break in the biting midge harbourage and breeding habitat in the monsoon forest. The 50m open wind buffer can include roads, footpaths, drains, mown grass etc, and should have a mature tree canopy coverage of no more than 10%, similar to the Rocklands Dve open wind buffer. The potential handover authority should be determined early in the planning process, due to the maintenance requirements for such an area.

- Appropriate building design should be recommended to prospective buyers; including having outward opening doors, elevated houses with verandas facing the prevailing breezes, and high powered outdoor fans in verandas and patios. Businesses should also consider using air curtains on front entrance doors to keep out flying insects.

- A biting midge warning note should be provided on the titles of the proposed rural lots in Muirhead North.

- Construction workers should be advised of the biting midge problem periods and appropriate personal protection measures. Biting midge problem periods for 2016 are outlined in Appendix 6, and can be downloaded from the Medical Entomology website for subsequent years. http://www.health.nt.gov.au/medical_entomology/. Personal protection measures can be found in Appendix 3.

8. Bibliography

Bishop, A. & Dyce, A. (1988), 'A manual of known larval habitats of Australian *Culicoides* spp.', National Arbovirus Monitoring program *Culicoides workshop 27-29 October 1998.*

Butterworth, V (2007), 'Creating ideal biting midge habitat, the Currimundi Lake experience', Published in Mosquito Bites in the Asia Pacific Region, Volume 2, Issue 2 December 2007.

Communicable Disease Centre (CDC), Department of Health and Community Services NT Factsheet (April 2003) 'Ross River virus'.

Communicable Disease Centre (CDC), Department of Health and Community Services NT Factsheet (April 2004) 'Murray Valley encephalitis virus'.

Communicable Disease Centre (CDC), Department of Health and Community Services NT Factsheet (May 2006) 'Mosquitoes'.

Dyce, A., & Wellings, G. (1998), '*Culicoides of Australasia* (Morphology-Taxonomy-Systematics-Biogeography & Techniques). A Manual in four parts I-IV.' National Arbovirus Monitoring Program, Gosford *Culicoides* Workshop 27-29 October 1998.

Dyce. A.L., Bellis, G.A. & Muller, M.J. (2007), 'Pictorial atlas of Australian *Culicoides* wings (Diptera:Ceratopogonidae)', Australian Government, Department of the Environment and Water Resources.

'Guidelines to minimise mosquito and biting midge problems in new development areas', Queensland Health 2002, Queensland Government.

Jacups, S.P. & Whelan, P.I. (2012), 'A comparison of adult mosquito trapping regimes across seasons and ecosystems in Darwin, Australia'. *Journal of Vector Ecology* 37 (2): 284-288. 2012.

Jacups, S.P., Watchot, A. & Whelan, P.I. (2012), 'Anthropogenic ecological change and impacts on mosquito breeding and control strategies in salt-marshes, Northern Territory, Australia. *Ecohealth* 9 (2): 183-194. 2012.

Kurucz, N., S.P. Jacups, P.I. Whelan, J. Carter, and J. McDonnell (2010), 'Salt marsh mosquito larval control in Leanyer coastal wetland, Northern Territory'. Northern Territory Dis. Contr. Bull. 17: 35-39.

Kurucz, N., P.I. Whelan, J. Carter, and S.P. Jacups (2009), 'Vegetation parameters as indicators for salt marsh mosquito larval control in coastal swamps in northern Australia'. Arbovir. Res. Aust. 10: 84-90.

Lee, D. J. (1944), 'An Atlas of the Mosquito Larvae of the Australasian Region. Tribes-Megarhinini and Culicini.' Department of Zoology, University of Sydney.

Lee, D. J. & Woodhill, A. R. (1944), 'The Anopheline Mosquitoes of the Australasian Region.' Publications of the University of Sydney, Department of Zoology. Monograph No. 2.

Lee, D. J., Hicks, M. M., Griffiths, M., Russell, R. C., & Marks, E. N. (1982), 'The Culicidae of the Australasian Region Vol. 2', Commonwealth Department of Health & Commonwealth Institute of Health incorporating School of Public Health and Tropical Medicine, Monograph Series, Entomology Monograph No. 2.

Lee, D. J., Hicks, M. M., Griffiths, M., Russell, R. C., & Marks, E. N. (1984), 'The Culicidae of the Australasian Region Vol. 3', Commonwealth Department of Health & Commonwealth Institute of Health incorporating School of Public Health and Tropical Medicine, Monograph Series, Entomology Monograph No. 2.

Lee, D. J., Hicks, M. M., Griffiths, M., Debenham, M. L., Bryan, J. H., Russell, R. C., Geary, M., & Marks, E. N. (1987), 'The Culicidae of the Australasian Region Vol. 4', Commonwealth Department of Health & School of Public Health and Tropical Medicine, Monograph Series, Entomology Monograph No. 2.

Lee, D. J., Hicks, M. M., Debenham, M. L., Griffiths, M., Marks, E. N. Bryan, J. H., & Russell, R. C., (1989), 'The Culicidae of the Australasian Region Vol. 7', University of Queensland and University of Sydney in collaboration with Commonwealth Department of Community Services and Health, Monograph Series, Entomology Monograph No. 2.

Lee, D. J., Hicks, M. M., Griffiths, M., Debenham, M. L., Bryan, J. H., Russell, R. C., Geary, M., & Marks, E. N. (1988), 'The Culicidae of the Australasian Region Vol. 8', Commonwealth Department of Health & School of Public Health and Tropical Medicine, Monograph Series, Entomology Monograph No. 2.

Lee, D. J., Hicks, M. M., Griffiths, M., Debenham, M. L., Bryan, J. H. & Marks, E. N. (1988a), 'The Culicidae of the Australasian Region Vol. 9', Commonwealth Department of Health & School of Public Health and Tropical Medicine, Monograph Series, Entomology Monograph No. 2.

Liehne, P. F. in consultation with Medical Entomology Branch (1985), 'Mosquito and Biting Midge Investigations, Palmerston 1982-85', Palmerston Development Authority.

Logan, D., Kelton, W. & Whelan, P. (1991), 'Bayview Haven Canal Estate Biting Insect Investigation', Medical Entomology Branch, Department of Health and Community Services.

Marks, E.N. and Reye, E.J, (1982), 'An atlas of common Queensland mosquitoes with a guide to common Queensland biting midges', Queensland Institute of Medical Research.

Medical Entomology annual report 2013/14. Medical Entomology, NT Department of Health.

Merianos, A., Farland, A. M., Patel, M., Currie, B., Whelan, P. I., Dentith, H. & Smith, D. (1992), 'A concurrent outbreak of Barmah Forest and Ross River virus disease in Nhulunbuy, Northern Territory', *Comm Dis Intel*, vol. 16, no. 6, pp. 110-111.

Rohe, D. L. & Fall, R. R. (1979), 'A miniature battery powered CO_2 baited light trap for mosquito borne encephalitis virus surveillance', *Bull Soc Vector Research*, 4, pp. 24-27.

Russell, R. C., (1986), 'Dispersal of the arbovirus vector *Culex annulirostris* Skuse (Diptera:Culicidae) in the Murray Valley of Australia', *Gen Appl Ent*, 18.

Russell, R. C. (1987), 'Seasonal abundance, longevity and population age composition of potential malaria vectors in northern and southern Australia'. Aust. J. Zool. 35:289-306.

Russell, R. C. (1999), 'Constructed wetlands and mosquitoes: Health hazards and management options – An Australian perspective', *Ecological Engineering* 1**2** (1999) 107 – 124.

Russell, R. C. & Kay, B.H. (2004), 'Medical Entomology: changes in the spectrum of mosquito-borne disease in Australia and other vector threats and risks, 1972-2004', *Australian Journal of Entomology* (2004) 43**,** 271-282.

Russell, R. C., Currie, B.J., Lindsay, M.D.A., Mackenzie, J.S., Ritchie, S.A., Walker, J.C. and Whelan, P.I. (2007), 'Climate change and vector-borne disease in Australia: what are the real threats from malaria, dengue and endemic arboviruses', A discussion paper prepared for NAMAC.

Shivas, M., Whelan, P. I., & Webb, C. (1997), 'The characterization of emergence sites of the biting midge *Culicoides ornatus* (Diptera:Ceratopogonidae) in mangroves near Darwin, NT, Australia', in *Arbovirus Research in Australia*, vol. 7, *Proceedings of the Seventh Arbovirus Research in Australia Symposium, & Second Mosquito Control Association of Australia Conference, 1996*, pp. 275-279.

Shivas, M. (1999), 'The larval biology of *Culicoides ornatus* Taylor in mangroves near Darwin, NT.' Faculty of Science, Northern Territory University Darwin. PHD Doctor of Philosophy.

Shivas, M., and Whelan, P. I. (2001), 'Biting midge research project' (Study undertaken on behalf of Department of Lands, Planning and Environment). Territory Health Services.

Standfast, H., Fanning, I., Maloney, L., Purdie, D., and Brown, M. (2003), 'Field evaluation of Bistar 80 S.C. as an effective insecticide harbourage treatment for biting midges and mosquitoes infesting peri-domestic situations in an urban environment'. *Bulletin MCAA* vol. 15; 2, pp 19-33.

Tai, K. S., Whelan, P. I., Patel, M. S. & Currie, B. (1993), 'An outbreak of epidemic polyarthritis (Ross River virus disease) in the Northern Territory during the 1990-1991 wet season. *Medical Journal of Australia*, vol. 158, pp. 522-525.

Warchot, A. & Whelan, P.I. (2008), 'Muirhead biting insect assessment. Report for GHD Ltd of behalf of Defence Housing Australia'. Medical Entomology Section, Department of Health and Community Services 2008.

Warchot, A., Kurucz, N. & Copley, N. (2015), 'Environmental changes – a challenge for mosquito control in the Lee Point area, Darwin, Northern Territory, Australia'. *The Northern Territory Disease Control Bulletin* Vol 22, No. 4 December 2015.

Whelan, P.I. (1990), 'Urban stormwater drainage and its effect on mosquito breeding habitats in an intertidal creek at Casuarina, Darwin NT'. *Bulletin of Mosquito Control Association of Australia* Vol 2 No 1 July 1990 pp 12-28.

Whelan, P. I. (1991), 'Biting midge investigations near Darwin and their implications for urban planning', in *Proc. Nat. Conf. on Biting Midges*, Surfers Paradise, Qld, 8-9 Feb, 1990, pp. 39-50.

Whelan, P. I. (1994), 'Construction practice near tidal areas in the NT', *Bulletin of the Mosquito Control Association of Australia*, Vol. 6, No. 1, pp. 18-39.

Whelan, P. I. (1995), 'Malaria and the receptive area of the Northern Territory', Medical Entomology Branch, Department of Health and Community Services.

Whelan, P.I. (1997a), 'Problems mosquito species in the Top End of the NT – Pest and vector status, habitat and breeding sites', Medical Entomology Branch, Department of Health and Community Services.

Whelan, P.I. (1997b), 'Arbovirus disease risk periods in the Northern Territory', Medical Entomology Branch, Department of Health and Community Services.

Whelan, P. I. (2003), 'Biting midges or "sand flies" in the Northern Territory.' *Northern Territory Disease Control Bulletin* Vol. 10, No.3, pp. 1-9, September 2003.

Whelan, P.I. (2004a), 'Common mosquito species in the Top End of the NT – Their biology and disease significance', Medical Entomology Branch, Department of Health and Community Services.

Whelan, P.I. (2004b), 'Summary of the biology of selected *Culicoides* species in the Top End of the Northern Territory & Seasonal prevalence of selected *Culicoides* species in the Top End of the Northern Territory', Medical Entomology Branch, Department of Health and Community Services.

Whelan, P.I., Booth, D. and Kelton, W. (1988), 'Biting insects in the proposed Newtown (Weddell) development, Darwin', Medical Entomology Branch, Department of Health and Community Services.

Whelan, P. I. and Hayes, G.A. (1992). Arbovirus Outbreak Nhulunbuy NT 1992 - Medical Entomology Aspects. December to March 1992, Medical Entomology Branch, Department of Health and Community Services.

Whelan, P.I., & Hayes, G.A., (1993), 'Biting insect investigations Darwin South, Stage I' (Study undertaken on behalf of the Dept of Lands, Housing and Local Government), NT Dept of Health & Community Services.

Whelan, P. I., Merianos, A., Patel, M., Tai, K. S. & Currie, B. (1993), 'The epidemiology of arbovirus infection in the Northern Territory 1980-92', *Arbovirus Research in Australia*, vol. 6, *Proc. of the 6th Arbovirus Conference, 1993*.

Whelan, P. I. & Weir, R. P. (1993), 'The isolation of alpha and flavi viruses from mosquitoes in the Northern Territory 1982-1992', *Arbovirus Research in Australia*, vol. 6, *Proceedings of the 6th Arbovirus Conference, 1992*.

Whelan, P. I., Montgomery, B.L., Hayes, G.A., Nowland, R.A. & Love, B.L. (1994), 'Biting insect investigations Darwin South Stage II. Twelve month baseline study of species, abundance and distribution of biting insects in the Darwin South area', Medical Entomology Branch report.

Whelan, P. I., Hayes, G., Montgomery, B. L. (1997a), 'Biting midge surveillance in Darwin Harbour, *Culicoides ornatus* (Diptera:Ceratopogonidae) abundance and dispersal', in *Arbovirus Research in Australia*, vol. 7, *Proceedings of the Seventh Arbovirus Research in Australia, & Second Mosquito Control Association of Australia Conference, 1996*, pp. 326-336.

Whelan, P. I., Merianos, A., Hayes, G., & Krause, V. (1997b), 'Ross River virus transmission in Darwin, Northern Territory, Australia', in *Arbovirus Research in Australia*, vol. 7, *Proceedings of the Seventh Arbovirus Research in Australia Symposium, & Second Mosquito Control Association of Australia Conference, 1996*, pp. 337-345.

Whelan, P., Kurucz. K., Warchot, A., Carter, J., Pettit. W., Shortus. M., Nguyen. H., Anderson. S., Copley. N., Whitters. R. & Pearce. T. (November 2007), 'Medical Entomology Branch Annual Report 2006/07 (Draft)', Medical Entomology Branch, Department of Health and Community Services.

WHO. 2002. Report of the fifth WHOPES working group meeting: review of Olyset Net and Bifenthrin 10%WP. WHO/CDS/WHOPES/2001.4

Wirth, W., & Hubert, A. (1989), '*Culicoides* of South East Asia.' The American Entomological Institute, Florida U.S.A.

Figures

Figure 1 - General Location of Muirhead North and 2CRU and relevant adult biting insect trap sites.

Figure 2 - Muirhead biting insect assessment. Adult CO_2 biting insect trap locations, potential Culicoides ornatus breeding sites and buffers. Full moon results C. ornatus.

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Legend

Potentially significant Culicoides ornatus breeding sites

1km urban biting insect buffer

6_DEC_06
4_APR_07
3_MAY_07
29_AUG_07
28_SEP_07

C. ornatus full moon results (max value 6,400 females)

130°53'30"E
130°54'0"E
130°54'30"E

12°20'0"S
12°20'30"S
12°21'0"S
12°21'30"S
12°22'0"S

MUI 1
MUI 2
MUI 3
MUI 4
MUI 5
MUI 6
MUI 7
MUI 8
MUI 9
MUI 10
MUI 11
MUI 12
MUI 13
MUI 14

2CRU
Muirhead North

1km urban biting insect buffer

0 125 250 500 750 1,000 Meters

Figure 3 - Muirhead biting insect assessment. Adult CO_2 biting insect trap locations, buffer zones, and full moon results C. sp. nr subimmaculatus.

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Legend

1km urban biting insect buffer

Open wind buffer, minimum 500m from landward mangrove margin

6 Dec 2006
4 Apr 2007
3 May 2007
29 Aug 2007
28 Sep 2007

C. sp. nr subimmaculatus full moon results. (Max value 9,280 females)

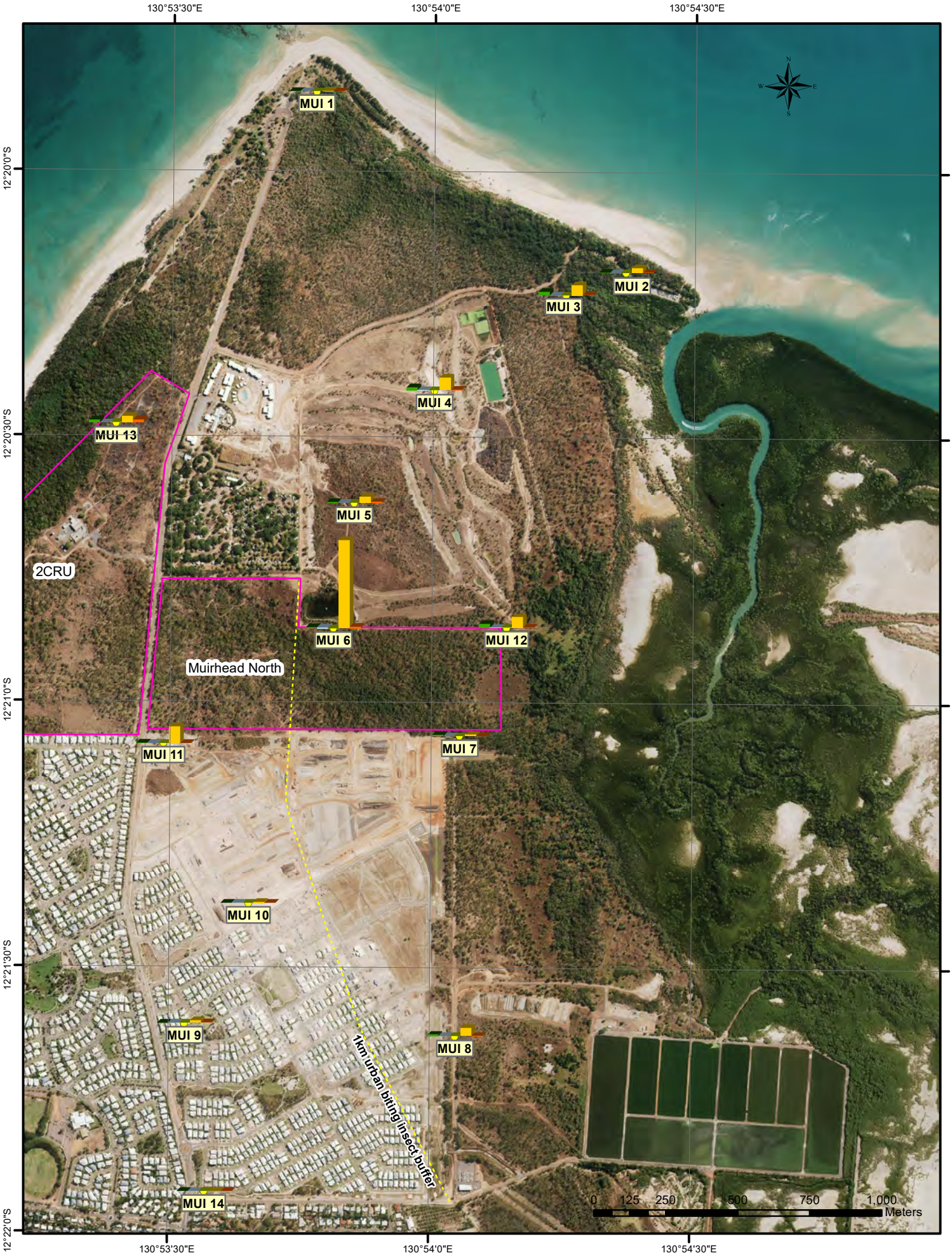

Figure 4 - Casuarina Coastal Reserve, Buffalo Creek Management area and western margin of Buffalo Creek mosquito breeding sites.

Legend

- Mosquito breeding sites
- Muirhead adult biting insect trap locations 2006-07
- Darwin routine weekly adult mosquito trap sites.
- Muirhead North and 2CRU

0 250 500 750 1,000 Meters

N W E S

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Figure 5 - Tidal swamps in the Darwin Northern Suburbs, and peak season Aedes vigilax trapping results November 2006.

Legend

Adult biting insect trap locations 14 & 18 November 2016 (Numbers denote single night Ae. vigilax trap counts.)

Muirhead North and 2CRU

0 1 2 3 4 Kilometers

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Figure 6 - Peak season Aedes vigilax trapping Darwin Northern Suburbs 29th-30th October 2012

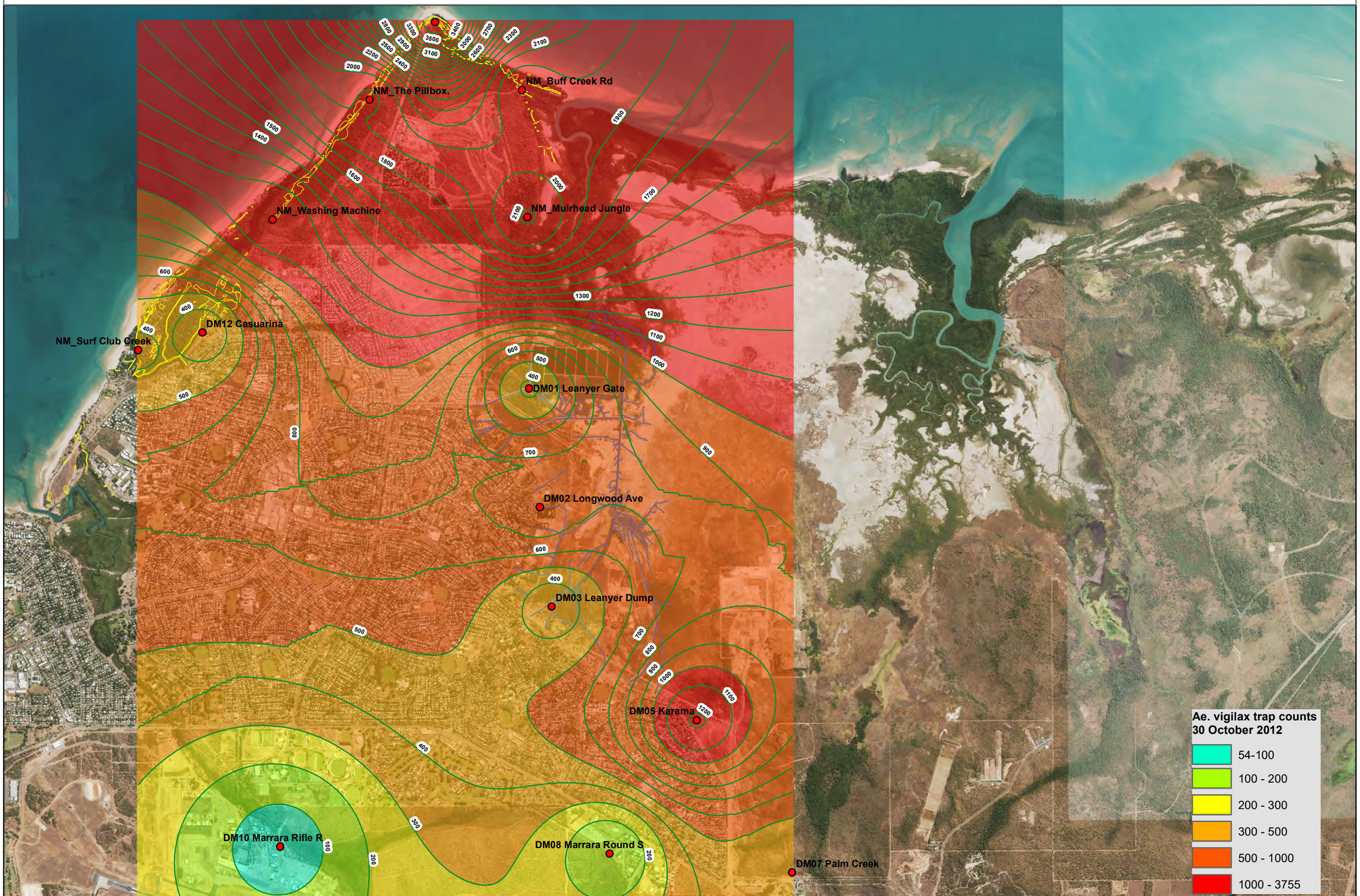

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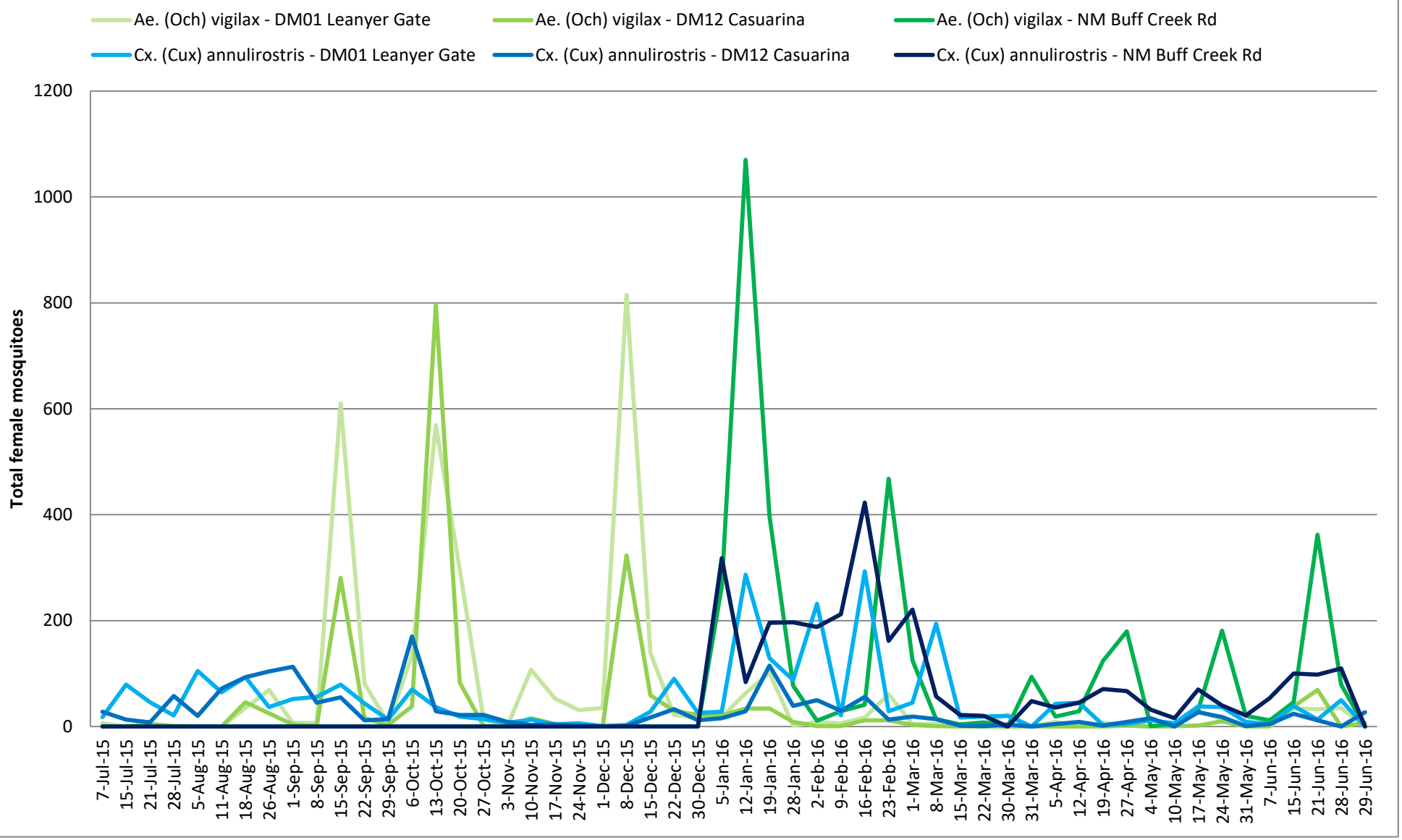
Figure 7 - Total numbers of adult *Aedes vigilax* and *Culex annulirostris* collected at the Leanyer Gate, Casuarina and Buffalo Creek road weekly CO2 baited trap sites July 2015 to June 2016.



Tables

Table 1 - Muirhead Biting Insect Assessment. Total number of adult female biting midges collected during all trapping dates at all sites.

Date collected	*C. (Ava) actoni*	*C. (Ava) obscurus*	*C. (Cla grp) clavipalpis*	*C. (Mar grp) marksi*	*C. (Mei) guttifer*	*C. (Mol grp) nr subimmaculatus (Northern Form)*	*C. (Orn grp) ornatus*	*C. (Orn grp) papuensis*	*C. (Orn grp) undescribed sp No 6*	*C. (Vic grp) bundyensis*	*C. (Vic grp) pallidothorax*	*C. (Vic grp) undescribed sp Vic 42*	*C. (Wil grp) austropalpalis*	*C. (Wil grp) narrabeenensis*	*C. (Wir) immaculatus*	*Culicoides unidentifiable*	*Lasiohelia sp.*	*Nil Biting midges*	*Not collected biting midges*	*not identified biting midges*	*Trap failure biting midges*	**Totals**	**% of total**	**No. of traps set**	**Average per trap**
18-Nov-2006 (set 4 nights before NM)	0	0	0	0	0	2527	506	0	1	0	0	0	0	0	0	20	0	0	0	0	1	3054	3.32	13	234.92
05-Dec-2006 (set night before FM)	0	0	0	9	0	3390	2017	0	45	0	0	0	0	0	1	0	0	0	0	0	2	5462	5.93	12	455.17
06-Dec-2006 (set night of FM)	0	0	0	37	0	1903	2746	0	15	0	0	0	0	0	0	13	2	0	0	0	1	4716	5.12	13	362.77
19-Dec-2006 (set 3 nights before NM)	5	0	0	5	0	3833	1535	0	26	0	0	0	0	0	0	1	0	0	1	0	1	5405	5.87	12	450.42
04-Apr-2007 (set night of FM)	17	0	16	7	1	142	4347	2	177	2	2	1	0	156	0	7	10	0	0	0	0	4887	5.31	14	349.07
03-May-2007 (set night of FM)	0	0	0	1	0	115	907	0	48	0	0	0	14	20	0	6	2	0	1	0	2	1113	1.21	11	101.18
04-May-2007	0	0	0	0	0	1	55	0	2	0	0	0	0	0	0	0	0	0	1	0	1	58	0.06	1	58.00
28-Aug-2007 (set 1 night before FM)	1	0	0	8	0	12762	7404	0	758	1	0	0	8	0	0	0	0	0	0	0	2	20942	22.74	12	1745.17
29-Aug-2007 (set night of FM)	0	2	0	6	0	17788	23965	320	1247	1	0	0	31	0	0	24	0	0	0	0	1	43384	47.10	13	3337.23
30-Aug-2007	0	0	0	0	0	112	68	0	16	0	0	0	0	0	0	0	4	0	0	0	0	200	0.22	1	200.00
28-Sep-2007 (set night of FM)	1	0	0	65	0	821	1961	0	35	0	0	0	0	0	0	3	0	0	0	0	0	2886	3.13	14	206.14
Totals	24	2	16	138	1	43394	45511	322	2370	4	2	1	53	176	1	74	18	0				92107	100.00	116	794.03
% of total	0.03	0.00	0.02	0.15	0.00	47.11	49.41	0.35	2.57	0.00	0.00	0.00	0.06	0.19	0.00	0.08	0.02	0.00				100.00			
Average per trap per trap night	0.21	0.02	0.14	1.19	0.01	374.09	392.34	2.78	20.43	0.03	0.02	0.01	0.46	1.52	0.01	0.64	0.16	0.00				794.03			

Table 2 - Muirhead Biting Insect Assessment. Total number of female biting midges collected at all trap sites during all trapping dates.

Trap location	*C. (Ava) actoni*	*C. (Ava) obscurus*	*C. (Cla grp) clavipalpis*	*C. (Mar grp) marksi*	*C. (Mei) guttifer*	*C. (Mol grp) nr subinmaculatus (Northern Form)*	*C. (Orn grp) ornatus*	*C. (Orn grp) papuensis*	*C. (Orn grp) undescribed sp No 6*	*C. (Vic grp) bundyensis*	*C. (Vic grp) pallidothorax*	*C. (Vic grp) undescribed sp Vic 42*	*C. (Wil grp) austropalpalis*	*C. (Wil grp) narrabeenensis*	*C. (Wir) immaculatus*	*Culicoides unidentifiable*	*Lasiohelia sp.*	*Nil Biting midges*	*Not collected biting midges*	*not identified biting midges*	*Trap failure biting midges*	**Totals**	**% of total**	**No. of trap nights**	**Average per trap per trap night**
MUI_1, Muirhead Site 1 Tip of Lee Point in monsoon vine forest	0	0	16	0	0	663	185	0	0	0	0	0	0	16	0	29	0	0	0	0	0	909	0.99	9	101.00
MUI_10, Muirhead Site 10 Centre of cleared area	0	0	0	0	0	242	138	0	21	0	0	0	0	7	0	14	4	0	0	0	1	426	0.46	9	47.33
MUI_11, Muirhead Site 11 northwest edge of cleared area	1	0	0	9	0	4499	4233	0	718	0	0	0	1	1	0	0	2	0	0	0	2	9464	10.28	8	1183.00
MUI_12, Muirhead Site 12 Lowlying area west of dense forest	5	0	0	37	0	2862	5461	0	91	0	0	0	0	0	0	0	5	0	0	1	2	8461	9.19	8	1057.63
MUI_13, Muirhead Site 13 Casuarina Coastal Reserve, on ridge inland of dense monsoon forest and Casuarina trees	5	0	0	8	0	3832	1517	0	494	1	0	0	30	0	0	3	4	0	0	0	0	5894	6.40	9	654.89
MUI_14, Muirhead Site 14 Near entrance to Fitzmaurice Dve	1	2	0	7	0	65	170	0	32	1	0	0	0	1	0	6	0	0	0	0	1	285	0.31	8	35.63
MUI_2, Muirhead Site 2 Buffalo creek road west of boat compound	0	0	0	0	0	1040	242	0	0	0	0	0	0	38	0	5	1	0	1	0	0	1326	1.44	8	165.75
MUI_3, Muirhead Site 3 Paperbark seepage area at mangrovve margin, near Buffalo Creek rd	0	0	0	4	0	7763	7540	0	47	0	0	0	0	0	1	0	2	0	0	0	0	15357	16.67	9	1706.33
MUI_4, Muirhead Site 4 On ridge south west of sewage ponds	0	0	0	40	0	4619	5123	0	26	0	0	0	14	5	0	0	0	0	0	0	1	9827	10.67	8	1228.38
MUI_5, Muirhead Site 5 Near east boundary of caravan park	11	0	0	15	0	2229	2801	0	276	1	1	1	0	3	0	0	0	0	0	0	1	5338	5.80	8	667.25
MUI_6, Muirhead Site 6 Top of dam wall, south side	0	0	0	0	1	13371	10618	320	363	0	1	0	0	30	0	0	0	0	2	0	0	24704	26.82	7	3529.14
MUI_7, Muirhead Site 7 Northeast boundary of Muirhead	0	0	0	0	0	651	2925	0	97	0	0	0	0	54	0	13	0	0	0	0	1	3740	4.06	8	467.50
MUI_8, Muirhead Site 8 East boundary of Muirhead, in line with Leanyer Sewage ponds	1	0	0	11	0	1089	3584	0	177	0	0	0	4	18	0	1	0	0	0	0	2	4885	5.30	8	610.63
MUI_9, Muirhead Site 9 southwest edge of cleared area	0	0	0	7	0	469	974	2	28	1	0	0	4	3	0	3	0	0	0	0	0	1491	1.62	9	165.67
Totals	24	2	16	138	1	43394	45511	322	2370	4	2	1	53	176	1	74	18	0				92107	100.00	116	794.03
% of total	0.03	0.00	0.02	0.15	0.00	47.11	49.41	0.35	2.57	0.00	0.00	0.00	0.06	0.19	0.00	0.08	0.02	0.00				100.00			
Average per trap per trap night	0.21	0.02	0.14	1.19	0.01	374.09	392.34	2.78	20.43	0.03	0.02	0.01	0.46	1.52	0.01	0.64	0.16	0.00	0.00	0.00	0.00	794.03			

Table 3 - Muirhead Biting Insect Assessment. Total number of female *Culicoides ornatus* collected during trapping at all sites.

Trap location	18-Nov-06	05-Dec-06	06-Dec-06	19-Dec-06	04-Apr-07	03-May-07	04-May-07	28-Aug-07	29-Aug-07	30-Aug-07	28-Sep-07	Totals	% of total	No. of trap nights	Average per trap per trap night
MUI_1, Muirhead Site 1 Tip of Lee Point in monsoon vine forest	6	36	3	2	73	4	0	14	11	0	36	185	0.41	9	20.56
MUI_10, Muirhead Site 10 Centre of cleared area	2	7	1	1	32	27	0	0	0	68	0	138	0.30	9	15.33
MUI_11, Muirhead Site 11 northwest edge of cleared area	7	143	40	6	900	0	0	980	2016	0	141	4233	9.30	8	529.13
MUI_12, Muirhead Site 12 Lowlying area west of dense forest	126	594	1221	0	200	0	55	364	2880	0	21	5461	12.00	8	682.63
MUI_13, Muirhead Site 13 Casuarina Coastal Reserve, on ridge inland of dense monsoon forest and Casuarina trees	4	124	28	80	168	175	0	288	480	0	170	1517	3.33	9	168.56
MUI_14, Muirhead Site 14 Near entrance to Fitzmaurice Dve	0	12	23	21	2	7	0	0	73	0	32	170	0.37	8	21.25
MUI_2, Muirhead Site 2 Buffalo creek road west of boat compound	18	17	9	0	14	3	0	16	96	0	69	242	0.53	8	30.25
MUI_3, Muirhead Site 3 Paperbark seepage area at mangrovve margin, near Buffalo Creek rd	24	546	308	420	423	71	0	980	4400	0	368	7540	16.57	9	837.78
MUI_4, Muirhead Site 4 On ridge south west of sewage ponds	27	0	450	300	368	322	0	1760	1680	0	216	5123	11.26	8	640.38
MUI_5, Muirhead Site 5 Near east boundary of caravan park	70	0	165	73	200	135	0	234	1600	0	324	2801	6.15	8	350.13
MUI_6, Muirhead Site 6 Top of dam wall, south side	48	24	0	22	1380	0	0	2520	6400	0	224	10618	23.33	7	1516.86
MUI_7, Muirhead Site 7 Northeast boundary of Muirhead	162	360	494	105	369	5	0	0	1258	0	172	2925	6.43	8	365.63
MUI_8, Muirhead Site 8 East boundary of Muirhead, in line with Leanyer Sewage ponds	0	40	0	19	184	84	0	160	2980	0	117	3584	7.88	8	448.00
MUI_9, Muirhead Site 9 southwest edge of cleared area	12	114	4	486	34	74	0	88	91	0	71	974	2.14	9	108.22
Totals	506	2017	2746	1535	4347	907	55	7404	23965	68	1961	45511	100.00	116	392.34
% of total	1.11	4.43	6.03	3.37	9.55	1.99	0.12	16.27	52.66	0.15	4.31	100.00			
No. of traps set	13	12	13	12	14	11	1	12	13	1	14	116			
Average per trap	38.92	168.08	211.23	127.92	310.50	82.45	55.00	617.00	1843.46	68.00	140.07	392.34			

Table 4 - Muirhead Biting Insect Assessment. Total number of adult female mosquitoes collected at all trap sites during all trapping dates.

Trap location	*Ad. (Adv.) catasticta*	*Ae. (Alm.) alboscutellatus*	*Ae. (Fin) kochi*	*Ae. (Fin) notoscriptus*	*Ae. (Fin) quasirubithorax s.l.*	*Ae. (Mac) tremulus*	*Ae. (Mac) alternans*	*Ae. (Neo) lineatopennis*	*Ae. (Och) vigilax*	*Ae. dalzielensis*	*An. (Ano) banceroftii*	*An. (Cel) annulipes s.l.*	*An. (Cel) kraatzi s.l.*	*An. (Cel) hilli*	*An. (Cel) meraukensis*	*Cq. (Coq.) xanthogaster*	*Cx. (Cul) pullus*	*Cx. (Cux) annulirostris*	*Cx. (Cux) pilipalpis*	*Cx. (Cux) quinquefasciatus*	*Cx. (Cux) sitiens*	*Cx. (Cux) Vishnui group*	*Cx. (Lep) atkinsoli*	*Cx. (Lep) hilli*	*Cx. (Lep) species 167*	*Ma. (Mod) uniformis*	*mosquitoes unidentifiable (damaged)*	*Nil mosquitoes*	*Tp. (Trp) magnetianus*	*Trap 8 clare mosquitoes*	*Ve. (Ver) linerea*	*Ve. (Ver) tenii*	**Totals**	**% of total**	**No. of trap nights**	**Average per trap per trap night**
MUI_1, Muirhead Site 1 Tip of Lee Point in monsoon vine fore	0	2	0	5	1	0	0	0	1309	2	29	0	15	0	0	12	2	489	0	0	1	45	0	0	2	2	0	0	0	0	8	0	1924	8.24	9	213.78
MUI_10, Muirhead Site 10 Centre of cleared area	6	0	3	0	0	0	0	0	567	0	13	0	3	11	6	9	0	254	0	1	2	0	0	0	0	0	0	0	0	1	1	0	876	3.75	9	97.33
MUI_11, Muirhead Site 11 northwest edge of cleared are	8	0	1	0	0	0	0	0	891	0	4	1	2	2	7	2	0	119	0	3	0	0	0	0	0	0	0	0	0	2	0	0	1040	4.45	8	130.00
MUI_12, Muirhead Site 12 Lowlying area west of dense fores	1	0	6	14	1	0	0	0	2758	0	25	3	0	4	2	17	0	289	0	0	0	0	0	0	0	0	0	0	0	2	11	0	3132	13.41	9	348.00
MUI_13, Muirhead Site 13 Casuarina Coastal Reserve, on ridge inland of dense monsoon forest and Casuarina tre	3	3	5	7	0	0	0	0	945	0	10	0	27	6	3	21	2	395	0	2	4	0	0	0	0	3	0	0	0	0	0	0	1436	6.15	9	159.56
MUI_14, Muirhead Site 14 Near entrance to Fitzmaurice Dv	0	0	4	24	0	1	0	1	781	0	2	0	6	5	0	7	1	100	0	9	0	0	1	0	0	0	0	0	0	1	3	0	945	4.05	8	118.13
MUI_2, Muirhead Site 2 Buffalo creek road west of boat compoun	1	1	0	1	0	0	0	0	809	5	10	0	3	1	0	4	1	291	0	0	4	13	0	0	0	0	0	0	0	0	2	0	1146	4.91	9	127.33
MUI_3, Muirhead Site 3 Paperbark seepage area at mangrovve margin, near Buffalo Creek r	0	0	3	1	0	0	0	0	1450	1	7	1	4	3	4	13	0	100	7	0	1	0	0	0	0	2	1	0	0	0	2	0	1600	6.85	9	177.78
MUI_4, Muirhead Site 4 On ridge south west of sewage pond	3	0	0	8	0	3	3	0	1449	0	14	1	16	2	3	19	0	256	0	1	3	1	0	0	0	0	0	0	0	1	0	0	1782	7.63	8	222.75
MUI_5, Muirhead Site 5 Near east boundary of caravan park	1	1	4	4	0	5	0	0	1400	1	10	1	23	3	13	14	0	218	0	1	0	1	0	4	4	0	0	0	0	1	10	2	1720	7.37	8	215.00
MUI_6, Muirhead Site 6 Top of dam wall, south sic	14	0	10	1	0	0	0	0	532	0	17	3	17	9	6	12	0	141	0	1	3	0	0	0	0	2	0	0	0	2	0	0	768	3.29	8	96.00
MUI_7, Muirhead Site 7 Northeast boundary of Muirhea	0	0	2	3	0	0	0	0	1183	0	30	1	30	0	2	35	2	596	0	0	3	6	1	0	0	0	0	0	1	1	7	2	1904	8.15	8	238.00
MUI_8, Muirhead Site 8 East boundary of Muirhead, in line with Leanyer Sewage pon	0	0	22	2	0	0	0	0	1987	0	22	2	17	32	3	14	2	616	0	7	1	0	0	0	0	1	0	0	0	1	2	0	2730	11.69	8	341.25
MUI_9, Muirhead Site 9 southwest edge of cleared area	2	0	1	11	0	0	0	0	1705	0	87	0	50	27	10	12	2	427	7	3	0	1	1	0	0	3	0	0	0	0	1	0	2350	10.06	9	261.11
Totals	39	7	61	81	2	9	3	1	17767	9	280	13	213	105	59	191	12	4291	14	28	22	67	3	4	6	13	1	0	1	4	47	4	23353	100.00	119	196.24
% of total	0.17	0.03	0.26	0.35	0.01	0.04	0.01	0.00	76.08	0.04	1.20	0.06	0.91	0.45	0.25	0.82	0.05	18.37	0.06	0.12	0.09	0.29	0.01	0.02	0.03	0.06	0.00	0.00	0.00	0.02	0.20	0.02	100.00			
Average per trap per trap night	0.33	0.06	0.51	0.68	0.02	0.08	0.03	0.01	149.30	0.08	2.35	0.11	1.79	0.88	0.50	1.61	0.10	36.06	0.12	0.24	0.18	0.56	0.03	0.03	0.05	0.11	0.01	0.00	0.01	0.03	0.39	0.03	196.24			

Table 5 - Muirhead Biting Insect Assessment. Total number of adult female mosquitoes collected during all trap nights at all trapping sites

Date collected	*Ad. (Ady) catasticta*	*Ae. (Adm) alboscutellatus*	*Ae. (Fin) kochi*	*Ae. (Fin) notoscriptus*	*Ae. (Fin) quasirubithorax s.l.*	*Ae. (Mac) species*	*Ae. (Mac) tremulus*	*Ae. (Muc) alternans*	*Ae. (Neo) lineatopennis*	*Ae. (Och) vigilax*	*Ae. daliensis*	*An. (Ano) bancroftii*	*An. (Cel) annulipes s.l.*	*An. (Cel) farauti s.l.*	*An. (Cel) hilli*	*An. (Cel) meraukensis*	*Cq. (Coq) xanthogaster*	*Cx. (Cui) pullus*	*Cx. (Cux) annulirostris*	*Cx. (Cux) palpalis*	*Cx. (Cux) quinquefasciatus*	*Cx. (Cux) sitiens*	*Cx. (Cux) Vishnui group*	*Cx. (Lop) cubiculi*	*Cx. (Lop) hilli*	*Cx. (Lop) species 167*	*Ma. (Mnd) uniformis*	*mosquitoes unidentifiable (damaged)*	*Nil mosquitoes*	*Tp. (Trp) magnesianus*	*Trap failure mosquitoes*	*Ve. (Ver) funerea*	*Ve. (Ver) reesi*	**Totals**	**% of total**	**No. of traps collected**	**Average per trap**
18-Nov-2006 (11 days after monthy high tide)	0	0	0	13	0	0	0	0	0	6750	0	0	0	0	0	0	5	0	204	0	0	0	0	0	4	4	0	0	0	0	0	18	2	7000	29.97	14	500.00
05-Dec-2006	0	0	1	0	0	0	0	0	0	60	0	0	0	0	1	0	1	0	68	0	2	0	0	0	0	0	0	0	0	0	2	0	0	133	0.57	12	11.08
06-Dec-2006	1	0	0	1	0	0	5	0	0	74	2	0	0	0	1	0	0	0	76	0	1	3	0	0	0	0	0	0	0	0	1	0	0	164	0.70	13	12.62
19-Dec-2006 (12 days after monthly high tide)	0	0	0	19	0	0	3	0	0	3646	0	0	0	0	12	0	31	0	60	14	1	1	0	0	0	2	0	0	0	0	1	13	0	3802	16.28	13	292.46
20-Dec-2006	0	0	0	9	0	0	0	0	0	979	0	0	0	0	0	0	9	0	18	0	0	0	0	0	0	0	0	0	0	0	0	9	0	1024	4.38	1	1024.00
04-Apr-2007	2	6	57	35	2	0	0	3	0	1012	0	152	0	68	6	34	96	12	841	0	1	5	66	3	0	0	8	0	0	1	0	7	2	2419	10.36	14	172.79
03-May-2007 (13 days after April monthly high	1	1	3	0	0	0	0	0	1	4267	0	92	0	136	20	23	7	0	1911	0	0	6	0	0	0	0	5	0	0	0	3	0	0	6473	27.72	11	588.45
04-May-2007	0	0	0	2	0	0	0	0	0	547	0	21	0	0	2	2	5	0	160	0	0	0	0	0	0	0	0	0	0	0	2	0	0	739	3.16	1	739.00
28-Aug-2007	22	0	0	0	0	0	1	0	0	189	1	1	4	4	20	0	12	0	324	0	4	2	1	0	0	0	0	1	0	0	2	0	0	586	2.51	12	48.83
29-Aug-2007	9	0	0	1	0	0	0	0	0	196	6	14	9	5	40	0	22	0	431	0	18	3	0	0	0	0	0	0	0	0	1	0	0	754	3.23	13	58.00
30-Aug-2007	4	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0.06	1	14.00
28-Sep-2007	0	0	0	1	0	0	0	0	0	44	0	0	0	0	3	0	3	0	191	0	1	2	0	0	0	0	0	0	0	0	0	0	0	245	1.05	14	17.50
Totals	39	7	61	81	2	0	9	3	1	17767	9	280	13	213	105	59	191	12	4291	14	28	22	67	3	4	6	13	1	0	1		47	4	23353	100.00	119	196.24
% of total	0.17	0.03	0.26	0.35	0.01	0.00	0.04	0.01	0.00	76.08	0.04	1.20	0.06	0.91	0.45	0.25	0.82	0.05	18.37	0.06	0.12	0.09	0.29	0.01	0.02	0.03	0.06	0.00	0.00	0.00		0.20	0.02	100.00			
Average per trap per trap night	0.33	0.06	0.51	0.68	0.02	0.00	0.08	0.03	0.01	149.30	0.08	2.35	0.11	1.79	0.88	0.50	1.61	0.10	36.06	0.12	0.24	0.18	0.56	0.03	0.03	0.05	0.11	0.01	0.00	0.01	0.00	0.39	0.03	196.24			

Table 6 - Muirhead Biting Insect Assessment. Total number of female *Aedes vigilax* collected during trapping at all sites.

Trap location	18-Nov-06	5-Dec-06	6-Dec-06	19-Dec-06	20-Dec-06	4-Apr-07	3-May-07	4-May-07	28-Aug-07	29-Aug-07	30-Aug-07	28-Sep-07	Totals	%	No. of trap nights	Average per trap per trap night
MUI_1, Muirhead Site 1 Tip of Lee Point in monsoon vine fores	368	1	1	431	0	113	376	0	13	3	0	3	1309	7.37	9	145.44
MUI_10, Muirhead Site 10 Centre of cleared area	87	0	0	126	0	115	233	0	3	0	3	0	567	3.19	9	63.00
MUI_11, Muirhead Site 11 northwest edge of cleared area	618	0	4	198	0	35	0	0	15	18	0	3	891	5.01	8	111.38
MUI_12, Muirhead Site 12 Lowlying area west of dense fores	1139	5	22	0	979	22	0	547	10	28	0	7	2759	15.53	9	306.56
MUI_13, Muirhead Site 13 Casuarina Coastal Reserve, on ridge inland of dense monsoon forest and Casuarina trees	67	1	1	394	0	88	376	0	8	6	0	4	945	5.32	9	105.00
MUI_14, Muirhead Site 14 Near entrance to Fitzmaurice Dv	474	1	0	127	0	3	167	0	0	9	0	0	781	4.40	8	97.63
MUI_2, Muirhead Site 2 Buffalo creek road west of boat compound	151	5	0	106	0	0	503	0	15	20	0	9	809	4.55	9	89.89
MUI_3, Muirhead Site 3 Paperbark seepage area at mangrovve margin, near Buffalo Creek rd	148	25	11	682	0	68	475	0	15	26	0	0	1450	8.16	9	161.11
MUI_4, Muirhead Site 4 On ridge south west of sewage ponds	421	0	7	187	0	129	671	0	21	10	0	3	1449	8.16	8	181.13
MUI_5, Muirhead Site 5 Near east boundary of caravan parl	636	0	8	431	0	85	207	0	23	6	0	4	1400	7.88	8	175.00
MUI_6, Muirhead Site 6 Top of dam wall, south side	305	8	5	34	0	101	0	0	52	23	0	4	532	2.99	8	66.50
MUI_7, Muirhead Site 7 Northeast boundary of Muirhead	348	13	14	480	0	13	301	0	0	12	0	2	1183	6.66	8	147.88
MUI_8, Muirhead Site 8 East boundary of Muirhead, in line with Leanyer Sewage ponds	1358	1	0	182	0	151	254	0	9	27	0	5	1987	11.18	8	248.38
MUI_9, Muirhead Site 9 southwest edge of cleared area	630	0	1	268	0	89	704	0	5	8	0	0	1705	9.60	9	189.44
Totals	6750	60	74	3646	979	1012	4267	547	189	196	3	44	17767	100.00	119	149.30
% of total	37.99	0.34	0.42	20.52	5.51	5.70	24.02	3.08	1.06	1.10	0.02	0.25	100.00			
No. of traps collected	14	12	13	13	1	14	11	1	12	13	1	14	119			
Average per trap per trap night	482.14	5.00	5.69	280.46	979.00	72.29	387.91	547.00	15.75	15.08	3.00	3.14	149.30			

Appendix 1 – Guidelines for preventing biting insect problems for new urban residential developments or subdivisions in the Top End of the NT.

Northern Territory Government

DEPARTMENT OF HEALTH

Guidelines for Preventing Biting Insect Problems for Urban Residential Developments or Subdivisions in the Top End of the NT

Medical Entomology
Centre for Disease Control
Department of Health
Northern Territory Government
Darwin NT

April 1997
Updated August 2014

Guidelines for Preventing Biting Insect Problems for Urban Residential Developments and Subdivisions in the Top End of the NT

Medical Entomology, Centre for Disease Control

NT Department of Health August 2014

1. Minimal Requirements

A complete plan of the development and drainage provisions, together with a contour map showing the Q100 line and/or seepage areas and maximum tidal limit is the minimal requirement for informed comment to planning applications. Contour intervals of 1m between maximum tide limit and 5m above maximum tide limit are required near tidal areas and at least 2m contours are required for other areas, particularly around wetlands and seepage areas.

All of each urban residential block must be above the Q100, seepage line, or maximum tide limit.

2. Buffer Zones

There should be a buffer zone between urban residential development and significant and uncontrolled sources of biting insects.

There should be no urban residential development within 1.6km of large uncontrolled areas of mosquito and biting midge breeding sites, unless specific medical entomology investigations are carried out and these investigations reveal urban residential development is suitable. The major potential mosquito breeding areas are tidally influenced and seasonally inundated brackish reed swamps or flood plains, and relatively large areas of mangroves that are only flooded by the highest tides of the year. The major biting midge breeding sites are relatively large areas of dendritic mangroves.

Wherever practical, a semi-rural or rural subdivision or industrial buffer should be incorporated into a residential subdivision design to increase the effectiveness of a mosquito or biting midge buffer zone, where these are required. Incorporating a rural residential or industrial buffer between major sources of biting insects and the urban component of a subdivision will generally allow the 1.6km urban residential buffer to be relaxed down to 1km.

As a general guide, lot sizes for those rural blocks located entirely within 300m of the landward margin of significant mosquito breeding sites or the landward

mangrove margin of major biting midge breeding areas are recommended to be 2ha or greater. Rural lots within 300-500m of these areas are recommended to be 1ha or greater, while rural lots located further than 500m from these areas are recommended to be 0.4ha or greater. Industrial buffers should incorporate the largest lots closest to the biting insect breeding areas. There should be a minimum 20m access buffer between the landward mangrove margin or wet season flooded/seepage area and the edge of all residential or industrial lots.

There should be no residential development within 1.6km of actual or planned soil, sand or gravel mining operations or mining leases unless such areas have been rehabilitated to the stage where they are not potential mosquito breeding sites.

There should be no urban development within 1.6km of sewage treatment plants and sites of effluent disposal, unless the facilities have been appropriately designed and constructed and have documented management plans to ensure they are not likely to be potential sources of mosquitoes.

3. Drains

Background

Stormwater drains and their discharge sites were the main cause of historic mosquito breeding issues in Darwin Urban, and have created mosquito breeding sites in all other towns in the NT. The main mosquito species that breed in poorly designed or maintained stormwater drains include the common banded mosquito *Culex annulirostris,* a known vector of Ross River virus (RRV), Barmah Forest virus (BFV), Murray Valley encephalitis virus (MVEV) and Kunjin virus (KUNV), and the brown house mosquito *Culex quinquefasciatus.* Drains subject to tide ponding can be productive breeding sites for the northern salt marsh mosquito *Aedes vigilax,* a known vector of RRV and BFV, and a serious pest mosquito.

Dry season low flows are the major contributor to creating mosquito breeding problems within drains, and at drain end points. Wet season low flow or seepage can also cause ponding issues, generally in areas downstream of the drain discharge site that are seasonally waterlogged and not free draining. Drains likely to receive low flows are those with large catchments eg outfall drains from urban subdivisions, and catchments that include schools, shops, sports ovals, parks, industrial and commercial areas, or areas of lawns and automatic watering systems. Subdivisions with sprinkler irrigated grassed verges alongside footpaths and roads can also have dry season low flow issues.

The discharging of urban stormwater drains to the natural surface is not recommended in any circumstance where there is likely to be dry season low flows in the drain, or if downstream areas are not completely free draining. The continual flow of water could promote long term surface water ponding and potential mosquito breeding in low lying areas downstream of the drain end point. Any dry season flows would allow water ponding to continue well into the dry season.

Roadside stormwater entry pits in piped stormwater drain systems can be mosquito breeding sites during the dry season, when irrigation and other water runoff flows into the pit. Mosquito species found breeding in side entry pits (SEP) in the NT include *Aedes notoscriptus,* a potential vector of RRV and BFV, and the brown house mosquito *Cx. quinquefasciatus.* Stormwater pits that are designed to pond water may also act as potential subterranean breeding sites for exotic dengue mosquitoes (*Aedes aegypti* and *Aedes albopictus*).

Plate 1 Dry season ponding and weed growth in stormwater drain, Marlows Lagoon. Drain completely overgrown with weeds due to the absence of a concrete low flow invert.

Plate 2. Dry season stagnant ponding in mangroves at drain end point, Sandy Creek, Tiwi. Waterlilies in mangroves, changed ecology due to un-seasonal freshwater flows.

Plate 3 Drain end point Royal Darwin Hospital, Tiwi. Dry season (August) low flow ponding.

Plate 4 Roadside side entry pit (SEP) in Nightcliff, dry season stagnant water ponding and mosquito breeding

Design criteria

An approved standard for drains is required for all urban residential development, which includes particular attention to the design and construction of the drains and the suitable location of the end points of such drains to prevent mosquito breeding. It is a requirement of the Public Health (General sanitation, Mosquito Prevention and Rat Exclusion) Regulations that stormwater drains do not become mosquito breeding sites.

Concrete sub soil drains, or open drains with concrete low flow capabilities are required for all urban residential drains and drains from urban facilities that are likely to have dry season low flows. These drains must be conveyed to a suitable end point that will not become a mosquito breeding site. Suitable end points are usually large rivers or daily flushed tidal areas. Guidelines on storm drains are attached as Appendix 1.

Sub-soil drainage systems must be entirely free draining. i.e. the invert of all stormwater pits (eg side entry pits, grate pits, letterbox pits etc) must be level with the invert of the outlet pipe. Structures such as Gross Pollutant Traps must not pond water or lead to impeded flow in the sub-soil pipe system.

Stormwater drain end points at the mangrove margin can pose several issues. Where possible, drain end points should be directed to a free draining mangrove area, which would usually be a small free draining tidal tributary. The upper tidal fringe at the headwaters of a tidal creek is usually unsuitable for stormwater drain discharge, as it is usually a poorly draining area. Where stormwater can not be discharged to a free draining tidal tributary, an unlined channel of suitable dimensions to convey low flows may need to be constructed from the mangrove margin to a free draining tidal area, usually at the 7m ACD level but subject to site investigations. Appropriate erosion control requirements must be adhered to when constructing drainage channels in tidal areas, as well as potential acid sulphate soil management. These requirements should be discussed with the relevant NT Government departments.

Stormwater drains across jurisdictional boundaries

Stormwater drains may be required to cross adjacent properties to reach a satisfactory end point such as a daily flushed tidal area or river. Urban stormwater drains must not terminate at the development boundary. When stormwater drains are required to pass through neighbouring properties, the relevant landholder should be consulted and a drainage easement declared on the neighbouring property, to allow the owner or manager of the stormwater drain to conduct annual maintenance.

There may be cross-jurisdictional requirements when constructing major drains from the edge of a subdivision to a suitable end point. Early in the planning process, the owners of the entire drainage system should be determined, and the relevant guidelines and requirements for each jurisdiction should be adhered to.

In terms of meeting the requirement of the Public and Environmental Health Act 2012 and associated regulations, the final drain design needs to prevent

mosquito breeding along its entire length, and at the discharge point. A suitable dry weather access easement along the entire length of the drain should also be installed, to allow routine maintenance and temporary insecticide control of mosquitoes when necessary.

4. Water features (dams, ponds, retention basins, detention basins, wetlands and bioretention basins)

Dams, ponds, retention basins or other constructed water features within or adjacent to an urban development should be constructed with steep sides (45° or greater) and be relatively deep (1.8m) to prevent the establishment of marginal semi-aquatic vegetation that promotes mosquito breeding. Management procedures for wetlands or water features should be in place to monitor and control mosquito breeding. This can include stocking ponds with native fish such as the delicate blue eye or black lined rainbow fish, and mechanical or herbicide methods to reduce marginal vegetation.

If constructed wetlands are planned, they would need to be constructed in accordance to the Medical Entomology guideline 'Constructed Wetlands in the Northern Territory - Guidelines for preventing Mosquito Breeding'.

Detention basins should be constructed as 'dry' basins, with the basin designed to completely drain within at least 5 days of initial water ponding. Detention basins are not recommended in or adjacent to tidal areas, as they will have a high potential to breed mosquitoes. Detention basins require a concrete low flow invert or low flow pipe from the inlet point into the basin, and through the basin to the outlet pit/culvert, to prevent low flow ponding within the basin. The outlet drain from the basin needs to have impervious low flow provisions to a suitable end point.

Bioretention basins are designed with the concept of short term ponding after the rain event (ie several hours). Appropriate design is required in the monsoon areas of the NT, to cater for the large amount of rainfall and groundwater that is likely to flow into the basin. Dry weather flows would also need to be catered for in catchments where dry season flows may occur.

Access provisions should be provided for all water features within or adjacent to a residential development, to allow machinery access to conduct routine maintenance such as desilting, or weed or mosquito management. Overflow provisions are required for all water features, with an appropriate end point with erosion prevention structures constructed at the overflow/discharge point. Water treatment and containment features need to have an annual inspection and maintenance program conducted by the relevant authority to prevent mosquito breeding.

5. Easements

Any open stormwater drain in and adjacent to a residential area should have a drainage easement to allow periodic maintenance of such drains, and be included in a register for maintenance and possible future upgrading when required by the relevant authority.

Drainage reserves or easements should be declared over permanent and semi-permanent swamps, lagoons, creek lines, or other wet season inundated areas within or adjacent to the development.

Drainage easements should be declared between water features that will be connected during the wet season, to prevent the impedance of water along natural flow lines within or adjacent to the development.

Any subdivision bordering freshwater swamp lagoons and other wetlands, waterways and tidal or tidally affected areas should maintain a 40m easement between residential boundaries and the Q100 or highest tide levels so that access is possible for the management of such areas and to minimise disturbance that would create new mosquito sites.

6. Site Planning

The natural flow of surface water must not be impeded by site development (eg. construction of access roads). Access roads may need to be fitted with culverts of sufficient size to prevent upstream flooding for periods that will enable mosquito breeding.

Any existing artificial depressions within the proposed development, or within 1km of the development boundary, that is capable of holding water for a period greater than 5 days must be rectified by filling or rendered free draining.

Any areas of intensive irrigation (eg. horticulture, landscaped areas, playing field or open spaces) within subdivisions or adjacent to the subdivisions must not create areas where water can pool for a period greater than 5 days.

7. Erosion and Sediment control

Temporary erosion and sediment control

Urban subdivisions require erosion and sediment control during the construction phase, as the clearing of vegetation increases the susceptibility of the development area to erosion, and construction of stormwater drains and roads leads to changed runoff regimes. Sediment control is required to prevent the siltation of natural drainage lines, flow paths, existing or new open drains (including end points) and underground stormwater systems, which can lead to

impeded drainage and mosquito breeding. Best practice erosion and sediment control advice should be sought from the Department of Resources and Land Management.

Although most temporary sediment control structures are removed when development has been completed, they can be short term mosquito breeding sites. Where possible, all sediment control devices should be designed to completely drain within 5 days to reduce the requirements for mosquito management. Adjacent to tidal areas, water retention should not exceed 3 consecutive days. This is required to prevent mosquito larvae from completing their larval stages.

There may be instances when temporary sediment control structures (eg. silt traps) cannot be designed to drain freely within the specified time to prevent mosquito breeding, due to the effect on sediment control performance or specific site levels. For development sites away from tidal areas, mosquito breeding can be prevented by constructing sediment control structures with steep sides (2:1 slope), with a sloping floor towards the downstream side of the sediment control structure, and appropriate erosion control structures constructed at the overflow/discharge point. Deep water ponding is recommended (1.8m wet season stabilised level), to allow wave action and minimise the growth of semi-aquatic reeds and grasses. Regular inspections are required to ensure the sediment control structure remains free of vegetation that can encourage mosquito breeding. Water retention adjacent to tidal areas should be avoided, otherwise weekly surveys by the developer will be required to monitor and control mosquito breeding. Temporary sediment control devices need to be appropriately removed and rehabilitated when no longer required.

Permanent erosion control structures

Permanent erosion prevention structures should also be provided where appropriate, to prevent erosion and siltation of downstream water features that will promote the creation of mosquito breeding sites. Best practice erosion and sediment control advice should be sought from the Department of Resources and Land Management.

8. Drain Maintenance

There should be no vegetation, cut off pools or silt deposits in drains. Drain maintenance such as silt removal, herbiciding or vegetation and debris removal for earth lined drains should be programmed on an annual basis. Maintenance easements should be included alongside all open earth lined drains. Drains that discharge into dams or lakes will require periodic silt removal at the discharge point into the water body to prevent the establishment of aquatic and semi aquatic vegetation.

When constructing stormwater drains, consideration should be given to the long term costs of maintaining the drain. Whilst drains with concrete low flow inverts incur a greater construction cost, the long term maintenance of drains with concrete low flow inverts is likely to be cheaper compared to unlined drains.

Plate 6 – Unlined and low flow concrete lined major drain. The upstream concrete lined section can be simply maintained with a backhoe. The downstream unlined section is waterlogged throughout the year, weed infested and would be more expensive to maintain.

9. Septic Tanks, Sewage Treatment and Dispersal

The NT Department of Health has certain requirements for the positioning, installation and maintenance of septic tanks, rainwater tanks and the reuse of sewage effluent.

Any septic tank and absorption trench should be sited on the area above the Q100 and not within 40m of the maximum tide limit. Septic tanks must be of an approved design and be completely screened to prevent mosquito entry. All septic tanks approved within urban areas should be entered on a registry for periodic inspection.

All rainwater tanks must be of an approved design and be completely screened to prevent mosquito entry. All approvals for rainwater tanks should be entered on a registry so that periodic inspections can be carried out.

Guidelines on the requirements for the treatment, storage and disposal of sewage effluent in regards to preventing mosquito breeding are attached as Appendix 2.

Approval for wastewater systems should be obtained from the Environmental Health Division of the NT Department of Health.

10. General Information

Advice on potential biting insect problems for residential development should be sought from the DoH at the initial subdivision application stage.

Detailed comments on areas for urban development should be sought at the detailed design stage and at least 12 months before the construction stage.

Medical Entomology is available for advice on what may constitute a potentially significant biting insect breeding site. In some instances a desktop analysis of the plans and topographic information may be sufficient to ascertain the necessary information for recommendations on a specific site, but in other instances brief site inspections or longer term studies may be necessary. In some instances where detailed entomological investigations are necessary, up to 12 months entomological monitoring may be required to gather sufficient information before the detailed planning stage, particularly in areas near potential biting insect sources or if reduction in the recommended buffer distance is sought.

Relevant documents on the various aspects regarding mosquito or biting midges are available from:-

Medical Entomology,

Department of Health

PO Box 40596

Casuarina NT 0811

Phone: (08) 8922 8901

Appendix 1

GUIDELINES ON URBAN MOSQUITO CONTROL DRAINS

Medical Entomology

NT Department of Health

1. Drains for mosquito control only need to be of dimensions that will drain an actual or potential flooded mosquito breeding site over a period of days, ie. the drain should be as small as possible to achieve the desired aim.

2. Drainage times for flooded areas that come under tidal influence at any time of the year should be three (3) days, while all freshwater areas should drain within five (5) days. If a drain overflows its banks during periods of high tides or heavy rainfall, the overflow water should drain back into the drain within the above times. When drains are constructed in low lying or level areas, any berm of spoil should have regular breaks to allow lateral drainage into the drain such that no pooling occurs outside the drain. In other situations the berm should be placed on the downhill side of the drain to prevent ponding uphill of the berm.

3. End points for drains that have a potential to breed mosquitoes should be such that the drains discharge directly into daily flushed tidal areas, to a formalised channel or creek that drains directly into a daily flushed tidal area, or a large body of water, without flowing through or into any low lying areas of restricted flow.

4. The ultimate standards for urban drains are impervious underground pipes or open lined channels with central concrete low flow inverts. Central impervious low flow capabilities are essential where there is a likelihood of dry season low flows in a particular drain. Concrete low flow inverts should be at least 1000mm in width, to reduce maintenance requirements caused by edge vegetation obstructing the invert.

5. Earth sided drains that do not have dry season low flows should be formalised, straight, smooth, have broad U shaped inverts where practical and flow direct to suitable end points. Maintenance easements should be included alongside all open earth lined drains.

6. The end point for 100 year flood drains without dry season low flows that flow into tidal areas should be constructed to just below the maximum high tide level or to the fringe of the mangroves, whichever is lower.

7. There should be no vegetation, cut off pools or silt deposits in drains. Drain maintenance such as silt removal, weediciding or vegetation and debris removal for earth lined drains should be programmed on an annual basis. Drains that discharge into dams or lakes will require periodic silt removal at the discharge point into the water body to prevent the establishment of aquatic and semi aquatic vegetation.

8. The invert of the end point of drains that require concrete inverts or have dry season low flows should be below the average high tide level or to a natural well defined tidal creek. A channel could be dug back from a tidal creek to satisfy this requirement.

9. Open earth lined drains should have erosion prevention drop structures of stone and mesh gabions installed wherever there is a likelihood of erosion within the drain.

10. Silt traps should be constructed in major drains from urban or industrial development areas before the drains enter freshwater or tidal creek lines. This is considered necessary before a new area is developed, particularly if the constructed drainage discharges into relatively wide level areas or to a creek or other water body. Any silt trap should have access for regular maintenance and silt removal.

11. Any land clearing operation should include the rectification of small depressions, particularly in low lying areas or near creek lines, such that no pooling will remain for more than five (5) days after flooding or rain. In or adjacent to tidal areas, disturbed areas should be rectified such that no pooling will remain for more than three (3) days after high tides or rain.

Appendix 2

MOSQUITO BREEDING AND SEWAGE POND TREATMENT IN THE NORTHERN TERRITORY

SUMMARY

The majority of effluent treatment in the NT occurs in sewage pond facilities. These sewage treatment facilities can be major sources of pest and vector mosquitoes near urban centres in the Northern Territory. Mosquito breeding is usually associated with inadequate design, operation, maintenance and final effluent disposal practices. This paper outlines the potential problems, gives some examples from previous or present treatment installations and suggests design and operational practices that can reduce mosquito breeding.

INTRODUCTION

Sewage and treated sewage effluent have been major artificial sources of mosquitoes near urban areas in the Northern Territory (Whelan, 1981, 1984, 1988). Nutrient rich sewage has the capacity to produce enormous numbers of mosquitoes, and as treatment facilities are relatively close to communities, they usually give rise to large and continuous problems from pest and vector mosquitoes.

Mosquito breeding is usually associated with inadequate design, operation and maintenance or faulty methods of effluent disposal or dispersal. Some of these practices can be relatively easily rectified, but there is a need for increased awareness of the nature of potential breeding places among planners, designers and operators of sewage treatment facilities.

The object of this paper is to emphasise the need for awareness of potential mosquito breeding in sewage facilities, and to outline some design considerations and operational practices that can reduce mosquito breeding.

MOSQUITO SPECIES

***Culex gelidus*:** 'The frosty mosquito'. This previously exotic mosquito species was first recorded in the NT sometime around 1996 (Whelan et al 2001), and has been in Australian since at least 1994 (Johnson et al 2006). It has been found breeding in high concentrations in primary, secondary and evaporation waste water ponds in the Top End of the NT, and in other high nutrient water bodies. This species also utilises many other habitats such as stormwater drains, artificial receptacles, septic tanks, and freshwater swamps with emergent vegetation (Johnson et al 2006).

Culex gelidus is a primary vector of Japanese encephalitis virus (JEV) in many parts of Asia (Williams et al 2005), and its introduction into Australia has been a concern. Recent testing of the vector competence of this species indicates it is highly susceptible to Murray Valley encephalitis virus, Kunjin virus and Ross River virus infection, indicating this species poses a potentially significant public health concern (Johnson et al 2006).

Culex quinquefasciatus: 'The brown house mosquito'. This species usually breeds in organically polluted water near human communities. It is frequently found breeding in high numbers in unsealed septic tanks and primary sewage ponds, although it will sometimes be found in organically overloaded secondary sewage ponds.

This is a very important pest species wherever favourable breeding sites exist. The females rarely travel more than two kilometres from their breeding sites. Due to the nature of the breeding sites, this species can be present throughout the year. *Culex quinquefasciatus* is a potential vector of arboviruses including West Nile virus, and is a possible vector of heartworm in dogs.

Culex annulirostris: 'The common banded mosquito', is the most common mosquito in the Northern Territory. It breeds in a variety of natural sites and is commonly found in open, shallow, vegetated freshwater swamps, streams and lagoons.

The most prolific artificial breeding places are in secondary sewage treatment and evaporation ponds and sewage pond effluent (Whelan, 1984, 1988). The larvae are most frequently found in still, sheltered areas where vegetation offers protection from disruptive wave action and aquatic predators.

This species can disperse up to 10 kilometres from the breeding area (Russell, 1986). It is abundant in the 'Top End' of the Northern Territory from January to August and in the southern region from October to April.

Culex annulirostris is the most numerous and common pest species in the Northern Territory, and is an important vector of a number of arboviruses (Russell, 2009). The most important disease carried by this species is the potentially fatal Murray Valley encephalitis. There have been confirmed cases of Murray Valley encephalitis in the Northern Territory, at an average of around one (1) case per year, and Murray Valley encephalitis virus (MVEV) is considered endemic to the Top End of the NT as far south as Tennant Creek (Kurucz et al 2005). *Culex annulirostris* also a vector of Kunjin virus (KUNV) disease, Ross River virus (RRV) disease and Barmah Forest virus (BFV) disease. Ross River virus disease is the most common and widespread mosquito borne disease in the Northern Territory. The most effective long term protection from these viruses lies in eliminating the breeding sites within flight range of urban areas.

Anopheles annulipes s.l.: 'The freshwater malaria mosquito' breeds in open, sunlit, temporary and permanent freshwater ground pools, streams or swamps. It is very rarely found in sewage ponds but it is frequently found in the lower organically loaded sewage effluent, particularly where the effluent flows into shallow, densely grassed areas.

The females can disperse up to two kilometres from their breeding places. The species is a potential vector of malaria where sufficient numbers occurs, and is a significant pest species in inland areas where suitable breeding sites exist.

DESIGN CONSIDERATIONS FOR EFFLUENT POND TREATMENT FACILITIES

Site Selection and Design

Disposal of Effluent

Appropriate planning for the final disposal is an important part of site selection. Disposal near the coast is relatively easy, but in inland areas can lead to major problems if appropriate disposal techniques are not used. These are discussed later.

Wind

Ideally ponds should be located in open windy areas since wind and the associated waves play an important part in preventing breeding by disrupting the larvae and pupae at the water surface. Also, wind action can restrict the growth of algae, aquatic floating ferns (*Azolla* sp.) and duck weed (*Lemna* sp.). These floating plants can shelter the larvae from both wave action and aquatic predators, unless they form a complete cover of a pond.

An example of bad siting was at Snake Bay, Melville Island, where small ponds with steep banks were protected from the wind by both a hill and a close, tall eucalypt forest. Colonisation of corner sections by duck weed (*Lemna* sp.) enabled *Cx. annulirostris* to breed in relatively large numbers.

Drainage

The choice of a site should consider the necessity to drain the ponds for maintenance without thereby creating swamps or pools of stagnant water. Effluent release from the final pond has usually been incorporated into design, but provision for emptying the intermediate ponds into suitable areas has often been overlooked.

Site design should ensure that there is no prevention of near site drainage pathways caused by any of the works. New diversionary drains should be constructed with erosion prevention principles to ensure there is no overland flow of surface water to the ponds or the disposal areas. Diversion drains should discharge to suitable endpoints that are free draining. Groundwater seepage from areas surrounding ponds or the ponds themselves should be intercepted by diversion drains to a free draining area. Long term ground water seepage will require drains with concrete inverts to promote flow and prevent vegetation growth.

With ponds constructed near tidal areas, particular consideration must be given to preserving existing tidal drainage patterns, or to ensure no dead tidal pockets are created. If upper mangrove drainage areas are blocked new breeding sites for salt water species of mosquitoes can be created. An example occurred at the Leanyer sewage ponds in Darwin, where considerable engineering work was required to drain non-draining tidal areas created by the location of the ponds and access embankments over tidal mud flats.

Access

Site design should allow for all weather access completely around the installation. Weed growth, tree growth, seepage, erosion and siltation must all be controlled, and fire prevention must be considered. There have been instances in Alice Springs of seepage from large pond systems causing swampy conditions and preventing vehicle access and hence control around the base of the ponds.

Pond Dimensions

Pond Size

Sewage pond size is primarily determined by engineering parameters related to design flow rates, pollution loadings, and the required effluent quality. Frequently there has been little consideration given the effect of pond size on mosquito breeding. Adoption of oversized ponds, either from inaccurate predictions of sewage volume or a desire to provide for future capacity, can lead to the ponds becoming shallow thickly vegetated swamps that are capable of breeding large numbers of mosquitoes.

This situation occurred at Batchelor and Tennant Creek, where the final evaporation ponds became swamplands breeding mosquitoes.

Consideration should be given to the staging of particularly evaporation pond construction, or the use of multiple smaller ponds rather than one large evaporation pond. In most cases, it is the margins of the ponds that provide the mosquito breeding conditions. Multiple small ponds can provide additional maintenance requirements so it is important to optimise the numbers and size of these ponds.

Attempts to reduce short-circuiting through a large pond by installing earthen peninsular barriers can markedly increase the mosquito breeding areas by providing additional margin length, and these are often inaccessible for mosquito control purposes.

Pond Depth

Selection of pond depth is usually dictated by the function of the pond, ie. primary, secondary, or evaporation. Adequate allowance must be made for solids deposition, particularly in primary ponds, otherwise excessive or longer term deposits will lead to siltation at the edges and corners, resulting in colonisation by vegetation and thus creating mosquito breeding locations.

Profiling the pond base, with the deepest side at the effluent entry point, can help alleviate the silt problem, particularly if there is a seasonal variation in input. For evaporation ponds, particularly those with earth sides or those which are operated on a continual basis, a minimum depth of two metres or more is recommended. This is to allow for the periodic drowning of any seasonal growth of grasses or semi aquatic vegetation such as *Eleocharis* sp. and *Typha* sp.

Construction Details

Concrete Margins

Vertical or sloping concrete margins have proven to be the most satisfactory engineering means of controlling mosquito breeding by promoting wave action, and maintaining margins free of vegetation and debris.

Vertical concrete walls have proven the most maintenance free and effective in reducing mosquito breeding. Sloping concrete margins have been tried in a number of locations. While better than unlined ponds, they have the drawback that wave action is damped by the slope. Debris and algae and organic matter can build up and enable emergent vegetation to establish. It is important that they have a concrete rim around the top to prevent landward inflow of water and silt, and sealed verges to prevent vegetation growth.

Concrete lining can be pre-cast for remote locations or constructed in situ, and are cost effective. They should be deep enough to allow for wide variation in water level and should have a concrete lined horizontal bench just above the bottom level of the pond, to prevent establishment of vegetation along the margin in the initial stages of operation, and to prevent silt accumulation in the longer term. Sealed verges around the top of the banks are desirable to facilitate maintenance and to prevent entry of soil into the pond. Walled ponds may still have problems with floatables and wind blown debris in the corners and cut off pools near entry and exit points. Truncated corners and multiple or underwater entry and exit points can help to eliminate these latter problems.

Unlined earth banks

Sewage ponds with unlined earth banks have the greatest capacity for mosquito breeding, particularly those with gentle slopes where marginal vegetation can grow. They are accordingly not recommended, except as temporary or emergency measures. The banks should be constructed using low porosity materials such as compacted clay. If neglected, unlined earth banks can become either eroded or overgrown with grass, shrubs and even trees such as *Acacia*, *Mimosa* and *Melaleuca* sp. Maintenance and corrective measures can be a major problem.

Other Linings

Various systems have been used to line earth banks as a temporary measure to reduce growth of vegetation, but they have not been entirely satisfactory.

Stone pitching of the margins is not satisfactory as it does not offer sufficient deterrent to vegetation growth, and mechanical maintenance of vegetation is subsequently difficult. Overlapping cement sheets have been used, but have problems with breakage and subsequent weed growth. Various types of bituminous or plastic sheeting have also been tried, and most have shown promise as short to medium term solutions. Problems encountered include inadequate anchoring, weed growth, ultraviolet deterioration, and human interference. The more modern ultra-violet resistant heavy duty plastics, anchored with earth mounds back from the rim of the ponds, have been more successful.

Maintenance

New pond systems

Before commissioning sewage pond systems, a general survey of the whole site should be conducted to ensure that mosquito breeding places have not been inadvertently created. Potential mosquito breeding sites include borrow pits formed during pond construction, pooling of water resulting from site drainage works, and pooling caused by road access blocking drainage paths. Any problems should be rectified before the ponds are commissioned.

Pond maintenance

Pond maintenance is a vital part of pond management. The highest levels of maintenance will be required for earth lined ponds with low and seasonally variable effluent flow rates. Some form of maintenance will be required, even for ponds with vertical concrete margins and sealed verges. Even those ponds in favourable locations, with ideal effluent characteristics, must have adequate provision for people and resources to carry out a regular and defined maintenance program.

Aspects of maintenance frequently overlooked include the regular control and removal of vegetation on the margins or the pond verges, the regular removal of floatables and other flotsam from accumulation points, and the repair of cracks and other failures that can allow pooling or increased soil moisture levels on the banks and subsequent vegetation growth.

For some ponds, a program of water level management may be adopted, which alternately floods and strands marginal vegetation or floatables. The form of maintenance will depend heavily on the pond design, effluent parameters, staff experience and staff availability.

Regrettably, it has been the NT experience that regular and adequate maintenance have been sometimes inadequate to prevent mosquito breeding. If there is any anticipation that regular and adequate maintenance can not be carried out, a maintenance-free design should be chosen.

EFFLUENT DISPOSAL OR DISPERSAL

Problems

Insufficient consideration was given to disposal of the effluent in many of the early sewage treatment facilities in the Territory. It was often assumed that 'adequate treatment' in the ponds was sufficient from an operational point, and therefore discharged treated effluent was frequently allowed to run down the nearest flow line. In practice this effluent often formed flooded, overgrown, stagnant pools that created prolific breeding grounds for *Culex* mosquitoes. Examples were the sewage treatment facilities at Coonawarra Naval Base and Nhulunbuy South in the 1970's, where there was a lack of provisions for proper disposal.

In some instances, effluent from sewage treatment ponds was channelled or piped just beyond the perimeter fence or to the nearest available low lying area. In some

situations, as at Nhulunbuy, the effluent was directed into sand dunes in the belief that infiltration would provide a satisfactory disposal method. This proved totally inadequate because the high organic loads of the effluent and algae invariably sealed against infiltration and resulted in pooling of effluent throughout the dunes.

Even after the final aerobic treatment in evaporation ponds, the resulting 'treated' effluent still retains a great capacity to breed mosquitoes. An example of this was the uncontrolled release of treated effluent into the Ilparpa Swamp area near Alice Springs during the period 1974-2002. The regular release of effluent created a large permanent vegetated swamp and very high numbers of *Cx. annulirostris* and *An. annulipes s.l*. This area has since been partially rectified by drainage measures in the swamp and a reorganisation of discharge practices (Kurucz et al 2002).

Large Evaporation Ponds

In the Northern Territory evaporation ponds, either designed or of 'ad hoc' design have commonly been used for effluent disposal in inland sites. Large evaporation ponds are rarely full to capacity for the entire year, and in many instances are just bunded areas containing effluent to prevent escape to other areas. Because of their large area, the often variable inflow and the variation in climate, large evaporation ponds often become shallow, flooded swamps with dense weed and reed vegetation for at least part of the year. These ponds can become considerable sources of *Culex annulirostris, Culex gelidus, Culex quinquefasciatus* or *Anopheles annulipes s.l.* Also, evaporation ponds that dry up and are then seasonally inundated during rainy periods can become breeding grounds for floodwater mosquitoes such as *Aedes normanensis*. The numerous aspects to be considered in designing large ponds to reduce the amount of mosquito breeding, include:

- initial and regular removal of all emergent vegetation within the evaporation area:
- levelling of the floor of the evaporation area:
- division of the evaporation area into a number of smaller areas;
- constructing a sloping floor to concentrate the water in a sink' area at the effluent entry point;
- concrete lining of the 'sink' area on the floor of the evaporation area and the lining of embankments.

Incorporating some of these aspects into the initial design can be expensive, but the alternatives are to have a regular maintenance program, which could be more expensive in the longer term. The alternative to well designed evaporation ponds is to consider a different effluent disposal method such as dispersal to land, sophisticated tertiary effluent plants, or effluent re-use schemes.

Small Evaporation Ponds

The use of small concrete lined evaporation ponds can be a very effective method of effluent disposal. The best designs incorporate a series of relatively small ponds that can progressively fill by gravity overflow. Such a system may be expensive to construct, particularly if the whole evaporation area required is relatively large. However, the method has the advantage of being relatively maintenance free and it can better prevent mosquito breeding when there are large seasonal variations in effluent volume.

Disposal to the Sea

Disposal direct to the sea or to a daily flushed tidal area is one of the most suitable methods for effluent disposal to prevent mosquito breeding. The critical aspect for tidal creeks is to ensure there is good drainage at low tides. However dispersal at the end of a relatively long, narrow or tortuous tidal creek can result in effluent build up in the creek which can also be pushed higher up the creek line by incoming tides into areas where mosquito breeding sites can develop.

Disposal onto large flat inadequately flushed tidal areas can create breeding sites for freshwater species of mosquitoes, as well as brackish water species such as *An. farauti s.l.* and *Verrallina funerea*, and salt water species such as *Cx. sitiens, An. hilli,* and *Ae. vigilax,* by creating a complex of fresh and brackish water habitats.

Disposal to Rivers

The suitability of discharge to rivers depends upon the volume of flow in the river, the seasonal variability of flow, and the downstream effects of the disposal. This method is unsuitable when the flow in the rivers or creeks is small or subject to wide seasonable variation, as eutrophication or ecological and vegetation changes will lead to mosquito breeding.

Disposal to Land

Large Sprinkler dispersal

This method has been relatively successful in areas where there have been particular problems with other disposal methods. It is most successful onto areas with well-developed stands of trees on well drained areas with soils of good permeability, but the success will depend on adequate resting of the disposal areas and the rate of volumes of effluent disposed to these areas.

Jabiru provided an example of an initially successful sprinkler dispersal scheme. The final effluent was automatically and periodically dispersed via a system of overhead sprinkler heads, onto a fenced area of open native eucalypt forest. Initial problems from fire damage of above ground plastic pipes and algal blocking of spray heads were rectified by the construction of an underground pipe system with tall metal risers and metal sprinkler heads. Over the longer term, this area became a major source of mosquitoes with dead trees, wet season ponding on-site and in downstream off-site flow lines, and tall, dense and uncontrollable grass-weeds in the dispersal site. It has become obvious that the initial site levelling and draining was not adequate, and off site wet season runoff into the disposal area has compounded the effluent ponding problems. The lack of regular slashing of grass led to intense fires that destroyed the trees, and hence reduced evapo-transpiration.

Ideally, sites should be relatively level but with good drainage during rainy periods. Off site run-off should be directed away from the disposal site. There should be adequate sprinklers to have areas off-line for up to a week for drying and weed maintenance. Feeder lines to spray heads should be laid out along contours, rather than at right angles to contours, so that water retained in the lines after the finish of spraying will remain in the lines rather than drain to the lowest sprinkler head. The sprinkler heads should be positioned on mounds of crushed rock to enable better infiltration and to reduce the probability of creating permanent pools of effluent near the sprinkler heads.

The area required will depend upon the volume of effluent to be disposed, and the long-term absorption capacity of the soil and the vegetation. In monsoonal areas, additional site selection and preparation is required to ensure that effluent contaminated runoff cannot pool in nearby flow lines or creeks.

Sprinkler dispersal of effluent can be used for tree and pasture growing or landscape watering, but the National Health and Medical Research Council Guidelines for the Reuse of Waste Water must be adhered to (NH & MRC, 1979). Tertiary chlorination has been used to provide a high quality effluent for drip irrigation and recreational area watering at Yulara. Sprinkler disposal using large spray heads has been successfully used on Blatherskite Park in Alice Springs, but potential problems exist in this area because of the high salinity of the water and rising water tables, which requires regular monitoring of the water table and suspension of irrigation when water tables are high.

Small sprinkler dispersal

When disposing of small volumes of effluent, the use of mini sprinklers fed by irrigation lines is a suitable alternative to drip irrigation. Small sprinklers tend to promote more evaporation compared to drippers by wetting larger areas and allowing greater soil infiltration. In addition it is easier to spot blockages with mini sprinklers compared to drippers. There is however a need to have regular maintenance of dispersal area to prevent grass and weeds from smothering the sprinklers.

Drip Irrigation

Disposal by dripper systems requires a high standard of effluent, usually with a tertiary chlorine treatment, to prevent dripper blockage by algae. Dripper systems can be used for both small or large scale disposal, but is usually only suitable for plantation situations where the vegetation growth at each dripper site can be practically and economically maintained. Drippers held off the ground can reduce root blockages of the drippers. Generally dripper systems are only suitable for the dispersal of small volumes of effluent per unit area or periodic release, and are generally expensive because of their high maintenance requirement.

There has been past issues with drip irrigation at Hermansburg, and Kings Canyon (Whelan 1994). The continuous volume of effluent released in both situations was too high for drip disposal, which created effluent ponding and mosquito breeding. Both systems did not receive adequate maintenance to prevent blockages of drippers, and treatment areas were not appropriately spelled. In both instances, a switch to sprinkler irrigation was required to adequately dispose of the required volumes of effluent over a wider area in the irrigation area.

This method is useful for relatively small volumes of effluent on sandy soil in low rainfall areas. A feeder channel is used to deliver effluent to a ploughed area of small furrows sloping gently away from the feeder channel. Disposal is by infiltration into the sandy soil. When infiltration becomes less efficient, the flow is directed to an adjacent ploughed area, and the original area is allowed to dry out and reploughed.

This system requires a considerable amount of attention and maintenance, but was used successfully at Perth Airport, largely due to the sandy soils and relatively low effluent volumes per unit area.

Channel Infiltration

In this system, permanent infiltration channels are constructed and effluent flow is directed down a number of groups of channels which are alternatively spelled and maintained. The method can be used on less porous soils than is possible for furrow irrigation. If this method is to be used for the irrigation of tree or bush crops, intensive monitoring is required to ensure viability of the crop in the long term. Small scale use of this method has been tried at Batchelor and at the Katherine Abattoirs, but proved to be relatively labour intensive. A variation of the method has been used on a larger scale at Ilparpa in Alice Springs, for the growth of eucalypt trees. Problems on the larger scale have included high labour input, weed control in the channels, siltation in the feeder channels, rising salinity levels and rising water tables.

Flood Bay Irrigation

The degree of land preparation for flood bay irrigation is usually considerable, as a system of correctly graded flood bays is necessary to allow for efficient flooding and to prevent pooling at the end of the flood bays. The bays are periodically flooded and the effluent is allowed to evaporate or infiltrate in the bays over a period of four to five days. This method has been used successfully to grow eucalypts in Ilparpa in Alice Springs. Problems with flood bay irrigation arise during extended rainy periods, when extended flooding of the bays can occur and can result in mosquito breeding. A more sophisticated delivery system for a flood disposal method has been designed for Gapuwiyak. It incorporates an automatic siphon and a distribution drain designed to release effluent evenly over a very large flood bay.

Vegetated Treatment Ponds

Vegetated treatment or polishing ponds, using large aquatic plants such as *Salvinia* (water lettuce) or *Eichornia* (water hyacinth) have been used overseas, but many of these have faced major problems with the maintenance or removal of vegetation, and have become major mosquito breeding sites. This has resulted in expensive re-design or maintenance issues, or in some instances they have had to be decommissioned. There has been some success with prostrate water plants such as duckweed (*Lemna* sp) which can form total cover over ponds, thus denying suitable oviposition sites and preventing air access for larvae. However the pond sizes need to be relatively small so that the duckweed is not blown into corners by wind and wave action.

BIOLOGICAL CONTROL

Biological control, though not usually applicable to primary ponds, can be a very efficient means of controlling mosquito larvae in secondary and evaporation ponds.

The major biological control agents are fish, aquatic beetles and aquatic bugs. Fish can control mosquito larval numbers directly by eating the larvae, or indirectly by eating or disturbing algae or aquatic weeds which provide protection from other predators or wave action. Fish are usually only suitable for the higher oxygenated waters. Several species have shown promise in the Northern Territory, including the herbivorous bony herring (*Nematalosa erebi*), which was successful in reducing surface algae in the former Ludmilla sewage ponds in Darwin, and rainbow fish (*Melanotaenia* sp.), which was a very efficient larval predator in the final evaporation ponds for the Ranger sewage treatment. Other suitable fish species includes the blue eyes (*Pseudomugil* sp.) and gudgeons (*Mogurnda* sp, *Hypseleotris* sp.).

It is essential that marginal vegetation such as couch grass and reeds be eliminated or kept to a minimum, so that fish can have physical access to the mosquito larvae. Actively growing *Eleocharis* sp. and *Typha* sp., with upright stems, may not restrict access. However, when these weed species die or lodge over, they prevent physical access for the fish and enable mosquito breeding.

Aquatic beetle larvae (Family: *Carabidae*) and aquatic bugs (Family: *Belostomatidae*) are the most efficient mosquito larvae predators in secondary and evaporation ponds. The aquatic bugs are able to live in higher organic water than the aquatic beetle larvae, and can be present in very high numbers. Again, physical impedance by thick vegetation at the margins will reduce the effectiveness of these predators. These insect predators can achieve almost total control of mosquito larvae in sewage ponds of suitable water quality, and narrow or sparse vegetation margins.

CHEMICAL CONTROL

The aim of chemical control of mosquito larvae should be to apply the minimum amount of insecticide to prevent the production of adult mosquitoes. Chemical control should not be used as a long term strategy in sewage treatment areas, in order to avoid insecticide resistance and unwanted effects on non-target organisms. However, it may be necessary to apply insecticides during the initial operational period or when proper maintenance has not been carried out. The insecticides of choice to control mosquito larvae in sewage ponds and effluents are either temephos, methoprene, *Bacillus thuringiensis* var. *israelensis* (*Bti*) or *Bacillus sphaericus* (*Bs*), with *Bs* having advantages over *Bti* due to its persistence after application. Correct rates for temephos must be strictly adhered to, as over treatment can kill fish and other aquatic insects.

MOSQUITO SAMPLING

Regular inspections for mosquito larvae should be carried out in sewage ponds and their effluents to determine whether breeding is occurring and to determine the necessity for weed control or chemical control. Chemical control with temephos or *Bti* may be necessary at weekly or longer intervals. Methoprene may give longer control if applied as pellets or briquettes. In general briquettes will give the longer residual effect but need to be tethered in netting on sticks near the surface of the water, so that they do not sink into the silt or mud. Methoprene applications do not necessarily kill larvae or pupae, so an experienced operator is required to assess treated areas or take pupal samples and check emergence efficiency. The presence of late instar

or pupae with the first two insecticides above indicates that control should have been carried out at shorter intervals. If only first and second instar larvae are present, then either biological control is quite efficient, or the mosquitoes have just started to breed in that area, and continued monitoring is necessary.

Mosquito larval or pupal samples can be collected by dipping into sheltered vegetated zones with a soup ladle. Generally care should be taken not to disturb the larvae by shadows or surface water agitation before dipping, and multiple dips should be performed to adequately assess population numbers. Any larvae collected should be stored in small vials with 70% alcohol or methylated spirits, together with information on collection locality, site, date and collector. Larval or pupal identifications should be checked by an entomologist.

Adult specimens collected by biting or harbourage collections can be sent for identification, packed loosely in tissue paper in a small box, together with all the details of collection.

Chironomid midge pupae or adults are often mistaken for mosquitoes and their presence has often resulted in control programs being instituted where none has been necessary.

SUMMARY

In the past, the design of sewage treatment ponds and their effluent disposal facilities in the NT has been largely dictated by engineering and microbiological principles. Little attention was paid to the possibility of breeding mosquito populations close to residential areas, with the resultant risk to public health. Appreciation of this potential risk followed by the application of design principles and adequate maintenance can reduce this problem. Biological control can then operate effectively. Chemical control can be used for start-up or emergency situations, although should not be relied on for ongoing mosquito control in ponds or effluent disposal areas.

REFERENCES

Johnson PH, van den Hurk AF, Jansen CC, Ritchie SA, Smith GA , Moore PR, Mackenzie D, Whelan PI (2006). 'Northern Exotics - vector competence of *Culex gelidus* and *Aedes albopictus* for arboviruses in Australia ' (Abstract presented at the 7 th Conference of the Mosquito Control Association of Australia. 15-18 August 2006).

Kurucz N, Whelan PI, Jacups SP, Broom A, Melville LF (2005). 'Rainfall, Mosquito Vector Numbers and Seroconversions in Sentinel Chickens to Murray Valley Encephalitis Virus in the Northern Territory' *Arbovirus Research in Australia .* 9:188-192.

Kurucz N, Whelan PI and Porigneaux P. (2002). 'Mosquito control in Ilparpa Swamp – A Big Step Forward'. *The Northern Territory Disease Control Bulletin.* 9:1:22-23.

NH & MRC (1979). 'Guidelines for Re-use of Wastewater', Australian Water Resources Council, National Health and Medical Research Council, Department of National Development, Canberra.

Russell, RC (1986). Dispersal of the arbovirus vector Culex annulirostris Skuse (Diptera: Culicidae) in the Murray Valley of Victoria Australia. Gen. App. Enn Ifl: 5_9.

Russell, RC (2009). Mosquito borne disease and climate change in Australia: time for a reality check. *Australian Journal of Entomology* (2009) 48**,** 1-7.

Williams CR, Ritchie SA and Whelan PI (2005). 'Potential distribution of the Asian disease vector *Culex gelidus* Theobald (Diptera: Culicidae) in Australia and New Zealand : a prediction based on climate suitability' *Aust. J. Ent.* 44:4:425-430.

Whelan, PI (1981). The vulnerability and receptivity of the Northern Territory mosquito borne disease. Transactions of the Menzies Foundation 2: 165-171.

Whelan, PI (1984). 'Mosquitoes of Public Health Importance in the Northern Territory and their Control'. (Northern Territory Department of Health, Darwin).

Whelan, PI (1988). 'Mosquito breeding and sewage treatment in the Northern Territory'. "Water" Journal of the Australian Water and Wastewater Association.

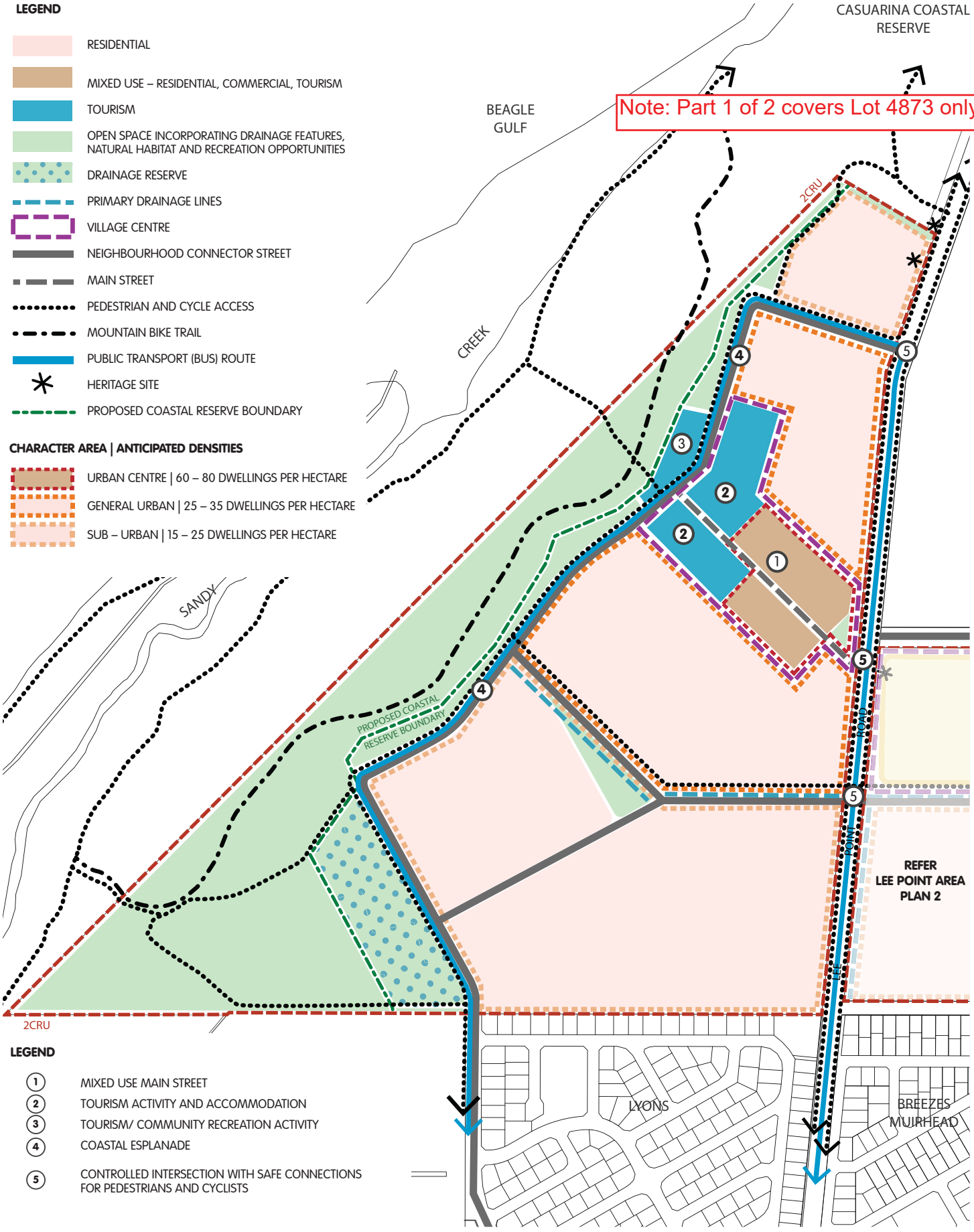
Whelan, PI (1994). Sewage effluent dispersal and mosquito breeding. Kings Canyon Resort 21-22 October 1994. Medical Entomology Branch, Territory Health Services.

Whelan P, Hayes G, Tucker G, Carter J, Wilson A & Haigh B. (2001). The detection of exotic mosquitoes in the Northern Territory of Australia. *Arbovirus Research in Australia* **8,** 395-404.

Appendix 2 – Lee Point Area Plans 1 and 2 (from PA2014/0992)

e - Proposed area plan to cover Lots 4873 and 9370

Note: Part 1 of 2 covers Lot 4873 only



DHA Defence Housing Australia

LEE POINT AREA PLAN 1

Lee Point Road, Lee Point
City of Darwin, Northern Territory

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REF NO	DRAW NO	REV
DHA LEE	RD 3104	B

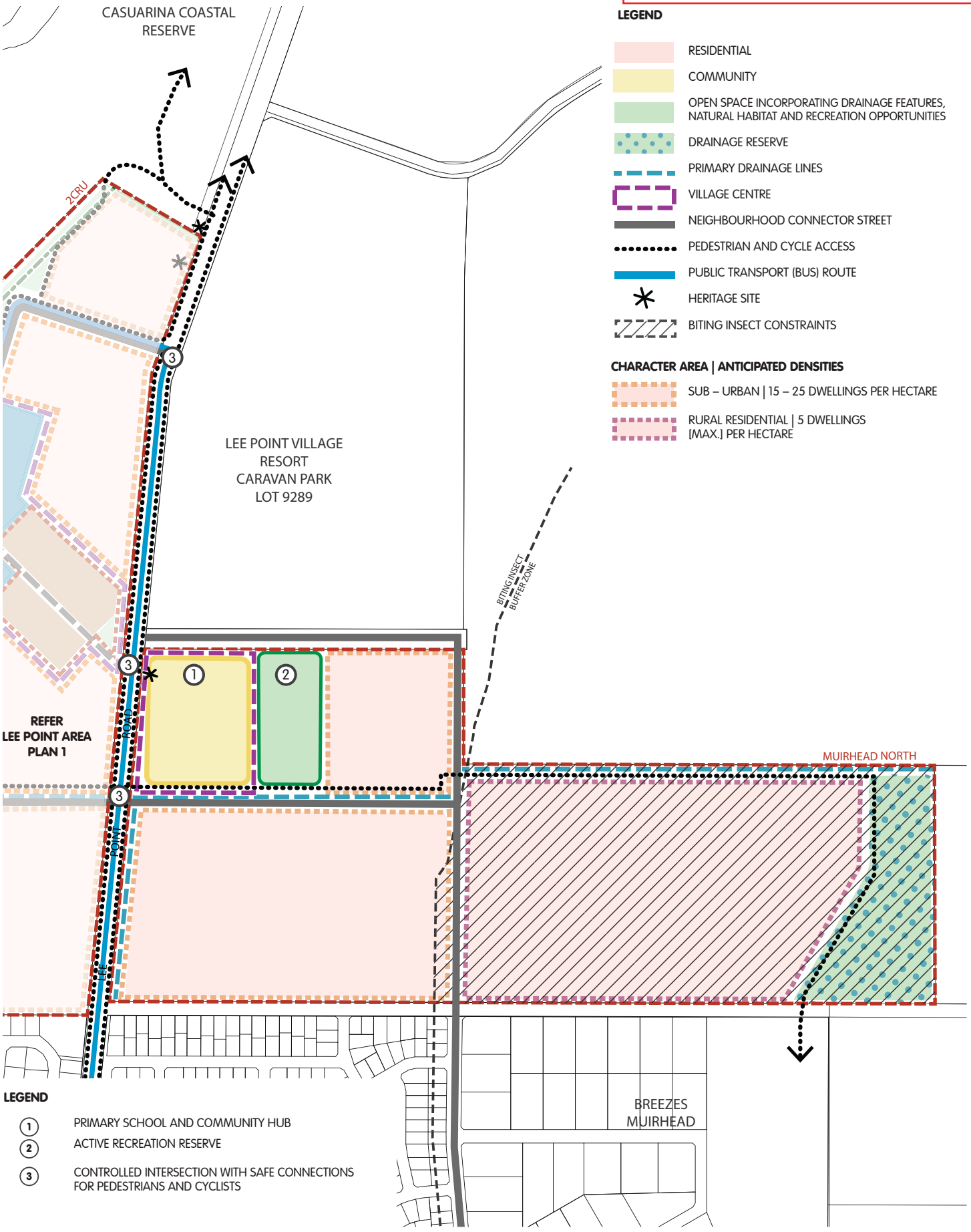
REV	DESCRIPTION	YYMMDD	DRAWN	APPR'D
B	LEGEND AMENDMENT	141112	JD	EP
A	FIRST ISSUE	141107	KT	EP

N

SCALE 1:7,500 SIZE A4

50 100 150 200 250 300m

Note: Part 2 of 2 covers Lot 9370 only



LEE POINT AREA PLAN 2

Lee Point Road, Lee Point
City of Darwin, Northern Territory

DHA Defence Housing Australia

NPC NORTHERN PLANNING CONSULTANTS

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REF NO	DRAW NO	REV
DHA LEE	RD 3105	A

REV	DESCRIPTION	YYMMDD	DRAWN	APPR'D
A	FIRST ISSUE	141107	KT	EP

N

SCALE 1:7,500 SIZE A4

50 100 150 200 250 300m

Appendix 3 – Personal protection from mosquitoes and biting midges in the NT

Northern Territory Government

DEPARTMENT OF **HEALTH**

Personal protection from mosquitoes & biting midges in the NT

Peter Whelan AM
Medical Entomology
Centre for Disease Control
Department of Health
Northern Territory Government

October 2011

Personal protection from mosquitoes & biting midges in the NT

P. I. Whelan

Department of Health

October 2011

(Revised February 2016)

Adapted from paper by P. Whelan in "Australian Mosquito Control Manual" by a panel of authors, Editors C. Morris and P. Dale. Australian Mosquito Control Association, 1998, ISBN 0-646-35310-1.

1.0 MOSQUITOES AND BITING MIDGE BITES

Mosquitoes and biting midges (genus *Culicoides* and sometimes erroneously called sand flies) can reach sufficient numbers in various localities to be considered serious pests. The bites themselves can be painful and extremely annoying, and people suffer varying degrees of reaction to bites (Lee 1975). However the possibility of the spread of various diseases by their blood sucking habits to either humans or animals is a more serious outcome. Mosquitoes can carry viruses such as Murray Valley encephalitis, Kunjin, Ross River, and Barmah Forest virus, which cause human disease (Russell 1995). Biting midges do not carry any pathogens in Australia that cause human disease.

Female mosquitoes or biting midges bite to take blood from their hosts, which is necessary for the development of eggs.

Mosquitoes and biting midges show considerable variation in their preference for hosts. Some species feed selectively on cattle, horses, marsupials, amphibians, birds or humans, while other species are relatively indiscriminate feeders.

The time of feeding varies for different species. Many mosquitoes feed just after sunset while others are more active at other times including late in the night, in the late afternoon, or in the early morning. Biting midges are most active in the evening and early morning.

The place of feeding by mosquitoes or biting midges is varied. Some species, such as the brown house mosquito, readily entering houses to feed on people, while others will only bite people outdoors.

When a mosquito or biting midge bites, fine stylets sheathed in the proboscis are inserted into small capillaries in the skin. Blood is sucked up through one of the channels in the stylets, while saliva is injected down an adjacent channel. This saliva contains histamine like substances that the human body recognises as foreign and

often stimulates a bite reaction. Sometimes the saliva can contain viruses or other pathogens that can cause disease.

Some people can become very sensitive after being bitten and suffer a general reaction from further bites. The bites may itch for days, producing restlessness, loss of sleep and nervous irritation. Scratched bites can lead to secondary infections and result in ugly scars. On the other hand, some people become tolerant to particular species and suffer little after-effects from repeated bites.

Biting insects create problems in the enjoyment of outdoor activities, causing a reluctance to enter certain areas after sundown or forcing people to be confined to insect-proof areas at certain times of the year. Personal protection and avoidance measures can offer considerable protection from bites, as well as offering protection against mosquito-borne disease.

2.0 MOSQUITO & BITING MIDGE AVOIDANCE

A sensible precaution to prevent biting insect attack is to avoid areas that are known to have high biting insect activity.

The upper high tide areas near creeks or low-lying areas, particularly near salt marsh habitats, can be significant sources of northern salt marsh mosquitoes *Aedes vigilax* and various other pest mosquitoes. The period of high salt marsh mosquito activity is usually during the late dry season and early wet season in tropical latitudes. Generally they are prevalent for one to two weeks after the highest tides of the month or appreciable rain. Salt marsh mosquito and midge pest calendars are available from the health website http://www.health.nt.gov.au/Medical_Entomology/index.aspx

Dense vegetation near the breeding sites should be avoided during the day over this period. Pest problems during the evening and night can occur within 3 km of productive breeding sites (Whelan et al., 1997).

Other areas of high mosquito activity are the large seasonally flooded areas associated with rivers or drainage lines, flooded coastal swamps, extensive reed swamps and lagoons, ill defined or poorly draining creeks, extensive irrigation areas, and wastewater disposal facilities. Densely shaded areas near these habitats should be avoided during the day, and accommodation areas should be at least 3 km from extensive areas of these habitats.

Extensive areas of mangroves with small dendritic creeks or estuarine areas with muddy banks are potential sources of mangrove biting midges. These midges have seasonal and monthly population peaks with the monthly peaks usually associated with the tidal regime. When camping or choosing a permanent living site, a separation distance of at least 2 km from these areas is recommended unless specific biting insect investigations indicate there are no seasonal pest problems (Whelan 1990, Whelan, Hayes et al. 1997).

If camping or selecting house sites near creeks, rivers or lagoons, choose localities of the water body which have steep margins or little marginal emergent vegetation, have swiftly running water with little marginal pooling or vegetation, or do not arise from or empty into a nearby swamp area. Exposed beaches or cliffs away from mangrove or estuary areas are preferred sites to avoid both mosquitoes and biting midges. In more inland areas, locations on hills or rises at least 3 km from ill defined drainage lines, poorly flowing creeks and seasonally flooded areas should avoid the worst mosquito problems.

In residential areas, a local source of mosquitoes may be the cause of the problem. Check nearby potential artificial sources of mosquitoes such as disused swimming pools, receptacles such as tyres, drums, fallen palm fronds, pot plant drip trays, plant striking buckets, animal water, garden equipment, plastic sheeting, blocked roof gutters, old fishponds, or localised ponding of drains. Sites with mosquitoes breeding can be rectified by physically removing the source or through the use of insecticides. Fish ponds or ponds used for frogs can be rectified by the addition of a few fish.

3.0 SCREENING

The best method of avoiding attack at night is to stay inside insect-screened houses. Screens can be made of galvanised iron, copper, bronze, aluminium or plastic. Near the coast, iron or copper screens are not recommended because of the corrosive action of salt sprays. Homes near biting midge breeding sites require either fine mesh screens or lightproof curtains.

Screens should be of the correct mesh, fit tightly and be in good repair. Biting insects frequently follow people into buildings and for this reason, screen doors should open outward and have automatic closing devices. Insecticides such as permethrin, deltamethrin, bifenthrin, or alpha-cypermethrin sprayed on or around screens may give added protection against mosquitoes or biting midges, but care is needed as some insecticides affect screens.

It is advisable to use an insect proof tent when camping near potential biting insect areas. Coastal areas subject to attack by biting midges require tents to be fitted with a finer mesh screening. Tents can be made more mosquito effective by spraying them inside and out with bifenthrin or alpha-cypermethrin.

4.0 MOSQUITO NETS

Mosquito nets are useful in temporary camps or in unscreened houses near biting insect breeding areas. Generally standard mosquito nets are not sufficient to prevent biting midge attack. White netting is best as mosquitoes accidentally admitted into the net are easily seen and killed. The net is suspended over the bed and tucked under the mattress. An aerosol pyrethrin spray can be used to kill mosquitoes that enter the net. Care is needed not to leave exposed parts of the body in contact with

the net, as mosquitoes will bite through the net. Nets can be made more effective by dipping impregnation with permethrin (Lines et al. 1985) or by spraying them inside and out with bifenthrin, lambda-cyhalothrin or alpha-cypermethrin..

5.0 INSECT PROOF CLOTHING

Head nets, gloves and boots can protect parts of the body, which are not covered by other clothing. Head nets with 1-1.5 meshes to the centimetre are recommended for good visibility and comfort, and additional treatment of the net with a repellent will discourage insect attack. Thick clothing or tightly woven material offers protection against bites. Light coloured, loose fitting long sleeved shirts and full-length trousers are recommended. Dark clothing such as dark blue denim or black clothing is much more attractive to salt marsh mosquitoes than white clothing. Many mosquitoes including salt marsh mosquitoes or *Anopheles bancroftii* will bite through tight fitting shirts or pants. For particular risk areas or occupations, protective clothing can be impregnated with permethrin or other synthetic pyrethroid insecticides such as bifenthrin to give added protection (Burgess et al. 1988). Sleeves and collars should be kept buttoned and trousers tucked in socks during biting insect risk periods. Protection is very necessary near areas of salt marsh, mangroves, or large fresh water swamps where the various species of mosquitoes may be very abundant during the day in shaded situations, as well as at night.

6.0 REPELLENTS

Relief from biting insect attack may be obtained by applying repellents to the skin and clothing (Schreck et al. 1984). Many repellents affect plastics and care is needed when applying them near mucous membranes such as the eyes and lips.

Repellents with the chemical diethyl-toluamide (DEET) or picaridin give good protection, with DEET based repellents the best. Some specific repellent products, such as standard Aerogard, which are formulated to repel flies, are generally not efficient against mosquitoes or biting midges. Brands with DEET such as Rid, Tropical Strength Aerogard, Bushman's, and Muskol, or products with picaridin such as Repel include specific products that are effective. Those products with higher amounts of DEET or picaridin are usually the most efficient. Many botanical based products do not offer sufficient protection. However, p-methane 3,8diol or PMD (extract of lemon eucalyptus) at a minimum concentration of 30% provides longer lasting protection compared to other botanicals and has a similar efficacy compared to the low DEET concentration products.

Application of repellents over large areas of the body or on extensive areas of children is not recommended particularly those repellents with concentrations of DEET greater than 20%. Protection from mosquito penetration through open weave or close fitting clothes can be obtained by applying a light application of aerosol repellent to the exterior of clothing. Repellents should be supplementary to protective clothing and should not be regarded as substitutes.

Personal repellents are available as sprays, creams or gels. The gels are best and creams usually last longer than the aerosol formulations. Repellents can prevent

bites from 1 to 4 hours, depending on the repellents, the species of biting insect, or the physical activity of the wearer. In general aerosol alcohol based repellents will only give one hour protection in the tropics so reapplication is necessary. Products labelled low irritant generally mean less active ingredient.

There are some new metofluthrin vapour active pyrethroid spatial repellents on the market where there is passive evaporation from impregnated strips or pads. These have been shown to be very effective in preventing landing or biting of many species of mosquitoes and midges, even in outdoor situations within a close surround of the devices, or within rooms in more enclosed areas.

Insecticide impregnated mosquito coils offer good protection in relatively wind protected areas, while the allethrin pad candle heated mosquito lanterns or gas operated allethrin mosquito protection devices offer excellent protection in patio or veranda or other outdoor situations. Mosquito lanterns or gas powered pad dispensers are cost effective for events such as barbeques or congregations of people, with two or more dispersed around the group to cater for breeze direction. Candle devices need care with the candles, while the gas powered models are safe and effective in situation on boats and vessels. They work best in still or very light breeze conditions.

Electronic insect repellers that emit ultrasonic or audible sounds do not offer any protection against mosquitoes or biting midges. They are based on a false premise and have been found to have no repellent effect under scientific testing (Curtis 1986). Electronic ultrasonic repellers do not repel mosquitoes or biting midges and should not be relied upon for personal protection (Mitchell 1992).

Plants with reported insecticidal properties such as neem trees and the citrosa plant have not been shown to act as mosquito repellents just by growing in the vicinity of people (Mitchell 1992, Matsuda et al. 1996). Growing or positioning these plants near evening activity areas will not prevent mosquito attack. However some plants have some repellency effects as smoke or liniments (see section 12, emergency biting insect protection)

7.0 ANIMAL DIVERSION

Camping upwind near congregations of stock or domestic animals will serve to divert mosquitoes or biting midges to alternative hosts. Similar considerations can be made when planning residential sites and animal holding areas in a rural situation. Dogs of darker colour tend to attract some species of mosquitoes more than lighter colours and can divert some pest problems from people in close vicinity in outdoor situations in the evening.

8.0 LIGHTING DIVERSION

Many mosquito and biting midge species are attracted to white light. This can cause pest problems in unscreened houses or when camping. The use of yellow or even better red incandescent bulbs or fluorescent tubes rather than white light will reduce the attractiveness of lights to insects. An incandescent or ultra violet light placed at a distance from a house or camp can serve to attract insects to an alternative area. This is more effective if the light is close to the breeding site, or between the breeding site and the accommodation area. The attractive lights should not be close to accommodation or directly down wind of accommodation areas. Light proof curtains or similar screening can be very effective in reducing the attraction of biting insects to areas that are illuminated at night.

9.0 ADULT INSECT CONTROL

If mosquitoes or biting midges have entered a screened area or house or premises they can be knocked down with hand held pyrethrin aerosols. Care should be taken by reading the label to ensure only knockdown aerosols suitable for spraying in the air are used in proximity to people or food.

There are automatic wall mounted dispensers of aerosol for killing adult mosquitoes or flies that dispense mainly pyrethrins. These are registered for use either indoors or outdoors so care is needed in reading the labels. Generally these dispense aerosol in short bursts every 20 to 40 seconds and can last up to 40 hours before refilling. Outdoors devices need to be in wind protected areas such as verandas and patios.

Other devices that can be effective at killing and/or repelling biting insects include mosquito coils (Charlwood & Jolley 1984) and electric plug in insecticide pads. The plug in pad devices are every effective inside buildings but care is needed in reading the labels These devices are only effective in relatively protected or closed areas such as patios, inside buildings or where there are only slight breezes. Use of coils in outdoor or unscreened areas should be backed up with other measures such as suitable protective clothing or repellents.

Large scale adult biting insect control can be achieved for short terms (hours) by using portable or industrial fog generators, backpack misters, or heavy duty ultra-low-volume aerosol generators to knock down active adult insects. The insecticides of choice in these machines are maldison, bioresmethrin or pyrethrum. Control relies on good access, open vegetation, and light breezes in the direction of the breeding or harbouring sites. Application should only be during the peak biting insect activity period of those insects actually causing the problem, which is usually the late evening and early night.

There are some synthetic pyrethroid aerosol products available as outdoor yard or patio repellents. Control may only be temporary (hours) and re-invasion will usually occur within hours or from one to a few days, depending on the species, nearby vegetation, proximity to breeding sites, environmental conditions and times of activity of the pest species.

Application of the older residual insecticides such as maldison, or permethrin sprayed as a mist spray to point of run off on building surfaces or nearby vegetation can sometimes give short term (a few days to a few weeks) relief. This method is useful as a barrier protection when large numbers of mosquitoes or biting midges are present near accommodation or outdoor use areas (Helson & Surgeoner 1985).

There are some longer term residual synthetic pyrethroids such as bifenthrin, lambda-cyhalothrin and alpha-cypermethrin that can be used as barrier sprays and provide excellent (up to 6 weeks) protection (Standfast et al 2003, Li et al 2010). These residual insecticides can be applied according to label recommendations with the aid of a garden sprayer for dark coloured walls, fences and solid surfaces on the outside of houses or back pack mechanical misters in a band 1-2 m high on low thick vegetation and shrubbery areas around houses. If there is no vegetation screen, black weed matting or shade cloth 1-2 m high all around fence lines in urban settings can substitute for vegetation as the application surface. Application should be at label rates and made to the point of just before runoff. For vegetation care is needed to apply under leaves as well as on leaves and surfaces. Use of these insecticides can give immediate relief from salt marsh mosquito plagues on a house block scale and the effect should last up to 4 weeks.

Application can be done by householders with appropriate equipment and familiarization with the chemical and provisions and safeguards for use, although generally it is advisable for applications to be done by a licensed pesticide company.

Care must be taken with all synthetic pyrethroids around fishponds, fish tanks and other nearby fish habitats to avoid spray drift or run off, as these insecticides are efficient fish poisons.

10.0 INSECTOCUTORS AND INSECT TRAPS

Electric insect insectocutors and other trap or killing devices utilising an attracting light or carbon dioxide have been claimed to clear areas of biting insects and thus protect people. These claims have not been substantiated in outdoor situations with people nearby. While trap devices can attract biting insects, as well as a range of other insects, these devices can not be relied on for protection from biting insect attack (Mitchell 1992). When used in outdoor situations it is possible that they can increase local problems by attracting insects to the vicinity of people. Attractive odours and carbon dioxide emitted by humans then divert the insects from the trap device to the people.

11.0 TREATMENT OF BITES

Relief from bites and prevention of secondary infection can be obtained by the application of various products, either to the skin or internally. The effectiveness of various products is variable, depending on individual reaction. Skin application products include proprietary products such as Eurax, Stingose, Medicreme, Katers

lotion, Dermocaine and Paraderm crème and topical antihistamine products, and non-proprietary products such as paw paw ointment, tea tree oil, eucalyptus oil, aloevera gel, ice, or methylated spirits.

Ice packs to the general bite site will give usually give immediate relief for painful and itchy bites and swelling or blisters from of mosquitoes and biting midges in particular. The sooner the ice pack is applied after bites or reactions, the better the relief, and can often avoid more intense reactions. Some people have had good results from the application of paw paw ointment following bite reactions in the reducing the itching and aiding the healing process.

Other products for internal application for more general symptoms include oral antihistamine products such as Phenergan, Telfast and Vallergan. Check with your doctor or pharmacist for any products for the latest product and safety information.

12.0 EMERGENCY BITING INSECT PROTECTION

There are a number of emergency measures that can be taken when exposed to biting insects with no protection. Sheltering downwind next to smoky fires can offer considerable protection. Burning dung or aromatic and oil producing foliage from plants such as *Hyptis* (horehound), *Vitex* (black plum), *Calytrix* (Turkey bush), *Melaleuca* species (Paper bark) and *Eucalyptus* species (gum trees) can make the smoke more effective. A small native plant *Pterocaulon serrulatum* (warnulpu) has sticky strongly aromatic leaves, and branches are burnt or the moist leaves are rubbed on the skin by Aborigines in the Katherine district to repel mosquitoes (Aborigines of the NT 1988). Climbing relatively high trees or choosing locations exposed to the wind can also offer protection from some species.

Some protection can be obtained by rubbing exposed skin areas with the leaves of certain plants such as eucalypts, turkey bush, warnulpu, paperbarks or tea-trees that contain volatile oils. However these are not as efficient as proprietary repellents containing DEET or picaridin. Other emergency protection measures include coating the skin with mud, or burying yourself in shallow sand with some form of head protection. If all else fails, keep running. The best form of protection and the most comfortable require an awareness of the potential problems and adequate preparation.

References

Aborigines of the Northern Territory of Australia (1988) Traditional Bush Medicines, An Aboriginal Pharmacopoeia, Greenhouse Publications pp 184-185.

Burgess, N., Carter, S., Dodd, G., & Shirley, C. (1988), 'Permethrin fabric treatment for the protection of personnel from biting insect and other arthropod attack', *International Pest Control*, vol. 30, no. 6.

Charlwood, J. D., & Jolley, D., (1984), 'The coil works (against mosquitoes in Papua New Guinea), *Trans Roy Soc Trop Med Hyg*, vol. 78.

Curtis, C. F. (1986), 'Fact and fiction in mosquito attraction and repulsion', *Parasitology Today*, vol. 2, no. 11.

Helson, B. & Surgeoner, G. (1983), 'Permethrin as a residual lawn spray for adult mosquito control', *Mosquito News,* vol. 43, no. 2.

Jacups S, Kurucz N, Whelan PI and Carter JM (2009) 'A comparison of *Aedes vigilax* larval population densities and associated vegetation categories in a coastal wetland, Northern Territory, Australia' *J. Vector Ecology* 34(2), pp. 311-316. (Dec09).

Jacups S, Whelan PI and Currie B. 2008. 'Ross River virus and Barmah Forest virus infections: a review of history, ecology and predictive models, with implications for tropical northern Australia' *Vector Borne and Zoonotic Diseases* 8:2; 283-97.

Kurucz N, Whelan PI, Carter JM and Jacups S (2009) 'A geospatial evaluation of *Aedes vigilax* larval control efforts across a coastal swampland, Northern Territory, Australia' *J. Vector Ecology* 34(2), pp. 317-323. (Dec09)

Kurucz N, Whelan PI, Jacups SP, Broom A, Melville LF. 2005. 'Rainfall, Mosquito Vector Numbers and Seroconversions in Sentinel Chickens to Murray Valley Encephalitis Virus in the Northern Territory'. *Arbovirus Research In Australia.* 9:188-192.

Lee, D. J. (1975), 'Arthropod bites and stings and other injurious effects', *School of Public Health & Tropical Medicine, University of Sydney.*

Li C. X., Wang Z. M., Dong Y. D., Yan T., Zhang Y. M., Guo X. X., Wu M. Y., Zhao T. Y., Xue R. D (2010). 'Evaluation of lambda cyhalothrin barrier spray on vegetation for control of *Aedes albopictus'*. *Journal of the American Mosquito Control Association,* vol. 26, no. 3, pp. 345-348.

Lines, J. D., Curtis, C. F., Myamba, J., Njau, R. (1985), 'Tests of repellent or insecticide impregnated curtains, bednets and anklets against malaria vectors in Tanzania', *WHO* VBC/85.920.

Matsuda, B. M., Surgeoner, G. A., Heal, J. D., Tucker, A. O., Maciarello, M. J. (1996), 'Essential oil analysis and field evaluation of the citrosa plant *Pelargonium citrosum* as a repellent against populations of *Aedes* mosquitoes', *Journal of the American Mosquito Control Association,* vol. 12, no. 1, pp. 69-74.

Mitchell, L. (1992), 'Mythical mosquito control', *Wing Beats*, vol. 3, no. 2, Florida Mosquito Control Association.

Russell, R. C. (1995), 'Arboviruses and their vectors in Australia: an update on the ecology and epidemiology of mosquito borne viruses', *Review of Medical Veterinary Entomology*, vol. 83, no. 4.

Schreck, C. E., Haile, D. G., Kline, D. L. (1984), 'The effectiveness of permethrin and deet alone or in combination for protection against *Aedes taeniorhynchus* ', *Am J Trop Med Hyg,* vol. 33, no. 4.

Standfast H., Fanning I. Maloney L., Purdie D. and Brown M. "Field evaluation of Bistar 80SC as an effective insecticide treatment for biting midges (Culicoides) and mosquitoes infesting peri-domestic situations in an urban environment" Bulletin Mos Cont Assoc Aust Vol 15 ;2 2003.

Whelan, P. I. (1990), 'Biting midge investigations near Darwin and their implications for urban planning', *Proceedings of the National Conference on Biting Midge, Surfers Paradise,* February 1990.

Whelan, P. I., Hayes, G., Montgomery, B. L.(1997), 'Biting midge surveillance in Darwin harbour, *Culicoides ornatus* (Diptera: Ceratopogonidae) abundance and dispersal', *Proceedings of the Seventh Symposium "Arbovirus Research in Australia, Second" Conference Mosquito Control Association of Australia*, Surfers Paradise.

Whelan PI. 2003. 'Biting Midges Or "Sand Flies" in the NT' 2003'. *The Northern Territory Disease Control Bulletin.* 10:3:1-9.

Whelan PI, Jacups SP, Melville L, Broom AK, Currie BJ, Krause VL, Brogan B, Smith F and Porigneaux P. 2003. 'Rainfall and vector mosquito numbers as risk indicators for mosquito borne disease in Central Australia'. *Communicable Disease Intelligence.* 27:1:110-116.

Whelan PI, Van Den Hurk A. 2003. 'Medically important insects in the Northern Territory and how disasters may affect them'. *The Northern Territory Disease Control Bulletin.* 10:1:27-38.

Whelan PI. 2005. 'Bites and stings in the Top End and how to avoid them'. *Northern*

Territory Disease Control Bulletin. 12:3:20-27.

Whelan PI. 2007. 'Mosquito Control in Leanyer Swamp'. *Northern Territory Disease Control Bulletin.* 14:2:19-20.

Whelan PI. 2007. 'Mosquito Vector Control in the Northern Territory'. *Northern Territory Disease Control Bulletin.* 14:2:12-18.

Whelan, P. I., Merianos, A., Hayes, G., & Krause, V.(1997) , 'Ross River virus transmission in Darwin, Northern Territory, Australia', *Proceedings of the Seventh Symposium "Arbovirus Research in Australia", Second Conference Mosquito Control Association of Australia*, Surfers Paradise.

Whelan P I 2008. 'Personal mosquito protection while overseas' *Northern Territory Disease Control Bulletin.* 15:1:18-19.

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Appendix 4 – Field evaluation of Bistar 80SC as an effective insecticide harbourage treatment for biting midges (Culicoides) and mosquitoes infesting peridomestic situations in an urban environment.

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FIELD EVALUATION OF BISTAR 80SC AS AN EFFECTIVE INSECTICIDE HARBOURAGE TREATMENT FOR BITING MIDGES (*CULICOIDES*) AND MOSQUITOES INFESTING PERIDOMESTIC SITUATIONS IN AN URBAN ENVIRONMENT

By

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Abstract

Excellent residual control of adult biting midges and mosquitoes was recorded at River Heads, Hervey Bay, by applying Bistar 80SC (FMC Chemicals) as a 0.1% bifenthrin in water mix to external resting surfaces in peri-domestic situations. Application of the mix as a coarse spray (150-200 micron droplets) resulted in a 97%-75% reduction in biting midge numbers in the first month of field evaluation, with a 65% mean reduction in numbers at six weeks post-treatment. Of the midge species controlled during this evaluation, 81% were *Culicoides ornatus*, and 19% *Culicoides subimmaculatus*.

With regards to the mosquitoes controlled during the evaluation, an even higher level of efficacy was achieved, with a 99%-94% reduction in numbers during the first month, and 94% mean reduction in numbers over the six week evaluation period. Of these, the saltmarsh arbovirus vector *Ochlerotatus vigilax* represented 78%.

These are significant results, as the authors are unaware of any other method which has achieved an effective, sustained reduction in adult biting midge numbers. Accordingly, the suitability of the method for provision of household protection and integration with existing vector control programs is discussed, and recommendations made for future management of this valuable insecticide.

Introduction

It is well documented that mosquitoes (Russell 1998) and biting midges (*Culicoides* spp.) (Kettle 1965, Howie 2002) seriously impact on human health in Australia. With respect to mosquitoes, several *Ochlerotatus*, *Aedes* and *Culex* species have been implicated in the transmission of arboviruses and canine filaria (Boreham and Marks 1986, Watson and Kay 1998, Hanna et al. 1999, Ryan et al. 1999, Boyd and Kay 2000). With biting midges, it is females from the genus *Culicoides* which impact most severely on the health and comfort of humans and animals (Kettle 1965, Linley et al. 1983, Kay and Standfast 1987). This biting behaviour can result in adverse economic effects on land development, property values, tourism, recreation and work-related activities (Linley and Davies 1971, Howie 2002). In Hervey Bay in 2002, the biting midge problem is estimated to have cost residents $61 million (Ratnayake et al. 2003). Additionally, *Culicoides* are also known to transmit protozoans, filarial worms, and viruses (Kettle 1965, Blanton and Wirth 1979, Linley et al. 1983).

In response to this threat, some larger coastal Queensland Local Governments allocate significant resources towards broadscale larviciding for mosquitoes (Brown et al. 1999). Unfortunately, there is no registered larvicide for biting midges. This is because the larvae occur in environmentally sensitive areas of the inter-tidal zone, and dispersal patterns are poorly know (Shivas 2001). Also, required dosages are environmentally damaging (Standfast unpub data). This leaves aerosol (thermal fogging and ULV) insecticide applications against adults as the only option available. The method only provides short-term relief from biting, and repeated applications are necessary and expensive. It is for these reasons that a sustained effective method is required, and one that provides household protection has been identified as a priority (Shivas 2001).

Accordingly, Bifenthrin (FMC Chemicals) was selected for evaluation as an effective insecticide surface treatment for biting midges and mosquitoes harbouring on ornamental plants, fences and walls surrounding domestic situations at River Heads, Hervey Bay (Queensland, Australia). This suburb was selected as a test site, as a recent public health study found that residents experience reduced health levels as a consequence of biting midges, and that an effective control method is desperately needed (Howie 2002). Bifenthrin, a non-alpha cyano (low skin irritant) synthetic pyrethroid, which is used world-wide against a range of agricultural pests, was considered an ideal candidate insecticide as it is characterized by:

1) low irritancy to mosquitoes, and thus increases mosquito-bifenthrin contact time (WHO 2002);
2) very low vapor pressure (1.81 10-7 mmHg);
3) low water solubility (<1 μg/litre) and good stability to hydrolysis and photolysis (2 years at 500C. under natural daylight); and
4) long residual efficacy against target insects (WHO 1998, 2002; Hougard et al. 2002; Yadav et al. 2003).
5) safety to humans: “Noting its safety and efficacy, Bifenthrin 10WP is recommended for indoor residual spraying” (WHO/CDS/WHOPES/2001.4).

In house-scale trials in India, Bifenthrin (10% wettable powder) applied at a rate of 25 mg/m^2 provided persistent (>80% mortality for 24 weeks) insecticidal activity against *Anopheles culicifacies* on mud and brick surfaces (Yadav 2003).

It was these characteristics that led to selection of an 8% water-based, no-odor, non-irritant, suspension concentrate (SC) formulation for evaluation in Queensland against biting midges. Although this FMC Chemicals formulation is registered in Australia as a surface treatment for mosquitoes, it has not been evaluated for efficacy against biting midges infesting domestic situations. Therefore, this study was undertaken to produce efficacy data for biting midges, and in doing so provide a tool for control of these insects of public health and economic importance. Additional efficacy data was also collected for mosquitoes.

Materials and Methods

Study Site. Public support for this evaluation at River Heads (Plate 1) was received at a River Heads public forum, held on the 2nd October 2002. There was 80% positive support from the public for this evaluation. The Environmental Protection Agency, and Department of Primary Industries – Fisheries, also supported the evaluation as it did not impact on the environmentally sensitive marine park surrounding River Heads. The evaluation was conducted under NRA Research Permit 5547.

Plate 1. River Heads, Hervey Bay, Queensland. Clean estuarine sand and muddy sand surrounding River Heads provides larval habitat for *Culicoides subimmaculatus* Lee & Reye, while estuarine mud produces *Culicoides ornatus* Taylor. Saltmarsh and mangrove habitats produce the mosquito arbovirus vector, *Ochlerotatus vigilax* (Skuse).

Once the above detailed approval had been obtained, eight houses comprised of four randomized pairs (1 treatment + 1 untreated control) were selected, and the householders consent obtained ca. 2 weeks prior to the treatment date (29th October, 2002).

Plate 2. On the properties selected for evaluation, external surfaces where mosquitoes and midges rest (fences, walls, ornamental plants and bushes) were identified for treatment.

Application of Bistar 80 SC (Active Ingredient: 8% bifenthrin). In order to obtain the required efficacy data for biting midges, the 8% SC formulation was applied as per the label directions for applications against mosquitoes under conditions of high pest pressure, and when maximum residual protection is desired. The label directions state that at a recommended rate of 125 mL/10L: "*on non-porous surfaces apply as a coarse spray at the rate of 1 litre of emulsion per 20 m^2. When treating non-porous surfaces do not exceed the point of run-off. On porous surfaces or use through power equipment, spray at the rate of 1 litre of emulsion per 10 m^2. When treating porous surfaces do not exceed the point of run-off. To control mosquitoes apply prepared emulsion to surfaces where insects rest or harbour. Reapply as necessary.*"

Accordingly, a 0.1% mix (125 mL/10L water) was applied as per the label instructions described above, to external building and ornamental plant surfaces (Plate 2). To do this a Solo Back Pack Sprayer (Solo, Germany) was calibrated by the Centre for Pesticide Application and Safety (University of Queensland, Gatton Campus) to deliver a dilute spray comprised of large (150-200 micron) droplets.

Table 1. Property treatment rates.

Treatment Property No.	Property Size	Volume of 8% SC Applied[1]
1	1012 m^2	875 ml
2	1012 m^2	750 ml
3	1012 m^2	500 ml
4	1012 m^2	625 ml

[1] The volume of 8% SC applied to the various properties varied according to house size and % ornamental coverage.

Surveillance and Identification. CDC-type light traps powered by a rechargeable 6 volt battery, were used to measure peri-domestic biting midge and mosquito populations in

Plate 3. Median midge and mosquito numbers caught overnight in unbaited vs baited light traps.

treatment and control properties. Light trap collections were made on the evening prior to treatment, and then each night for 9 nights post-treatment. Sampling frequency was then reduced to weekly collections for six weeks post-treatment.

To do this, one trap was hung from a tree within the fenced-off yard of each treatment and control property. On each sampling occasion, each trap was baited with 750 g dry ice and 2.5 ml Octenol (1 Octen-3-ol). The dry ice was housed in the purpose built 1 litre ice container, and the Octenol contained in a 4 ml microreaction vial. An exposed cotton pipe cleaner wick was used to release the Octenol. The traps were operated from 1500 to 0700 hours. Each day the collections were transported to the laboratory for sorting, counting, and identification according to the descriptions in Marks (1982). All collections were stored in 70% ethanol. The above described baited light trapping method was chosen on the basis of catches recorded in an evaluation of trapping efficacy conducted between 1500 and 0700 hours, 7 days prior to the application of the 8%SC formulation. In order to determine if un-baited traps would provide sufficient numbers for statistical analyses, the catches recorded from 5 x un-baited light traps were compared with what was caught in 5 x light traps baited with CO_2 and Octenol.

Environmental data. Environmental parameters in terms of wind speed, direction, temperature and humidity were measured on a vacant allotment at River Heads using a portable EnvironData Weather Master 2000 (EnvironData, 44 Percy St, Warwick, QLD. 4370 Australia).

Statistical Quantification of Treatment Efficacy. For both biting midges and mosquitoes, 12 hours pre-treatment and six weeks post-treatment field data, comprising 62 light trap collections were made. As the pre-treatment data was normally distributed, a t-test was used to test for significant differences between treatment and control properties. For the post-treatment data, and pre-treatment comparison of light trapping efficiency, a non-parametric Mann-Whitney Rank Sum Test was used to test for statistically significant differences in the median values between counts from treatment and control properties, and baited vs un-baited light-traps, respectively. This non-parametric test was utilized as the collected data failed a test for normality (see skewness values Table 5). We did not expect the long-term data to be normally distributed as biting midge and mosquito populations exhibit both spatial and temporal variability (Shivas 2001). Factors such as wind direction and speed, humidity, topography, harborage and emergence patterns all contribute to patchy distribution. Accordingly, we utilized the Henderson & Tilton (1955) formula to calculate weekly % reduction for fluctuating test populations:

$$\% \text{ control} = 100 \times \left[1 - \frac{Ta \times Cb}{Tb \times Ca}\right]$$

Where: Ta = population in treatment post-treatment
Tb = population in treatment pre-treatment
Ca = population in control post-treatment
Cb = population in control pre-treatment

Results

The field evaluation from late October to mid December was conducted in warm, humid, calm conditions (Table 2).

Table 2. Mean ± SD 24 hour environmental conditions during field evaluation.

Temperature ^{O}C.	% Relative Humidity	Wind Speed km/hr	Wind Direction (Degrees)
23 ± 3	78 ± 17	7 ± 3	118 ± 66

In the pre-treatment evaluation of trapping efficiency, baited light traps caught significantly (P<0.01) higher biting midge and mosquito numbers (Plate 3). On the night prior to treatment, there was no statistically significant difference in the numbers of biting midges (P<0.43) or mosquitoes (P<0.51) collected from properties identified for treatment or untreated controls (Table 3).

Table 3. 12-hour pre-treatment biting midge and mosquito numbers on properties selected for evaluation of Bistar 80SC efficacy.

Group	N	Mean	Std Dev	t	Df	95%CI	*P*
Pre-Treatment Biting Midges	4	51	81	0.84	6	-65 to 134	0.43
Control Biting Midges	4	17	11				
Pre-Treatment Mosquitoes	4	56	38	0.70	6	-408 to 227	0.51
Control Mosquitoes	4	147	257				

In contrast, over the six week post-treatment period, a statistically highly significant difference in the median numbers of biting midges (P<0.02) and mosquitoes (P<0.01) collected from treated and control properties was recorded (Table 4). In contrast to an average of 441 biting midges and 25 mosquitoes collected from treated properties, 2,989 biting midges and 169 mosquitoes were collected from untreated control properties (Table 5). In terms of species composition, 78% of the collected mosquitoes species were the saltmarsh *Oc. vigilax*, with *C. ornatus* and *C. subimmaculatus* representing 81% and 19% of the collected biting midge species, respectively.

Table 4. Mann-Whitney Rank Sum analysis for six weeks biting midge and mosquito field data.

Group	N	Median Number	25%	75%	T	*P*
Biting Midge						
Treatments	54	276	66	682	2652	<0.02
Controls	54	425	122	1856		
Mosquitoes						
Treatments	54	8	4	34	1802	<0.01
Controls	54	106	46	210		

Table 5. Descriptive Statistics for 6 weeks field Data.

Biting Midge (n = 54 trap collections)

	Skewness	Range	Max	Min	Median	Mean
Treatment	1.46	2,011	2,012	1	276	441
Control	2.21	21,914	21,948	34	425	2,989

Mosquitoes (n = 54 trap collections)

	Skewness	Range	Max	Min	Median	Mean
Treatment	2.50	186	186	0	8	25
Control	2.40	875	879	4	106	169

In terms of % reduction over time, biting midge numbers were reduced by 97% to 75% in the first month, with a 65% mean reduction over the 6 week study period (Fig. 1). Mosquito numbers were reduced by 99% to 94% in the first month, with a 94% mean reduction over the 6 week study period. Rainfall events were recorded in the first, third, fifth and sixth weeks of the study (Hervey Bay Airport Meteorological Data) (Fig. 1).

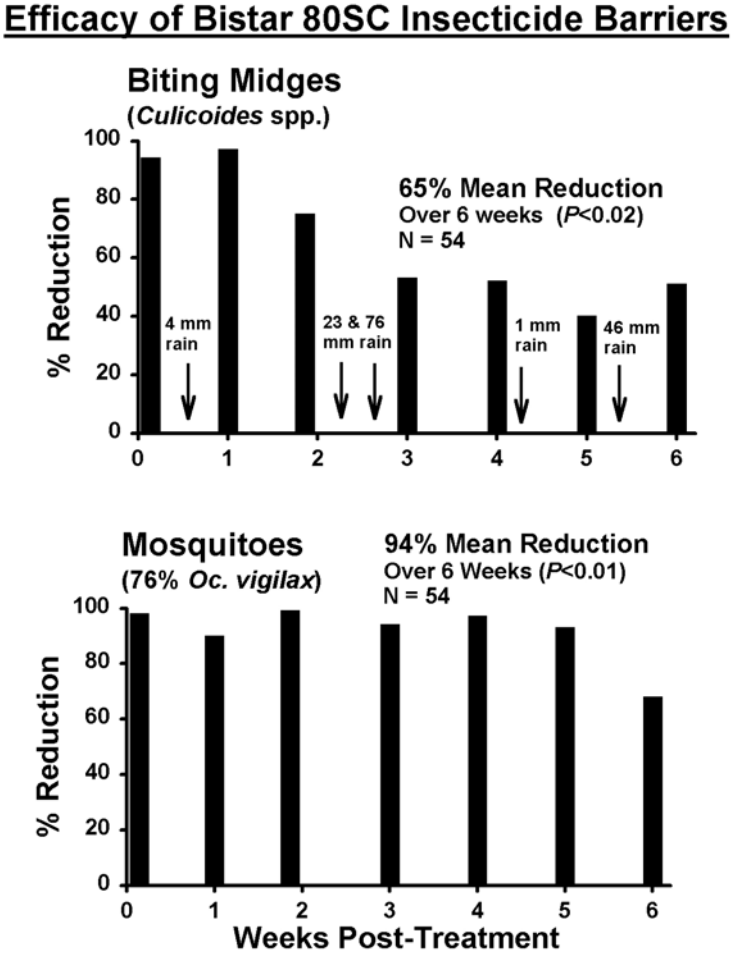

Fig. 1. % Reduction of peri-domestic biting midge and mosquito numbers over a six week study period. Rainfall events are also recorded.

Discussion

The authors are unaware of any other study which details effective, sustained reduction in adult biting midge numbers. The successful Bistar 80SC application was achieved during periods of peak biting midge and saltmarsh mosquito emergence, and despite rainfall events on six occasions. In doing so, the method meets Shivas (2001) recommendation for biting midge control, in that a sustained, effective method is required, and one that provides household protection is a priority. The peri-domestic applications also satisfied the EPA and Fisheries concerns, as they provide a safe alternative to broadscale application of organophosphates to sensitive estuarine habitats, at rates that would be ecologically disastrous. Also, in terms of comfort to the Local Government personnel

applying the product, and the residents of treated properties, the bifenthrin molecules non-alpha-cyano characteristics were appreciated. No skin or eye irritation characteristics occurred, and as expected with a bifenthrin SC formulation, no staining of peoples properties or phyto-toxic effects were recorded.

This study also highlights the fact that harborage treatments are suitable for integration with existing Local Government vector control programs. Mosquito arbovirus vectors such as *Oc. vigilax* and *Culex annulirostris* Skuse have the ability to disperse over great distances (Johansen et al. 2001). This makes thorough treatment of the numerous and often unidentified larval habitats expensive, problematic, and often impossible. Effective vector control programs are required, as arboviruses such as dengue in north Queesland, and West Nile in the USA are increasing in prevalence.

In refining this method, accurate laboratory determination of the Bistar 80SC concentration-mortality relationship for major biting midge and mosquito species of public health importance is essential. The incorporation of a discriminating dose test (2x LC_{95}) in routine monitoring programs will aid early detection of developing bifenthrin tolerance if it occurs. Future research efforts should also be dedicated towards determination of the longevity of control effected by Bistar 80SC applications on various resting surfaces. Surfaces such as treated and untreated wood, bricks, and waxy leaf surfaces would all retain bifenthrin at differing concentrations over time. Re-treatment strategies could vary depending on the predominant harborage or resting surface present in a given domestic situation. Accordingly, the authors recommend that a resistance management strategy be developed to safeguard the longevity of this valuable formulation. Bistar 80SC is one of the few effective options we have available for control of these adult insects of major public health significance.

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References

Blanton, F. S., and W. W. Wirth. 1979. The Sand Flies (*Culicoides*) (Diptera: Ceratopogonidae) of Florida. Gainsville, FL, Florida Department of Agriculture and consumer Services. Arthropods of Florida and Neighboring Land Areas. 10: 1-204.

Boreham, P., and E. Marks. 1986. Human filariasis in Australia: introduction, investigation, and elimination. Proc. R. Soc. Qld. 97: 23-52.

Boyd, A. M., and B. H. Kay. 2000. Vector competence of *Aedes aegypti*, *Culex sitiens*, *Culex annulirostris*, and *Culex quinquefasciatus* (Diptera: Culicidae) for Barmah Forest virus. J. Med. Entomol. 37: 660-663.

Brown, M. D., D. Thomas, P. Mason, J. G. Greenwood and B. H. Kay. 1999. Laboratory and field evaluation of the efficacy of four insecticides for *Aedes vigilax* (Diptera: Culicidae) and toxicity to the non-target shrimp *Leander tenuiornis* (Decapoda: Palaemonidae). J. Econ. Entomol. 92: 1045-1051.

Hanna, J. N. S., S. A. Ritchie, D. A. Phillips, J. M. Lee, S. L. Hills, A. F. van den Hurk, A. T. Pyke, C. A. Johansen, and J. S. Mackenzie. 1999. Japanese encephalitis in north Queensland, Australia. Med. J. Aust. 170: 533-536.

Henderson, C. F., and E. W. Tilton. 1955. Tests with acaricides against the brow wheat mite. J. Econ. Entomol. 48: 157-161.

Hougard, J. M., S. Duchon, M. Zaim and P. Guillet. 2002. Bifenthrin: a useful pyrethroid insecticide for treatment of mosquito nets. J. Med. Entomol. 39: 526-533.

Howie, J. 2002. The public health impacts associated with biting midge (Diptera: Ceratopogonidae) in Hervey Bay, Queensland, Australia. Honors Thesis, University of the Sunshine Coast.

Johansen. C.A., R.A. Farrow, A. Morrisen, P. Foley, A.F. van den Hurk, H. Seriat, B. Montgomery, J.S. Mackenzie, and S.A. Ritchie. 2001. Wind-borne mosquitoes: Could they be a mechanism of incursion of Japanese encephalitis virus into Australia? Arbovirus Res. Aust. 8: 180-186.

Kay, B. H. and H. A. Standfast. 1987. Ecology of arboviruses and their vectors in Australia. Current Topics in Vector Research. 3: 1-36.

Kettle, D. S. 1965. Biting ceratopogonids as vectors of human and animal diseases. Acta Trop. 22: 356-362.

Linley, J. R. and J. B. Davies. 1971. Sandflies and tourism in Florida and the Bahamas and Caribbean area. J. Econ. Entomol. 64: 264-278.

Linley, J. R., A. L. Hoch, and F. P. Pinheiro. 1983. Biting midges (Diptera: Ceratopogonidae) and human health. J. Med. Entomol. 20: 347-364.

Marks, E. N. 1982. An atlas of common Queensland mosquitoes. Queensland Institute of Medical Research, Brisbane, Australia.

Ratnayake, J., P. Dale, P. Daniels, and N. Sipe. 2003. Economic impact of biting midges in Hervey Bay. Report for Hervey Bay City Council, Griffith University, Faculty of Environmental Sciences, Nathan Campus, Australia.

Russell, R. C. 1998. Vectors vs. humans in Australia: Who is on top down under? An update on vector-borne disease and research on vectors in Australia. J. Vect. Ecol. 23: 1-46.

Ryan, P. A., K. A. Do, and B. H. Kay. 1999. Definition of Ross River virus vectors in Maroochy Shire, Australia. J. Med. Entomol. 37: 146-152.

Shivas, M. 2001. Hervey Bay Biting Midge Review 2001: Previous studies and research priorities. Hervey Bay City Council, PO Box 5045, Torquay, Hervey Bay, Queensland, 4655, Australia.

Watson, T. M., and B. H. Kay. 1998. Vector competence of *Aedes notoscriptus* (Diptera: Culicidae) for Ross River virus in Queensland, Australia. J. Med. Entomol. 35: 508-514.

WHO. 1998. The WHO recommended classification of pesticides by hazard and guidelines to classification 1998-1999. WHO/PCS/98.21/Rev.1 World Health Organization, Geneva, Switzerland.

WHO. 2002. Report of the fifth WHOPES working group meeting: review of Olyset Net and Bifenthrin 10%WP. WHO/CDS/WHOPES/2001.4

Yadav, R. S., H. C. Srivastava, T. Adak, N. Nanda, B. R. Thapar, C. S. Pant, M. Zaim, and S. K. Subbarao. 2003. House-scale evaluation of bifenthrin indoor residual spraying for malaria vector control in India. J. Med. Entomol. 40: 58-63.

Appendix 5 – Salt marsh mosquito *(Aedes vigilax*) pest calendar 2016.

Northern Territory Government

DEPARTMENT OF **HEALTH**

Salt Marsh Mosquito Pest Calendar for Coastal NT 2016

Aedes vigilax – northern salt marsh mosquito

Medical Entomology
Centre for Disease Control
Department of Health
Northern Territory Government
www.health.nt.gov.au/Medical_Entomology

Salt marsh mosquito lifecycle

The northern salt marsh mosquito *Aedes vigilax* is the most important pest mosquito in the Top End of the NT due to its aggressive biting habits, its ability to bite during the day as well as the night, and its sudden emergence in very high numbers. This calendar shows periods when *Ae. vigilax* pest numbers are expected in the Darwin area in 2016 in relation to Darwin Harbour tides. Other coastal areas of the NT near breeding sites will have pest problems at around the same time. Heavy rainfall can cause high numbers outside the indicated pest periods.

Aedes vigilax breeding sites include the upper tidal section of extensive mangrove areas, brackish swamps with extensive reed growth and flood plains associated with tidal rivers. The mosquitoes lay their eggs in moist mud. The eggs hatch when the habitat is flooded by large tides or heavy rain. Newly emerged adult mosquitoes start flying 9 days after the tide or rain and persist in high numbers for 7 to 14 days, depending on the humidity. They can disperse over long distances of up to 50km but are generally more common within 5km of breeding sites.

In Darwin a tide of 7.5m in late April or May initiates the season, with mosquito numbers increasing after each succeeding spring tide and heavy rain between August and January. Very high *Ae. vigilax* numbers can usually be expected between October and mid-January, depending on tides and rain. The mosquitoes are largely absent from February to late March or April as the major habitats are flooded, preventing the mosquitoes from laying eggs.

Disease risk

Aedes vigilax can transmit Ross River and Barmah Forest virus. The highest risk period for these viruses in the Top End is December and January. Older mosquitoes present at the tail ends of the highest pest periods pose a higher potential risk for Ross River virus transmission, as they have had more time to acquire the virus from animal reservoirs.

Personal protection

Personal protection, such as full-length trousers, long-sleeved shirts, socks and shoes, and the use of insect repellents containing DEET or picaridin is needed to provide protection from salt marsh mosquitoes.

For more information please contact: Medical Entomology, CDC, Department of Health, Darwin on (08) 8922 8901

Disclaimer:

- This Pest Calendar has been developed to provide an indication of potential *Ae. vigilax* pest periods, and therefore should only be used as an indicator.

2016 Salt Marsh Mosquito Pest Calendar for coastal NT

JANUARY						
S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

FEBRUARY						
S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29					

MARCH						
S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

APRIL						
S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
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MAY						
S	M	T	W	T	F	S
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15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

JUNE						
S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

JULY						
S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

AUGUST						
S	M	T	W	T	F	S
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14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

SEPTEMBER						
S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

OCTOBER						
S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

NOVEMBER						
S	M	T	W	T	F	S
		1	2	3	4	5
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13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

DECEMBER						
S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

Very high peaks of *Ae. vigilax* High peaks of *Ae. vigilax* Moderate peaks of *Ae. vigilax*

Note:

January 2016:

Due to the predicted late onset of monsoonal rain this wet season, *Ae. vigilax* numbers could still occur in high numbers in early January, as indicated in the calendar.

April - June 2016:

Due to predicted above average tide heights in April to June, moderate numbers of *Ae. vigilax* might occur, as indicated in the calendar.

Appendix 6 – Biting midge (*Culicoides ornatus*) pest calendar 2016.

Northern Territory Government

DEPARTMENT OF **HEALTH**

Biting Midge Pest Calendar for Coastal NT 2016

Culicoides ornatus

Medical Entomology
Centre for Disease Control
Department of Health
Northern Territory Government
www.health.nt.gov.au/Medical_Entomology

Biting Midge Pest Periods in Coastal Northern Territory Areas

The mangrove biting midge, *Culicoides ornatus* can be an appreciable pest close to its breeding sites. In the NT, *C. ornatus* causes the greatest pest problems around extensive coastal and tidal river mangrove areas up to 2km inland from the mangrove margin.

Primary breeding sites are in the upper reaches of small tidal creeks, and are associated with mud and *Rhizophora* and *Avicennia* mangrove pneumatophores. The more of these small mangrove creeks in an area, the greater is the potential for severe pest problems. Less productive breeding sites include muddy foreshores with extensive areas of the woodland mangrove species *Sonneratia alba*. The *Sonneratia* breeding sites can cause a minor pest problem starting 2 to 3 days earlier than the main pest periods indicated in this pest calendar.

Mangrove biting midge abundance is usually highest 3 days either side of the full moon and to a lesser extent 3 days either side of the new moon. Relatively low numbers occur during the wet season, with an increase from April to July. Highest numbers occur between August and November, coinciding with the increase in high tide levels each month during this period.

Biting midges do not transmit diseases to humans in Australia but scratching of the bites may lead to secondary bacterial infection. *Culicoides ornatus* are most active in the 2 hour period before and after sunrise and sunset. However, bites can also occur at other times and during the day in or adjacent to their breeding sites.

Personal protection, such as full-length trousers, long-sleeved shirts, socks and shoes, and the use of insect repellents containing DEET or picaridin will generally be required within 2 km of biting midge breeding sites. Protection is also provided by mosquito lanterns and electric plug in devices. Barrier sprays near outdoor patio or recreation areas applied to screening shrubs and external walls and fences up to 2m high can also offer very good protection for extended periods.

This calendar shows periods when high *C. ornatus* numbers are expected in NT coastal areas in 2016.

For more information on biting midges or personal protection, please contact:

Medical Entomology, CDC, DoH Darwin on (08) 89228901

Disclaimer:

This Pest Calendar has been developed to provide an indication of potential *C. ornatus* pest periods, and therefore should only be used as an indicator.

2016 Biting Midge Pest Calendar for coastal NT

JANUARY						
S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10●	11	12	13	14	15	16
17	18	19	20	21	22	23
24○	25	26	27	28	29	30
31						

FEBRUARY						
S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9●	10	11	12	13
14	15	16	17	18	19	20
21	22	23○	24	25	26	27
28	29					

MARCH						
S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9●	10	11	12
13	14	15	16	17	18	19
20	21	22	23○	24	25	26
27	28	29	30	31		

APRIL						
S	M	T	W	T	F	S
					1	2
3	4	5	6	7●	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22○	23
24	25	26	27	28	29	30

MAY						
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8	9	10	11	12	13	14
15	16	17	18	19	20	21
22○	23	24	25	26	27	28
29	30	31				

JUNE						
S	M	T	W	T	F	S
			1	2	3	4
5●	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20○	21	22	23	24	25
26	27	28	29	30		

JULY						
S	M	T	W	T	F	S
					1	2
3	4●	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20○	21	22	23
24	25	26	27	28	29	30
31						

AUGUST						
S	M	T	W	T	F	S
	1	2	3●	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18○	19	20
21	22	23	24	25	26	27
28	29	30	31			

SEPTEMBER						
S	M	T	W	T	F	S
				1●	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17○
18	19	20	21	22	23	24
25	26	27	28	29	30	

OCTOBER						
S	M	T	W	T	F	S
						1●
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16○	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31●					

NOVEMBER						
S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14○	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29●	30			

DECEMBER						
S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14○	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29●	30	31

Very high peaks of *C. ornatus*

Moderate peaks of *C. ornatus*

High peaks of *C.ornatus*

Low to moderate peaks of *C. ornatus*

○ Full moon ● New moon

APPENDIX H

Noise Impact Assessment report – 2CRU

Noise Impact Assessment

Darwin 2CRU Development

F070_DC1603

Prepared for
Defence Housing Australia

14 December 2016

Cardno
Shaping the Future

Document Information

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Executive Summary

Cardno has been commissioned to undertake a noise impact assessment for the 2CRU development at the northern end of Lee point Road, Lee Point, Darwin.

The greenfield site is situated on the western side of Lee Point Road and is currently vacant and covered by existing vegetation. The 2CRU site is approximately 82 hectares, with 44 hectares suitable for future developments.

This noise impact assessment was conducted on the behalf of Defence Housing Australia. The assessment has been carried out to determine the predicted noise impacts associated on and from the development of the 2CRU project.

Noise modelling has been carried out to determine predicted construction noise impacts upon neighbouring noise sensitive receivers from construction of the site, and to determine predicted road traffic noise impacts on the future developments from Lee Point Road. This assessment considers the following noise impacts:

- Noise impacts from construction of the project in accordance with the *Northern Territory Environmental Protection Authority's Noise guidelines for development sites In the Northern Territory* for the control of construction noise impacts.
- Construction vibration from the project in accordance with *AS 2436 Guide to Noise and Vibration Control on Construction, Maintenance and Demolition Sites*, as outlined in the *Noise guidelines for development sites In the Northern Territory* for assessing vibration.
- Potential impacts from road traffic noise as a result of the development in accordance with the *Northern Territory Government's policy on Road Traffic Noise on NT Government Controlled Roads 2014* and supported by the *Queensland Road Traffic Noise Management Code of Practice 2013* and the *Queensland Environmental Protection (Noise) Policy 2008*.

This assessment considers the following policies and guidelines:

Construction Noise & Vibration:

- NT Noise Guidelines for development sites In the Northern Territory (NTEPA January 2013)
- QLD Road Traffic Noise Management Code of Practice 2014 Volume 2 (TMR CoP Vol 2)

Operational Road Traffic Noise:

- NT Road Traffic Noise on NT Government Controlled Roads (NT Department of Transport November 2014)
- QLD Road Traffic Noise Management Code of Practice 2013 Volume 1 (TMR CoP Vol 1)

The prediction of future road traffic noise levels has been based on projected traffic volumes, as outlined in the traffic impact assessment for the Muirhead North Development & 2CRU prepared in July 2015 by SMEC and DHA. Modelling assumptions have been outlined in Section 5.2 of this report.

Assessment Conclusions

The assessment identified the following conclusions:

Operational Road Traffic Noise

- Modelling indicates that the noise limit of $L_{A10, 18hour}$ 63 dB(A) for residential areas without any external noise mitigation (such as noise barriers) is predicted to be exceeded at 12 of the proposed lots by road traffic noise from Lee Point Road. Four of the 12 lots show exceedances for both ground and first floor levels.
- With the inclusion of 1.8 metre high noise barriers along the boundary of the development site with Lee Point Road, road traffic noise at 9 lots are predicted to exceed the criterion. The 9 exceedances are all located on first floor levels, indicating that double storey dwellings may require consideration of building materials for first floor levels where the noise limit is exceeded, unless additional external mitigation is implemented such as higher noise barriers between the affected lots and Lee Point Road.
- The assessment concludes that noise barriers are not required between Lee Point Road and the northern part of the development to achieve compliance with the 63 dB(A) external noise limit, due to the smaller projected traffic volumes at the northern end of Lee Point Road.
- The assessment indicates that non-residential noise sensitive uses, such as schools, childcare or hospitals, are not recommended to be located immediately adjacent to Lee Point Road as the applicable $L_{A10, 18hour}$ of 58 dB(A) criterion is predicted to be exceeded at 70 receivers without the inclusion of noise barriers adjacent to Lee Point Road
- With the provision of 1.8 metre high noise barriers between the development site and Lee Point Road, road traffic noise is predicted to exceed the 58 dB(A) noise limit at 29 Lots.
- The noise contour maps indicate that road traffic noise impact upon the development site is primarily occurring at the southern end of the development site. The noise contour maps also show that the inclusion of 1.8 metre high noise barriers provides a significant amount of noise mitigation at ground floor levels of affected Lots.
- The noise modelling indicated that most of the lots will require building construction in accordance with either AS 3671 Category 1 or 2. However 48 receivers, distributed across 26 lots, will require building construction in accordance with AS 3671 Category 3 without the provision of noise barriers.
- The number of receivers requiring AS 3671 Category 3 construction reduces to 15 (all at first floor levels) with the provision of 1.8 metre high noise barriers as shown in Figure A-1 and Figure A-2 in Appendix A.
- Acoustic design principles should be taken into account during the final stage when considering overall layout and building orientation and shielding effects. Some principles to consider are listed below.
    - The building to be set back from the transport corridor as far as possible;
    - The building to shape away from the transport corridor;
    - The building to shield courtyards and open space areas from the corridor; and
    - Noise sensitive spaces, such as bedrooms, should be shielded from noise by positioning less sensitive spaces, such as the garage, bathrooms and laundry, closer to the corridor.

Construction Noise Impacts

- Construction noise levels are predicted to exceed the design benchmark noise limits for worst case scenarios where work is conducted at the boundary of the development or where Lee Point Road is upgraded.
- The exceedances are due to limited separation distance between the site and neighbouring receivers and the high noise levels typically generated by construction plant. However it is worth noting that the predicted construction noise levels only are applicable where work is conducted at locations in close vicinity to the affected receivers which will be for shorter durations only, as clearing of vegetation and general construction work will move around the development site as work progresses.

- Maximum noise levels have been predicted to the nearest affected residential receivers to allow a review of the potential for sleep disturbance from construction activities at night. The results indicate that maximum construction noise levels at the nearest noise sensitive receivers are likely to exceed the sleep disturbance criteria, when construction works are located nearby. For this reason it is recommended that activities with potentially high maximum levels such as the use of pneumatic tools and truck air-braking are minimised or not carried out at these locations during the night-time period.
- It should be noted that this assessment has endeavoured to carry out "worst case" noise modelling, and noise levels are predicted based on a moving point source representative of the total construction noise level moving along the length of the project. Should the work sites or plant and equipment be relocated so that other receivers are located closer to the works, these receivers are likely to be affected more significantly than predicted in this report.
- The predicted exceedances are generally a result of works being located in close proximity to the adjacent receivers. This modelling has been carried out to provide a worst case scenario and it may be possible to reduce the number of plant operating simultaneously, particularly at night, once detailed construction schedules are known. This can be investigated further during preparation of the construction noise and vibration management plan for the project.
- Provision of temporary noise barriers is likely to be required between local construction sites and receivers, if night-time works are required near noise sensitive receivers.
- Best practice mitigation measures are recommended in Section 8 of this report.
- A detailed construction noise and vibration management plan should be prepared for the project prior to construction commencement to incorporate the recommendations detailed in Section 8 and updated to reflect the proposed staging and plant to be adopted for the project.

Construction Vibration Impacts

- Sensitive structures are located immediately adjacent to the Lee Point Road transport corridor at the southern part of Lee Point Road indicating that consideration of vibration impacts will be required during the upgrade of the southern part of the transport corridor.
- The nearest sensitive receivers adjacent to the northern section of Lee Point Road are located in excess of 15 metres from the transport corridor, indicating that larger plant items may be used for the upgrade of this section of road.
- Human discomfort may be felt should large vibratory rollers be used within 100 metres of nearby receivers. Therefore, vibratory rolling should only be carried out at night if the vibratory roller is rated less than 100 kN and the distance to vibration sensitive receivers is in excess of 20 metres to avoid the risk of human discomfort and sleep disturbance.
- A detailed construction noise and vibration management plan should be prepared for the project prior to construction commencement to incorporate the recommendations detailed in Section 8 and updated to reflect the proposed staging and plant to be adopted for the project.

Table of Contents

Executive Summary iii
Construction Noise & Vibration: iii
Operational Road Traffic Noise: iii
Assessment Conclusions iii
Operational Road Traffic Noise iv
Construction Noise Impacts iv
Construction Vibration Impacts v
Technical Terms 9
1 Introduction 10
1.1 Assessment Objectives 10
1.2 Project Description 10
1.2.1 Existing Site Description 10
1.2.2 Proposed Project 11
2 Existing Noise Environment 13
3 Statutory Noise & Vibration Criteria 15
3.1 NT EPA Noise Guidelines for Development Sites in the Northern Territory 15
3.2 QLD EPA EcoAccess Planning For Noise Control 16
3.3 NT Government - *Road Traffic Noise on NT Government Controlled Roads (RTNNTGCR)* 17
3.4 QLD TMR Road Traffic Noise Management Code of Practice 2014 Volume 2 – Construction Noise & Vibration 18
3.5 Australian & International Standards 18
4 Design Benchmarks 20
4.1 Construction Noise 20
4.2.1 Human Comfort Criteria 20
4.2.2 Building Damage Criteria 21
4.3 Road Traffic Noise 21
4.3.1 External Noise Objectives 21
4.3.2 Internal Noise Objectives 22
5 Operational Noise & Vibration Impacts 23
5.1 General Modelling Methodology 23
5.1.1 Application of Correction Factors 23
5.1.2 Modelled Scenarios 23
5.2 Noise Modelling Inputs & Assumptions 24
5.2.1 General Modelling Input Data 24
5.2.2 Modelled Road Segments 24
5.2.3 Traffic Volumes and Posted Speed 25
5.3 Modelled Receivers 26
5.4 Predicted Noise Levels 26
5.5 Result Overview 26
6 Construction Noise Impact Assessment 27
6.1 Construction Noise Assessment Methodology 27
6.2 Modelled Construction Phases 27
6.3 Noise Sensitive Areas 27
6.4 Construction Timing 27
6.5 Construction Plant & Equipment 28

6.6 Predicted Construction Noise Levels 29
6.7 Construction Noise Results Summary 30
6.7.1 Continuous Construction Noise 30
6.7.2 Sleep Disturbance 31
7 Construction Vibration Assessment 31
7.1 Vibration Limits 31
7.1.1 Vibration Assessment 32
8 Recommended Mitigation Measures 33
8.1 General Construction Noise & Vibration 33
8.2 Site Specific Measures 33
8.2.1 Plant Controls 33
8.2.2 Manage of Hours of Operation 34
8.2.3 Management and Behaviour Controls 34
9 Conclusions 35
9.1 Operational Road Traffic Noise Impacts 35
9.2 Construction Noise Impacts 35
9.3 Construction Vibration Impacts 36

Appendices

Appendix A Receivers Within the Development
Appendix B Predicted Noise Levels for Modelled Receivers in the 2CRU Development
Appendix C Noise Contour Maps – Road Traffic Noise Impact
Appendix D Noise Contour Maps – Construction Noise Impact

Tables

Table 2-1 Estimated Average Background Noise Levels for Different Areas in Australia 13
Table 2-2 Adopted Assessment Background Noise Levels, dB(A) 14
Table 3-1 NT EPA Construction Noise Criteria during Acceptable Construction Times 15
Table 3-2 Target Road Traffic Noise Objectives for Land Uses Adjacent to Arterial Roads 17
Table 3-3 Recommended design internal noise levels – AS/NZS 2107:2000 19
Table 4-1 Construction Noise Limits 20
Table 4-3 Structural Damage Criteria 21
Table 4-4 Vibration Damage to Infrastructure & Assets – Transient Vibration 21
Table 4-6 Recommended Internal Project Specific Noise Criteria 22
Table 5-1 Modelled Scenarios 24
Table 5-2 Modelling Assumptions 24
Table 5-3 Projected (2025) Daily Traffic Volumes and Speeds 25
Table 6-1 Construction Plant Sound Power Levels 28
Table 6-2 Predicted Construction Noise Levels – Clearing and Site Establishment 29
Table 6-3 Predicted Construction Noise Levels – Bulk Earthworks 29
Table 6-4 Predicted Construction Noise Levels – Drainage Infrastructure 30
Table 6-5 Predicted Construction Noise Levels – Road Surfacing Works 30

Table 7-1 Recommended Minimum Working Distance 32
Table B-1 Predicted Noise Levels for Year 2026 for the 2CRU development – with no Mitigation 41
Table B-2 Predicted Noise Levels for Year 2026 for the 2CRU development – with 1.8 metre Noise Barriers 70

Figures

Figure 1-1 Site Location and Surrounding Land Uses 11
Figure 1-2 Proposed 2CRU Zoning 12
Figure 5-1 Modelled Road Segments 25
Figure A-1 Modelled Noise Sensitive Receivers and Modelled Noise Barrier Locations for the Southern Part of 2CRU. 38
Figure A-2 Modelled Noise Sensitive Receivers and Modelled Noise Barrier Locations for the Northern Part of 2CRU. 39
Figure C-1 Façade Corrected Noise Contour Map without Noise Barriers $L_{10,\ 18hour}$ Modelled at Ground Floor Level. 100
Figure C-2 Façade Corrected Noise Contour Map without Noise Barriers $L_{10,\ 18hour}$ Modelled at First Floor Level. 101
Figure C-3 Façade Corrected Noise Contour Map with 1.8m High Noise Barriers $L_{10,\ 18hour}$ Modelled at Ground Floor Level. 102
Figure C-4 Façade Corrected Noise Contour Map with 1.8m High Noise Barriers $L_{10,\ 18hour}$ Modelled at First Floor Level. 103
Figure D-1 Noise Contour Map for Clearing of Vegetation and Site Establishment 105
Figure D-2 Noise Contour Map for Bulk Earthworks 106
Figure D-3 Noise Contour Map for Drainage Infrastructure 107
Figure D-4 Noise Contour Map for Road Surfacing Works 108

Technical Terms

Term	Definition
Adverse Weather	Weather effects that enhance noise (that is, wind and rain) that occur at a site for a significant period of time (that is, wind exceeding 5 m/s and rain exceeding 0.5 mm per hour during any measurement period.)
A-weighted Level	As per dB(A) defined below.
Ambient Sound	Of an environment: the all-encompassing sound associated with that environment, being a composite of sounds from many sources, near and far.
Background Sound Level	The average of the lowest levels of the sound levels measured in an affected area in the absence of noise from occupants and from unwanted external ambient noise sources.
CoRTN	Calculation of Road Traffic Noise, 1988
dB(A)	Unit of acoustic measurement electronically weighted to approximate the sensitivity of human hearing to sound frequency.
Decibel, dB	Unit of acoustic measurement. Measurements of power, pressure and intensity may be expressed in dB relative to standard reference levels.
L90, L10 etc.	A statistical measurement giving the sound pressure level which is exceeded for the given percentile of an observation period, i.e. L90 is the level which is exceeded for 90 percent of an observation period. L90 is commonly referred to as a basis for measuring the background sound level.
LAbg, T	The A-weighted background sound level measured over a time interval T.
LAeq, T	Equivalent continuous A-weighted sound pressure level. This is the value of the A-weighted sound pressure level of a continuous steady sound that, within a measurement time interval T, has the same A-weighted sound energy as the actual time-varying sound.
SEL	Sound Exposure Level (SEL) is the constant sound level which, if maintained for a period of 1 second would have the same acoustic energy as the measured noise event. SEL noise measurements are useful as they can be converted to obtain Leq sound levels over any period of time and can be used for predicting noise at various locations.
Sound Pressure Level, Lp, dB, of a sound	A measurement obtained directly obtained using a microphone and sound level meter. Sound pressure level varies with distance from a source and with changes to the measuring environment. Sound pressure level equals 20 times the logarithm to the base 10 of the ratio of the r.m.s. sound pressure to the reference sound pressure of 20 microPascals.
Sound Power Level, Lw, dB of a source	Sound power level is a measure of the sound energy emitted by a source, does not change with distance, and cannot be directly measured. Sound power level of a machine may vary depending on the actual operating load and is calculated from sound pressure level measurements with appropriate corrections for distance and/or environmental conditions. Sound power level is equal to 10 times the logarithm to the base 10 of the ratio of the sound power of the source to the reference sound power of 1 picoWatt.

1 Introduction

A noise impact assessment was undertaken for the proposed 2CRU development on the western side of Lee Point Road approximately 15 km northeast of Darwin. The assessment has been undertaken to determine the following:

- Predicted construction noise impact upon neighbouring noise sensitive receivers as a result of clearing and construction of the development sites.
- Predicted road traffic noise impacts on the development site as a result of traffic on Lee Point Road.

Noise mitigation measures were determined for both construction noise and for noise generated by traffic on Lee Point Road, where required.

This assessment considers the following policies and guidelines:

- NT Noise Guidelines for development sites In the Northern Territory (NTEPA January 2013)
- NT Road Traffic Noise on NT Government Controlled Roads (NT Department of Transport November 2014)
- QLD Road Traffic Noise Management Code of Practice 2013 Volume 1 (TMR CoP Vol 1)
- QLD Road Traffic Noise Management Code of Practice 2014 Volume 2 (Construction Noise) (TMR CoP Vol 2)

This assessment has used the UK "Calculation of Road Traffic Noise (CoRTN)" method to assess operational traffic noise in accordance with the Northern Territory's Department of Transport requirements. The Northern Territory's Department of Transport has indicated target road traffic noise objectives for land uses adjacent to arterial roads. It should be noted that Lee Point Road is not a state controlled road but a local council road. However due to the absence of road traffic noise criteria for roads operated by Darwin Council, the criteria outlined in the Northern Territory Government's Road Traffic Noise on NT Government Controlled Roads has been adopted.

Furthermore it should be noted that noise monitoring to determine existing background noise levels was not conducted as part of this assessment.

1.1 Assessment Objectives

The assessment objectives are:

1. To determine the predicted levels of noise and vibration impact on sensitive receivers located near to the project site during the construction period, and to determine the levels of mitigation likely to be required, if applicable, to enable compliance with the current Northern Territory legislation.
2. To determine the predicted levels of road traffic noise from Lee Point Road impacting on the 2CRU project site, and determine the levels of mitigation likely to be required, if applicable, to enable compliance with the current Northern Territory legislation.

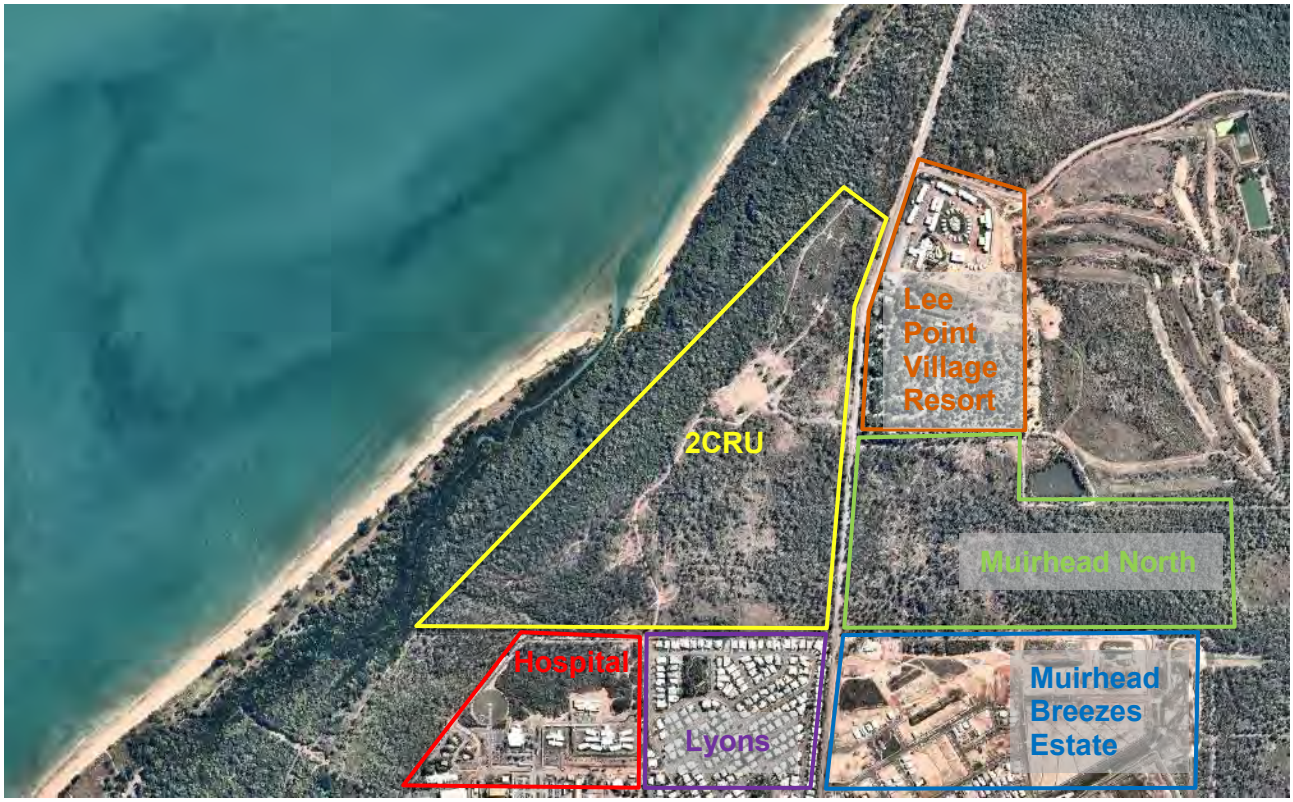
1.2 Project Description

1.2.1 Existing Site Description

The proposed development site is located 15 km northeast of Darwin in a currently rural area in nature but scheduled for several residential subdivisions and other developments in the future.

Figure 1-1 shows the location of the 2CRU site as well as current and future developments adjacent to the site.

Figure 1-1 Site Location and Surrounding Land Uses



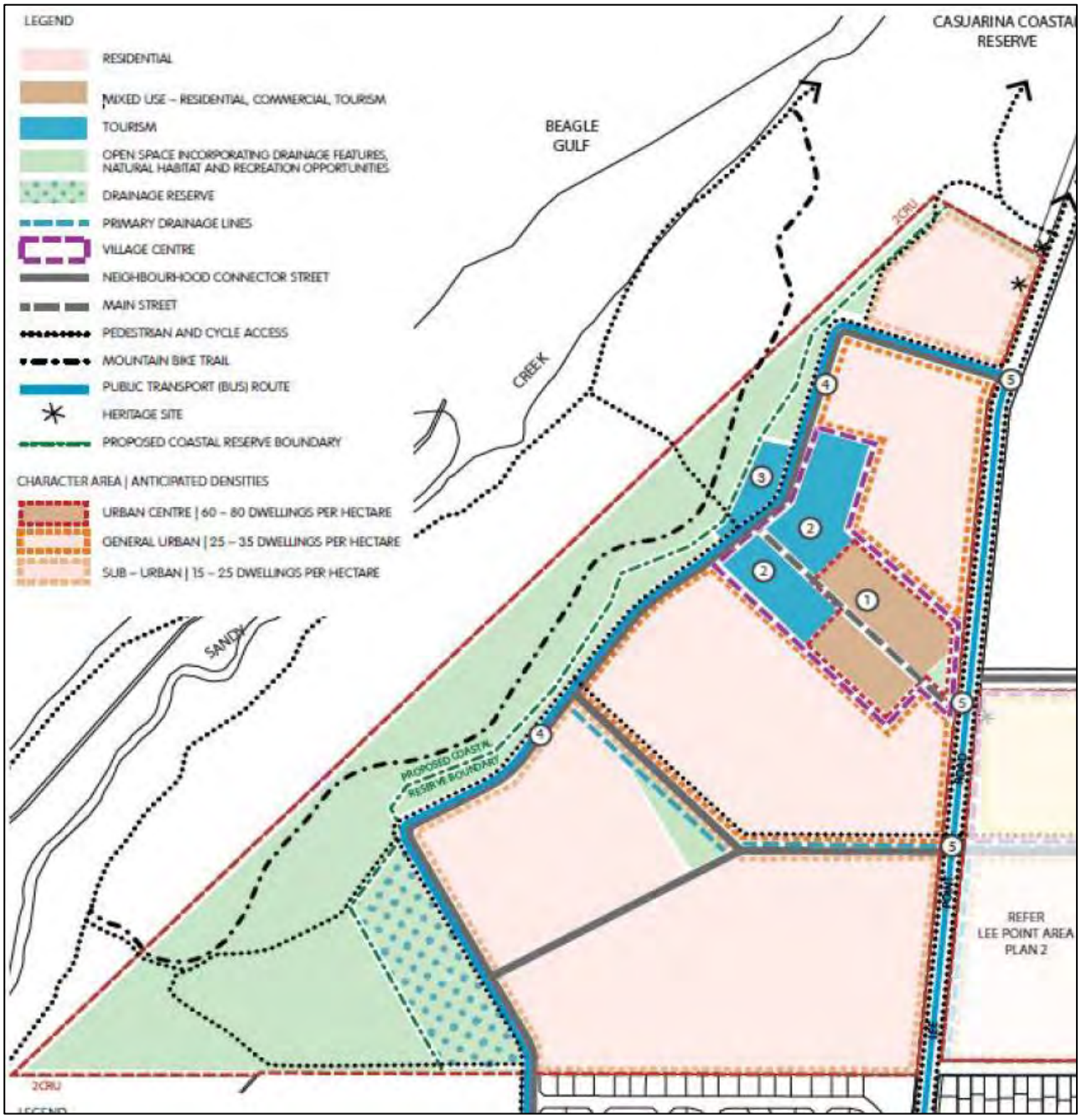
1.2.2 Proposed Project

Defence Housing Australia propose to develop the currently vacant land on lot 4873 denoted as 2CRU. The 2CRU development is proposed to accommodate residential dwellings along with serviced apartments, hotels, private apartments as well as tourist, commercial and retail area.

The proposed plans for the 2CRU site indicate that the only development within 150 metre from Lee Point Road is either residential dwellings or mixed use (residential, commercial and tourism), whereas a dedicated tourism area is proposed far (greater than 150 metres) from Lee Point Road near the beach.

Figure 1-2 shows the proposed zoning for the 2CRU development.

Figure 1-2 Proposed 2CRU Zoning



2 Existing Noise Environment

The existing ambient noise is likely to vary throughout the area. Ambient noise levels would be low in the middle of the site and increase closer to roads, the ocean, the hospital or construction works at other development sites such as the Muirhead Breezes Estate. The existing ambient noise levels have not been measured, as the current site conditions will change as the development sites progress, and are not reflective of the finished or intermediate ambient conditions. On this basis, the ambient noise levels have been estimated in accordance with Australian Standard AS1055.2 – "Acoustics – Description & Measurement of Environmental Noise", to determine appropriate construction noise limits.

Table 2-1 is an extract from Appendix A of AS1055.2 which summarises the estimated average background A-weighted sound pressure levels ($L_{A90,T}$) for different areas containing residences in Australia.

Table 2-1 Estimated Average Background Noise Levels for Different Areas in Australia

Noise Area Category	Description of Neighbourhood	Average background A-weighted sound pressure level, $L_{A90,T}$					
		Monday to Saturday			Sunday and public holidays		
		0700-1800	1800-2200	2200-0700	0900-1800	1800-2200	2200-0900
R1	Areas with negligible transportation	40	35	30	40	35	30
R2	Areas with low density transportation	45	40	35	45	40	35
R3	Areas with medium density transportation or some commerce or industry	50	45	40	50	45	40
R4	Areas with dense transportation or some commerce or industry	55	50	45	55	50	45

The nature reserves and the residential areas surrounding the project site have been considered as: "Noise Area Category R2" and are described as: "Areas with low density transportation".

The hospital site is considered as: "Noise Area Category R3", described as: "Areas with medium density transportation or some commerce or industry", due to typical higher traffic volumes associated with hospitals (staff and visitors).

On this basis the ambient noise levels outlined in Table 2-2 have been adopted for each of the receiver areas located around the subject site:

Table 2-2 Adopted Assessment Background Noise Levels, dB(A)

Sensitive Receiver	Adopted AS 1055.2 Category	Assumed Background A-Weighted Sound Pressure Level, $L_{A90,T}$		
		0700-1800	1800-2200	2200-0700
Lyons	R2	40	35	30
Lee Point Village Resort	R2	40	35	30
Muirhead Breezes Estate	R2	40	35	30
Hospital	R3	50	45	40
Northern Reserve	R2	40	35	30
Western Reserve	R2	40	35	30
Eastern Reserve	R2	40	35	30

The established construction noise limits for the project are shown in Table 4-1.

3 Statutory Noise & Vibration Criteria

3.1 NT EPA Noise Guidelines for Development Sites in the Northern Territory

The Northern Territory Environmental Protection Authority's Noise Guidelines for Development Sites in the Northern Territory May 2014 outline acceptable construction times and noise levels that should not be exceeded during those times.

The guideline states that construction activities should be restricted to:

a. between the hours of 7am and 7pm Monday to Saturday; and

b. between the hours of 9am and 6pm on a Sunday or public holiday.

Table 3-1 outlines the specified construction noise limits for work undertaken during the acceptable construction times.

Table 3-1 NT EPA Construction Noise Criteria during Acceptable Construction Times

Designation Area	Construction Noise Limit $L_{Aeq, 15min}$
Residential	Ambient noise* plus 5 dB(A)
Mixed commercial/residential	60 dB(A)
Commercial	65 dB(A)
Industrial	70 dB(A)

* Ambient noise is not explained in the Noise Guidelines for Development Sites in the Northern Territory, it has therefore been assumed to be the background noise level typically described as the L_{A90} noise descriptor.

The levels specified in Table 3-1 apply within 15 metres of a Noise Sensitive Receptor (NSR) or at or on the boundary of the NSR (including when adjusted +5 dB each for for tonality or modulation, and +10 dB for impulsiveness).

Those responsible for development sites and construction activities are advised of their obligations under Part 3 of the Act, which stipulates their responsibility to notify of an incident, where there is reason to believe that the incident has caused or is threatening to cause pollution. The guideline further states that noise from a development site may be considered an environmental nuisance or pollution and may be considered an offence under the Act if:

a. the construction activity is conducted:
   i. outside the hours of 7am and 7pm Monday to Saturday; or
   ii. on a Sunday or public holiday outside the hours of 9am and 6pm;

b. the construction activity generates noise which exceeds the construction noise levels defined in these guidelines;

c. the construction activity was not carried out in accordance with „AS 2436 Guide to Noise and Vibration Control on Construction, Maintenance and Demolition Sites"; and

d. 48 hours' notice was not given to the occupiers of all noise-receiving premises where noise levels for the development site are likely to be of concern including;

   i. a description of proposed construction activity likely to cause a nuisance;
   ii. the date(s), time(s) and duration for the construction activity likely to cause a nuisance; and
   iii. the name and phone number of the person to whom a complaint may be made about noise emissions from the site;

OR

a. the activity was not carried out in accordance with a Noise Management Plan (NMP) registered with the NT EPA.

The guideline recommends community consultation in order to reduce the likelihood of complaints, where an isolated (i.e. one-off) activity is likely to occur which may cause environmental nuisance, the NT EPA recommends any NSRs (such as surrounding residential/commercial premises) in the area around the development site be given at least 48 notification about the noise activity and given the opportunity to provide feedback. Any feedback received should then be considered and accommodated. The guideline outlines that a NMP is required if noise resulting from a construction activity is to be emitted from a development site:

a. outside the times 7am to 7pm Monday to Saturday; or

b. outside the times 9am to 6pm on a Sunday or public holiday; or

c. is likely to exceed the construction noise levels defined in these guidelines; AND

d. the construction work is proposed, or taking place on, land within or directly adjacent to land zoned Commercial or Residential,

the party responsible for the development site must develop and register a NMP with the NT EPA. NMPs should comply with „AS 2436: Guide to Noise and Vibration Control on Construction, Maintenance and Demolition Sites".

A NMP must include management and mitigation strategies to prevent an environmental nuisance caused by construction noise. The NMP is to include, as a minimum:

a. justification for work on the development site, that is likely to be undertaken outside of the acceptable construction times (between the hours of 7am and 7pm Monday to Saturday and/or between the hours of 9am to 6pm on a Sunday or public holiday);

b. details and the duration of the activities on the development site likely to cause noise emissions that may exceed the construction noise levels defined in these guidelines;

c. details clearly demonstrating how site activity will comply with „AS 2436 Guide to Noise and Vibration Control on Construction, Maintenance and Demolition Sites";

d. documented complaint response procedures and how the procedures will be implemented;

e. documentation of the verifiable consultation and feedback program with occupants of all affected premises, demonstrating that all occupants were provided with advice on dates, times and nature of any potentially noisy and disruptive activity including measures proposed to mitigate such activity as well as noise complaint contact details;

f. a copy of any feedback received from any affected premises and an explanation on how the feedback was considered and accommodated in the NMP; and

g. name of the onsite person who will be responsible for implementing the NMP and the name and phone number of the person to whom a complaint may be made about noise emissions from the site.

3.2 QLD EPA EcoAccess Planning For Noise Control

In the absence of NT specific crteria for sleep disturbance relevant guidelines from the World Health Organiszation and the QLD EPA EcoAccess Planning for Noise Control Guideline have been refenced.

The World Health Organisation (WHO) issued its "Guidelines for Community Noise" in April 1999. The WHO guideline states the following in regard to sleep disturbance from continuous noise from activities such as mining operations:

"Where noise is continuous, the equivalent sound pressure level should not exceed 30 dB(A) indoors, if negative effects on sleep are to be avoided. When noise is composed of large proportion of low-frequency sounds a still lower guideline

value is recommended, because low-frequency noise (e.g. from a ventilation system) can disturb rest and sleep even at low sound pressure levels."

The EcoAccess Guideline "Planning for Noise Control", is referring to the World Health Organisation guideline, makes the following general recommendations regarding short term transient noise events:

"As a rule in planning for short-term or transient noise events, for good sleep over eight hours, the indoor sound pressure level measured as a maximum instantaneous value should not exceed approximately L_{Amax} *45 dB(A) more than 10 to 15 times per night."*

For less regular night events, the allowable internal noise level is higher, as follows:

- Approximately 3 events per night, L_{Amax} 50 dB(A)
- Approximately 1 event per night, L_{Amax} 65 dB(A)

In the EcoAccess Guideline it is proposed that the noise reduction provided by a typical residential building façade is 5 to 10 dB(A) assuming open windows. That is, with an external noise source, a 5 to 10 dB(A) reduction in noise levels from outside a house to inside a house is expected when windows are fully open. Thus the indoor noise levels noted above could be considered as the following external noise levels:

- Approximately 10-15 events per night, L_{Amax} 50 to 55 dB(A)
- Approximately 3 events per night L_{Amax} 55 to 60 dB(A)
- Approximately 1 event per night, L_{Amax} 70 to 75 dB(A)

3.3 NT Government - *Road Traffic Noise on NT Government Controlled Roads (RTNNTGCR)*

In the absence of road traffic noise criteria for roads operated by the City of Darwin the criteria outlined in the Northern Territory Government's Road Traffic Noise on NT Government Controlled Roads is adopted.

Table 3-2 outlines the target noise levels for particular types of road situations for residential and noise-sensitive land uses adjacent to arterial roads. The target levels outlined in Table 3-2 are not mandatory but are levels which the NT Department of Transport will consider for application within budgetary and physical constraints.

Table 3-2 Target Road Traffic Noise Objectives for Land Uses Adjacent to Arterial Roads

Project Type	Existing Residential Use	Existing Noise-Sensitive use	Future Residential or Noise-Sensitive Use
Existing Road Existing Road Upgrade Future Road Currently Planned	No target - no required action	No target - no required action	Responsibility rests with the proponent (private or government agency)
Future Road Not Currently Planned	Target 63 dB(A) $L_{10,18hr}$	Target 58 dB(A) $L_{10,18hr}$	

An Explanation of the terms shown in Table 3-2 is detailed below:

$L_{10,18hr}$ - unless otherwise stated, these values are measured at 1 metre from the façade of a building in accordance with Australian Standard 2702-1984 "Acoustics – Methods for the measurement of road traffic noise" and the method described above.

Existing road – an existing arterial road; includes a road subject to activities such as routine maintenance or minor development including new intersection turn lanes or other upgrading, traffic management measures such as a new roundabout or traffic signals, or normal traffic growth over time.

Existing Road Upgrade - a major upgrade to an existing arterial road such as the addition of new lane(s) or carriageway(s) or where the traffic mix or volume is significantly altered as a result of changes at the network level,

where the information has been available in the public domain for identification by way of publicly available government (i.e. Departmental) plans or documents at the time of development of the adjacent land.

Future Road Currently Planned - a new road or road corridor which has been identified in publicly available government plans or documents at the time of development of the adjacent land.

Future Road Not Currently Planned - any new roads or corridors which are not currently identified in publicly available government plans or documents at the time of release of this policy.

Existing Residential - residential land use immediately adjacent to arterial roads.

Existing Noise-Sensitive - includes aged care facilities, hospices and nursing homes and may include schools, libraries and hospitals. Commercial accommodation facilities relying on passing trade are not considered as noise sensitive developments under this policy.

Future Residential or Noise-Sensitive - any residential or noise sensitive land use adjacent to or in the vicinity of arterial roads which does not exist at the time of the release of this policy.

The Road Traffic Noise on NT Government Controlled Roads further states:

- Any noise management regimes and ameliorative measures for developments adjacent to planned or existing roads shall be in accordance with the requirements of the approval issued under the land use planning process, and shall be contained fully within the properties concerned; and
- New land development adjacent to an arterial road should be planned and developed in accordance with the provisions of the approval issued under the land use planning process stipulating an appropriate target $L_{10,18hr}$ noise level.

3.4 QLD TMR Road Traffic Noise Management Code of Practice 2014 Volume 2 – Construction Noise & Vibration

In the absence of NT Policies or guidelines with respect to construction vibration limits, relevant criteria has been referenced from the QLD TMR COP Volume 2 for both human comfort and building damage related vibration limits.

The CoP Volume 2 provides a section on the assessment of construction vibration form road projects. The criteria from this code of practice have been adopted for this assessment.

Vibration criteria for both human comfort and building damage due to ground borne vibration caused by construction activities (e.g. pile driving, compaction and blasting) are provided in this section. It should be noted that compliance in most cases with the human comfort criteria would also achieve the building damage criteria.

The British Standard BS 5228-2:2009 provides an alternative approach to those historically used to assess human comfort presented in the British Standard BS 6472-1:2008. While BS 6472-1 provides guidance on human response to vibration in buildings in terms of VDV, BS 5228-2 Table B.1 provides guidance on the use of PPV which is typically measured to determine potential building damage.

For human comfort in order to minimise annoyance due to ground borne construction vibration, this Code adopts vibration levels with lower and upper limits as presented in Table 4-2. The low limits are generally considered to be just perceptible if just exceeded. The upper limits are considered to cause significant annoyance if exceeded.

All reasonable and practicable measures should be implemented to achieve the lower limit. Exceedance of the upper limit requires immediate action and extensive community consultation to determine further mitigation measures.

The criteria associated with building damage are summarised in Section 4, in Table 4-3 and Table 4-4.

3.5 Australian & International Standards

Other relevant criteria and assessment methodologies are contained in Australian Standards. The following Australian Standards have been referenced in this assessment.

- Australian Standard AS1055: "Acoustics – Description and measurement of environmental noise"
- Australian Standard AS/NZS 2107:2000 "Recommended design sound levels and reverberation times for building interiors.
- Australian Standard AS 2702 – 1984, Methods for the Measurement of Road Traffic Noise.
- Australian Standard AS3671:1989, "Acoustics – Road Traffic Noise Intrusion – Building Siting & Construction"
- German Standard DIN 4150: "Structural Vibration – Effects of vibration on structures"
- British Standard BS 7385.2: 1993, "Evaluation and measurement for vibration in buildings" - Part 2.
- Australian Standard AS 2436:2010, "Acoustics – "Guide to Noise & Vibration Control on Construction, Demolition & Maintenance Sites"

3.5.1.1 AS/NZS 2107:2000

Table 3-3, referenced from the Australian Standard AS/NZS 2107:2000 states the following guidelines for internal sound levels, in a wide range of buildings and provides internal noise guidelines for residential buildings in areas that are located near major roads.

Table 3-3 Recommended design internal noise levels – AS/NZS 2107:2000

Type of Receiver	Acceptable Noise Level, L_{Aeq} dB(A)	Recommended Maximum L_{Aeq}, dB(A)
7. Residential Buildings		
Houses and Apartments near major roads-		
Sleeping Areas	30	40
Living Areas	35	45
Work Areas	35	45
Apartment common areas	45	55

3.5.1.2 AS3671:1989

AS 3671 provides methods to determine the required Traffic Noise Reduction and the types of construction required to achieve this reduction. The standard references the internal design sound levels listed in AS/NZS 2107. In accordance with Clause 3.2 of AS3671, the worst case Traffic Noise Reduction (TNR) can be calculated and associated category construction adopted. The required categories are defined as follows:

3.2.1 Category 1. Standard construction; openings, including open windows and doors may comprise up to 10% of the exposed facade. TNR of approximately 10 dB(A) is expected.

3.2.2 Category 2. Standard construction, except for lightweight elements, such as fibrous cement, or metal cladding, or all glass facades. Windows, doors and other openings must be closed. TNR of approximately 25 dB(A) is expected.

3.2.3 Category 3. Special construction, chosen in accordance with Clause 3.4. Windows, doors and other openings must be closed. TNR between 25 and 35 is expected.

4 Design Benchmarks

4.1 Construction Noise

The project area is surrounded by nature reserves, and residential areas north of Darwin hospital. In the absence of specific relevant noise criteria for hospitals and the nature reserve, the criteria for residential receivers has been adopted.

The existing ambient noise levels were not measured but estimated as outlined in Section 2. The estimated ambient noise levels have been referenced to establish the construction noise limits.

Works may have to be carried out, outside of standard hours due to the tropical climate. For this reason construction noise limits have been calculated for both standard and non-standard hours.

Taking into consideration the estimated ambient noise levels in Section 2 and the criteria from Section 3.1, the applicable construction noise limits for the project are shown in Table 4-1.

Table 4-1 Construction Noise Limits

Noise Area	Construction Noise Limit, $L_{Aeq,15\ min}$		Sleep Disturbance from 10pm to 7am, L_{Amax} Externally
	Monday to Saturday from 7am to 7pm	Sunday and public holidays from 9am to 6pm	
Residential	50	50	65
Nature Reserve	50	50	65
Hospital	55	55	65

4.2 Construction Vibration

4.2.1 Human Comfort Criteria

The following vibration criteria for human comfort apply to this project.

Table 4-2 Preferred & Maximum Levels for Human Comfort

Building	Work Period	Examples	
		Lower Limit	Upper Limit
Dwellings (including hotels and motels)	Standard hours	1.0	2.0
	Non-Standard hours - evening	0.3	1.0
	Non-Standard hours - night-time		
Medical/health buildings (wards, surgeries, operating theatres, consulting rooms)	All	0.3	1.0
Educational facilities (rooms designated for teaching purposes)	While In Use		
Court of Law (Court rooms)			
Court of Law (Court reporting and transcript areas, Judges' chambers)			

Building	Work Period	Examples	
		Lower Limit	Upper Limit
Community buildings (Libraries, places of worship)	While In Use	1.0	2.0

4.2.2 Building Damage Criteria

The minimum 'safe limit' of vibration at low frequencies for commercial and industrial buildings are presented in DIN 4150.3 as follows:

Table 4-3 Structural Damage Criteria

Applicable Assessment Criteria	Assessment Criteria , mm/s	
	Day (7 AM–10 PM)	Night (10 PM–7 AM)
Dwellings (including hotels and motels)	5 (rms) at 1-10Hz 5 to 15 (rms) at 10-50Hz 15 to 20 (rms) at 50-100Hz	German Standard DIN 4150
	3 (rms) at 1-10Hz 3 (rms) to 8 at 10-50Hz 8 to 10 (rms) at 50-100Hz	German Standard DIN 4150

Table 4-4 Vibration Damage to Infrastructure & Assets – Transient Vibration

Type of Building	Resultant PPV in Frequency Range of Dominant Pulse, mm/s	
	4 to 15Hz	15Hz and above
Reinforced or framed structures. Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	-
Unreinforced or light framed structure. Residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

4.3 Road Traffic Noise

4.3.1 External Noise Objectives

In the absence of road traffic noise criteria for roads operated by the City of Darwin the criteria outlined in the Northern Territory Government's Road Traffic Noise on NT Government Controlled Roads is adopted. Table 4-5 below shows the applicable road traffic noise limits.

Table 4-5 Summary of External Road Traffic Noise Limits

Receiver Description	Applicable Road Traffic Noise Limits	
	Noise descriptor	External noise level in dB(A)
Residential, Hotels and Tourist Precincts	$L_{10,18hr}$	63
School, Day Care, Library and Community Building	$L_{10,18hr}$	58
Outdoor Educational and Passive Recreational Areas	$L_{10,18hr}$	58
Hospital, Aged Care Facility and Nursing Home	$L_{10,18hr}$	58

4.3.2 Internal Noise Objectives

The Northern Territory Government's Road Traffic Noise on NT Government Controlled Roads does not take night-time traffic volumes into consideration. To determine required façade noise reduction to achieve compliance with the recommendations outlined in AS 2107 we recommend that night time traffic noise levels be determined and assessed against the Acceptable Noise Levels as outlined in AS 2107. Table 4-6 shows the recommended internal noise levels for residential buildings adjacent to Lee Point Road. Previous noise measurements indicate that traffic noise levels typically are 3 dB(A) lower at night compared to the day time, this conversion factor has been used to determine night-time traffic noise levels.

Table 4-6 Recommended Internal Project Specific Noise Criteria

Area	Applicable Rooms	Recommended Internal Design Sound Objective, $L_{eq,(T)}$, dB(A)
7. Residential Buildings		
Houses and Apartments near major roads-		
Sleeping Areas	All bedrooms	30
Living Areas	Lounge rooms within dwellings	35
Work Areas		35
Apartment common areas		45

5 Operational Noise & Vibration Impacts

The prediction of road traffic noise was conducted with the 3D noise modelling software SoundPLAN 7.4. SoundPLAN software applies the algorithm from the Calculation of Road Traffic Noise, UK Department of Transport, Welsh Office 1988 (CoRTN). CoRTN methodology is commonly used for road traffic noise assessment throughout Australia. The modelling predicts expected road traffic noise impacts based on the following input data.

- Existing 3D topography of the site, surrounds and nearby road alignments.
- Proposed Site topography.
- Road traffic flows.
- Posted road traffic speeds, and % heavy vehicles.
- Pavement surface type

5.1 General Modelling Methodology

The traffic noise model was used to predict post-development road traffic noise impacts on the dwellings located within the proposed development in the year 2026. The predicted noise levels were compared to the relevant noise criteria and exceedances determined.

Recommendations relating to feasible and reasonable mitigation measures were then developed.

The CoRTN assessment methodology was adopted for this assessment. The CoRTN modelling methodology sets traffic sources at a height of 0.5 metres above the road.

5.1.1 Application of Correction Factors

The following correction factors have been applied to the modelling:

- Pavement surface corrections of 0 dB(A) for dense graded asphalt (DGAC)
- An AustRoads correction factor to convert standard CoRTN outputs to Australian Conditions of -1.7 dB(A) was applied to the modelling results for receivers associated with future buildings.
- The standard conversion (referenced from AS 3671) of $L_{A10,18hr} = L_{Aeq,\ day} + 3$ dB(A) was also applied.
- A conversion factor of $L_{Aeq,\ night} = L_{Aeq,\ day} + 3$ dB(A) was applied to determine night-time traffic noise levels.
- A façade correction factor of + 2.5 dB(A) was applied to modelled receivers to allow for façade correction once the buildings are located on each Lot.

5.1.2 Modelled Scenarios

Table 5-1 below, shows the modelled scenarios:

Table 5-1 Modelled Scenarios

Modelled Scenario	Description
Year 2026 – post-development road traffic noise	Traffic noise generated between 6am and midnight, based on predicted post-development road traffic volumes for year 2026
Year 2026 – post-development road traffic noise with noise barriers	Traffic noise generated between 6am and midnight, based on predicted post-development road traffic volumes for year 2026

5.2 Noise Modelling Inputs & Assumptions

5.2.1 General Modelling Input Data

Table 5-2 details the modelling input asumptions used for the modelling:

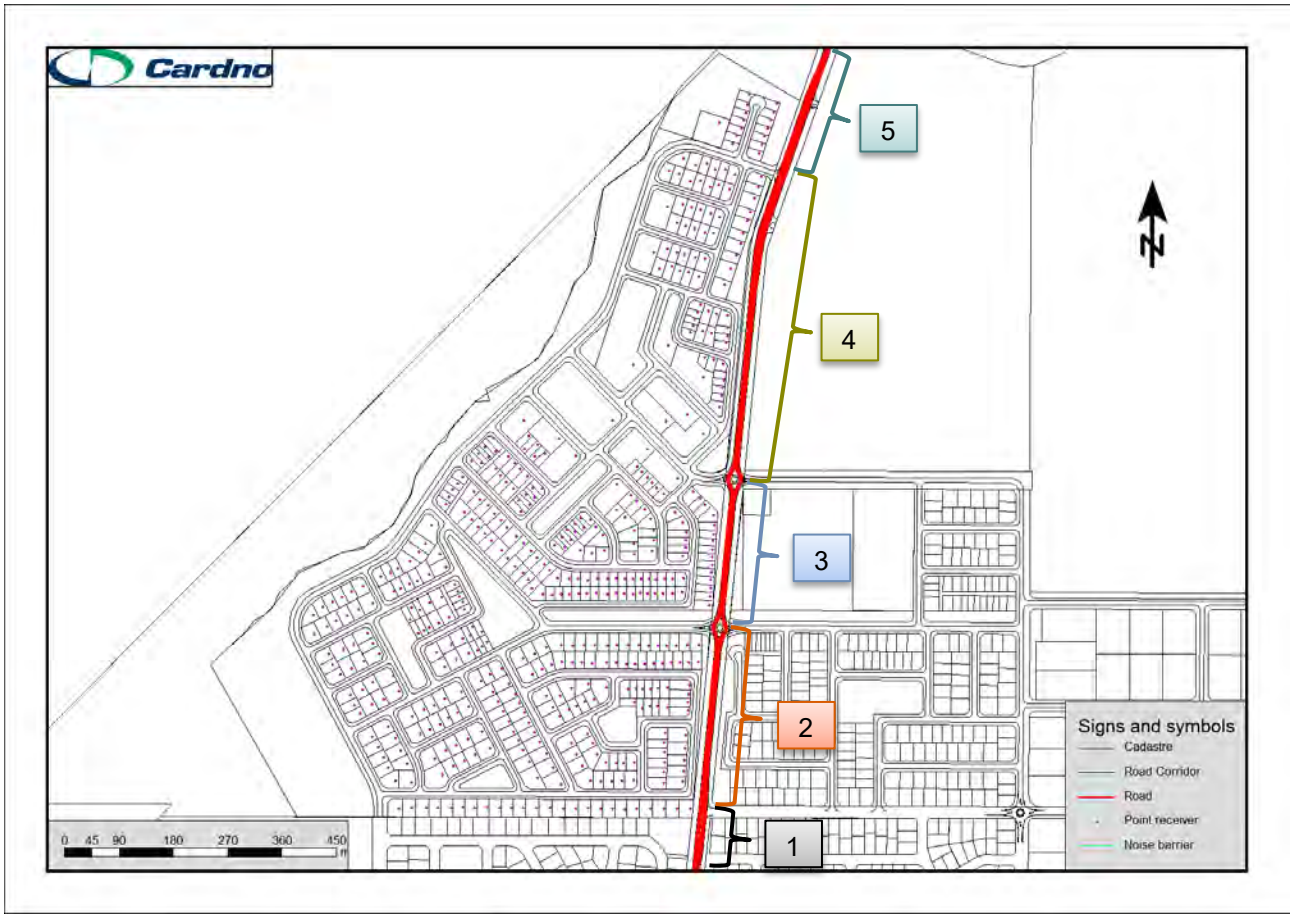
Table 5-2 Modelling Assumptions

Modelling Element	Input / Assumption. Source Reference
Ground Elevation Geometry	Provided by Cardno
Proposed Elevation Geometry	Provided by Cardno
Road Alignment	Provided by Cardno
Site Traffic Flow Data	Provided by SMEC & DHA detailed in Table 5-3.
Road Traffic Speed	Provided by Cardno detailed in Table 5-3.
Road pavement surfaces	Assumed to be DGA with no pavement correction factors added.
Ground Absorption	50% over soft ground
Methodology	Calculation of Road Traffic Noise, UK Department of Transport, 1988
Weather conditions	Calm Conditions
Façade Reflection	+2.5 dB(A) – applied to traffic prediction models, for receivers associated with future buildings.
L_{A10} and L_{Aeq} conversions	$L_{Aeq,day} = L_{A10,18hr} - 3$ dB(A)
Day time to night-time conversion	$L_{Aeq,night} = L_{Aeq,day} - 3$ dB(A)
AustRoads Correction to CoRTN for Façade Corrected Australian Conditions	-1.7 dB(A) CoRTN correction for Australian conditions (with reference to AustRoads.)
Receiver Height	Assumed to be 1.8 and 4.6 metres above ground level.

5.2.2 Modelled Road Segments

Figure 5-1 below shows the modelled road segments:

Figure 5-1 Modelled Road Segments



5.2.3 Traffic Volumes and Posted Speed

Projected (2026) traffic volumes within the project area were obtained from the traffic impact assessment for the Muirhead North Development & 2CRU prepared in July 2015 by SMEC and DHA. The traffic impact assessment report projected traffic volumes for year 2025 for the finished development of the green field sites north of Lions and Muirhead Breezes Estate. For this assessment it is assumed that traffic volumes for year 2026 is identical to year 2025 as no further developments are likely to occur and that Lee Point Road is a dead end road north of the 2CRU development.

The percentage of heavy vehicles (HV) were stated as 0.0% in the traffic impact assessment report, the Cardno traffic engineers however, advised that 5% HV should be used as a conservative assumption, which is in line with previous noise impact assessments carried out for residential developments. Projected traffic volumes and traffic speeds, for the noise modelling are presented in Table 5-3.

Table 5-3 Projected (2025) Daily Traffic Volumes and Speeds

Road Segment	Projected Daily Vehicles (AADT)	Projected 18 Hour Traffic Volumes Between 6am and Midnight (94% of AADT)	% Heavy Vehicles	Proposed Speed
1	9128	8580	5 %	60 Km/h
2	8352	7851	5 %	60 Km/h
3	5459	5131	5 %	60 Km/h
4	1732	1628	5 %	60 Km/h
5	763	717	5 %	60 Km/h

5.3 Modelled Receivers

Locations of the modelled receivers and the modelled noise barriers are detailed in Appendix A.

5.4 Predicted Noise Levels

Modelled $L_{A10, 18hr}$ road traffic noise levels, without noise barriers, are presented for all modelled receivers in Appendix B. The predicted noise levels outlined in Appendix B also include the required building envelope construction in accordance with AS 3671 for the "no external mitigation" scenario.

Appendix B also shows predicted $L_{A10, 18hr}$ road traffic noise levels with a 1.8 metre high noise barrier included as well as the associated building envelope construction in accordance with AS 3671.

Noise predictions in the form of noise contour maps are presented in Appendix C.

5.5 Result Overview

A review of the noise results shows that road traffic noise is predicted to exceed the 63 dB(A) criteria at 16 (4 ground floor and 12 first floor) of the nearest receivers without any external mitigation installed (such as noise barriers). The results also show that this number is reduced to 9 with the inclusion of 1.8 metre high noise barrier located along the site boundary with Lee Point Road, with all of these exceedances being first floor exceedances.

The results also indicate that the location of noise sensitive uses, such as schools, childcare centres, retirement accommodation or hospitals, is not recommended immediately adjacent to Lee Point Road. The noise limit of 58 dB(A) for non-residential noise sensitive use is predicted to be exceeded at 70 receivers without the inclusion of noise barriers. This number is reduced to 29 with the inclusion of 1.8 metre high noise barriers located along the site boundary with Lee Point Road.

The noise contour maps show that noise impact from road traffic upon the development site is primarily occurring at the southern end of the development, due to the higher traffic volumes at this location. The noise contour maps also show that the inclusion of 1.8 metre high noise barriers provide a significant amount of noise mitigation for ground floor levels.

The noise contour maps also show that noise barriers aren't required between Lee Point Road and the northern part of the development to achieve compliance with the $L_{A10, 18hour}$ of 63 dB(A) for residential use.

The results indicate that most of the lots will require building construction in accordance with either AS 3671 Category 1 or Category 2.

48 receivers (26 lots) will require building construction in accordance with AS 3671 Category 3 without the provision of 1.8 metre high noise barriers. The number of receivers requiring building construction in accordance with AS 3671 Category 3 reduces to 15 (all at first floor levels) with the provision of 1.8 metre high noise barriers.

6 Construction Noise Impact Assessment

6.1 Construction Noise Assessment Methodology

A preliminary assessment on the potential level of construction noise impact associated with construction of the development has been carried out to determine whether mitigation measures will be required, and to determine appropriate management controls.

Construction equipment requirements are not yet known. The type and number of plant and equipment associated with the proposed works was therefore assumed based upon experience from similar projects and the plant noise data provided in Australian Standard AS 2436:2010, "Acoustics – "Guide to Noise & Vibration Control on Construction, Demolition & Maintenance Sites". A more detailed assessment will be required as part of preparation of a Construction Noise & Vibration Management Plan once final construction staging detail becomes available during the next phase of the project.

The general construction phases for the project have been assumed based on similar previous projects. This has outlined that the following works, with the potential to generate significant noise, which are detailed below in Section 6.2.

6.2 Modelled Construction Phases

The following construction stages have been modelled:

Phase No.	Construction Phase Description
1	Clearing of Vegetation & Site Establishment
2	Bulk Earthworks
3	Drainage Infrastructure
4	Road Surfacing Works

To provide an indicative assessment of construction noise impact, a noise model was created for each of the above construction phases.

6.3 Noise Sensitive Areas

Noise modelling was conducted to determine the predicted level of noise impact at sensitive locations surrounding the project.

Works associated with the modelled stages will move around the project site, construction noise impacting on sensitive receivers will increase as the works is closer to them, and naturally decrease when works is far away. Construction works have therefore been modelled at three separate locations for each construction phase to provide a worst case predicted noise levels at three separate sensitive locations. Sensitive areas have been grouped into noise catchment areas as shown in Figure 1-1.

Noise contour maps showing the predicted noise levels for the modelled construction works are detailed in Appendix D.

6.4 Construction Timing

Some construction works are likely to be conducted outside of standard hours in addition to standard hours due to the tropical climate.

6.5 Construction Plant & Equipment

The construction plant included in the noise models are presented in Table 6-1. The equipment sound power levels were sourced from AS 2436 and Cardno's plant & equipment noise level library.

Table 6-1 Construction Plant Sound Power Levels

Plant	Number of Plant	Sound Power Level, L_{Aeq}, dB(A)
Scenario 1 – Clearing of Vegetation & Site Establishment	**Total L_{Aeq}** **Total L_{Amax}**	**121** **131**
Bulldozer D9	1	116
Excavator	2	110
Chainsaw	2	114
Tub Grinder / Mulcher	1	116
Dump Truck	4 per hour	110
Scenario 2 – Bulk Earthworks	**Total L_{Aeq}** **Total L_{Amax}**	**123** **133**
Bulldozer D9	1	116
Scraper 651	1	110
Excavator	1	110
Hydraulic Hammer	1	122
Grader	1	113
Dump Truck	8 per hour	110
Compactor	1	106
Roller	1	109
Water Cart	1	107
Scenario 3 – Drainage Infrastructure	**Total L_{Aeq}** **Total L_{Amax}**	**115** **116**
Backhoe	1	110
Franna Crane 20t	1	98
Excavator	1	110
Concrete Truck	4 per hour	109
Truck Compressor	1	75
Vibratory Roller	1	109
Road Truck	4 per hour	108
Scenario 4 – Road Surfacing Works	**Total L_{Aeq}** **Total L_{Amax}**	**118** **130**
Asphalt Paver	1	114
Concrete Truck	1	109
Kerb Extruder	1	107

Plant	Number of Plant	Sound Power Level, L_{Aeq}, dB(A)
Roller	1	107
Dump Truck	4 per hour	110
Asphalt Truck & Sprayer	1	103

6.6 Predicted Construction Noise Levels

The predicted noise impact from construction activities in the form of noise contour maps are presented in Appendix D. Predicted construction noise levels at each modelled receiver and scenario are shown below in Table 6-2 to Table 6-5.

The levels below represent the predicted noise impact when the construction plant is closest to each receiver and all plant is operating simultaneously thus providing a worst case scenario. A line Source has been used to model noise impact from works undertaken along Lee Point Road.

It should be noted that existing noise barriers as well as other natural noise screening topography has been included in the noise model, whereas proposed operational noise barriers and buildings have not been included. The predicted noise levels should therefore be considered as conservative. Noise levels as a result of construction activities are likely to be lower than these levels for most of the construction period.

Table 6-2 Predicted Construction Noise Levels – Clearing and Site Establishment

Receiver	Predicted Construction Noise Level, dB(A)	Predicted Maximum Construction Noise Level, dB(A)	Criteria, dB(A)		Predicted Worst Case Exceedance of Criteria, dB(A)	
	L_{Aeq}	L_{Amax}	L_{Aeq}	L_{Amax}	L_{Aeq}	L_{Amax}
Darwin Hospital	63	72	55	65	8	7
Lee Point Village Resort	72	82	50	65	22	17
Lyons Estate	81	91	50	65	31	26
Current dwellings at Muirhead Breezes Estate (June 2016)	54	62	50	65	4	-
Potential future dwellings at Muirhead Breezes Estate	81	91	50	65	31	26
Nature Reserve	69	79	50	65	19	14

Table 6-3 Predicted Construction Noise Levels – Bulk Earthworks

Receiver	Predicted Construction Noise Level, dB(A)	Predicted Maximum Construction Noise Level, dB(A)	Criteria, dB(A)		Predicted Worst Case Exceedance of Criteria, dB(A)	
	L_{Aeq}	L_{Amax}	L_{Aeq}	L_{Amax}	L_{Aeq}	L_{Amax}
Darwin Hospital	65	75	55	65	10	10
Lee Point Village Resort	72	82	50	65	22	17
Lyons Estate	85	95	50	65	35	30
Current dwellings at Muirhead Breezes Estate (June 2016)	62	71	50	65	12	6

Receiver	Predicted Construction Noise Level, dB(A)	Predicted Maximum Construction Noise Level, dB(A)	Criteria, dB(A)		Predicted Worst Case Exceedance of Criteria, dB(A)	
	L_{Aeq}	L_{Amax}	L_{Aeq}	L_{Amax}	L_{Aeq}	L_{Amax}
Potential future dwellings at Muirhead Breezes Estate	85	95	50	65	35	30
Nature Reserve	72	82	50	65	22	17

Table 6-4 Predicted Construction Noise Levels – Drainage Infrastructure

Receiver	Predicted Construction Noise Level, dB(A)	Predicted Maximum Construction Noise Level, dB(A)	Criteria, dB(A)		Predicted Worst Case Exceedance of Criteria, dB(A)	
	L_{Aeq}	L_{Amax}	L_{Aeq}	L_{Amax}	L_{Aeq}	L_{Amax}
Darwin Hospital	57	58	55	65	2	-
Lee Point Village Resort	64	65	50	65	14	-
Lyons Estate	77	78	50	65	27	13
Current dwellings at Muirhead Breezes Estate (June 2016)	54	54	50	65	4	-
Potential future dwellings at Muirhead Breezes Estate	77	78	50	65	27	13
Nature Reserve	64	65	50	65	14	-

Table 6-5 Predicted Construction Noise Levels – Road Surfacing Works

Receiver	Predicted Construction Noise Level, dB(A)	Predicted Maximum Construction Noise Level, dB(A)	Criteria, dB(A)		Predicted Worst Case Exceedance of Criteria, dB(A)	
	L_{Aeq}	L_{Amax}	L_{Aeq}	L_{Amax}	L_{Aeq}	L_{Amax}
Darwin Hospital	59	71	55	65	4	6
Lee Point Village Resort	67	79	50	65	17	14
Lyons Estate	74	86	50	65	24	21
Current dwellings at Muirhead Breezes Estate (June 2016)	57	68	50	65	7	3
Potential future dwellings at Muirhead Breezes Estate	74	86	50	65	24	21
Nature Reserve	64	76	50	65	14	11

6.7 Construction Noise Results Summary

6.7.1 Continuous Construction Noise

Construction noise levels are predicted to exceed the design benchmark noise limits for worst case scenarios where work is conducted at the boundary of the development and during upgrade work of Lee Point Road. The exceedances

are due to limited separation distance between the site and neighbouring receivers and the high noise levels typically generated by construction plant. However it is worth noting that the predicted construction noise levels only are applicable where work is conducted at locations in close vicinity to the affected receivers which will be for shorter durations only, as clearing of vegetation and general construction work will move around the development site as work progresses. The assessment also assumes that all the noisiest items of plant will be operating simultaneously which is not likely to occur often.

6.7.2 Sleep Disturbance

The most likely source of potential sleep disturbance from the night construction works will be from the use of pneumatic hammer/s or saw cutting during services relocation and/ or road pavement works or from truck movements on site, in particular the application of air brakes.

Maximum noise levels have been predicted to the nearest affected residential receivers to allow a review of the potential for sleep disturbance from construction activities at night. Noise levels have been calculated based on a worst case scenario when plant is located at the closest point to each receiver. On this basis, the results (L_{Amax}) summarised in Table 6-2 to Table 6-5 indicate that maximum construction noise levels at the nearest noise sensitive receivers are likely to exceed the sleep disturbance criteria, when construction works are located nearby. For this reason it is recommended that activities with potentially high maximum levels such as the use of pneumatic tools and truck air-braking are minimised or not operated at these locations during the night-time period.

7 Construction Vibration Assessment

7.1 Vibration Limits

Vibration from construction activities associated with the project could potentially impact on the amenity of the occupants of dwellings or buildings located close to the construction works. Generally, vibration impact can be summarised into two categories:

a Effect on human comfort; and

b Structural or cosmetic damage to buildings.

The CoP Volume 2 provides a section on the assessment of construction vibration from road projects. The criteria from this code of practice have been adopted for this assessment.

Vibration criteria for both human comfort and building damage due to ground borne vibration caused by construction activities (e.g. pile driving, compaction and blasting) are provided in section 4. It should be noted that compliance in most cases with the human comfort criteria would also achieve the building damage criteria.

The British Standard BS 5228-2:2009 provides an alternative approach to those historically used to assess human comfort presented in the British Standard BS 6472-1:2008. While BS 6472-1 provides guidance on human response to vibration in buildings in terms of VDV, BS 5228-2 Table B.1 provides guidance on the use of PPV which is typically measured to determine potential building damage.

For human comfort in order to minimise annoyance due to ground borne construction vibration, this Code adopts vibration levels with lower and upper limits as presented in Table 4-2. The low limits are generally considered to be just perceptible if just exceeded. The upper limits are considered to cause significant annoyance if exceeded.

All reasonable and practicable measures should be implemented to achieve the lower limit. Exceedance of the upper limit requires immediate action and extensive community consultation to determine further mitigation measures.

The criteria associated with building damage are summarised in Section 4, in Table 4-3 and Table 4-4.

7.1.1 Vibration Assessment

As proposed construction equipment and construction works has not been determined yet it is not possible to provide a specific minimum separation distance in metres. However Table 7-1 outlines recommended minimum separation distances between sensitive structures and typical vibration generating plant for probable construction areas.

Table 7-1 Recommended Minimum Working Distance

Receiver	Nearest Potential Construction Area	Distance to Nearest Sensitive Structure, metre	Maximum size of Vibratory Roller	Maximum size of Hydraulic Hammer
Darwin Hospital	2CRU Site	175	> 300 kN > 18 tonnes	1600 kg – 18 to 34t excavator
Lee Point Village Resort	Lee Point Road Traffic Corridor	15	< 300 kN Typically 7-13 tonnes	900 kg – 12 to 18t excavator
Lyons Estate	2CRU Site and Lee Point Road Traffic Corridor	1.5	< 50 kN Typically 1-2 tonnes	300 kg - 5 to 12t excavator
Current dwellings at Muirhead Breezes Estate (June 2016)	Lee Point Road Traffic Corridor	50	> 300 kN > 18 tonnes	1600 kg – 18 to 34t excavator
Potential future dwellings at Muirhead Breezes Estate	Lee Point Road Traffic Corridor	15	< 300 kN Typically 7-13 tonnes	900 kg – 12 to 18t excavator

8 Recommended Mitigation Measures

8.1 General Construction Noise & Vibration

The following best practice construction noise and vibration mitigation measures are based on recommendations provided within the QLD TMR CoP Volume 2 and Australian Standard AS 2436-1981: Guide to Noise Control on Construction, Maintenance and Demolition Sites. The following best practice measures apply to the proposed construction activities.

Construction noise and vibration should be minimised as far as is practically possible using methods such as:

- Development and implementation of all reasonable and feasible site specific mitigation measures to meet noise criteria applicable to the proposal in consultation with residents.
- Use of noise attenuating controls at the source, such as mufflers, acoustic screens, etc.
- Keeping plant and equipment well maintained.
- Locating static sources of noise such as the generators as remotely as possible from noise sensitive receivers.
- Developing proposed hours of operation in consultation with the residents / occupants of the affected receivers, and NT EPA with a view to minimising potential impacts as far as is practically feasible.
- Allowing construction to occur only during approved construction hours, unless otherwise required due to climatic conditions or safety requirements.
- Informing potentially affected receivers with adequate notice of the construction program and any planned activities that may exceed noise and vibration targets.
- Conducting noise monitoring during operations for the purposes of assisting in noise mitigation and to verify the findings of this noise assessment, if complaints are received or proposed activities and number of plant exceed those assumed in this assessment.
- Use of temporary noise barriers where practical.
- Application of respite periods for noisy activities.
- Use of broadband reversing alarms, or “quackers”, on mobile equipment in accordance with the relevant health and safety regulations.
- Modification of work activities where noise or vibration is found to cause unacceptable impact.
- Implementing a procedure for dealing with complaints to ensure that all complaints are registered and dealt with appropriately.

An operational Noise and Vibration Management Plan should be prepared for the project, to include, but not be limited to, the above measures.

8.2 Site Specific Measures

The following site specific mitigation measures are recommended:

8.2.1 Plant Controls

- Mulchers should be located away from noise sensitive receivers.
- Reduce the number of plant operating at one time where works are required to be carried out outside of standard hours and close to existing sensitive receivers.
- Program the works to occur away from noise sensitive receivers and use temporary noise barriers, where night-works are required for climatic or safety reasons.
- Investigate whether “at plant” mitigation or muffled plant is available.

- Keep all plant and equipment well maintained.
- Use of broadband reversing alarms, or “quackers”, on mobile equipment in accordance with the relevant health and safety regulations.
- Preference should be for electric powered plant over combustion engine powered plant.
- Preference should be for hydraulic or electric powered plant over pneumatic powered plant.
- Avoid metal to metal contact on equipment to reduce impulsive or scraping noise.
- Avoid vibration intensive work at night to minimise the risk of sleep disturbance.

8.2.2 Manage of Hours of Operation

- Carrying out works within daytime hours as follows:
    - 7:00 am to 7:00 pm Monday to Saturday, 9:00 am to 6:00 pm on Sundays or public holidays.
- Do not carry out operations during evening or night-time hours, unless absolutely necessary due to climatic or safety reasons.
- Where evening or night-time hours cannot be avoided the following mitigation measures may be required;
    - Notification via letterbox or phone call
    - Provision of respite periods
    - Provision of alternative accommodation

8.2.3 Management and Behaviour Controls

- Ensure that managers effectively communicate acceptable and unacceptable work practices for the site, through staff site inductions, notice boards, and prestart meetings.
- Avoid the need for reversing in the construction area by creating a loop road or similar.
- Avoid dropping materials from height.
- Workers should avoid shouting, minimise talking loudly, and avoid slamming vehicle doors.

9 Conclusions

The following conclusions apply to this assessment:

9.1 Operational Road Traffic Noise Impacts

- Modelling indicates that the noise limit of $L_{A10,\ 18hour}$ 63 dB(A) for residential areas without any external noise mitigation (such as noise barriers) is predicted to be exceeded at 12 of the proposed lots by road traffic noise from Lee Point Road. Four of the 12 lots show exceedances for both ground and first floor levels.
- With the inclusion of 1.8 metre high noise barriers along the boundary of the development site with Lee Point Road, road traffic noise at 9 lots are predicted to exceed the criterion. The 9 exceedances are all located on first floor levels, indicating that double storey dwellings may require consideration of building materials for first floor levels where the noise limit is exceeded, unless additional external mitigation is implemented such as higher noise barriers between the affected lots and Lee Point Road.
- The assessment concludes that noise barriers are not required between Lee Point Road and the northern part of the development to achieve compliance with the 63 dB(A) external noise limit, due to the smaller projected traffic volumes at the northern end of Lee Point Road.
- The assessment indicates that non-residential noise sensitive uses, such as schools, childcare or hospitals, are not recommended to be located immediately adjacent to Lee Point Road as the applicable $L_{A10,\ 18hour}$ of 58 dB(A) criterion is predicted to be exceeded at 70 receivers without the inclusion of noise barriers adjacent to Lee Point Road
- With the provision of 1.8 metre high noise barriers between the development site and Lee Point Road, road traffic noise at is predicted to exceed the 58 dB(A) noise limit at 29 Lots.
- The noise contour maps indicate that road traffic noise impact upon the development site is primarily occurring at the southern end of the development site. The noise contour maps also show that the inclusion of 1.8 metre high noise barriers provides a significant amount of noise mitigation at ground floor levels of affected Lots.
- The noise modelling indicated that most of the lots will require building construction in accordance with either AS 3671 Category 1 or 2. However 48 receivers, distributed across 26 lots, will require building construction in accordance with AS 3671 Category 3 without the provision of noise barriers.
- The number of receivers requiring AS 3671 Category 3 construction reduces to 15 (all at first floor levels) with the provision of 1.8 metre high noise barriers as shown in Figure A-1 and Figure A-2 in Appendix A.
- Acoustic design principles should be taken into account during the final stage when considering overall layout and building orientation and shielding effects. Some principles to consider are listed below.
    - The building to be set back from the transport corridor as far as possible;
    - The building to shape away from the transport corridor;
    - The building to shield courtyards and open space areas from the corridor; and
- Noise sensitive spaces, such as bedrooms, should be shielded from noise by positioning less sensitive spaces, such as the garage, bathrooms and laundry, closer to the corridor.

9.2 Construction Noise Impacts

- Construction noise levels are predicted to exceed the design benchmark noise limits for worst case scenarios where work is conducted at the boundary of the development or where Lee Point Road is upgraded.
- The exceedances are due to limited separation distance between the site and neighbouring receivers and the high noise levels typically generated by construction plant. However it is worth noting that the predicted

construction noise levels only are applicable where work is conducted at locations in close vicinity to the affected receivers which will be for shorter durations only, as clearing of vegetation and general construction work will move around the development site as work progresses.

- Maximum noise levels have been predicted to the nearest affected residential receivers to allow a review of the potential for sleep disturbance from construction activities at night. The results indicate that maximum construction noise levels at the nearest noise sensitive receivers are likely to exceed the sleep disturbance criteria, when construction works are located nearby. For this reason it is recommended that activities with potentially high maximum levels such as the use of pneumatic tools and truck air-braking are minimised or not carried out at these locations during the night-time period.
- It should be noted that this assessment has endeavoured to carry out "worst case" noise modelling, and noise levels are predicted based on a moving point source representative of the total construction noise level moving along the length of the project. Should the work sites or plant and equipment be relocated so that other receivers are located closer to the works, these receivers are likely to be affected more significantly than predicted in this report.
- The predicted exceedances are generally a result of works being located in close proximity to the adjacent receivers. This modelling has been carried out to provide a worst case scenario and it may be possible to reduce the number of plant operating simultaneously, particularly at night, once detailed construction schedules are known. This can be investigated further during preparation of the construction noise and vibration management plan for the project.
- Provision of temporary noise barriers is likely to be required between local construction sites and receivers, if night-time works are required near noise sensitive receivers.
- Best practice mitigation measures are recommended in Section 8 of this report.
- A detailed construction noise and vibration management plan should be prepared for the project prior to construction commencement to incorporate the recommendations detailed in Section 8 and updated to reflect the proposed staging and plant to be adopted for the project.

9.3 Construction Vibration Impacts

- Sensitive structures are located immediately adjacent to the Lee Point Road transport corridor at the southern part of Lee Point Road indicating that consideration of vibration impacts will be required during the upgrade of the southern part of the transport corridor.
- The nearest sensitive receivers adjacent to the northern section of Lee Point Road are located in excess of 15 metres from the transport corridor, indicating that larger plant items may be used for the upgrade of this section of road.
- Human discomfort may be felt should large vibratory rollers be used within 100 metres of nearby receivers. Therefore, vibratory rolling should only be carried out at night if the vibratory roller is rated less than 100 kN and the distance to vibration sensitive receivers is in excess of 20 metres to avoid the risk of human discomfort and sleep disturbance.
- A detailed construction noise and vibration management plan should be prepared for the project prior to construction commencement to incorporate the recommendations detailed in Section 8 and updated to reflect the proposed staging and plant to be adopted for the project.

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APPENDIX A
RECEIVERS WITHIN THE DEVELOPMENT

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Figure A-1 Modelled Noise Sensitive Receivers and Modelled Noise Barrier Locations for the Southern Part of 2CRU.

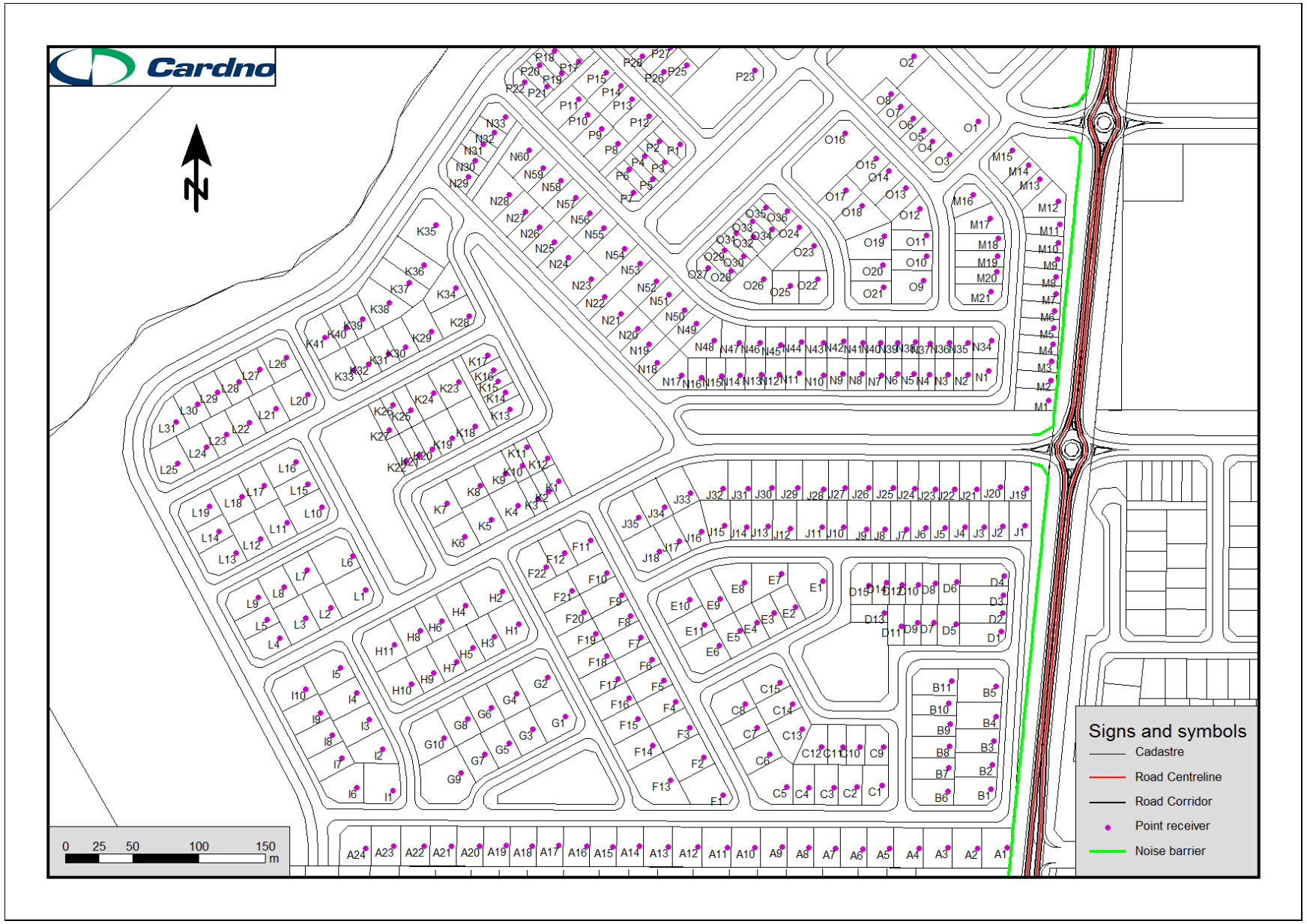
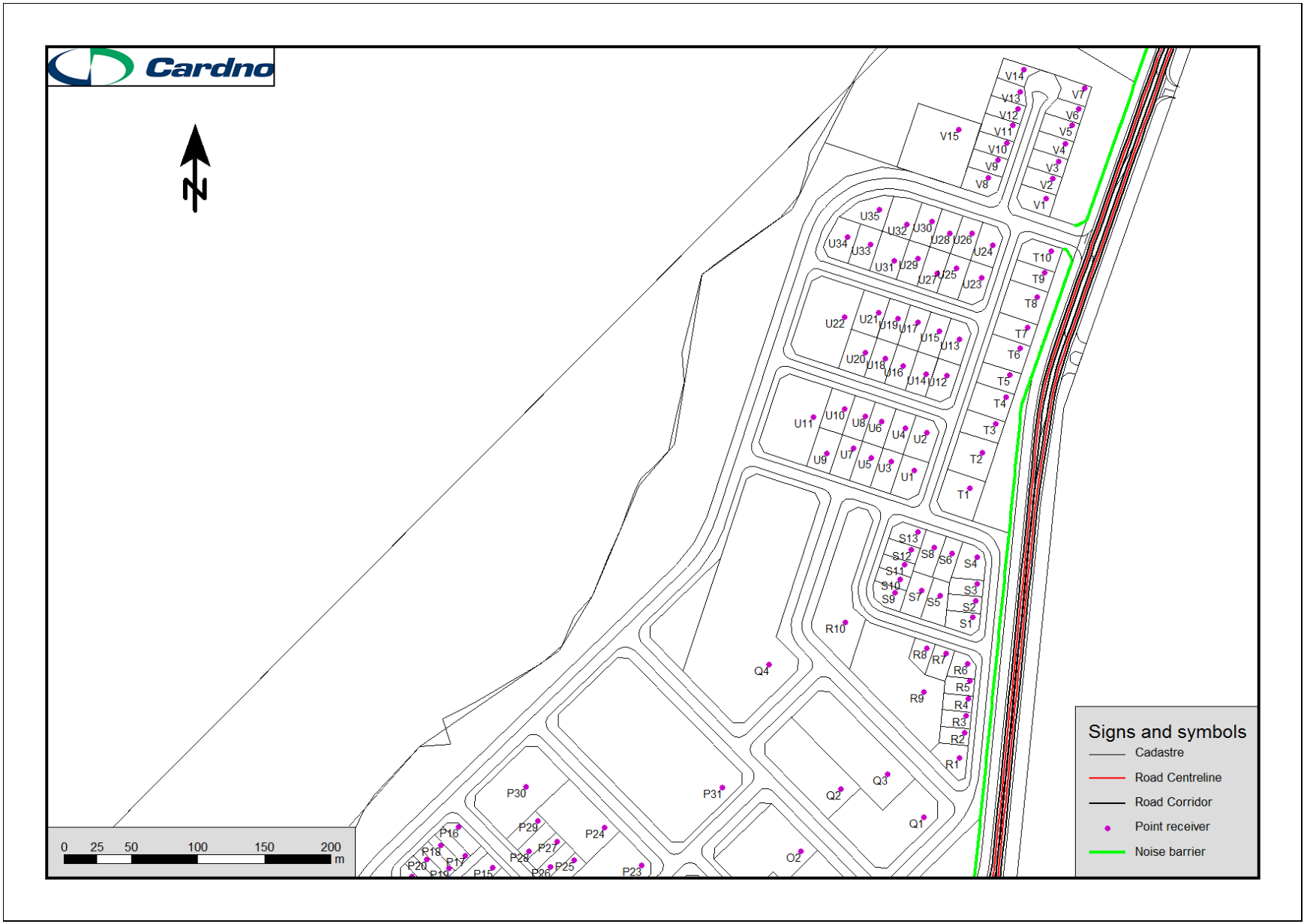


Figure A-2 Modelled Noise Sensitive Receivers and Modelled Noise Barrier Locations for the Northern Part of 2CRU.



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APPENDIX B

PREDICTED NOISE LEVELS FOR MODELLED RECEIVERS IN THE 2CRU DEVELOPMENT

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Table B-1 Predicted Noise Levels for Year 2026 for the 2CRU development – with no Mitigation

Receiver	Flr	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq,\ night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq,\ night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
A1	Ground	66	63	3	58	8	60	30	30	3
A1	First	67	63	4	58	9	61	30	31	3
A2	Ground	61	63	-	58	3	55	30	25	2
A2	First	62	63	-	58	4	56	30	26	3
A3	Ground	58	63	-	58	-	52	30	22	2
A3	First	59	63	-	58	1	53	30	23	2
A4	Ground	56	63	-	58	-	50	30	20	2
A4	First	57	63	-	58	-	51	30	21	2
A5	Ground	55	63	-	58	-	49	30	19	2
A5	First	56	63	-	58	-	50	30	20	2
A6	Ground	53	63	-	58	-	47	30	17	2
A6	First	54	63	-	58	-	48	30	18	2
A7	Ground	52	63	-	58	-	46	30	16	2
A7	First	53	63	-	58	-	47	30	17	2
A8	Ground	51	63	-	58	-	45	30	15	2
A8	First	52	63	-	58	-	46	30	16	2
A9	Ground	50	63	-	58	-	44	30	14	2
A9	First	51	63	-	58	-	45	30	15	2
A10	Ground	49	63	-	58	-	43	30	13	2
A10	First	51	63	-	58	-	45	30	15	2
A11	Ground	48	63	-	58	-	42	30	12	2
A11	First	50	63	-	58	-	44	30	14	2
A12	Ground	48	63	-	58	-	42	30	12	2
A12	First	49	63	-	58	-	43	30	13	2
A13	Ground	47	63	-	58	-	41	30	11	2
A13	First	48	63	-	58	-	42	30	12	2
A14	Ground	46	63	-	58	-	40	30	10	1
A14	First	48	63	-	58	-	42	30	12	2
A15	Ground	46	63	-	58	-	40	30	10	1
A15	First	47	63	-	58	-	41	30	11	2
A16	Ground	45	63	-	58	-	39	30	9	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
A16	First	47	63	-	58	-	41	30	11	2
A17	Ground	45	63	-	58	-	39	30	9	1
A17	First	46	63	-	58	-	40	30	10	1
A18	Ground	44	63	-	58	-	38	30	8	1
A18	First	45	63	-	58	-	39	30	9	1
A19	Ground	43	63	-	58	-	37	30	7	1
A19	First	45	63	-	58	-	39	30	9	1
A20	Ground	43	63	-	58	-	37	30	7	1
A20	First	44	63	-	58	-	38	30	8	1
A21	Ground	42	63	-	58	-	36	30	6	1
A21	First	44	63	-	58	-	38	30	8	1
A22	Ground	41	63	-	58	-	35	30	5	1
A22	First	43	63	-	58	-	37	30	7	1
A23	Ground	41	63	-	58	-	35	30	5	1
A23	First	43	63	-	58	-	37	30	7	1
A24	Ground	40	63	-	58	-	34	30	4	1
A24	First	42	63	-	58	-	36	30	6	1
B1	Ground	62	63	-	58	4	56	30	26	3
B1	First	63	63	-	58	5	57	30	27	3
B2	Ground	62	63	-	58	4	56	30	26	3
B2	First	63	63	-	58	5	57	30	27	3
B3	Ground	62	63	-	58	4	56	30	26	3
B3	First	63	63	-	58	5	57	30	27	3
B4	Ground	62	63	-	58	4	56	30	26	3
B4	First	63	63	-	58	5	57	30	27	3
B5	Ground	62	63	-	58	4	56	30	26	3
B5	First	63	63	-	58	5	57	30	27	3
B6	Ground	58	63	-	58	-	52	30	22	2
B6	First	59	63	-	58	1	53	30	23	2
B7	Ground	58	63	-	58	-	52	30	22	2
B7	First	59	63	-	58	1	53	30	23	2
B8	Ground	58	63	-	58	-	52	30	22	2
B8	First	59	63	-	58	1	53	30	23	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
B9	Ground	58	63	-	58	-	52	30	22	2
B9	First	59	63	-	58	1	53	30	23	2
B10	Ground	58	63	-	58	-	52	30	22	2
B10	First	59	63	-	58	1	53	30	23	2
B11	Ground	58	63	-	58	-	52	30	22	2
B11	First	59	63	-	58	1	53	30	23	2
C1	Ground	54	63	-	58	-	48	30	18	2
C1	First	55	63	-	58	-	49	30	19	2
C2	Ground	53	63	-	58	-	47	30	17	2
C2	First	54	63	-	58	-	48	30	18	2
C3	Ground	52	63	-	58	-	46	30	16	2
C3	First	53	63	-	58	-	47	30	17	2
C4	Ground	51	63	-	58	-	45	30	15	2
C4	First	53	63	-	58	-	47	30	17	2
C5	Ground	51	63	-	58	-	45	30	15	2
C5	First	52	63	-	58	-	46	30	16	2
C6	Ground	50	63	-	58	-	44	30	14	2
C6	First	51	63	-	58	-	45	30	15	2
C7	Ground	50	63	-	58	-	44	30	14	2
C7	First	51	63	-	58	-	45	30	15	2
C8	Ground	50	63	-	58	-	44	30	14	2
C8	First	51	63	-	58	-	45	30	15	2
C9	Ground	54	63	-	58	-	48	30	18	2
C9	First	56	63	-	58	-	50	30	20	2
C10	Ground	53	63	-	58	-	47	30	17	2
C10	First	54	63	-	58	-	48	30	18	2
C11	Ground	53	63	-	58	-	47	30	17	2
C11	First	54	63	-	58	-	48	30	18	2
C12	Ground	52	63	-	58	-	46	30	16	2
C12	First	53	63	-	58	-	47	30	17	2
C13	Ground	51	63	-	58	-	45	30	15	2
C13	First	52	63	-	58	-	46	30	16	2
C14	Ground	51	63	-	58	-	45	30	15	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
C14	First	52	63	-	58	-	46	30	16	2
C15	Ground	51	63	-	58	-	45	30	15	2
C15	First	52	63	-	58	-	46	30	16	2
D1	Ground	62	63	-	58	4	56	30	26	3
D1	First	63	63	-	58	5	57	30	27	3
D2	Ground	62	63	-	58	4	56	30	26	3
D2	First	63	63	-	58	5	57	30	27	3
D3	Ground	61	63	-	58	3	55	30	25	2
D3	First	63	63	-	58	5	57	30	27	3
D4	Ground	61	63	-	58	3	55	30	25	2
D4	First	62	63	-	58	4	56	30	26	3
D5	Ground	58	63	-	58	-	52	30	22	2
D5	First	59	63	-	58	1	53	30	23	2
D6	Ground	58	63	-	58	-	52	30	22	2
D6	First	59	63	-	58	1	53	30	23	2
D7	Ground	56	63	-	58	-	50	30	20	2
D7	First	58	63	-	58	-	52	30	22	2
D8	Ground	56	63	-	58	-	50	30	20	2
D8	First	57	63	-	58	-	51	30	21	2
D9	Ground	56	63	-	58	-	50	30	20	2
D9	First	57	63	-	58	-	51	30	21	2
D10	Ground	55	63	-	58	-	49	30	19	2
D10	First	57	63	-	58	-	51	30	21	2
D11	Ground	55	63	-	58	-	49	30	19	2
D11	First	56	63	-	58	-	50	30	20	2
D12	Ground	55	63	-	58	-	49	30	19	2
D12	First	56	63	-	58	-	50	30	20	2
D13	Ground	54	63	-	58	-	48	30	18	2
D13	First	55	63	-	58	-	49	30	19	2
D14	Ground	54	63	-	58	-	48	30	18	2
D14	First	55	63	-	58	-	49	30	19	2
D15	Ground	53	63	-	58	-	47	30	17	2
D15	First	54	63	-	58	-	48	30	18	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
E1	Ground	52	63	-	58	-	46	30	16	2
E1	First	53	63	-	58	-	47	30	17	2
E2	Ground	51	63	-	58	-	45	30	15	2
E2	First	52	63	-	58	-	46	30	16	2
E3	Ground	50	63	-	58	-	44	30	14	2
E3	First	51	63	-	58	-	45	30	15	2
E4	Ground	50	63	-	58	-	44	30	14	2
E4	First	51	63	-	58	-	45	30	15	2
E5	Ground	50	63	-	58	-	44	30	14	2
E5	First	51	63	-	58	-	45	30	15	2
E6	Ground	49	63	-	58	-	43	30	13	2
E6	First	50	63	-	58	-	44	30	14	2
E7	Ground	51	63	-	58	-	45	30	15	2
E7	First	52	63	-	58	-	46	30	16	2
E8	Ground	50	63	-	58	-	44	30	14	2
E8	First	51	63	-	58	-	45	30	15	2
E9	Ground	49	63	-	58	-	43	30	13	2
E9	First	50	63	-	58	-	44	30	14	2
E10	Ground	49	63	-	58	-	43	30	13	2
E10	First	50	63	-	58	-	44	30	14	2
E11	Ground	49	63	-	58	-	43	30	13	2
E11	First	50	63	-	58	-	44	30	14	2
F1	Ground	49	63	-	58	-	43	30	13	2
F1	First	50	63	-	58	-	44	30	14	2
F2	Ground	48	63	-	58	-	42	30	12	2
F2	First	50	63	-	58	-	44	30	14	2
F3	Ground	48	63	-	58	-	42	30	12	2
F3	First	49	63	-	58	-	43	30	13	2
F4	Ground	48	63	-	58	-	42	30	12	2
F4	First	49	63	-	58	-	43	30	13	2
F5	Ground	48	63	-	58	-	42	30	12	2
F5	First	49	63	-	58	-	43	30	13	2
F6	Ground	48	63	-	58	-	42	30	12	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
F6	First	49	63	-	58	-	43	30	13	2
F7	Ground	47	63	-	58	-	41	30	11	2
F7	First	49	63	-	58	-	43	30	13	2
F8	Ground	47	63	-	58	-	41	30	11	2
F8	First	48	63	-	58	-	42	30	12	2
F9	Ground	47	63	-	58	-	41	30	11	2
F9	First	48	63	-	58	-	42	30	12	2
F10	Ground	47	63	-	58	-	41	30	11	2
F10	First	48	63	-	58	-	42	30	12	2
F11	Ground	46	63	-	58	-	40	30	10	1
F11	First	47	63	-	58	-	41	30	11	2
F12	Ground	46	63	-	58	-	40	30	10	1
F12	First	47	63	-	58	-	41	30	11	2
F13	Ground	48	63	-	58	-	42	30	12	2
F13	First	49	63	-	58	-	43	30	13	2
F14	Ground	47	63	-	58	-	41	30	11	2
F14	First	48	63	-	58	-	42	30	12	2
F15	Ground	47	63	-	58	-	41	30	11	2
F15	First	48	63	-	58	-	42	30	12	2
F16	Ground	47	63	-	58	-	41	30	11	2
F16	First	48	63	-	58	-	42	30	12	2
F17	Ground	47	63	-	58	-	41	30	11	2
F17	First	48	63	-	58	-	42	30	12	2
F18	Ground	47	63	-	58	-	41	30	11	2
F18	First	48	63	-	58	-	42	30	12	2
F19	Ground	46	63	-	58	-	40	30	10	1
F19	First	48	63	-	58	-	42	30	12	2
F20	Ground	46	63	-	58	-	40	30	10	1
F20	First	47	63	-	58	-	41	30	11	2
F21	Ground	46	63	-	58	-	40	30	10	1
F21	First	47	63	-	58	-	41	30	11	2
F22	Ground	45	63	-	58	-	39	30	9	1
F22	First	47	63	-	58	-	41	30	11	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
G1	Ground	45	63	-	58	-	39	30	9	1
G1	First	47	63	-	58	-	41	30	11	2
G2	Ground	45	63	-	58	-	39	30	9	1
G2	First	46	63	-	58	-	40	30	10	1
G3	Ground	45	63	-	58	-	39	30	9	1
G3	First	46	63	-	58	-	40	30	10	1
G4	Ground	44	63	-	58	-	38	30	8	1
G4	First	46	63	-	58	-	40	30	10	1
G5	Ground	44	63	-	58	-	38	30	8	1
G5	First	46	63	-	58	-	40	30	10	1
G6	Ground	43	63	-	58	-	37	30	7	1
G6	First	45	63	-	58	-	39	30	9	1
G7	Ground	43	63	-	58	-	37	30	7	1
G7	First	45	63	-	58	-	39	30	9	1
G8	Ground	43	63	-	58	-	37	30	7	1
G8	First	45	63	-	58	-	39	30	9	1
G9	Ground	42	63	-	58	-	36	30	6	1
G9	First	44	63	-	58	-	38	30	8	1
G10	Ground	42	63	-	58	-	36	30	6	1
G10	First	44	63	-	58	-	38	30	8	1
H1	Ground	45	63	-	58	-	39	30	9	1
H1	First	46	63	-	58	-	40	30	10	1
H2	Ground	45	63	-	58	-	39	30	9	1
H2	First	46	63	-	58	-	40	30	10	1
H3	Ground	44	63	-	58	-	38	30	8	1
H3	First	46	63	-	58	-	40	30	10	1
H4	Ground	43	63	-	58	-	37	30	7	1
H4	First	45	63	-	58	-	39	30	9	1
H5	Ground	43	63	-	58	-	37	30	7	1
H5	First	45	63	-	58	-	39	30	9	1
H6	Ground	43	63	-	58	-	37	30	7	1
H6	First	44	63	-	58	-	38	30	8	1
H7	Ground	43	63	-	58	-	37	30	7	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
H7	First	44	63	-	58	-	38	30	8	1
H8	Ground	42	63	-	58	-	36	30	6	1
H8	First	44	63	-	58	-	38	30	8	1
H9	Ground	42	63	-	58	-	36	30	6	1
H9	First	44	63	-	58	-	38	30	8	1
H10	Ground	41	63	-	58	-	35	30	5	1
H10	First	43	63	-	58	-	37	30	7	1
H11	Ground	41	63	-	58	-	35	30	5	1
H11	First	43	63	-	58	-	37	30	7	1
I1	Ground	41	63	-	58	-	35	30	5	1
I1	First	42	63	-	58	-	36	30	6	1
I2	Ground	41	63	-	58	-	35	30	5	1
I2	First	42	63	-	58	-	36	30	6	1
I3	Ground	40	63	-	58	-	34	30	4	1
I3	First	42	63	-	58	-	36	30	6	1
I4	Ground	40	63	-	58	-	34	30	4	1
I4	First	42	63	-	58	-	36	30	6	1
I5	Ground	40	63	-	58	-	34	30	4	1
I5	First	41	63	-	58	-	35	30	5	1
I6	Ground	40	63	-	58	-	34	30	4	1
I6	First	41	63	-	58	-	35	30	5	1
I7	Ground	39	63	-	58	-	33	30	3	1
I7	First	41	63	-	58	-	35	30	5	1
I8	Ground	39	63	-	58	-	33	30	3	1
I8	First	41	63	-	58	-	35	30	5	1
I9	Ground	39	63	-	58	-	33	30	3	1
I9	First	41	63	-	58	-	35	30	5	1
I10	Ground	39	63	-	58	-	33	30	3	1
I10	First	40	63	-	58	-	34	30	4	1
J1	Ground	63	63	-	58	5	57	30	27	3
J1	First	64	63	1	58	6	58	30	28	3
J2	Ground	61	63	-	58	3	55	30	25	2
J2	First	62	63	-	58	4	56	30	26	3

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
J3	Ground	59	63	-	58	1	53	30	23	2
J3	First	60	63	-	58	2	54	30	24	2
J4	Ground	58	63	-	58	-	52	30	22	2
J4	First	59	63	-	58	1	53	30	23	2
J5	Ground	56	63	-	58	-	50	30	20	2
J5	First	57	63	-	58	-	51	30	21	2
J6	Ground	56	63	-	58	-	50	30	20	2
J6	First	57	63	-	58	-	51	30	21	2
J7	Ground	55	63	-	58	-	49	30	19	2
J7	First	56	63	-	58	-	50	30	20	2
J8	Ground	54	63	-	58	-	48	30	18	2
J8	First	55	63	-	58	-	49	30	19	2
J9	Ground	53	63	-	58	-	47	30	17	2
J9	First	54	63	-	58	-	48	30	18	2
J10	Ground	52	63	-	58	-	46	30	16	2
J10	First	53	63	-	58	-	47	30	17	2
J11	Ground	52	63	-	58	-	46	30	16	2
J11	First	53	63	-	58	-	47	30	17	2
J12	Ground	51	63	-	58	-	45	30	15	2
J12	First	52	63	-	58	-	46	30	16	2
J13	Ground	50	63	-	58	-	44	30	14	2
J13	First	51	63	-	58	-	45	30	15	2
J14	Ground	50	63	-	58	-	44	30	14	2
J14	First	51	63	-	58	-	45	30	15	2
J15	Ground	49	63	-	58	-	43	30	13	2
J15	First	50	63	-	58	-	44	30	14	2
J16	Ground	49	63	-	58	-	43	30	13	2
J16	First	50	63	-	58	-	44	30	14	2
J17	Ground	48	63	-	58	-	42	30	12	2
J17	First	49	63	-	58	-	43	30	13	2
J18	Ground	48	63	-	58	-	42	30	12	2
J18	First	49	63	-	58	-	43	30	13	2
J19	Ground	63	63	-	58	5	57	30	27	3

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
J19	First	64	63	1	58	6	58	30	28	3
J20	Ground	60	63	-	58	2	54	30	24	2
J20	First	61	63	-	58	3	55	30	25	2
J21	Ground	58	63	-	58	-	52	30	22	2
J21	First	59	63	-	58	1	53	30	23	2
J22	Ground	57	63	-	58	-	51	30	21	2
J22	First	58	63	-	58	-	52	30	22	2
J23	Ground	56	63	-	58	-	50	30	20	2
J23	First	57	63	-	58	-	51	30	21	2
J24	Ground	55	63	-	58	-	49	30	19	2
J24	First	56	63	-	58	-	50	30	20	2
J25	Ground	54	63	-	58	-	48	30	18	2
J25	First	55	63	-	58	-	49	30	19	2
J26	Ground	53	63	-	58	-	47	30	17	2
J26	First	54	63	-	58	-	48	30	18	2
J27	Ground	52	63	-	58	-	46	30	16	2
J27	First	53	63	-	58	-	47	30	17	2
J28	Ground	52	63	-	58	-	46	30	16	2
J28	First	53	63	-	58	-	47	30	17	2
J29	Ground	51	63	-	58	-	45	30	15	2
J29	First	52	63	-	58	-	46	30	16	2
J30	Ground	50	63	-	58	-	44	30	14	2
J30	First	51	63	-	58	-	45	30	15	2
J31	Ground	50	63	-	58	-	44	30	14	2
J31	First	51	63	-	58	-	45	30	15	2
J32	Ground	49	63	-	58	-	43	30	13	2
J32	First	50	63	-	58	-	44	30	14	2
J33	Ground	48	63	-	58	-	42	30	12	2
J33	First	49	63	-	58	-	43	30	13	2
J34	Ground	48	63	-	58	-	42	30	12	2
J34	First	49	63	-	58	-	43	30	13	2
J35	Ground	47	63	-	58	-	41	30	11	2
J35	First	48	63	-	58	-	42	30	12	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
K1	Ground	46	63	-	58	-	40	30	10	1
K1	First	47	63	-	58	-	41	30	11	2
K2	Ground	45	63	-	58	-	39	30	9	1
K2	First	47	63	-	58	-	41	30	11	2
K3	Ground	45	63	-	58	-	39	30	9	1
K3	First	46	63	-	58	-	40	30	10	1
K4	Ground	45	63	-	58	-	39	30	9	1
K4	First	46	63	-	58	-	40	30	10	1
K5	Ground	44	63	-	58	-	38	30	8	1
K5	First	46	63	-	58	-	40	30	10	1
K6	Ground	44	63	-	58	-	38	30	8	1
K6	First	45	63	-	58	-	39	30	9	1
K7	Ground	44	63	-	58	-	38	30	8	1
K7	First	45	63	-	58	-	39	30	9	1
K8	Ground	44	63	-	58	-	38	30	8	1
K8	First	45	63	-	58	-	39	30	9	1
K9	Ground	45	63	-	58	-	39	30	9	1
K9	First	46	63	-	58	-	40	30	10	1
K10	Ground	45	63	-	58	-	39	30	9	1
K10	First	46	63	-	58	-	40	30	10	1
K11	Ground	45	63	-	58	-	39	30	9	1
K11	First	46	63	-	58	-	40	30	10	1
K12	Ground	45	63	-	58	-	39	30	9	1
K12	First	47	63	-	58	-	41	30	11	2
K13	Ground	45	63	-	58	-	39	30	9	1
K13	First	46	63	-	58	-	40	30	10	1
K14	Ground	44	63	-	58	-	38	30	8	1
K14	First	46	63	-	58	-	40	30	10	1
K15	Ground	44	63	-	58	-	38	30	8	1
K15	First	46	63	-	58	-	40	30	10	1
K16	Ground	44	63	-	58	-	38	30	8	1
K16	First	45	63	-	58	-	39	30	9	1
K17	Ground	44	63	-	58	-	38	30	8	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
K17	First	45	63	-	58	-	39	30	9	1
K18	Ground	44	63	-	58	-	38	30	8	1
K18	First	45	63	-	58	-	39	30	9	1
K19	Ground	44	63	-	58	-	38	30	8	1
K19	First	45	63	-	58	-	39	30	9	1
K20	Ground	43	63	-	58	-	37	30	7	1
K20	First	45	63	-	58	-	39	30	9	1
K21	Ground	43	63	-	58	-	37	30	7	1
K21	First	44	63	-	58	-	38	30	8	1
K22	Ground	43	63	-	58	-	37	30	7	1
K22	First	44	63	-	58	-	38	30	8	1
K23	Ground	44	63	-	58	-	38	30	8	1
K23	First	45	63	-	58	-	39	30	9	1
K24	Ground	43	63	-	58	-	37	30	7	1
K24	First	45	63	-	58	-	39	30	9	1
K25	Ground	43	63	-	58	-	37	30	7	1
K25	First	44	63	-	58	-	38	30	8	1
K26	Ground	43	63	-	58	-	37	30	7	1
K26	First	44	63	-	58	-	38	30	8	1
K27	Ground	43	63	-	58	-	37	30	7	1
K27	First	44	63	-	58	-	38	30	8	1
K28	Ground	44	63	-	58	-	38	30	8	1
K28	First	45	63	-	58	-	39	30	9	1
K29	Ground	43	63	-	58	-	37	30	7	1
K29	First	44	63	-	58	-	38	30	8	1
K30	Ground	43	63	-	58	-	37	30	7	1
K30	First	44	63	-	58	-	38	30	8	1
K31	Ground	42	63	-	58	-	36	30	6	1
K31	First	44	63	-	58	-	38	30	8	1
K32	Ground	42	63	-	58	-	36	30	6	1
K32	First	43	63	-	58	-	37	30	7	1
K33	Ground	42	63	-	58	-	36	30	6	1
K33	First	43	63	-	58	-	37	30	7	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
K34	Ground	43	63	-	58	-	37	30	7	1
K34	First	45	63	-	58	-	39	30	9	1
K35	Ground	43	63	-	58	-	37	30	7	1
K35	First	44	63	-	58	-	38	30	8	1
K36	Ground	43	63	-	58	-	37	30	7	1
K36	First	44	63	-	58	-	38	30	8	1
K37	Ground	43	63	-	58	-	37	30	7	1
K37	First	44	63	-	58	-	38	30	8	1
K38	Ground	42	63	-	58	-	36	30	6	1
K38	First	44	63	-	58	-	38	30	8	1
K39	Ground	42	63	-	58	-	36	30	6	1
K39	First	43	63	-	58	-	37	30	7	1
K40	Ground	41	63	-	58	-	35	30	5	1
K40	First	43	63	-	58	-	37	30	7	1
K41	Ground	41	63	-	58	-	35	30	5	1
K41	First	42	63	-	58	-	36	30	6	1
L1	Ground	40	63	-	58	-	34	30	4	1
L1	First	42	63	-	58	-	36	30	6	1
L2	Ground	39	63	-	58	-	33	30	3	1
L2	First	42	63	-	58	-	36	30	6	1
L3	Ground	39	63	-	58	-	33	30	3	1
L3	First	41	63	-	58	-	35	30	5	1
L4	Ground	39	63	-	58	-	33	30	3	1
L4	First	40	63	-	58	-	34	30	4	1
L5	Ground	39	63	-	58	-	33	30	3	1
L5	First	40	63	-	58	-	34	30	4	1
L6	Ground	40	63	-	58	-	34	30	4	1
L6	First	42	63	-	58	-	36	30	6	1
L7	Ground	39	63	-	58	-	33	30	3	1
L7	First	42	63	-	58	-	36	30	6	1
L8	Ground	39	63	-	58	-	33	30	3	1
L8	First	41	63	-	58	-	35	30	5	1
L9	Ground	38	63	-	58	-	32	30	2	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
L9	First	40	63	-	58	-	34	30	4	1
L10	Ground	40	63	-	58	-	34	30	4	1
L10	First	42	63	-	58	-	36	30	6	1
L11	Ground	39	63	-	58	-	33	30	3	1
L11	First	41	63	-	58	-	35	30	5	1
L12	Ground	38	63	-	58	-	32	30	2	1
L12	First	40	63	-	58	-	34	30	4	1
L13	Ground	38	63	-	58	-	32	30	2	1
L13	First	39	63	-	58	-	33	30	3	1
L14	Ground	38	63	-	58	-	32	30	2	1
L14	First	39	63	-	58	-	33	30	3	1
L15	Ground	40	63	-	58	-	34	30	4	1
L15	First	42	63	-	58	-	36	30	6	1
L16	Ground	40	63	-	58	-	34	30	4	1
L16	First	42	63	-	58	-	36	30	6	1
L17	Ground	39	63	-	58	-	33	30	3	1
L17	First	41	63	-	58	-	35	30	5	1
L18	Ground	38	63	-	58	-	32	30	2	1
L18	First	40	63	-	58	-	34	30	4	1
L19	Ground	38	63	-	58	-	32	30	2	1
L19	First	39	63	-	58	-	33	30	3	1
L20	Ground	41	63	-	58	-	35	30	5	1
L20	First	42	63	-	58	-	36	30	6	1
L21	Ground	40	63	-	58	-	34	30	4	1
L21	First	41	63	-	58	-	35	30	5	1
L22	Ground	39	63	-	58	-	33	30	3	1
L22	First	41	63	-	58	-	35	30	5	1
L23	Ground	38	63	-	58	-	32	30	2	1
L23	First	40	63	-	58	-	34	30	4	1
L24	Ground	38	63	-	58	-	32	30	2	1
L24	First	40	63	-	58	-	34	30	4	1
L25	Ground	38	63	-	58	-	32	30	2	1
L25	First	39	63	-	58	-	33	30	3	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
L26	Ground	40	63	-	58	-	34	30	4	1
L26	First	42	63	-	58	-	36	30	6	1
L27	Ground	39	63	-	58	-	33	30	3	1
L27	First	41	63	-	58	-	35	30	5	1
L28	Ground	39	63	-	58	-	33	30	3	1
L28	First	41	63	-	58	-	35	30	5	1
L29	Ground	39	63	-	58	-	33	30	3	1
L29	First	40	63	-	58	-	34	30	4	1
L30	Ground	38	63	-	58	-	32	30	2	1
L30	First	40	63	-	58	-	34	30	4	1
L31	Ground	38	63	-	58	-	32	30	2	1
L31	First	39	63	-	58	-	33	30	3	1
M1	Ground	64	63	1	58	6	58	30	28	3
M1	First	65	63	2	58	7	59	30	29	3
M2	Ground	64	63	1	58	6	58	30	28	3
M2	First	65	63	2	58	7	59	30	29	3
M3	Ground	64	63	1	58	6	58	30	28	3
M3	First	64	63	1	58	6	58	30	28	3
M4	Ground	63	63	-	58	5	57	30	27	3
M4	First	64	63	1	58	6	58	30	28	3
M5	Ground	63	63	-	58	5	57	30	27	3
M5	First	64	63	1	58	6	58	30	28	3
M6	Ground	63	63	-	58	5	57	30	27	3
M6	First	64	63	1	58	6	58	30	28	3
M7	Ground	63	63	-	58	5	57	30	27	3
M7	First	64	63	1	58	6	58	30	28	3
M8	Ground	63	63	-	58	5	57	30	27	3
M8	First	64	63	1	58	6	58	30	28	3
M9	Ground	63	63	-	58	5	57	30	27	3
M9	First	64	63	1	58	6	58	30	28	3
M10	Ground	62	63	-	58	4	56	30	26	3
M10	First	63	63	-	58	5	57	30	27	3
M11	Ground	62	63	-	58	4	56	30	26	3

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
M11	First	63	63	-	58	5	57	30	27	3
M12	Ground	62	63	-	58	4	56	30	26	3
M12	First	63	63	-	58	5	57	30	27	3
M13	Ground	59	63	-	58	1	53	30	23	2
M13	First	60	63	-	58	2	54	30	24	2
M14	Ground	58	63	-	58	-	52	30	22	2
M14	First	59	63	-	58	1	53	30	23	2
M15	Ground	56	63	-	58	-	50	30	20	2
M15	First	57	63	-	58	-	51	30	21	2
M16	Ground	55	63	-	58	-	49	30	19	2
M16	First	56	63	-	58	-	50	30	20	2
M17	Ground	56	63	-	58	-	50	30	20	2
M17	First	57	63	-	58	-	51	30	21	2
M18	Ground	57	63	-	58	-	51	30	21	2
M18	First	57	63	-	58	-	51	30	21	2
M19	Ground	57	63	-	58	-	51	30	21	2
M19	First	58	63	-	58	-	52	30	22	2
M20	Ground	57	63	-	58	-	51	30	21	2
M20	First	58	63	-	58	-	52	30	22	2
M21	Ground	57	63	-	58	-	51	30	21	2
M21	First	58	63	-	58	-	52	30	22	2
N1	Ground	57	63	-	58	-	51	30	21	2
N1	First	58	63	-	58	-	52	30	22	2
N2	Ground	56	63	-	58	-	50	30	20	2
N2	First	57	63	-	58	-	51	30	21	2
N3	Ground	55	63	-	58	-	49	30	19	2
N3	First	56	63	-	58	-	50	30	20	2
N4	Ground	54	63	-	58	-	48	30	18	2
N4	First	55	63	-	58	-	49	30	19	2
N5	Ground	54	63	-	58	-	48	30	18	2
N5	First	55	63	-	58	-	49	30	19	2
N6	Ground	53	63	-	58	-	47	30	17	2
N6	First	54	63	-	58	-	48	30	18	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
N7	Ground	53	63	-	58	-	47	30	17	2
N7	First	54	63	-	58	-	48	30	18	2
N8	Ground	52	63	-	58	-	46	30	16	2
N8	First	53	63	-	58	-	47	30	17	2
N9	Ground	52	63	-	58	-	46	30	16	2
N9	First	52	63	-	58	-	46	30	16	2
N10	Ground	51	63	-	58	-	45	30	15	2
N10	First	52	63	-	58	-	46	30	16	2
N11	Ground	50	63	-	58	-	44	30	14	2
N11	First	51	63	-	58	-	45	30	15	2
N12	Ground	50	63	-	58	-	44	30	14	2
N12	First	51	63	-	58	-	45	30	15	2
N13	Ground	49	63	-	58	-	43	30	13	2
N13	First	50	63	-	58	-	44	30	14	2
N14	Ground	49	63	-	58	-	43	30	13	2
N14	First	50	63	-	58	-	44	30	14	2
N15	Ground	49	63	-	58	-	43	30	13	2
N15	First	50	63	-	58	-	44	30	14	2
N16	Ground	48	63	-	58	-	42	30	12	2
N16	First	49	63	-	58	-	43	30	13	2
N17	Ground	48	63	-	58	-	42	30	12	2
N17	First	49	63	-	58	-	43	30	13	2
N18	Ground	47	63	-	58	-	41	30	11	2
N18	First	48	63	-	58	-	42	30	12	2
N19	Ground	47	63	-	58	-	41	30	11	2
N19	First	48	63	-	58	-	42	30	12	2
N20	Ground	47	63	-	58	-	41	30	11	2
N20	First	48	63	-	58	-	42	30	12	2
N21	Ground	46	63	-	58	-	40	30	10	1
N21	First	47	63	-	58	-	41	30	11	2
N22	Ground	46	63	-	58	-	40	30	10	1
N22	First	47	63	-	58	-	41	30	11	2
N23	Ground	46	63	-	58	-	40	30	10	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
N23	First	47	63	-	58	-	41	30	11	2
N24	Ground	45	63	-	58	-	39	30	9	1
N24	First	46	63	-	58	-	40	30	10	1
N25	Ground	45	63	-	58	-	39	30	9	1
N25	First	46	63	-	58	-	40	30	10	1
N26	Ground	44	63	-	58	-	38	30	8	1
N26	First	46	63	-	58	-	40	30	10	1
N27	Ground	44	63	-	58	-	38	30	8	1
N27	First	45	63	-	58	-	39	30	9	1
N28	Ground	44	63	-	58	-	38	30	8	1
N28	First	45	63	-	58	-	39	30	9	1
N29	Ground	43	63	-	58	-	37	30	7	1
N29	First	44	63	-	58	-	38	30	8	1
N30	Ground	43	63	-	58	-	37	30	7	1
N30	First	44	63	-	58	-	38	30	8	1
N31	Ground	43	63	-	58	-	37	30	7	1
N31	First	44	63	-	58	-	38	30	8	1
N32	Ground	43	63	-	58	-	37	30	7	1
N32	First	44	63	-	58	-	38	30	8	1
N33	Ground	43	63	-	58	-	37	30	7	1
N33	First	44	63	-	58	-	38	30	8	1
N34	Ground	57	63	-	58	-	51	30	21	2
N34	First	58	63	-	58	-	52	30	22	2
N35	Ground	56	63	-	58	-	50	30	20	2
N35	First	57	63	-	58	-	51	30	21	2
N36	Ground	55	63	-	58	-	49	30	19	2
N36	First	56	63	-	58	-	50	30	20	2
N37	Ground	54	63	-	58	-	48	30	18	2
N37	First	55	63	-	58	-	49	30	19	2
N38	Ground	54	63	-	58	-	48	30	18	2
N38	First	55	63	-	58	-	49	30	19	2
N39	Ground	53	63	-	58	-	47	30	17	2
N39	First	54	63	-	58	-	48	30	18	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
N40	Ground	52	63	-	58	-	46	30	16	2
N40	First	53	63	-	58	-	47	30	17	2
N41	Ground	52	63	-	58	-	46	30	16	2
N41	First	53	63	-	58	-	47	30	17	2
N42	Ground	51	63	-	58	-	45	30	15	2
N42	First	52	63	-	58	-	46	30	16	2
N43	Ground	51	63	-	58	-	45	30	15	2
N43	First	52	63	-	58	-	46	30	16	2
N44	Ground	50	63	-	58	-	44	30	14	2
N44	First	51	63	-	58	-	45	30	15	2
N45	Ground	50	63	-	58	-	44	30	14	2
N45	First	51	63	-	58	-	45	30	15	2
N46	Ground	49	63	-	58	-	43	30	13	2
N46	First	50	63	-	58	-	44	30	14	2
N47	Ground	49	63	-	58	-	43	30	13	2
N47	First	50	63	-	58	-	44	30	14	2
N48	Ground	48	63	-	58	-	42	30	12	2
N48	First	49	63	-	58	-	43	30	13	2
N49	Ground	48	63	-	58	-	42	30	12	2
N49	First	49	63	-	58	-	43	30	13	2
N50	Ground	48	63	-	58	-	42	30	12	2
N50	First	49	63	-	58	-	43	30	13	2
N51	Ground	47	63	-	58	-	41	30	11	2
N51	First	48	63	-	58	-	42	30	12	2
N52	Ground	47	63	-	58	-	41	30	11	2
N52	First	48	63	-	58	-	42	30	12	2
N53	Ground	47	63	-	58	-	41	30	11	2
N53	First	47	63	-	58	-	41	30	11	2
N54	Ground	46	63	-	58	-	40	30	10	1
N54	First	47	63	-	58	-	41	30	11	2
N55	Ground	46	63	-	58	-	40	30	10	1
N55	First	47	63	-	58	-	41	30	11	2
N56	Ground	45	63	-	58	-	39	30	9	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
N56	First	46	63	-	58	-	40	30	10	1
N57	Ground	45	63	-	58	-	39	30	9	1
N57	First	46	63	-	58	-	40	30	10	1
N58	Ground	44	63	-	58	-	38	30	8	1
N58	First	46	63	-	58	-	40	30	10	1
N59	Ground	44	63	-	58	-	38	30	8	1
N59	First	45	63	-	58	-	39	30	9	1
N60	Ground	44	63	-	58	-	38	30	8	1
N60	First	45	63	-	58	-	39	30	9	1
O1	Ground	54	63	-	58	-	48	30	18	2
O1	First	55	63	-	58	-	49	30	19	2
O2	Ground	51	63	-	58	-	45	30	15	2
O2	First	52	63	-	58	-	46	30	16	2
O3	Ground	53	63	-	58	-	47	30	17	2
O3	First	54	63	-	58	-	48	30	18	2
O4	Ground	52	63	-	58	-	46	30	16	2
O4	First	53	63	-	58	-	47	30	17	2
O5	Ground	52	63	-	58	-	46	30	16	2
O5	First	53	63	-	58	-	47	30	17	2
O6	Ground	51	63	-	58	-	45	30	15	2
O6	First	52	63	-	58	-	46	30	16	2
O7	Ground	51	63	-	58	-	45	30	15	2
O7	First	52	63	-	58	-	46	30	16	2
O8	Ground	51	63	-	58	-	45	30	15	2
O8	First	51	63	-	58	-	45	30	15	2
O9	Ground	53	63	-	58	-	47	30	17	2
O9	First	54	63	-	58	-	48	30	18	2
O10	Ground	53	63	-	58	-	47	30	17	2
O10	First	54	63	-	58	-	48	30	18	2
O11	Ground	53	63	-	58	-	47	30	17	2
O11	First	54	63	-	58	-	48	30	18	2
O12	Ground	53	63	-	58	-	47	30	17	2
O12	First	54	63	-	58	-	48	30	18	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
O13	Ground	52	63	-	58	-	46	30	16	2
O13	First	53	63	-	58	-	47	30	17	2
O14	Ground	51	63	-	58	-	45	30	15	2
O14	First	52	63	-	58	-	46	30	16	2
O15	Ground	51	63	-	58	-	45	30	15	2
O15	First	52	63	-	58	-	46	30	16	2
O16	Ground	50	63	-	58	-	44	30	14	2
O16	First	51	63	-	58	-	45	30	15	2
O17	Ground	50	63	-	58	-	44	30	14	2
O17	First	51	63	-	58	-	45	30	15	2
O18	Ground	51	63	-	58	-	45	30	15	2
O18	First	52	63	-	58	-	46	30	16	2
O19	Ground	52	63	-	58	-	46	30	16	2
O19	First	53	63	-	58	-	47	30	17	2
O20	Ground	52	63	-	58	-	46	30	16	2
O20	First	53	63	-	58	-	47	30	17	2
O21	Ground	52	63	-	58	-	46	30	16	2
O21	First	53	63	-	58	-	47	30	17	2
O22	Ground	50	63	-	58	-	44	30	14	2
O22	First	51	63	-	58	-	45	30	15	2
O23	Ground	50	63	-	58	-	44	30	14	2
O23	First	51	63	-	58	-	45	30	15	2
O24	Ground	49	63	-	58	-	43	30	13	2
O24	First	50	63	-	58	-	44	30	14	2
O25	Ground	50	63	-	58	-	44	30	14	2
O25	First	51	63	-	58	-	45	30	15	2
O26	Ground	49	63	-	58	-	43	30	13	2
O26	First	50	63	-	58	-	44	30	14	2
O27	Ground	48	63	-	58	-	42	30	12	2
O27	First	49	63	-	58	-	43	30	13	2
O28	Ground	48	63	-	58	-	42	30	12	2
O28	First	49	63	-	58	-	43	30	13	2
O29	Ground	48	63	-	58	-	42	30	12	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
O29	First	49	63	-	58	-	43	30	13	2
O30	Ground	48	63	-	58	-	42	30	12	2
O30	First	49	63	-	58	-	43	30	13	2
O31	Ground	48	63	-	58	-	42	30	12	2
O31	First	49	63	-	58	-	43	30	13	2
O32	Ground	49	63	-	58	-	43	30	13	2
O32	First	49	63	-	58	-	43	30	13	2
O33	Ground	48	63	-	58	-	42	30	12	2
O33	First	49	63	-	58	-	43	30	13	2
O34	Ground	49	63	-	58	-	43	30	13	2
O34	First	50	63	-	58	-	44	30	14	2
O35	Ground	49	63	-	58	-	43	30	13	2
O35	First	49	63	-	58	-	43	30	13	2
O36	Ground	49	63	-	58	-	43	30	13	2
O36	First	50	63	-	58	-	44	30	14	2
P1	Ground	47	63	-	58	-	41	30	11	2
P1	First	48	63	-	58	-	42	30	12	2
P2	Ground	46	63	-	58	-	40	30	10	1
P2	First	47	63	-	58	-	41	30	11	2
P3	Ground	46	63	-	58	-	40	30	10	1
P3	First	47	63	-	58	-	41	30	11	2
P4	Ground	46	63	-	58	-	40	30	10	1
P4	First	47	63	-	58	-	41	30	11	2
P5	Ground	46	63	-	58	-	40	30	10	1
P5	First	47	63	-	58	-	41	30	11	2
P6	Ground	46	63	-	58	-	40	30	10	1
P6	First	47	63	-	58	-	41	30	11	2
P7	Ground	46	63	-	58	-	40	30	10	1
P7	First	47	63	-	58	-	41	30	11	2
P8	Ground	45	63	-	58	-	39	30	9	1
P8	First	46	63	-	58	-	40	30	10	1
P9	Ground	45	63	-	58	-	39	30	9	1
P9	First	46	63	-	58	-	40	30	10	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
P10	Ground	45	63	-	58	-	39	30	9	1
P10	First	46	63	-	58	-	40	30	10	1
P11	Ground	44	63	-	58	-	38	30	8	1
P11	First	45	63	-	58	-	39	30	9	1
P12	Ground	46	63	-	58	-	40	30	10	1
P12	First	47	63	-	58	-	41	30	11	2
P13	Ground	45	63	-	58	-	39	30	9	1
P13	First	46	63	-	58	-	40	30	10	1
P14	Ground	45	63	-	58	-	39	30	9	1
P14	First	46	63	-	58	-	40	30	10	1
P15	Ground	45	63	-	58	-	39	30	9	1
P15	First	46	63	-	58	-	40	30	10	1
P16	Ground	44	63	-	58	-	38	30	8	1
P16	First	45	63	-	58	-	39	30	9	1
P17	Ground	44	63	-	58	-	38	30	8	1
P17	First	45	63	-	58	-	39	30	9	1
P18	Ground	44	63	-	58	-	38	30	8	1
P18	First	45	63	-	58	-	39	30	9	1
P19	Ground	44	63	-	58	-	38	30	8	1
P19	First	45	63	-	58	-	39	30	9	1
P20	Ground	43	63	-	58	-	37	30	7	1
P20	First	45	63	-	58	-	39	30	9	1
P21	Ground	44	63	-	58	-	38	30	8	1
P21	First	45	63	-	58	-	39	30	9	1
P22	Ground	43	63	-	58	-	37	30	7	1
P22	First	45	63	-	58	-	39	30	9	1
P23	Ground	48	63	-	58	-	42	30	12	2
P23	First	48	63	-	58	-	42	30	12	2
P24	Ground	47	63	-	58	-	41	30	11	2
P24	First	47	63	-	58	-	41	30	11	2
P25	Ground	46	63	-	58	-	40	30	10	1
P25	First	47	63	-	58	-	41	30	11	2
P26	Ground	46	63	-	58	-	40	30	10	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
P26	First	47	63	-	58	-	41	30	11	2
P27	Ground	46	63	-	58	-	40	30	10	1
P27	First	47	63	-	58	-	41	30	11	2
P28	Ground	45	63	-	58	-	39	30	9	1
P28	First	46	63	-	58	-	40	30	10	1
P29	Ground	45	63	-	58	-	39	30	9	1
P29	First	46	63	-	58	-	40	30	10	1
P30	Ground	45	63	-	58	-	39	30	9	1
P30	First	46	63	-	58	-	40	30	10	1
P31	Ground	48	63	-	58	-	42	30	12	2
P31	First	49	63	-	58	-	43	30	13	2
Q1	Ground	55	63	-	58	-	49	30	19	2
Q1	First	56	63	-	58	-	50	30	20	2
Q2	Ground	51	63	-	58	-	45	30	15	2
Q2	First	52	63	-	58	-	46	30	16	2
Q3	Ground	53	63	-	58	-	47	30	17	2
Q3	First	53	63	-	58	-	47	30	17	2
Q4	Ground	48	63	-	58	-	42	30	12	2
Q4	First	49	63	-	58	-	43	30	13	2
R1	Ground	57	63	-	58	-	51	30	21	2
R1	First	58	63	-	58	-	52	30	22	2
R2	Ground	57	63	-	58	-	51	30	21	2
R2	First	58	63	-	58	-	52	30	22	2
R3	Ground	57	63	-	58	-	51	30	21	2
R3	First	58	63	-	58	-	52	30	22	2
R4	Ground	57	63	-	58	-	51	30	21	2
R4	First	58	63	-	58	-	52	30	22	2
R5	Ground	57	63	-	58	-	51	30	21	2
R5	First	58	63	-	58	-	52	30	22	2
R6	Ground	56	63	-	58	-	50	30	20	2
R6	First	57	63	-	58	-	51	30	21	2
R7	Ground	54	63	-	58	-	48	30	18	2
R7	First	55	63	-	58	-	49	30	19	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
R8	Ground	53	63	-	58	-	47	30	17	2
R8	First	54	63	-	58	-	48	30	18	2
R9	Ground	53	63	-	58	-	47	30	17	2
R9	First	54	63	-	58	-	48	30	18	2
R10	Ground	50	63	-	58	-	44	30	14	2
R10	First	51	63	-	58	-	45	30	15	2
S1	Ground	56	63	-	58	-	50	30	20	2
S1	First	57	63	-	58	-	51	30	21	2
S2	Ground	56	63	-	58	-	50	30	20	2
S2	First	57	63	-	58	-	51	30	21	2
S3	Ground	56	63	-	58	-	50	30	20	2
S3	First	57	63	-	58	-	51	30	21	2
S4	Ground	55	63	-	58	-	49	30	19	2
S4	First	57	63	-	58	-	51	30	21	2
S5	Ground	53	63	-	58	-	47	30	17	2
S5	First	54	63	-	58	-	48	30	18	2
S6	Ground	54	63	-	58	-	48	30	18	2
S6	First	55	63	-	58	-	49	30	19	2
S7	Ground	52	63	-	58	-	46	30	16	2
S7	First	53	63	-	58	-	47	30	17	2
S8	Ground	53	63	-	58	-	47	30	17	2
S8	First	54	63	-	58	-	48	30	18	2
S9	Ground	51	63	-	58	-	45	30	15	2
S9	First	52	63	-	58	-	46	30	16	2
S10	Ground	51	63	-	58	-	45	30	15	2
S10	First	52	63	-	58	-	46	30	16	2
S11	Ground	51	63	-	58	-	45	30	15	2
S11	First	52	63	-	58	-	46	30	16	2
S12	Ground	51	63	-	58	-	45	30	15	2
S12	First	52	63	-	58	-	46	30	16	2
S13	Ground	51	63	-	58	-	45	30	15	2
S13	First	52	63	-	58	-	46	30	16	2
T1	Ground	54	63	-	58	-	48	30	18	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
T1	First	55	63	-	58	-	49	30	19	2
T2	Ground	55	63	-	58	-	49	30	19	2
T2	First	56	63	-	58	-	50	30	20	2
T3	Ground	56	63	-	58	-	50	30	20	2
T3	First	57	63	-	58	-	51	30	21	2
T4	Ground	57	63	-	58	-	51	30	21	2
T4	First	58	63	-	58	-	52	30	22	2
T5	Ground	56	63	-	58	-	50	30	20	2
T5	First	57	63	-	58	-	51	30	21	2
T6	Ground	57	63	-	58	-	51	30	21	2
T6	First	58	63	-	58	-	52	30	22	2
T7	Ground	57	63	-	58	-	51	30	21	2
T7	First	58	63	-	58	-	52	30	22	2
T8	Ground	56	63	-	58	-	50	30	20	2
T8	First	58	63	-	58	-	52	30	22	2
T9	Ground	56	63	-	58	-	50	30	20	2
T9	First	57	63	-	58	-	51	30	21	2
T10	Ground	55	63	-	58	-	49	30	19	2
T10	First	57	63	-	58	-	51	30	21	2
U1	Ground	51	63	-	58	-	45	30	15	2
U1	First	52	63	-	58	-	46	30	16	2
U2	Ground	51	63	-	58	-	45	30	15	2
U2	First	52	63	-	58	-	46	30	16	2
U3	Ground	49	63	-	58	-	43	30	13	2
U3	First	51	63	-	58	-	45	30	15	2
U4	Ground	49	63	-	58	-	43	30	13	2
U4	First	51	63	-	58	-	45	30	15	2
U5	Ground	48	63	-	58	-	42	30	12	2
U5	First	50	63	-	58	-	44	30	14	2
U6	Ground	48	63	-	58	-	42	30	12	2
U6	First	50	63	-	58	-	44	30	14	2
U7	Ground	48	63	-	58	-	42	30	12	2
U7	First	49	63	-	58	-	43	30	13	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
U8	Ground	48	63	-	58	-	42	30	12	2
U8	First	49	63	-	58	-	43	30	13	2
U9	Ground	47	63	-	58	-	41	30	11	2
U9	First	48	63	-	58	-	42	30	12	2
U10	Ground	47	63	-	58	-	41	30	11	2
U10	First	49	63	-	58	-	43	30	13	2
U11	Ground	46	63	-	58	-	40	30	10	1
U11	First	48	63	-	58	-	42	30	12	2
U12	Ground	51	63	-	58	-	45	30	15	2
U12	First	52	63	-	58	-	46	30	16	2
U13	Ground	50	63	-	58	-	44	30	14	2
U13	First	52	63	-	58	-	46	30	16	2
U14	Ground	50	63	-	58	-	44	30	14	2
U14	First	51	63	-	58	-	45	30	15	2
U15	Ground	49	63	-	58	-	43	30	13	2
U15	First	51	63	-	58	-	45	30	15	2
U16	Ground	49	63	-	58	-	43	30	13	2
U16	First	50	63	-	58	-	44	30	14	2
U17	Ground	48	63	-	58	-	42	30	12	2
U17	First	50	63	-	58	-	44	30	14	2
U18	Ground	48	63	-	58	-	42	30	12	2
U18	First	49	63	-	58	-	43	30	13	2
U19	Ground	47	63	-	58	-	41	30	11	2
U19	First	49	63	-	58	-	43	30	13	2
U20	Ground	47	63	-	58	-	41	30	11	2
U20	First	49	63	-	58	-	43	30	13	2
U21	Ground	46	63	-	58	-	40	30	10	1
U21	First	48	63	-	58	-	42	30	12	2
U22	Ground	45	63	-	58	-	39	30	9	1
U22	First	47	63	-	58	-	41	30	11	2
U23	Ground	50	63	-	58	-	44	30	14	2
U23	First	52	63	-	58	-	46	30	16	2
U24	Ground	50	63	-	58	-	44	30	14	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
U24	First	52	63	-	58	-	46	30	16	2
U25	Ground	49	63	-	58	-	43	30	13	2
U25	First	50	63	-	58	-	44	30	14	2
U26	Ground	48	63	-	58	-	42	30	12	2
U26	First	50	63	-	58	-	44	30	14	2
U27	Ground	48	63	-	58	-	42	30	12	2
U27	First	50	63	-	58	-	44	30	14	2
U28	Ground	47	63	-	58	-	41	30	11	2
U28	First	49	63	-	58	-	43	30	13	2
U29	Ground	47	63	-	58	-	41	30	11	2
U29	First	49	63	-	58	-	43	30	13	2
U30	Ground	47	63	-	58	-	41	30	11	2
U30	First	48	63	-	58	-	42	30	12	2
U31	Ground	46	63	-	58	-	40	30	10	1
U31	First	48	63	-	58	-	42	30	12	2
U32	Ground	46	63	-	58	-	40	30	10	1
U32	First	48	63	-	58	-	42	30	12	2
U33	Ground	45	63	-	58	-	39	30	9	1
U33	First	47	63	-	58	-	41	30	11	2
U34	Ground	44	63	-	58	-	38	30	8	1
U34	First	46	63	-	58	-	40	30	10	1
U35	Ground	45	63	-	58	-	39	30	9	1
U35	First	47	63	-	58	-	41	30	11	2
V1	Ground	52	63	-	58	-	46	30	16	2
V1	First	53	63	-	58	-	47	30	17	2
V2	Ground	51	63	-	58	-	45	30	15	2
V2	First	53	63	-	58	-	47	30	17	2
V3	Ground	51	63	-	58	-	45	30	15	2
V3	First	53	63	-	58	-	47	30	17	2
V4	Ground	51	63	-	58	-	45	30	15	2
V4	First	52	63	-	58	-	46	30	16	2
V5	Ground	51	63	-	58	-	45	30	15	2
V5	First	52	63	-	58	-	46	30	16	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
V6	Ground	51	63	-	58	-	45	30	15	2
V6	First	52	63	-	58	-	46	30	16	2
V7	Ground	51	63	-	58	-	45	30	15	2
V7	First	52	63	-	58	-	46	30	16	2
V8	Ground	48	63	-	58	-	42	30	12	2
V8	First	50	63	-	58	-	44	30	14	2
V9	Ground	48	63	-	58	-	42	30	12	2
V9	First	49	63	-	58	-	43	30	13	2
V10	Ground	48	63	-	58	-	42	30	12	2
V10	First	50	63	-	58	-	44	30	14	2
V11	Ground	48	63	-	58	-	42	30	12	2
V11	First	49	63	-	58	-	43	30	13	2
V12	Ground	47	63	-	58	-	41	30	11	2
V12	First	49	63	-	58	-	43	30	13	2
V13	Ground	47	63	-	58	-	41	30	11	2
V13	First	49	63	-	58	-	43	30	13	2
V14	Ground	47	63	-	58	-	41	30	11	2
V14	First	49	63	-	58	-	43	30	13	2
V15	Ground	46	63	-	58	-	40	30	10	1
V15	First	47	63	-	58	-	41	30	11	2
Number of Ground Floor exceedances				**4**		**29**	**Number of AS3671 Category 1 – Ground Floor**			**176**
Number of First Floor exceedances				**12**		**41**	**Number of AS3671 Category 1 – First Floor**			**140**
							Number of AS3671 Category 2 – Ground Floor			**273**
							Number of AS3671 Category 2 – First Floor			**305**
							Number of AS3671 Category 3 – Ground Floor			**22**
							Number of AS3671 Category 3 – First Floor			**26**

Table B-2 Predicted Noise Levels for Year 2026 for the 2CRU development – with 1.8 metre Noise Barriers

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
A1	Ground	61	63	-	58	3	55	30	25	2
A1	First	67	63	4	58	9	61	30	31	3
A2	Ground	56	63	-	58	-	50	30	20	2
A2	First	59	63	-	58	1	53	30	23	2
A3	Ground	54	63	-	58	-	48	30	18	2
A3	First	56	63	-	58	-	50	30	20	2
A4	Ground	52	63	-	58	-	46	30	16	2
A4	First	54	63	-	58	-	48	30	18	2
A5	Ground	51	63	-	58	-	45	30	15	2
A5	First	52	63	-	58	-	46	30	16	2
A6	Ground	50	63	-	58	-	44	30	14	2
A6	First	51	63	-	58	-	45	30	15	2
A7	Ground	49	63	-	58	-	43	30	13	2
A7	First	50	63	-	58	-	44	30	14	2
A8	Ground	48	63	-	58	-	42	30	12	2
A8	First	49	63	-	58	-	43	30	13	2
A9	Ground	47	63	-	58	-	41	30	11	2
A9	First	48	63	-	58	-	42	30	12	2
A10	Ground	46	63	-	58	-	40	30	10	1
A10	First	47	63	-	58	-	41	30	11	2
A11	Ground	46	63	-	58	-	40	30	10	1
A11	First	46	63	-	58	-	40	30	10	1
A12	Ground	45	63	-	58	-	39	30	9	1
A12	First	46	63	-	58	-	40	30	10	1
A13	Ground	44	63	-	58	-	38	30	8	1
A13	First	45	63	-	58	-	39	30	9	1
A14	Ground	44	63	-	58	-	38	30	8	1
A14	First	45	63	-	58	-	39	30	9	1
A15	Ground	43	63	-	58	-	37	30	7	1
A15	First	44	63	-	58	-	38	30	8	1
A16	Ground	43	63	-	58	-	37	30	7	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
A16	First	43	63	-	58	-	37	30	7	1
A17	Ground	42	63	-	58	-	36	30	6	1
A17	First	43	63	-	58	-	37	30	7	1
A18	Ground	42	63	-	58	-	36	30	6	1
A18	First	43	63	-	58	-	37	30	7	1
A19	Ground	41	63	-	58	-	35	30	5	1
A19	First	42	63	-	58	-	36	30	6	1
A20	Ground	41	63	-	58	-	35	30	5	1
A20	First	42	63	-	58	-	36	30	6	1
A21	Ground	40	63	-	58	-	34	30	4	1
A21	First	41	63	-	58	-	35	30	5	1
A22	Ground	40	63	-	58	-	34	30	4	1
A22	First	41	63	-	58	-	35	30	5	1
A23	Ground	39	63	-	58	-	33	30	3	1
A23	First	40	63	-	58	-	34	30	4	1
A24	Ground	39	63	-	58	-	33	30	3	1
A24	First	40	63	-	58	-	34	30	4	1
B1	Ground	57	63	-	58	-	51	30	21	2
B1	First	61	63	-	58	3	55	30	25	2
B2	Ground	57	63	-	58	-	51	30	21	2
B2	First	61	63	-	58	3	55	30	25	2
B3	Ground	57	63	-	58	-	51	30	21	2
B3	First	61	63	-	58	3	55	30	25	2
B4	Ground	57	63	-	58	-	51	30	21	2
B4	First	61	63	-	58	3	55	30	25	2
B5	Ground	56	63	-	58	-	50	30	20	2
B5	First	60	63	-	58	2	54	30	24	2
B6	Ground	53	63	-	58	-	47	30	17	2
B6	First	56	63	-	58	-	50	30	20	2
B7	Ground	53	63	-	58	-	47	30	17	2
B7	First	55	63	-	58	-	49	30	19	2
B8	Ground	53	63	-	58	-	47	30	17	2
B8	First	55	63	-	58	-	49	30	19	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
B9	Ground	53	63	-	58	-	47	30	17	2
B9	First	55	63	-	58	-	49	30	19	2
B10	Ground	53	63	-	58	-	47	30	17	2
B10	First	55	63	-	58	-	49	30	19	2
B11	Ground	53	63	-	58	-	47	30	17	2
B11	First	55	63	-	58	-	49	30	19	2
C1	Ground	50	63	-	58	-	44	30	14	2
C1	First	51	63	-	58	-	45	30	15	2
C2	Ground	49	63	-	58	-	43	30	13	2
C2	First	50	63	-	58	-	44	30	14	2
C3	Ground	49	63	-	58	-	43	30	13	2
C3	First	49	63	-	58	-	43	30	13	2
C4	Ground	48	63	-	58	-	42	30	12	2
C4	First	49	63	-	58	-	43	30	13	2
C5	Ground	47	63	-	58	-	41	30	11	2
C5	First	48	63	-	58	-	42	30	12	2
C6	Ground	47	63	-	58	-	41	30	11	2
C6	First	48	63	-	58	-	42	30	12	2
C7	Ground	47	63	-	58	-	41	30	11	2
C7	First	47	63	-	58	-	41	30	11	2
C8	Ground	46	63	-	58	-	40	30	10	1
C8	First	47	63	-	58	-	41	30	11	2
C9	Ground	50	63	-	58	-	44	30	14	2
C9	First	51	63	-	58	-	45	30	15	2
C10	Ground	49	63	-	58	-	43	30	13	2
C10	First	50	63	-	58	-	44	30	14	2
C11	Ground	49	63	-	58	-	43	30	13	2
C11	First	50	63	-	58	-	44	30	14	2
C12	Ground	48	63	-	58	-	42	30	12	2
C12	First	49	63	-	58	-	43	30	13	2
C13	Ground	48	63	-	58	-	42	30	12	2
C13	First	49	63	-	58	-	43	30	13	2
C14	Ground	48	63	-	58	-	42	30	12	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
C14	First	48	63	-	58	-	42	30	12	2
C15	Ground	47	63	-	58	-	41	30	11	2
C15	First	48	63	-	58	-	42	30	12	2
D1	Ground	56	63	-	58	-	50	30	20	2
D1	First	60	63	-	58	2	54	30	24	2
D2	Ground	56	63	-	58	-	50	30	20	2
D2	First	60	63	-	58	2	54	30	24	2
D3	Ground	56	63	-	58	-	50	30	20	2
D3	First	60	63	-	58	2	54	30	24	2
D4	Ground	56	63	-	58	-	50	30	20	2
D4	First	60	63	-	58	2	54	30	24	2
D5	Ground	53	63	-	58	-	47	30	17	2
D5	First	55	63	-	58	-	49	30	19	2
D6	Ground	53	63	-	58	-	47	30	17	2
D6	First	55	63	-	58	-	49	30	19	2
D7	Ground	52	63	-	58	-	46	30	16	2
D7	First	53	63	-	58	-	47	30	17	2
D8	Ground	52	63	-	58	-	46	30	16	2
D8	First	53	63	-	58	-	47	30	17	2
D9	Ground	51	63	-	58	-	45	30	15	2
D9	First	53	63	-	58	-	47	30	17	2
D10	Ground	51	63	-	58	-	45	30	15	2
D10	First	53	63	-	58	-	47	30	17	2
D11	Ground	51	63	-	58	-	45	30	15	2
D11	First	52	63	-	58	-	46	30	16	2
D12	Ground	51	63	-	58	-	45	30	15	2
D12	First	52	63	-	58	-	46	30	16	2
D13	Ground	50	63	-	58	-	44	30	14	2
D13	First	51	63	-	58	-	45	30	15	2
D14	Ground	50	63	-	58	-	44	30	14	2
D14	First	51	63	-	58	-	45	30	15	2
D15	Ground	50	63	-	58	-	44	30	14	2
D15	First	50	63	-	58	-	44	30	14	2

Receiver	Flr	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq,\ night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq,\ night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
E1	Ground	48	63	-	58	-	42	30	12	2
E1	First	49	63	-	58	-	43	30	13	2
E2	Ground	47	63	-	58	-	41	30	11	2
E2	First	48	63	-	58	-	42	30	12	2
E3	Ground	47	63	-	58	-	41	30	11	2
E3	First	48	63	-	58	-	42	30	12	2
E4	Ground	47	63	-	58	-	41	30	11	2
E4	First	47	63	-	58	-	41	30	11	2
E5	Ground	46	63	-	58	-	40	30	10	1
E5	First	47	63	-	58	-	41	30	11	2
E6	Ground	46	63	-	58	-	40	30	10	1
E6	First	47	63	-	58	-	41	30	11	2
E7	Ground	47	63	-	58	-	41	30	11	2
E7	First	48	63	-	58	-	42	30	12	2
E8	Ground	46	63	-	58	-	40	30	10	1
E8	First	47	63	-	58	-	41	30	11	2
E9	Ground	46	63	-	58	-	40	30	10	1
E9	First	47	63	-	58	-	41	30	11	2
E10	Ground	45	63	-	58	-	39	30	9	1
E10	First	46	63	-	58	-	40	30	10	1
E11	Ground	46	63	-	58	-	40	30	10	1
E11	First	46	63	-	58	-	40	30	10	1
F1	Ground	46	63	-	58	-	40	30	10	1
F1	First	47	63	-	58	-	41	30	11	2
F2	Ground	45	63	-	58	-	39	30	9	1
F2	First	46	63	-	58	-	40	30	10	1
F3	Ground	45	63	-	58	-	39	30	9	1
F3	First	46	63	-	58	-	40	30	10	1
F4	Ground	45	63	-	58	-	39	30	9	1
F4	First	46	63	-	58	-	40	30	10	1
F5	Ground	45	63	-	58	-	39	30	9	1
F5	First	45	63	-	58	-	39	30	9	1
F6	Ground	45	63	-	58	-	39	30	9	1

Receiver	Flr	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq,\ night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq,\ night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
F6	First	45	63	-	58	-	39	30	9	1
F7	Ground	44	63	-	58	-	38	30	8	1
F7	First	45	63	-	58	-	39	30	9	1
F8	Ground	44	63	-	58	-	38	30	8	1
F8	First	45	63	-	58	-	39	30	9	1
F9	Ground	44	63	-	58	-	38	30	8	1
F9	First	45	63	-	58	-	39	30	9	1
F10	Ground	44	63	-	58	-	38	30	8	1
F10	First	44	63	-	58	-	38	30	8	1
F11	Ground	44	63	-	58	-	38	30	8	1
F11	First	44	63	-	58	-	38	30	8	1
F12	Ground	43	63	-	58	-	37	30	7	1
F12	First	44	63	-	58	-	38	30	8	1
F13	Ground	45	63	-	58	-	39	30	9	1
F13	First	45	63	-	58	-	39	30	9	1
F14	Ground	45	63	-	58	-	39	30	9	1
F14	First	45	63	-	58	-	39	30	9	1
F15	Ground	44	63	-	58	-	38	30	8	1
F15	First	45	63	-	58	-	39	30	9	1
F16	Ground	44	63	-	58	-	38	30	8	1
F16	First	45	63	-	58	-	39	30	9	1
F17	Ground	44	63	-	58	-	38	30	8	1
F17	First	44	63	-	58	-	38	30	8	1
F18	Ground	44	63	-	58	-	38	30	8	1
F18	First	44	63	-	58	-	38	30	8	1
F19	Ground	44	63	-	58	-	38	30	8	1
F19	First	44	63	-	58	-	38	30	8	1
F20	Ground	43	63	-	58	-	37	30	7	1
F20	First	44	63	-	58	-	38	30	8	1
F21	Ground	43	63	-	58	-	37	30	7	1
F21	First	44	63	-	58	-	38	30	8	1
F22	Ground	43	63	-	58	-	37	30	7	1
F22	First	43	63	-	58	-	37	30	7	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
G1	Ground	43	63	-	58	-	37	30	7	1
G1	First	43	63	-	58	-	37	30	7	1
G2	Ground	43	63	-	58	-	37	30	7	1
G2	First	43	63	-	58	-	37	30	7	1
G3	Ground	42	63	-	58	-	36	30	6	1
G3	First	43	63	-	58	-	37	30	7	1
G4	Ground	42	63	-	58	-	36	30	6	1
G4	First	43	63	-	58	-	37	30	7	1
G5	Ground	42	63	-	58	-	36	30	6	1
G5	First	42	63	-	58	-	36	30	6	1
G6	Ground	41	63	-	58	-	35	30	5	1
G6	First	42	63	-	58	-	36	30	6	1
G7	Ground	41	63	-	58	-	35	30	5	1
G7	First	42	63	-	58	-	36	30	6	1
G8	Ground	41	63	-	58	-	35	30	5	1
G8	First	42	63	-	58	-	36	30	6	1
G9	Ground	40	63	-	58	-	34	30	4	1
G9	First	42	63	-	58	-	36	30	6	1
G10	Ground	40	63	-	58	-	34	30	4	1
G10	First	41	63	-	58	-	35	30	5	1
H1	Ground	42	63	-	58	-	36	30	6	1
H1	First	43	63	-	58	-	37	30	7	1
H2	Ground	42	63	-	58	-	36	30	6	1
H2	First	43	63	-	58	-	37	30	7	1
H3	Ground	41	63	-	58	-	35	30	5	1
H3	First	42	63	-	58	-	36	30	6	1
H4	Ground	41	63	-	58	-	35	30	5	1
H4	First	42	63	-	58	-	36	30	6	1
H5	Ground	41	63	-	58	-	35	30	5	1
H5	First	42	63	-	58	-	36	30	6	1
H6	Ground	40	63	-	58	-	34	30	4	1
H6	First	42	63	-	58	-	36	30	6	1
H7	Ground	40	63	-	58	-	34	30	4	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
H7	First	42	63	-	58	-	36	30	6	1
H8	Ground	40	63	-	58	-	34	30	4	1
H8	First	41	63	-	58	-	35	30	5	1
H9	Ground	40	63	-	58	-	34	30	4	1
H9	First	41	63	-	58	-	35	30	5	1
H10	Ground	39	63	-	58	-	33	30	3	1
H10	First	41	63	-	58	-	35	30	5	1
H11	Ground	39	63	-	58	-	33	30	3	1
H11	First	40	63	-	58	-	34	30	4	1
I1	Ground	39	63	-	58	-	33	30	3	1
I1	First	40	63	-	58	-	34	30	4	1
I2	Ground	39	63	-	58	-	33	30	3	1
I2	First	40	63	-	58	-	34	30	4	1
I3	Ground	38	63	-	58	-	32	30	2	1
I3	First	40	63	-	58	-	34	30	4	1
I4	Ground	38	63	-	58	-	32	30	2	1
I4	First	39	63	-	58	-	33	30	3	1
I5	Ground	38	63	-	58	-	32	30	2	1
I5	First	39	63	-	58	-	33	30	3	1
I6	Ground	38	63	-	58	-	32	30	2	1
I6	First	39	63	-	58	-	33	30	3	1
I7	Ground	38	63	-	58	-	32	30	2	1
I7	First	39	63	-	58	-	33	30	3	1
I8	Ground	38	63	-	58	-	32	30	2	1
I8	First	39	63	-	58	-	33	30	3	1
I9	Ground	38	63	-	58	-	32	30	2	1
I9	First	39	63	-	58	-	33	30	3	1
I10	Ground	38	63	-	58	-	32	30	2	1
I10	First	38	63	-	58	-	32	30	2	1
J1	Ground	58	63	-	58	-	52	30	22	2
J1	First	64	63	1	58	6	58	30	28	3
J2	Ground	56	63	-	58	-	50	30	20	2
J2	First	59	63	-	58	1	53	30	23	2

Receiver	Flr	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq,\ night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq,\ night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
J3	Ground	54	63	-	58	-	48	30	18	2
J3	First	57	63	-	58	-	51	30	21	2
J4	Ground	53	63	-	58	-	47	30	17	2
J4	First	55	63	-	58	-	49	30	19	2
J5	Ground	52	63	-	58	-	46	30	16	2
J5	First	54	63	-	58	-	48	30	18	2
J6	Ground	51	63	-	58	-	45	30	15	2
J6	First	53	63	-	58	-	47	30	17	2
J7	Ground	51	63	-	58	-	45	30	15	2
J7	First	52	63	-	58	-	46	30	16	2
J8	Ground	50	63	-	58	-	44	30	14	2
J8	First	51	63	-	58	-	45	30	15	2
J9	Ground	49	63	-	58	-	43	30	13	2
J9	First	50	63	-	58	-	44	30	14	2
J10	Ground	48	63	-	58	-	42	30	12	2
J10	First	49	63	-	58	-	43	30	13	2
J11	Ground	48	63	-	58	-	42	30	12	2
J11	First	49	63	-	58	-	43	30	13	2
J12	Ground	47	63	-	58	-	41	30	11	2
J12	First	48	63	-	58	-	42	30	12	2
J13	Ground	47	63	-	58	-	41	30	11	2
J13	First	47	63	-	58	-	41	30	11	2
J14	Ground	46	63	-	58	-	40	30	10	1
J14	First	47	63	-	58	-	41	30	11	2
J15	Ground	46	63	-	58	-	40	30	10	1
J15	First	46	63	-	58	-	40	30	10	1
J16	Ground	46	63	-	58	-	40	30	10	1
J16	First	46	63	-	58	-	40	30	10	1
J17	Ground	45	63	-	58	-	39	30	9	1
J17	First	46	63	-	58	-	40	30	10	1
J18	Ground	45	63	-	58	-	39	30	9	1
J18	First	45	63	-	58	-	39	30	9	1
J19	Ground	58	63	-	58	-	52	30	22	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
J19	First	63	63	-	58	5	57	30	27	3
J20	Ground	56	63	-	58	-	50	30	20	2
J20	First	58	63	-	58	-	52	30	22	2
J21	Ground	54	63	-	58	-	48	30	18	2
J21	First	56	63	-	58	-	50	30	20	2
J22	Ground	53	63	-	58	-	47	30	17	2
J22	First	54	63	-	58	-	48	30	18	2
J23	Ground	52	63	-	58	-	46	30	16	2
J23	First	53	63	-	58	-	47	30	17	2
J24	Ground	51	63	-	58	-	45	30	15	2
J24	First	52	63	-	58	-	46	30	16	2
J25	Ground	50	63	-	58	-	44	30	14	2
J25	First	51	63	-	58	-	45	30	15	2
J26	Ground	49	63	-	58	-	43	30	13	2
J26	First	50	63	-	58	-	44	30	14	2
J27	Ground	49	63	-	58	-	43	30	13	2
J27	First	49	63	-	58	-	43	30	13	2
J28	Ground	48	63	-	58	-	42	30	12	2
J28	First	49	63	-	58	-	43	30	13	2
J29	Ground	47	63	-	58	-	41	30	11	2
J29	First	48	63	-	58	-	42	30	12	2
J30	Ground	47	63	-	58	-	41	30	11	2
J30	First	47	63	-	58	-	41	30	11	2
J31	Ground	46	63	-	58	-	40	30	10	1
J31	First	47	63	-	58	-	41	30	11	2
J32	Ground	46	63	-	58	-	40	30	10	1
J32	First	46	63	-	58	-	40	30	10	1
J33	Ground	45	63	-	58	-	39	30	9	1
J33	First	46	63	-	58	-	40	30	10	1
J34	Ground	45	63	-	58	-	39	30	9	1
J34	First	45	63	-	58	-	39	30	9	1
J35	Ground	44	63	-	58	-	38	30	8	1
J35	First	45	63	-	58	-	39	30	9	1

Receiver	Flr	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq,\ night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq,\ night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
K1	Ground	43	63	-	58	-	37	30	7	1
K1	First	44	63	-	58	-	38	30	8	1
K2	Ground	43	63	-	58	-	37	30	7	1
K2	First	43	63	-	58	-	37	30	7	1
K3	Ground	43	63	-	58	-	37	30	7	1
K3	First	43	63	-	58	-	37	30	7	1
K4	Ground	42	63	-	58	-	36	30	6	1
K4	First	43	63	-	58	-	37	30	7	1
K5	Ground	42	63	-	58	-	36	30	6	1
K5	First	42	63	-	58	-	36	30	6	1
K6	Ground	41	63	-	58	-	35	30	5	1
K6	First	42	63	-	58	-	36	30	6	1
K7	Ground	41	63	-	58	-	35	30	5	1
K7	First	42	63	-	58	-	36	30	6	1
K8	Ground	42	63	-	58	-	36	30	6	1
K8	First	42	63	-	58	-	36	30	6	1
K9	Ground	42	63	-	58	-	36	30	6	1
K9	First	43	63	-	58	-	37	30	7	1
K10	Ground	42	63	-	58	-	36	30	6	1
K10	First	43	63	-	58	-	37	30	7	1
K11	Ground	43	63	-	58	-	37	30	7	1
K11	First	43	63	-	58	-	37	30	7	1
K12	Ground	43	63	-	58	-	37	30	7	1
K12	First	43	63	-	58	-	37	30	7	1
K13	Ground	42	63	-	58	-	36	30	6	1
K13	First	43	63	-	58	-	37	30	7	1
K14	Ground	42	63	-	58	-	36	30	6	1
K14	First	43	63	-	58	-	37	30	7	1
K15	Ground	42	63	-	58	-	36	30	6	1
K15	First	42	63	-	58	-	36	30	6	1
K16	Ground	42	63	-	58	-	36	30	6	1
K16	First	42	63	-	58	-	36	30	6	1
K17	Ground	42	63	-	58	-	36	30	6	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
K17	First	42	63	-	58	-	36	30	6	1
K18	Ground	42	63	-	58	-	36	30	6	1
K18	First	42	63	-	58	-	36	30	6	1
K19	Ground	41	63	-	58	-	35	30	5	1
K19	First	42	63	-	58	-	36	30	6	1
K20	Ground	41	63	-	58	-	35	30	5	1
K20	First	42	63	-	58	-	36	30	6	1
K21	Ground	41	63	-	58	-	35	30	5	1
K21	First	41	63	-	58	-	35	30	5	1
K22	Ground	40	63	-	58	-	34	30	4	1
K22	First	41	63	-	58	-	35	30	5	1
K23	Ground	41	63	-	58	-	35	30	5	1
K23	First	42	63	-	58	-	36	30	6	1
K24	Ground	41	63	-	58	-	35	30	5	1
K24	First	42	63	-	58	-	36	30	6	1
K25	Ground	41	63	-	58	-	35	30	5	1
K25	First	41	63	-	58	-	35	30	5	1
K26	Ground	40	63	-	58	-	34	30	4	1
K26	First	41	63	-	58	-	35	30	5	1
K27	Ground	40	63	-	58	-	34	30	4	1
K27	First	41	63	-	58	-	35	30	5	1
K28	Ground	41	63	-	58	-	35	30	5	1
K28	First	42	63	-	58	-	36	30	6	1
K29	Ground	41	63	-	58	-	35	30	5	1
K29	First	41	63	-	58	-	35	30	5	1
K30	Ground	40	63	-	58	-	34	30	4	1
K30	First	41	63	-	58	-	35	30	5	1
K31	Ground	40	63	-	58	-	34	30	4	1
K31	First	41	63	-	58	-	35	30	5	1
K32	Ground	40	63	-	58	-	34	30	4	1
K32	First	41	63	-	58	-	35	30	5	1
K33	Ground	39	63	-	58	-	33	30	3	1
K33	First	40	63	-	58	-	34	30	4	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
K34	Ground	41	63	-	58	-	35	30	5	1
K34	First	42	63	-	58	-	36	30	6	1
K35	Ground	40	63	-	58	-	34	30	4	1
K35	First	41	63	-	58	-	35	30	5	1
K36	Ground	40	63	-	58	-	34	30	4	1
K36	First	41	63	-	58	-	35	30	5	1
K37	Ground	40	63	-	58	-	34	30	4	1
K37	First	41	63	-	58	-	35	30	5	1
K38	Ground	40	63	-	58	-	34	30	4	1
K38	First	41	63	-	58	-	35	30	5	1
K39	Ground	40	63	-	58	-	34	30	4	1
K39	First	40	63	-	58	-	34	30	4	1
K40	Ground	39	63	-	58	-	33	30	3	1
K40	First	40	63	-	58	-	34	30	4	1
K41	Ground	39	63	-	58	-	33	30	3	1
K41	First	40	63	-	58	-	34	30	4	1
L1	Ground	39	63	-	58	-	33	30	3	1
L1	First	40	63	-	58	-	34	30	4	1
L2	Ground	38	63	-	58	-	32	30	2	1
L2	First	39	63	-	58	-	33	30	3	1
L3	Ground	38	63	-	58	-	32	30	2	1
L3	First	39	63	-	58	-	33	30	3	1
L4	Ground	37	63	-	58	-	31	30	1	1
L4	First	38	63	-	58	-	32	30	2	1
L5	Ground	37	63	-	58	-	31	30	1	1
L5	First	38	63	-	58	-	32	30	2	1
L6	Ground	38	63	-	58	-	32	30	2	1
L6	First	40	63	-	58	-	34	30	4	1
L7	Ground	38	63	-	58	-	32	30	2	1
L7	First	39	63	-	58	-	33	30	3	1
L8	Ground	38	63	-	58	-	32	30	2	1
L8	First	38	63	-	58	-	32	30	2	1
L9	Ground	37	63	-	58	-	31	30	1	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
L9	First	38	63	-	58	-	32	30	2	1
L10	Ground	38	63	-	58	-	32	30	2	1
L10	First	40	63	-	58	-	34	30	4	1
L11	Ground	38	63	-	58	-	32	30	2	1
L11	First	39	63	-	58	-	33	30	3	1
L12	Ground	37	63	-	58	-	31	30	1	1
L12	First	38	63	-	58	-	32	30	2	1
L13	Ground	37	63	-	58	-	31	30	1	1
L13	First	37	63	-	58	-	31	30	1	1
L14	Ground	37	63	-	58	-	31	30	1	1
L14	First	37	63	-	58	-	31	30	1	1
L15	Ground	38	63	-	58	-	32	30	2	1
L15	First	39	63	-	58	-	33	30	3	1
L16	Ground	38	63	-	58	-	32	30	2	1
L16	First	39	63	-	58	-	33	30	3	1
L17	Ground	37	63	-	58	-	31	30	1	1
L17	First	38	63	-	58	-	32	30	2	1
L18	Ground	37	63	-	58	-	31	30	1	1
L18	First	38	63	-	58	-	32	30	2	1
L19	Ground	37	63	-	58	-	31	30	1	1
L19	First	37	63	-	58	-	31	30	1	1
L20	Ground	38	63	-	58	-	32	30	2	1
L20	First	40	63	-	58	-	34	30	4	1
L21	Ground	38	63	-	58	-	32	30	2	1
L21	First	39	63	-	58	-	33	30	3	1
L22	Ground	37	63	-	58	-	31	30	1	1
L22	First	38	63	-	58	-	32	30	2	1
L23	Ground	37	63	-	58	-	31	30	1	1
L23	First	38	63	-	58	-	32	30	2	1
L24	Ground	37	63	-	58	-	31	30	1	1
L24	First	38	63	-	58	-	32	30	2	1
L25	Ground	37	63	-	58	-	31	30	1	1
L25	First	37	63	-	58	-	31	30	1	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
L26	Ground	38	63	-	58	-	32	30	2	1
L26	First	39	63	-	58	-	33	30	3	1
L27	Ground	38	63	-	58	-	32	30	2	1
L27	First	39	63	-	58	-	33	30	3	1
L28	Ground	37	63	-	58	-	31	30	1	1
L28	First	38	63	-	58	-	32	30	2	1
L29	Ground	37	63	-	58	-	31	30	1	1
L29	First	38	63	-	58	-	32	30	2	1
L30	Ground	37	63	-	58	-	31	30	1	1
L30	First	38	63	-	58	-	32	30	2	1
L31	Ground	37	63	-	58	-	31	30	1	1
L31	First	37	63	-	58	-	31	30	1	1
M1	Ground	59	63	-	58	1	53	30	23	2
M1	First	65	63	2	58	7	59	30	29	3
M2	Ground	59	63	-	58	1	53	30	23	2
M2	First	65	63	2	58	7	59	30	29	3
M3	Ground	58	63	-	58	-	52	30	22	2
M3	First	64	63	1	58	6	58	30	28	3
M4	Ground	58	63	-	58	-	52	30	22	2
M4	First	64	63	1	58	6	58	30	28	3
M5	Ground	58	63	-	58	-	52	30	22	2
M5	First	64	63	1	58	6	58	30	28	3
M6	Ground	58	63	-	58	-	52	30	22	2
M6	First	64	63	1	58	6	58	30	28	3
M7	Ground	58	63	-	58	-	52	30	22	2
M7	First	64	63	1	58	6	58	30	28	3
M8	Ground	58	63	-	58	-	52	30	22	2
M8	First	63	63	-	58	5	57	30	27	3
M9	Ground	58	63	-	58	-	52	30	22	2
M9	First	63	63	-	58	5	57	30	27	3
M10	Ground	58	63	-	58	-	52	30	22	2
M10	First	63	63	-	58	5	57	30	27	3
M11	Ground	58	63	-	58	-	52	30	22	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
M11	First	63	63	-	58	5	57	30	27	3
M12	Ground	57	63	-	58	-	51	30	21	2
M12	First	62	63	-	58	4	56	30	26	3
M13	Ground	55	63	-	58	-	49	30	19	2
M13	First	58	63	-	58	-	52	30	22	2
M14	Ground	54	63	-	58	-	48	30	18	2
M14	First	56	63	-	58	-	50	30	20	2
M15	Ground	53	63	-	58	-	47	30	17	2
M15	First	55	63	-	58	-	49	30	19	2
M16	Ground	51	63	-	58	-	45	30	15	2
M16	First	52	63	-	58	-	46	30	16	2
M17	Ground	52	63	-	58	-	46	30	16	2
M17	First	54	63	-	58	-	48	30	18	2
M18	Ground	52	63	-	58	-	46	30	16	2
M18	First	54	63	-	58	-	48	30	18	2
M19	Ground	52	63	-	58	-	46	30	16	2
M19	First	54	63	-	58	-	48	30	18	2
M20	Ground	52	63	-	58	-	46	30	16	2
M20	First	55	63	-	58	-	49	30	19	2
M21	Ground	52	63	-	58	-	46	30	16	2
M21	First	54	63	-	58	-	48	30	18	2
N1	Ground	53	63	-	58	-	47	30	17	2
N1	First	55	63	-	58	-	49	30	19	2
N2	Ground	53	63	-	58	-	47	30	17	2
N2	First	54	63	-	58	-	48	30	18	2
N3	Ground	52	63	-	58	-	46	30	16	2
N3	First	53	63	-	58	-	47	30	17	2
N4	Ground	51	63	-	58	-	45	30	15	2
N4	First	52	63	-	58	-	46	30	16	2
N5	Ground	50	63	-	58	-	44	30	14	2
N5	First	51	63	-	58	-	45	30	15	2
N6	Ground	50	63	-	58	-	44	30	14	2
N6	First	51	63	-	58	-	45	30	15	2

Receiver	Flr	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq,\ night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq,\ night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
N7	Ground	49	63	-	58	-	43	30	13	2
N7	First	50	63	-	58	-	44	30	14	2
N8	Ground	49	63	-	58	-	43	30	13	2
N8	First	50	63	-	58	-	44	30	14	2
N9	Ground	48	63	-	58	-	42	30	12	2
N9	First	49	63	-	58	-	43	30	13	2
N10	Ground	48	63	-	58	-	42	30	12	2
N10	First	48	63	-	58	-	42	30	12	2
N11	Ground	47	63	-	58	-	41	30	11	2
N11	First	48	63	-	58	-	42	30	12	2
N12	Ground	47	63	-	58	-	41	30	11	2
N12	First	47	63	-	58	-	41	30	11	2
N13	Ground	46	63	-	58	-	40	30	10	1
N13	First	47	63	-	58	-	41	30	11	2
N14	Ground	46	63	-	58	-	40	30	10	1
N14	First	46	63	-	58	-	40	30	10	1
N15	Ground	45	63	-	58	-	39	30	9	1
N15	First	46	63	-	58	-	40	30	10	1
N16	Ground	45	63	-	58	-	39	30	9	1
N16	First	46	63	-	58	-	40	30	10	1
N17	Ground	45	63	-	58	-	39	30	9	1
N17	First	45	63	-	58	-	39	30	9	1
N18	Ground	44	63	-	58	-	38	30	8	1
N18	First	45	63	-	58	-	39	30	9	1
N19	Ground	44	63	-	58	-	38	30	8	1
N19	First	44	63	-	58	-	38	30	8	1
N20	Ground	44	63	-	58	-	38	30	8	1
N20	First	44	63	-	58	-	38	30	8	1
N21	Ground	43	63	-	58	-	37	30	7	1
N21	First	44	63	-	58	-	38	30	8	1
N22	Ground	43	63	-	58	-	37	30	7	1
N22	First	44	63	-	58	-	38	30	8	1
N23	Ground	43	63	-	58	-	37	30	7	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
N23	First	43	63	-	58	-	37	30	7	1
N24	Ground	42	63	-	58	-	36	30	6	1
N24	First	43	63	-	58	-	37	30	7	1
N25	Ground	42	63	-	58	-	36	30	6	1
N25	First	43	63	-	58	-	37	30	7	1
N26	Ground	42	63	-	58	-	36	30	6	1
N26	First	42	63	-	58	-	36	30	6	1
N27	Ground	42	63	-	58	-	36	30	6	1
N27	First	42	63	-	58	-	36	30	6	1
N28	Ground	41	63	-	58	-	35	30	5	1
N28	First	42	63	-	58	-	36	30	6	1
N29	Ground	41	63	-	58	-	35	30	5	1
N29	First	41	63	-	58	-	35	30	5	1
N30	Ground	41	63	-	58	-	35	30	5	1
N30	First	41	63	-	58	-	35	30	5	1
N31	Ground	41	63	-	58	-	35	30	5	1
N31	First	41	63	-	58	-	35	30	5	1
N32	Ground	41	63	-	58	-	35	30	5	1
N32	First	41	63	-	58	-	35	30	5	1
N33	Ground	41	63	-	58	-	35	30	5	1
N33	First	41	63	-	58	-	35	30	5	1
N34	Ground	53	63	-	58	-	47	30	17	2
N34	First	55	63	-	58	-	49	30	19	2
N35	Ground	52	63	-	58	-	46	30	16	2
N35	First	54	63	-	58	-	48	30	18	2
N36	Ground	51	63	-	58	-	45	30	15	2
N36	First	53	63	-	58	-	47	30	17	2
N37	Ground	51	63	-	58	-	45	30	15	2
N37	First	52	63	-	58	-	46	30	16	2
N38	Ground	50	63	-	58	-	44	30	14	2
N38	First	51	63	-	58	-	45	30	15	2
N39	Ground	50	63	-	58	-	44	30	14	2
N39	First	50	63	-	58	-	44	30	14	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
N40	Ground	49	63	-	58	-	43	30	13	2
N40	First	50	63	-	58	-	44	30	14	2
N41	Ground	48	63	-	58	-	42	30	12	2
N41	First	49	63	-	58	-	43	30	13	2
N42	Ground	48	63	-	58	-	42	30	12	2
N42	First	49	63	-	58	-	43	30	13	2
N43	Ground	47	63	-	58	-	41	30	11	2
N43	First	48	63	-	58	-	42	30	12	2
N44	Ground	47	63	-	58	-	41	30	11	2
N44	First	48	63	-	58	-	42	30	12	2
N45	Ground	46	63	-	58	-	40	30	10	1
N45	First	47	63	-	58	-	41	30	11	2
N46	Ground	46	63	-	58	-	40	30	10	1
N46	First	46	63	-	58	-	40	30	10	1
N47	Ground	46	63	-	58	-	40	30	10	1
N47	First	46	63	-	58	-	40	30	10	1
N48	Ground	45	63	-	58	-	39	30	9	1
N48	First	46	63	-	58	-	40	30	10	1
N49	Ground	45	63	-	58	-	39	30	9	1
N49	First	45	63	-	58	-	39	30	9	1
N50	Ground	44	63	-	58	-	38	30	8	1
N50	First	45	63	-	58	-	39	30	9	1
N51	Ground	44	63	-	58	-	38	30	8	1
N51	First	45	63	-	58	-	39	30	9	1
N52	Ground	44	63	-	58	-	38	30	8	1
N52	First	44	63	-	58	-	38	30	8	1
N53	Ground	44	63	-	58	-	38	30	8	1
N53	First	44	63	-	58	-	38	30	8	1
N54	Ground	43	63	-	58	-	37	30	7	1
N54	First	44	63	-	58	-	38	30	8	1
N55	Ground	43	63	-	58	-	37	30	7	1
N55	First	43	63	-	58	-	37	30	7	1
N56	Ground	43	63	-	58	-	37	30	7	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
N56	First	43	63	-	58	-	37	30	7	1
N57	Ground	42	63	-	58	-	36	30	6	1
N57	First	43	63	-	58	-	37	30	7	1
N58	Ground	42	63	-	58	-	36	30	6	1
N58	First	42	63	-	58	-	36	30	6	1
N59	Ground	42	63	-	58	-	36	30	6	1
N59	First	42	63	-	58	-	36	30	6	1
N60	Ground	41	63	-	58	-	35	30	5	1
N60	First	42	63	-	58	-	36	30	6	1
O1	Ground	51	63	-	58	-	45	30	15	2
O1	First	52	63	-	58	-	46	30	16	2
O2	Ground	48	63	-	58	-	42	30	12	2
O2	First	49	63	-	58	-	43	30	13	2
O3	Ground	50	63	-	58	-	44	30	14	2
O3	First	51	63	-	58	-	45	30	15	2
O4	Ground	49	63	-	58	-	43	30	13	2
O4	First	50	63	-	58	-	44	30	14	2
O5	Ground	48	63	-	58	-	42	30	12	2
O5	First	50	63	-	58	-	44	30	14	2
O6	Ground	48	63	-	58	-	42	30	12	2
O6	First	49	63	-	58	-	43	30	13	2
O7	Ground	48	63	-	58	-	42	30	12	2
O7	First	49	63	-	58	-	43	30	13	2
O8	Ground	47	63	-	58	-	41	30	11	2
O8	First	48	63	-	58	-	42	30	12	2
O9	Ground	50	63	-	58	-	44	30	14	2
O9	First	51	63	-	58	-	45	30	15	2
O10	Ground	50	63	-	58	-	44	30	14	2
O10	First	51	63	-	58	-	45	30	15	2
O11	Ground	49	63	-	58	-	43	30	13	2
O11	First	51	63	-	58	-	45	30	15	2
O12	Ground	49	63	-	58	-	43	30	13	2
O12	First	50	63	-	58	-	44	30	14	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
O13	Ground	48	63	-	58	-	42	30	12	2
O13	First	49	63	-	58	-	43	30	13	2
O14	Ground	48	63	-	58	-	42	30	12	2
O14	First	49	63	-	58	-	43	30	13	2
O15	Ground	47	63	-	58	-	41	30	11	2
O15	First	48	63	-	58	-	42	30	12	2
O16	Ground	47	63	-	58	-	41	30	11	2
O16	First	47	63	-	58	-	41	30	11	2
O17	Ground	47	63	-	58	-	41	30	11	2
O17	First	48	63	-	58	-	42	30	12	2
O18	Ground	47	63	-	58	-	41	30	11	2
O18	First	48	63	-	58	-	42	30	12	2
O19	Ground	48	63	-	58	-	42	30	12	2
O19	First	49	63	-	58	-	43	30	13	2
O20	Ground	48	63	-	58	-	42	30	12	2
O20	First	49	63	-	58	-	43	30	13	2
O21	Ground	49	63	-	58	-	43	30	13	2
O21	First	49	63	-	58	-	43	30	13	2
O22	Ground	47	63	-	58	-	41	30	11	2
O22	First	48	63	-	58	-	42	30	12	2
O23	Ground	47	63	-	58	-	41	30	11	2
O23	First	47	63	-	58	-	41	30	11	2
O24	Ground	46	63	-	58	-	40	30	10	1
O24	First	47	63	-	58	-	41	30	11	2
O25	Ground	46	63	-	58	-	40	30	10	1
O25	First	47	63	-	58	-	41	30	11	2
O26	Ground	46	63	-	58	-	40	30	10	1
O26	First	46	63	-	58	-	40	30	10	1
O27	Ground	45	63	-	58	-	39	30	9	1
O27	First	45	63	-	58	-	39	30	9	1
O28	Ground	45	63	-	58	-	39	30	9	1
O28	First	46	63	-	58	-	40	30	10	1
O29	Ground	45	63	-	58	-	39	30	9	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
O29	First	45	63	-	58	-	39	30	9	1
O30	Ground	45	63	-	58	-	39	30	9	1
O30	First	46	63	-	58	-	40	30	10	1
O31	Ground	45	63	-	58	-	39	30	9	1
O31	First	46	63	-	58	-	40	30	10	1
O32	Ground	45	63	-	58	-	39	30	9	1
O32	First	46	63	-	58	-	40	30	10	1
O33	Ground	45	63	-	58	-	39	30	9	1
O33	First	46	63	-	58	-	40	30	10	1
O34	Ground	46	63	-	58	-	40	30	10	1
O34	First	46	63	-	58	-	40	30	10	1
O35	Ground	45	63	-	58	-	39	30	9	1
O35	First	46	63	-	58	-	40	30	10	1
O36	Ground	46	63	-	58	-	40	30	10	1
O36	First	47	63	-	58	-	41	30	11	2
P1	Ground	44	63	-	58	-	38	30	8	1
P1	First	44	63	-	58	-	38	30	8	1
P2	Ground	43	63	-	58	-	37	30	7	1
P2	First	44	63	-	58	-	38	30	8	1
P3	Ground	44	63	-	58	-	38	30	8	1
P3	First	44	63	-	58	-	38	30	8	1
P4	Ground	43	63	-	58	-	37	30	7	1
P4	First	44	63	-	58	-	38	30	8	1
P5	Ground	43	63	-	58	-	37	30	7	1
P5	First	44	63	-	58	-	38	30	8	1
P6	Ground	43	63	-	58	-	37	30	7	1
P6	First	43	63	-	58	-	37	30	7	1
P7	Ground	43	63	-	58	-	37	30	7	1
P7	First	44	63	-	58	-	38	30	8	1
P8	Ground	43	63	-	58	-	37	30	7	1
P8	First	43	63	-	58	-	37	30	7	1
P9	Ground	42	63	-	58	-	36	30	6	1
P9	First	43	63	-	58	-	37	30	7	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
P10	Ground	42	63	-	58	-	36	30	6	1
P10	First	43	63	-	58	-	37	30	7	1
P11	Ground	42	63	-	58	-	36	30	6	1
P11	First	42	63	-	58	-	36	30	6	1
P12	Ground	43	63	-	58	-	37	30	7	1
P12	First	44	63	-	58	-	38	30	8	1
P13	Ground	43	63	-	58	-	37	30	7	1
P13	First	43	63	-	58	-	37	30	7	1
P14	Ground	42	63	-	58	-	36	30	6	1
P14	First	43	63	-	58	-	37	30	7	1
P15	Ground	42	63	-	58	-	36	30	6	1
P15	First	43	63	-	58	-	37	30	7	1
P16	Ground	41	63	-	58	-	35	30	5	1
P16	First	42	63	-	58	-	36	30	6	1
P17	Ground	41	63	-	58	-	35	30	5	1
P17	First	42	63	-	58	-	36	30	6	1
P18	Ground	41	63	-	58	-	35	30	5	1
P18	First	42	63	-	58	-	36	30	6	1
P19	Ground	41	63	-	58	-	35	30	5	1
P19	First	42	63	-	58	-	36	30	6	1
P20	Ground	41	63	-	58	-	35	30	5	1
P20	First	42	63	-	58	-	36	30	6	1
P21	Ground	41	63	-	58	-	35	30	5	1
P21	First	42	63	-	58	-	36	30	6	1
P22	Ground	41	63	-	58	-	35	30	5	1
P22	First	42	63	-	58	-	36	30	6	1
P23	Ground	45	63	-	58	-	39	30	9	1
P23	First	45	63	-	58	-	39	30	9	1
P24	Ground	44	63	-	58	-	38	30	8	1
P24	First	44	63	-	58	-	38	30	8	1
P25	Ground	43	63	-	58	-	37	30	7	1
P25	First	44	63	-	58	-	38	30	8	1
P26	Ground	43	63	-	58	-	37	30	7	1

Receiver	Flr	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq,\ night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq,\ night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
P26	First	44	63	-	58	-	38	30	8	1
P27	Ground	43	63	-	58	-	37	30	7	1
P27	First	44	63	-	58	-	38	30	8	1
P28	Ground	43	63	-	58	-	37	30	7	1
P28	First	43	63	-	58	-	37	30	7	1
P29	Ground	43	63	-	58	-	37	30	7	1
P29	First	43	63	-	58	-	37	30	7	1
P30	Ground	42	63	-	58	-	36	30	6	1
P30	First	43	63	-	58	-	37	30	7	1
P31	Ground	45	63	-	58	-	39	30	9	1
P31	First	46	63	-	58	-	40	30	10	1
Q1	Ground	52	63	-	58	-	46	30	16	2
Q1	First	54	63	-	58	-	48	30	18	2
Q2	Ground	48	63	-	58	-	42	30	12	2
Q2	First	49	63	-	58	-	43	30	13	2
Q3	Ground	49	63	-	58	-	43	30	13	2
Q3	First	51	63	-	58	-	45	30	15	2
Q4	Ground	45	63	-	58	-	39	30	9	1
Q4	First	46	63	-	58	-	40	30	10	1
R1	Ground	53	63	-	58	-	47	30	17	2
R1	First	57	63	-	58	-	51	30	21	2
R2	Ground	53	63	-	58	-	47	30	17	2
R2	First	57	63	-	58	-	51	30	21	2
R3	Ground	53	63	-	58	-	47	30	17	2
R3	First	57	63	-	58	-	51	30	21	2
R4	Ground	53	63	-	58	-	47	30	17	2
R4	First	57	63	-	58	-	51	30	21	2
R5	Ground	52	63	-	58	-	46	30	16	2
R5	First	56	63	-	58	-	50	30	20	2
R6	Ground	52	63	-	58	-	46	30	16	2
R6	First	55	63	-	58	-	49	30	19	2
R7	Ground	50	63	-	58	-	44	30	14	2
R7	First	53	63	-	58	-	47	30	17	2

Receiver	Flr	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq,\ night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq,\ night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
R8	Ground	50	63	-	58	-	44	30	14	2
R8	First	51	63	-	58	-	45	30	15	2
R9	Ground	50	63	-	58	-	44	30	14	2
R9	First	52	63	-	58	-	46	30	16	2
R10	Ground	47	63	-	58	-	41	30	11	2
R10	First	48	63	-	58	-	42	30	12	2
S1	Ground	51	63	-	58	-	45	30	15	2
S1	First	55	63	-	58	-	49	30	19	2
S2	Ground	51	63	-	58	-	45	30	15	2
S2	First	55	63	-	58	-	49	30	19	2
S3	Ground	52	63	-	58	-	46	30	16	2
S3	First	55	63	-	58	-	49	30	19	2
S4	Ground	51	63	-	58	-	45	30	15	2
S4	First	54	63	-	58	-	48	30	18	2
S5	Ground	49	63	-	58	-	43	30	13	2
S5	First	52	63	-	58	-	46	30	16	2
S6	Ground	50	63	-	58	-	44	30	14	2
S6	First	52	63	-	58	-	46	30	16	2
S7	Ground	49	63	-	58	-	43	30	13	2
S7	First	50	63	-	58	-	44	30	14	2
S8	Ground	49	63	-	58	-	43	30	13	2
S8	First	51	63	-	58	-	45	30	15	2
S9	Ground	48	63	-	58	-	42	30	12	2
S9	First	49	63	-	58	-	43	30	13	2
S10	Ground	48	63	-	58	-	42	30	12	2
S10	First	49	63	-	58	-	43	30	13	2
S11	Ground	48	63	-	58	-	42	30	12	2
S11	First	49	63	-	58	-	43	30	13	2
S12	Ground	48	63	-	58	-	42	30	12	2
S12	First	50	63	-	58	-	44	30	14	2
S13	Ground	48	63	-	58	-	42	30	12	2
S13	First	50	63	-	58	-	44	30	14	2
T1	Ground	51	63	-	58	-	45	30	15	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
T1	First	53	63	-	58	-	47	30	17	2
T2	Ground	51	63	-	58	-	45	30	15	2
T2	First	54	63	-	58	-	48	30	18	2
T3	Ground	52	63	-	58	-	46	30	16	2
T3	First	56	63	-	58	-	50	30	20	2
T4	Ground	52	63	-	58	-	46	30	16	2
T4	First	57	63	-	58	-	51	30	21	2
T5	Ground	51	63	-	58	-	45	30	15	2
T5	First	56	63	-	58	-	50	30	20	2
T6	Ground	51	63	-	58	-	45	30	15	2
T6	First	56	63	-	58	-	50	30	20	2
T7	Ground	51	63	-	58	-	45	30	15	2
T7	First	56	63	-	58	-	50	30	20	2
T8	Ground	50	63	-	58	-	44	30	14	2
T8	First	56	63	-	58	-	50	30	20	2
T9	Ground	50	63	-	58	-	44	30	14	2
T9	First	55	63	-	58	-	49	30	19	2
T10	Ground	51	63	-	58	-	45	30	15	2
T10	First	55	63	-	58	-	49	30	19	2
U1	Ground	47	63	-	58	-	41	30	11	2
U1	First	49	63	-	58	-	43	30	13	2
U2	Ground	48	63	-	58	-	42	30	12	2
U2	First	49	63	-	58	-	43	30	13	2
U3	Ground	46	63	-	58	-	40	30	10	1
U3	First	48	63	-	58	-	42	30	12	2
U4	Ground	46	63	-	58	-	40	30	10	1
U4	First	48	63	-	58	-	42	30	12	2
U5	Ground	46	63	-	58	-	40	30	10	1
U5	First	47	63	-	58	-	41	30	11	2
U6	Ground	46	63	-	58	-	40	30	10	1
U6	First	47	63	-	58	-	41	30	11	2
U7	Ground	45	63	-	58	-	39	30	9	1
U7	First	46	63	-	58	-	40	30	10	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
U8	Ground	45	63	-	58	-	39	30	9	1
U8	First	46	63	-	58	-	40	30	10	1
U9	Ground	44	63	-	58	-	38	30	8	1
U9	First	45	63	-	58	-	39	30	9	1
U10	Ground	45	63	-	58	-	39	30	9	1
U10	First	46	63	-	58	-	40	30	10	1
U11	Ground	44	63	-	58	-	38	30	8	1
U11	First	45	63	-	58	-	39	30	9	1
U12	Ground	48	63	-	58	-	42	30	12	2
U12	First	49	63	-	58	-	43	30	13	2
U13	Ground	46	63	-	58	-	40	30	10	1
U13	First	49	63	-	58	-	43	30	13	2
U14	Ground	47	63	-	58	-	41	30	11	2
U14	First	48	63	-	58	-	42	30	12	2
U15	Ground	45	63	-	58	-	39	30	9	1
U15	First	47	63	-	58	-	41	30	11	2
U16	Ground	46	63	-	58	-	40	30	10	1
U16	First	47	63	-	58	-	41	30	11	2
U17	Ground	44	63	-	58	-	38	30	8	1
U17	First	46	63	-	58	-	40	30	10	1
U18	Ground	45	63	-	58	-	39	30	9	1
U18	First	46	63	-	58	-	40	30	10	1
U19	Ground	44	63	-	58	-	38	30	8	1
U19	First	46	63	-	58	-	40	30	10	1
U20	Ground	44	63	-	58	-	38	30	8	1
U20	First	45	63	-	58	-	39	30	9	1
U21	Ground	43	63	-	58	-	37	30	7	1
U21	First	45	63	-	58	-	39	30	9	1
U22	Ground	42	63	-	58	-	36	30	6	1
U22	First	44	63	-	58	-	38	30	8	1
U23	Ground	46	63	-	58	-	40	30	10	1
U23	First	48	63	-	58	-	42	30	12	2
U24	Ground	46	63	-	58	-	40	30	10	1

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
U24	First	48	63	-	58	-	42	30	12	2
U25	Ground	45	63	-	58	-	39	30	9	1
U25	First	47	63	-	58	-	41	30	11	2
U26	Ground	45	63	-	58	-	39	30	9	1
U26	First	47	63	-	58	-	41	30	11	2
U27	Ground	44	63	-	58	-	38	30	8	1
U27	First	46	63	-	58	-	40	30	10	1
U28	Ground	44	63	-	58	-	38	30	8	1
U28	First	46	63	-	58	-	40	30	10	1
U29	Ground	43	63	-	58	-	37	30	7	1
U29	First	45	63	-	58	-	39	30	9	1
U30	Ground	43	63	-	58	-	37	30	7	1
U30	First	45	63	-	58	-	39	30	9	1
U31	Ground	43	63	-	58	-	37	30	7	1
U31	First	45	63	-	58	-	39	30	9	1
U32	Ground	43	63	-	58	-	37	30	7	1
U32	First	45	63	-	58	-	39	30	9	1
U33	Ground	42	63	-	58	-	36	30	6	1
U33	First	44	63	-	58	-	38	30	8	1
U34	Ground	41	63	-	58	-	35	30	5	1
U34	First	43	63	-	58	-	37	30	7	1
U35	Ground	42	63	-	58	-	36	30	6	1
U35	First	44	63	-	58	-	38	30	8	1
V1	Ground	48	63	-	58	-	42	30	12	2
V1	First	50	63	-	58	-	44	30	14	2
V2	Ground	47	63	-	58	-	41	30	11	2
V2	First	50	63	-	58	-	44	30	14	2
V3	Ground	46	63	-	58	-	40	30	10	1
V3	First	49	63	-	58	-	43	30	13	2
V4	Ground	46	63	-	58	-	40	30	10	1
V4	First	49	63	-	58	-	43	30	13	2
V5	Ground	45	63	-	58	-	39	30	9	1
V5	First	49	63	-	58	-	43	30	13	2

Receiver	Flr	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit $L_{A10, 18hr}$ dB(A)	Predicted Exceedance $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level $L_{Aeq, night}$ dB(A)	Internal Noise Limit in Bedrooms $L_{Aeq, night}$ dB(A)	Required Façade Reduction dB(A)	Required AS 3671 Category
V6	Ground	45	63	-	58	-	39	30	9	1
V6	First	49	63	-	58	-	43	30	13	2
V7	Ground	45	63	-	58	-	39	30	9	1
V7	First	49	63	-	58	-	43	30	13	2
V8	Ground	44	63	-	58	-	38	30	8	1
V8	First	46	63	-	58	-	40	30	10	1
V9	Ground	44	63	-	58	-	38	30	8	1
V9	First	46	63	-	58	-	40	30	10	1
V10	Ground	44	63	-	58	-	38	30	8	1
V10	First	46	63	-	58	-	40	30	10	1
V11	Ground	44	63	-	58	-	38	30	8	1
V11	First	46	63	-	58	-	40	30	10	1
V12	Ground	44	63	-	58	-	38	30	8	1
V12	First	46	63	-	58	-	40	30	10	1
V13	Ground	43	63	-	58	-	37	30	7	1
V13	First	46	63	-	58	-	40	30	10	1
V14	Ground	43	63	-	58	-	37	30	7	1
V14	First	45	63	-	58	-	39	30	9	1
V15	Ground	42	63	-	58	-	36	30	6	1
V15	First	44	63	-	58	-	38	30	8	1
Number of Ground Floor exceedances				**-**		**3**	**Number of AS3671 Category 1 – Ground Floor**			**283**
Number of First Floor exceedances				**9**		**26**	**Number of AS3671 Category 1 – First Floor**			**253**
							Number of AS3671 Category 2 – Ground Floor			**188**
							Number of AS3671 Category 2 – First Floor			**203**
							Number of AS3671 Category 3 – Ground Floor			**-**
							Number of AS3671 Category 3 – First Floor			**15**

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APPENDIX C

NOISE CONTOUR MAPS – ROAD TRAFFIC NOISE IMPACT

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Figure C-1 Façade Corrected Noise Contour Map without Noise Barriers $L_{10, 18hour}$ Modelled at Ground Floor Level.

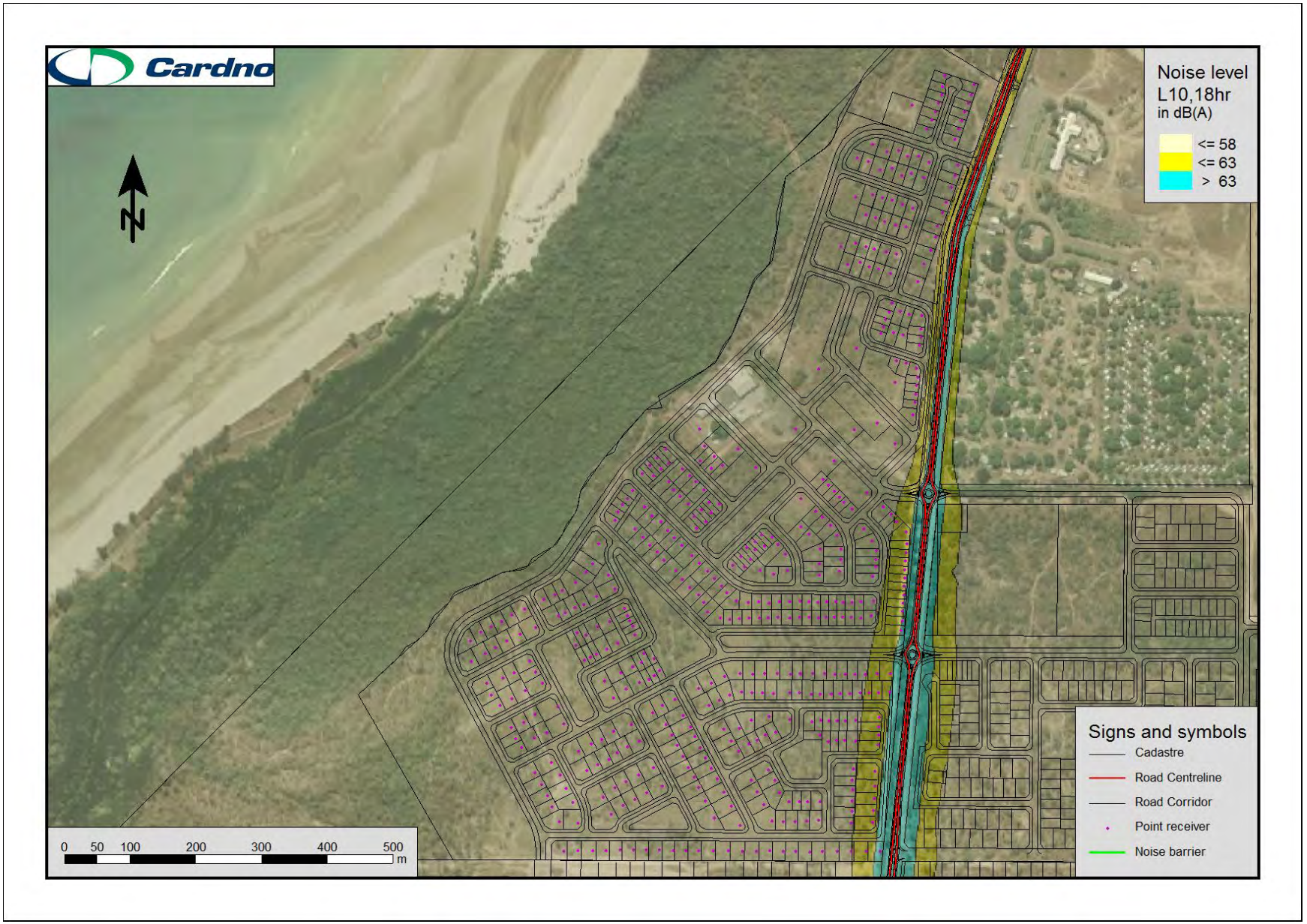


Figure C-2 Façade Corrected Noise Contour Map without Noise Barriers $L_{10, 18hour}$ Modelled at First Floor Level.

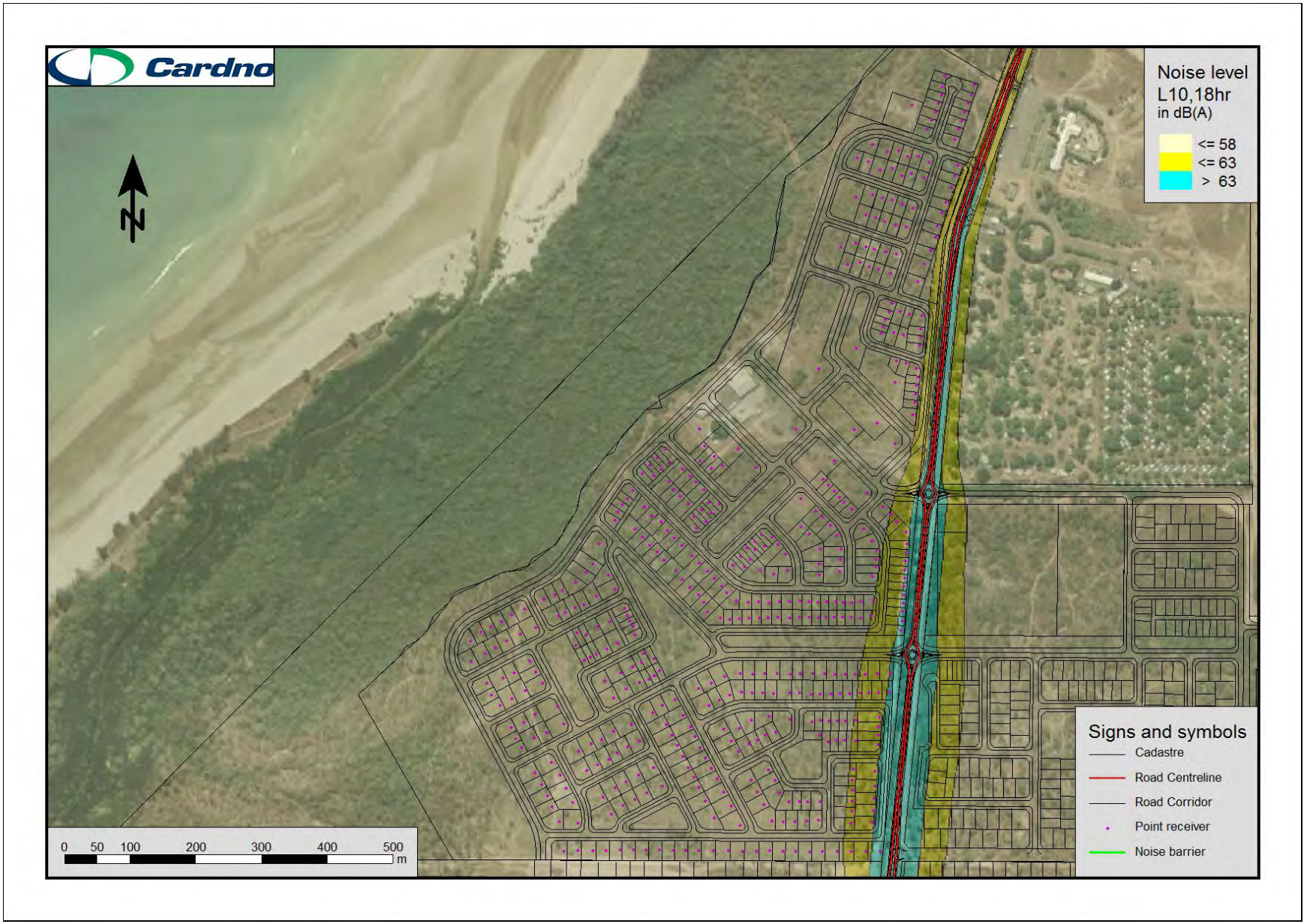


Figure C-3 Façade Corrected Noise Contour Map with 1.8m High Noise Barriers $L_{10, 18hour}$ Modelled at Ground Floor Level.

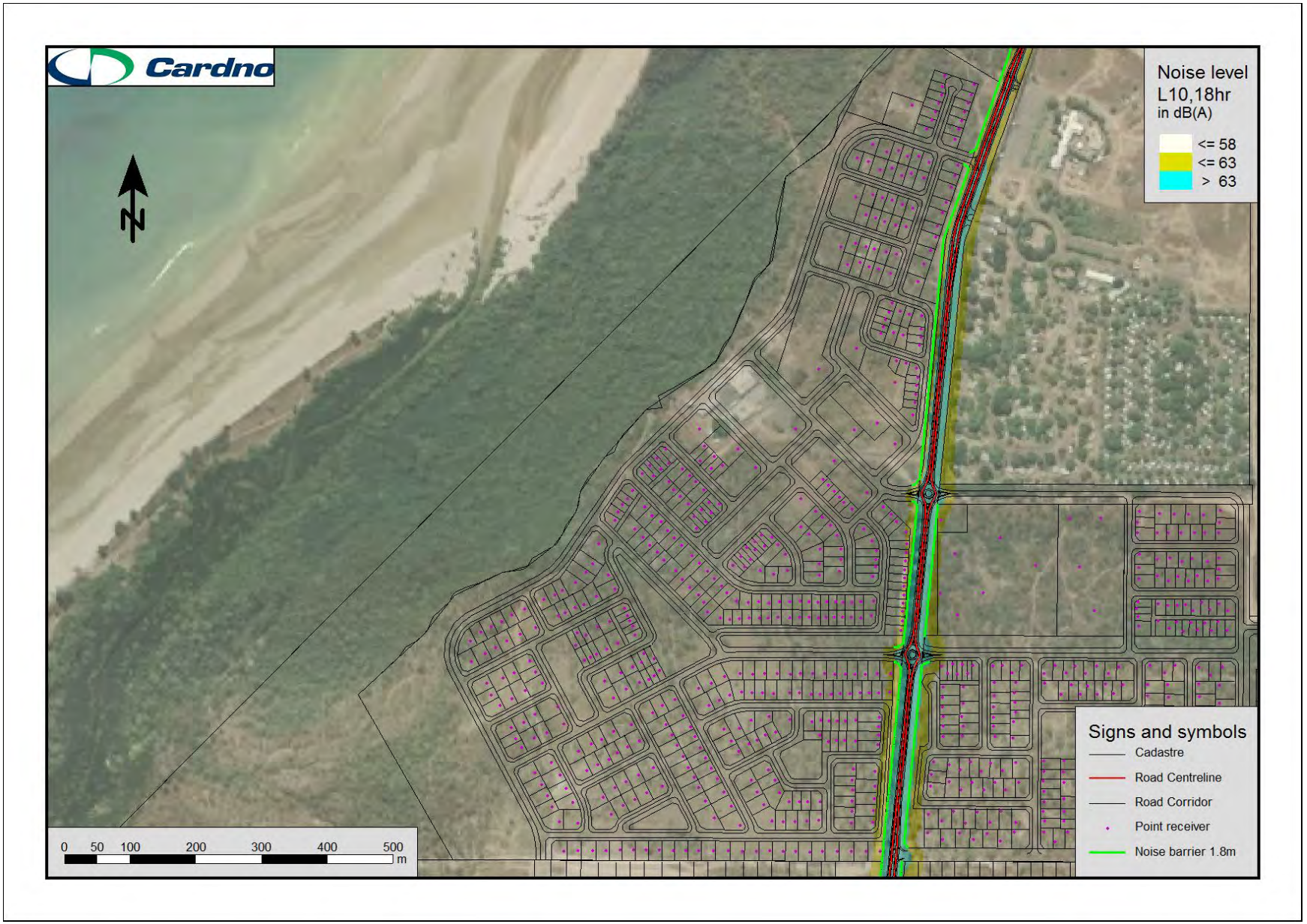
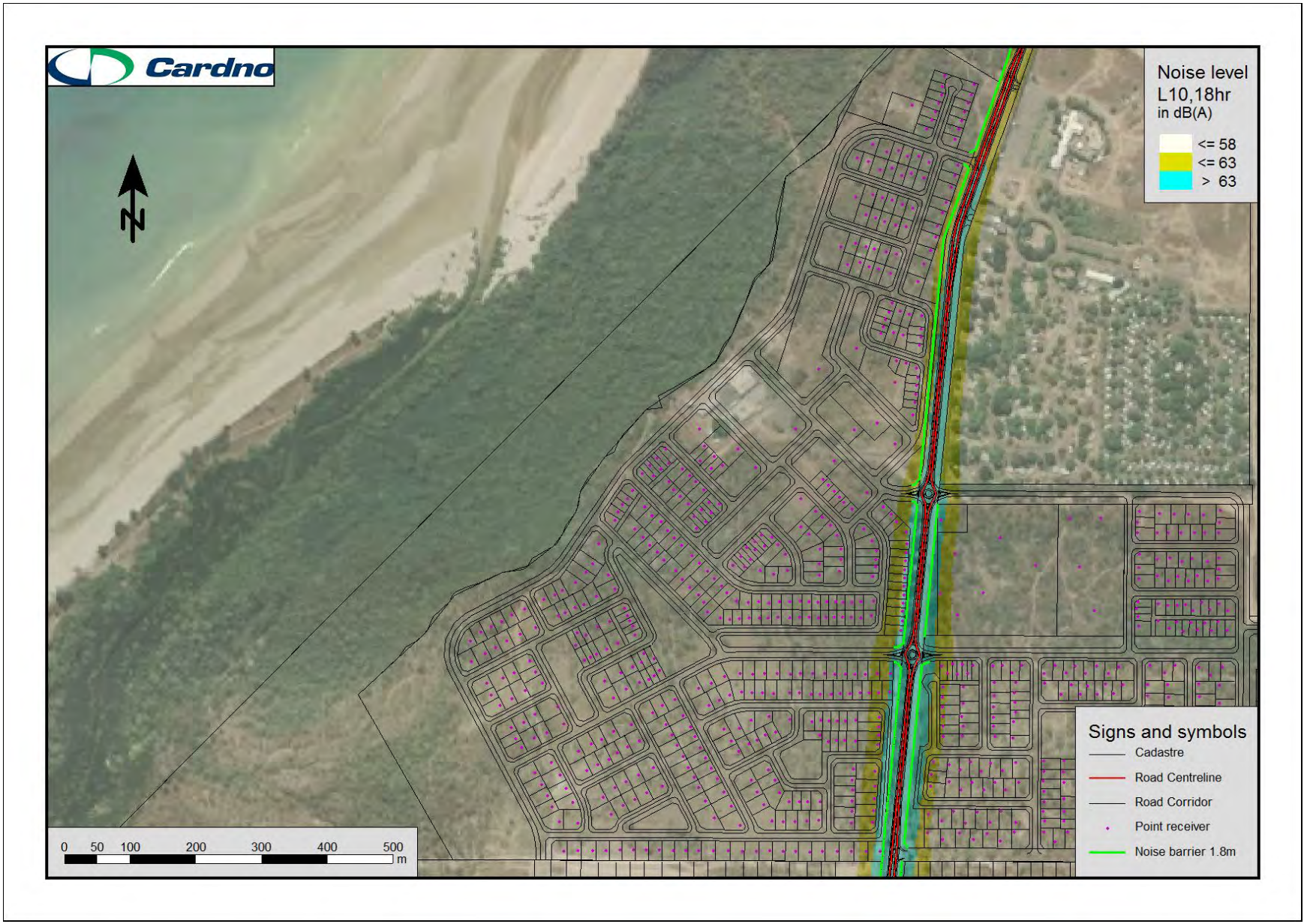


Figure C-4 Façade Corrected Noise Contour Map with 1.8m High Noise Barriers $L_{10, 18hour}$ Modelled at First Floor Level.



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APPENDIX D

NOISE CONTOUR MAPS – CONSTRUCTION NOISE IMPACT

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Figure D-1 Noise Contour Map for Clearing of Vegetation and Site Establishment

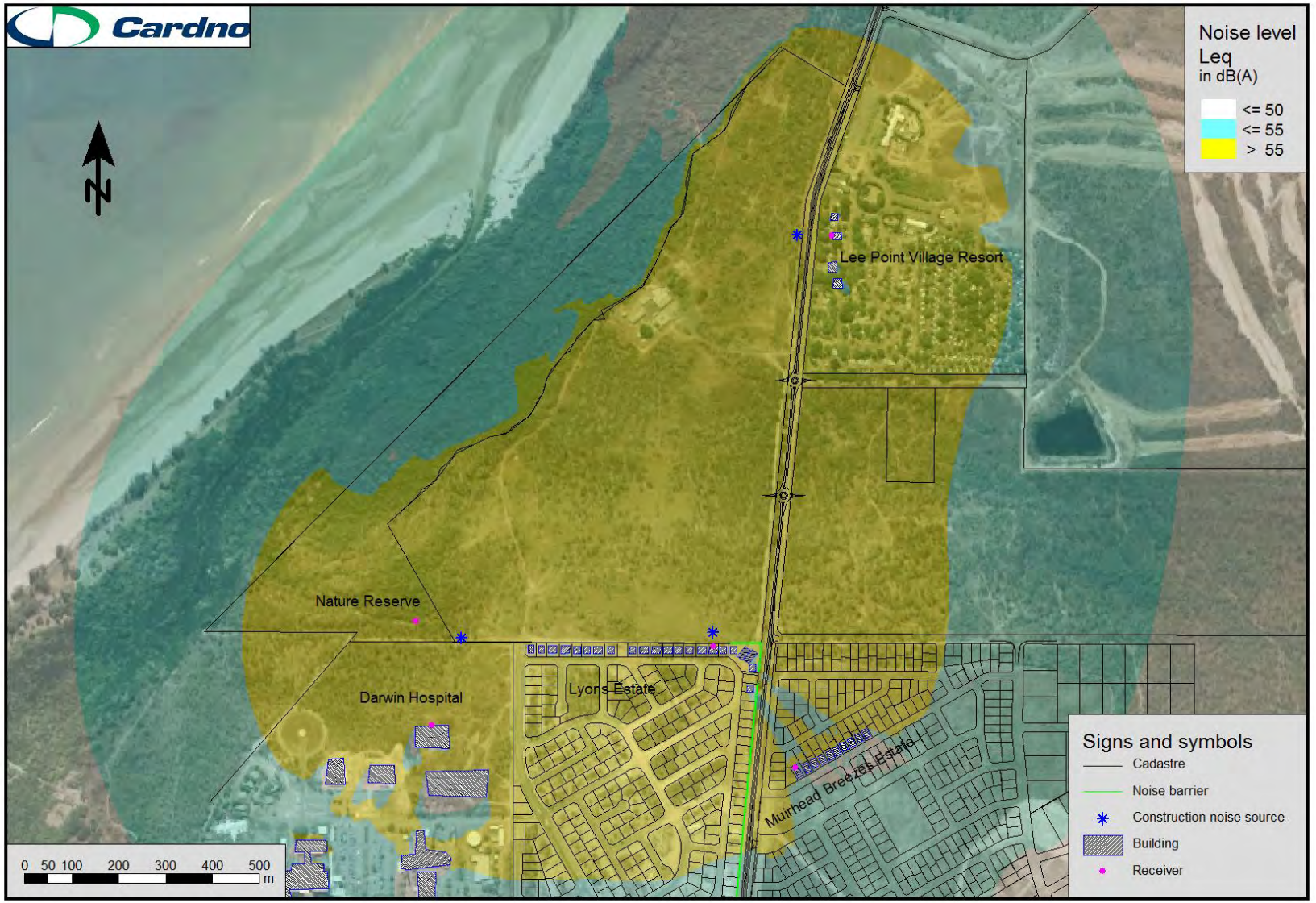


Figure D-2 Noise Contour Map for Bulk Earthworks

Figure D-3 Noise Contour Map for Drainage Infrastructure

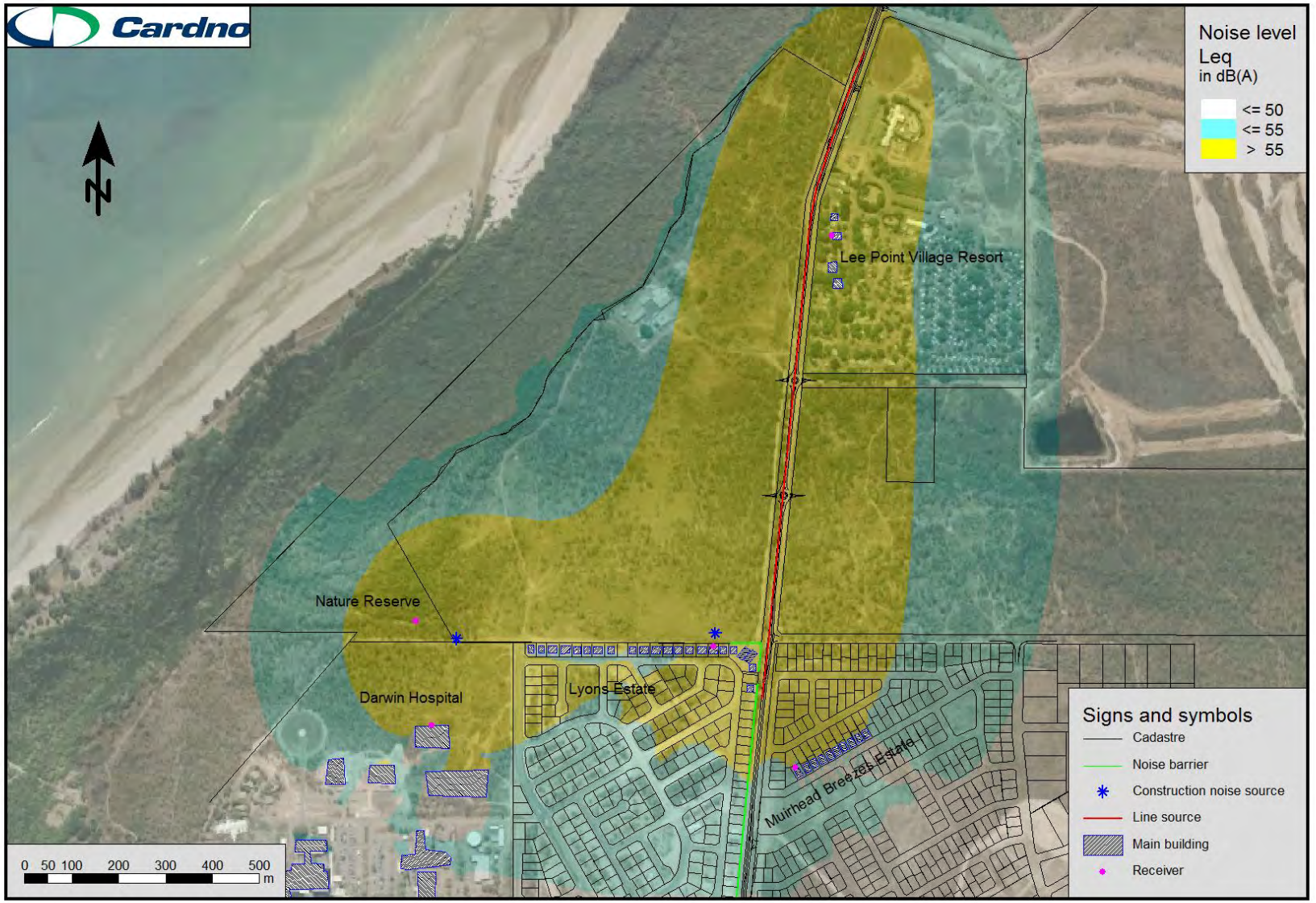
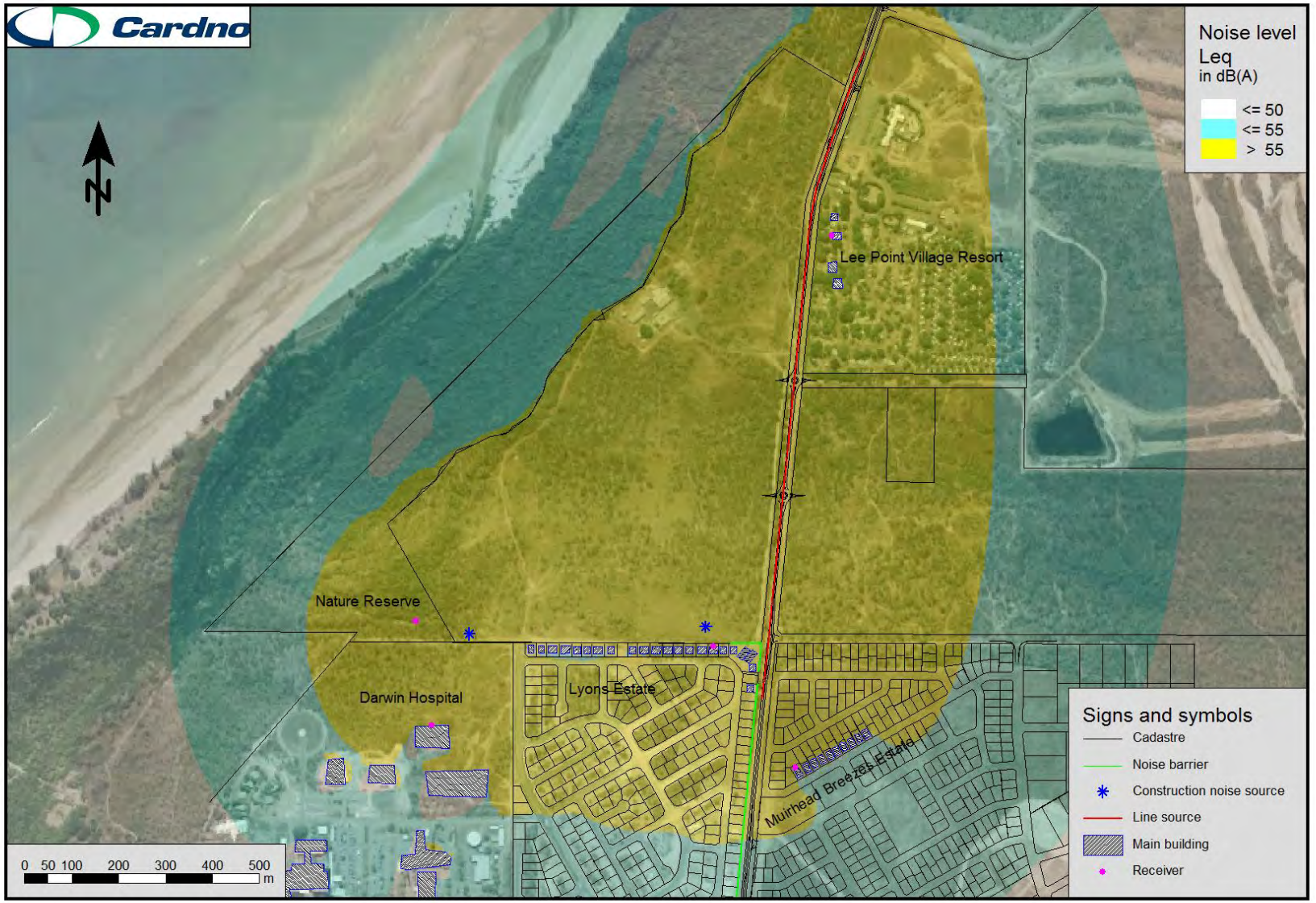


Figure D-4 Noise Contour Map for Road Surfacing Works



APPENDIX I

Noise Impact Assessment report – Muirhead North

Noise Impact Assessment

Muirhead North Development,
Darwin

F070_DC1603

Prepared for
Defence Housing Australia

15 December 2016

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Executive Summary

Cardno has been commissioned to undertake a noise impact assessment for the Muirhead North development at the northern end of Lee point Road, Lee Point, Darwin.

The greenfield site is situated on the eastern side of Lee Point Road and is currently vacant and covered by existing vegetation. The Muirhead North site is approximately 49 hectares with 44 hectares suitable for future developments.

This noise impact assessment was conducted on the behalf of Defence Housing Australia. The assessment has been carried out to determine the predicted noise impacts associated on and from the development of the Muirhead North project.

Noise modelling has been carried out to determine predicted construction noise impacts upon neighbouring noise sensitive receivers from construction of the sites, and to determine predicted road traffic noise impacts on the future developments from Lee Point Road. This assessment considers the following noise impacts:

- Noise impacts from construction of the project in accordance with the *Northern Territory Environmental Protection Authority's Noise guidelines for development sites In the Northern Territory* for the control of construction noise impacts.
- Construction vibration from the project in accordance with *AS 2436 Guide to Noise and Vibration Control on Construction, Maintenance and Demolition Sites*, as outlined in the *Noise guidelines for development sites In the Northern Territory* for assessing vibration.
- Potential impacts from road traffic noise as a result of the developments in accordance with the *Northern Territory Government's policy on Road Traffic Noise on NT Government Controlled Roads 2014* and supported by the *Queensland Road Traffic Noise Management Code of Practice 2013* and the *Queensland Environmental Protection (Noise) Policy 2008*.

This assessment considers the following policies and guidelines:

Construction Noise & Vibration:

- NT Noise Guidelines for development sites In the Northern Territory (NTEPA January 2013)
- QLD Road Traffic Noise Management Code of Practice 2014 Volume 2 (TMR CoP Vol 2)

Operational Road Traffic Noise:

- NT Road Traffic Noise on NT Government Controlled Roads (NT Department of Transport November 2014)
- QLD Road Traffic Noise Management Code of Practice 2013 Volume 1 (TMR CoP Vol 1)

The prediction of future road traffic noise levels has been based on projected traffic volumes, as outlined in the traffic impact assessment for the Muirhead North Development & 2CRU prepared in July 2015 by SMEC and DHA. Modelling assumptions have been outlined in Section 5.2 of this report.

Assessment Conclusions

The assessment identified the following conclusions:

Operational Road Traffic Noise

- Modelling indicates that the noise limit of $L_{A10, 18hour}$ 58 dB(A) is not predicted to be exceeded for outdoor free field receivers by road traffic noise from Lee Point Road. As such, the predicted noise levels indicate that noise barriers between Lee Point Road and the development site are not required to allow compliance with the noise limit for the proposed sportsgrounds and playgrounds.
- The predicted noise levels at the residential lots indicate that road traffic noise levels are not predicted to exceed the 63 dB(A) criteria, with no noise barriers. As such the predicted noise levels at the proposed residential lots indicate that noise barriers are not required for the Muirhead North development.
- The predicted noise levels at the proposed school buildings and proposed community centre indicate exceedances of the noise limit of $L_{A10, 18hour}$ 58 dB(A) for non-residential noise sensitive use. Without the provision of a 1.8 metre noise barrier between the school site and Lee Point Road 5 (2 ground floor and 3 first floor) exceedances are predicted. This number is reduced to 3 (1 ground floor and 2 first floor) with the inclusion of 1.8 metre high noise barriers located along the site boundary with Lee Point Road, as shown in Figure A-1.
- Noise modelling therefore indicates that the school buildings and the community centre building should be placed further away from Lee Point Road or that noise mitigation options, such as provision of a noise barrier between the proposed school site and Lee point Road, should be included in the design to allow compliance with the noise limit of 58 dB(A) for non-residential noise sensitive use.
- The noise contour maps show that noise levels of less than 58 dB(A) are predicted at distances in excess of approximately 50 metres from Lee Point Road, without included noise amelioration. The noise contour maps also show that the inclusion of noise barriers provide a significant amount of noise reduction for ground floor levels.
- The results indicate that all of the proposed residential lots will require building construction in accordance with either AS 3671 Category 1 or 2.
- The community centre building and the nearest school building will require building construction in accordance with AS 3671 Category 3 with no barriers. If a barrier is installed, the Category 3 construction requirements are only applicable for the first floor levels of the two buildings.
- Acoustic design principles should be taken into account during the final stage when considering overall layout and building orientation and shielding effects. Some principles to consider are listed below.
    - The building to be set back from the transport corridor as far as possible;
    - The building to shape away from the transport corridor;
    - The building to shield courtyards and open space areas from the corridor; and
- Noise sensitive spaces, such as bedrooms, should be shielded from noise by positioning less sensitive spaces, such as the garage, bathrooms and laundry, closer to the corridor.

Construction Noise Impacts

- Construction noise levels are predicted to exceed the design benchmark noise limits for worst case scenarios where work is conducted at the boundary of the development site or where Lee Point Road is upgraded.
- The exceedances are due to limited separation distance between the site and neighbouring receivers and the high noise levels typically generated by construction plant. However it is worth noting that the predicted construction noise levels only are applicable where work is conducted at locations in close vicinity to the affected receivers which will be for shorter durations only, as clearing of vegetation and general construction work will move around the development site as work progresses.

- Maximum noise levels have been predicted to the nearest affected residential receivers to allow a review of the potential for sleep disturbance from construction activities at night. The results indicate that maximum construction noise levels at the nearest noise sensitive receivers are likely to exceed the sleep disturbance criteria, when construction works are located nearby. For this reason it is recommended that activities with potentially high maximum levels such as the use of pneumatic tools and truck air-braking are minimised or not carried out at these locations during the night-time period.
- It should be noted that this assessment has endeavoured to carry out "worst case" noise modelling, and noise levels are predicted based on a moving point source representative of the total construction noise level moving along the length of the project. Should the work sites or plant and equipment be relocated so that other receivers are located closer to the works, these receivers are likely to be affected more significantly than predicted in this report.
- The predicted exceedances are generally a result of works being located in close proximity to the adjacent receivers. This modelling has been carried out to provide a worst case scenario and it may be possible to reduce the number of plant operating simultaneously, particularly at night, once detailed construction schedules are known. This can be investigated further during preparation of the construction noise and vibration management plan for the project.
- Provision of temporary noise barriers is likely to be required between local construction sites and receivers, if night-time works are required near noise sensitive receivers.
- Best practice mitigation measures are recommended in Section 8 of this report.
- A detailed construction noise and vibration management plan should be prepared for the project prior to construction commencement to incorporate the recommendations detailed in Section 8 and updated to reflect the proposed staging and plant to be adopted for the project.

Construction Vibration Impacts

- Sensitive structures are located immediately adjacent to the Lee Point Road transport corridor indicating that consideration of vibration impacts will be required during the upgrade of the southern part of the transport corridor.
- Human discomfort may be felt should large vibratory rollers be used within 100 metres of nearby receivers. Therefore, vibratory rolling should only be carried out at night if the vibratory roller is rated less than 100 kN and the distance to vibration sensitive receivers is in excess of 20 metres to avoid the risk of human discomfort and sleep disturbance.
- A detailed construction noise and vibration management plan should be prepared for the project prior to construction commencement to incorporate the recommendations detailed in Section 8 and updated to reflect the proposed staging and plant to be adopted for the project.

Table of Contents

Executive Summary iii
Construction Noise & Vibration: iii
Operational Road Traffic Noise: iii
Assessment Conclusions iii
Operational Road Traffic Noise iv
Construction Noise Impacts iv
Construction Vibration Impacts v
Technical Terms 9
1 Introduction 10
1.1 Assessment Objectives 10
1.2 Project Description 10
1.2.1 Existing Site Description 10
1.2.2 Proposed Project 11
2 Existing Noise Environment 14
3 Statutory Noise & Vibration Criteria 16
3.1 NT EPA Noise Guidelines for Development Sites in the Northern Territory 16
3.2 QLD EPA EcoAccess Planning For Noise Control 17
3.3 NT Government - *Road Traffic Noise on NT Government Controlled Roads (RTNNTGCR)* 18
3.4 QLD TMR Road Traffic Noise Management Code of Practice 2014 Volume 2 – Construction Noise & Vibration 19
3.5 Australian & International Standards 19
4 Design Benchmarks 21
4.1 Construction Noise 21
4.2.1 Human Comfort Criteria 21
4.2.2 Building Damage Criteria 22
4.3 Road Traffic Noise 22
4.3.1 External Noise Objectives 22
4.3.2 Internal Noise Objectives 23
5 Operational Noise & Vibration Impacts 24
5.1 General Modelling Methodology 24
5.1.1 Application of Correction Factors 24
5.1.2 Modelled Scenarios 24
5.2 Noise Modelling Inputs & Assumptions 25
5.2.1 General Modelling Input Data 25
5.2.2 Modelled Road Segments 25
5.2.3 Traffic Volumes and Posted Speed 26
5.3 Modelled Receivers 27
5.4 Predicted Noise Levels 27
5.5 Result Overview 27
6 Construction Noise Impact Assessment 28
6.1 Construction Noise Assessment Methodology 28
6.2 Modelled Construction Phases 28
6.3 Noise Sensitive Areas 28
6.4 Construction Timing 28
6.5 Construction Plant & Equipment 29

6.6 Predicted Construction Noise Levels 30
6.7 Construction Noise Results Summary 32
6.7.1 Continuous Construction Noise 32
6.7.2 Sleep Disturbance 32
7 Construction Vibration Assessment 32
7.1 Vibration Limits 32
7.1.1 Vibration Assessment 33
8 Recommended Mitigation Measures 34
8.1 General Construction Noise & Vibration 34
8.2 Site Specific Measures 34
8.2.1 Plant Controls 34
8.2.2 Manage of Hours of Operation 35
8.2.3 Management and Behaviour Controls 35
9 Conclusions 36
9.1 Operational Road Traffic Noise Impacts 36
9.2 Construction Noise Impacts 36
9.3 Construction Vibration Impacts 37

Appendices

Appendix A Modelled Receivers and Noise Barriers Within the Development
Appendix B Predicted Noise Levels for Modelled Receivers in the Development
Appendix C Noise Contour Maps – Road Traffic Noise Impact
Appendix D Noise Contour Maps – Construction Noise Impact

Tables

Table 2-1 Estimated Average Background Noise Levels for Different Areas in Australia 14
Table 2-2 Adopted Assessment Background Noise Levels, dB(A) 15
Table 3-1 NT EPA Construction Noise Criteria during Acceptable Construction Times 16
Table 3-2 Target Road Traffic Noise Objectives for Land Uses Adjacent to Arterial Roads 18
Table 3-3 Recommended design internal noise levels – AS/NZS 2107:2000 20
Table 4-1 Construction Noise Limits 21
Table 4-3 Structural Damage Criteria 22
Table 4-4 Vibration Damage to Infrastructure & Assets – Transient Vibration 22
Table 4-6 Recommended Internal Project Specific Noise Criteria 23
Table 5-1 Modelled Scenarios 25
Table 5-2 Modelling Assumptions 25
Table 5-3 Projected (2025) Daily Traffic Volumes and Speeds 26
Table 6-1 Construction Plant Sound Power Levels 29
Table 6-2 Predicted Construction Noise Levels – Clearing and Site Establishment 30
Table 6-3 Predicted Construction Noise Levels – Bulk Earthworks 30
Table 6-4 Predicted Construction Noise Levels – Drainage Infrastructure 31
Table 6-5 Predicted Construction Noise Levels – Road Surfacing Works 31

Table 7-1 Recommended Minimum Working Distance 33
Table B-1 Predicted Noise Levels at the Facades of Potential Buildings for Year 2026 for the Muirhead North Development – with no Mitigation 41
Table B-2 Predicted Noise Levels at the Facades of Potential Buildings for Year 2026 for the Muirhead North Development – with 1.8 Metre Barriers 58
Table B-3 Predicted Noise Levels for Free Field Receivers for Year 2026 for the Muirhead North Development – with no Mitigation 75
Table B-4 Predicted Noise Levels for Free Field Receivers for Year 2026 for the Muirhead North Development – with 1.8 Metre Barriers 75

Figures

Figure 1-1 Site Location and Surrounding Land Uses 11
Figure 1-2 Proposed Muirhead North Zoning 12
Figure 1-3 Proposed School and Community Hub in the Muirhead North Development 13
Figure 5-1 Modelled Road Segments 26
Figure A-1 Modelled Noise Sensitive Receivers and Modelled Noise Barrier Locations for Muirhead North. 39
Figure C-1 Façade Corrected Noise Contour Map without Noise Barriers $L_{10,\ 18hour}$ Modelled at Ground Floor Level. 77
Figure C-2 Façade Corrected Noise Contour Map without Noise Barriers $L_{10,\ 18hour}$ Modelled at First Floor Level. 78
Figure C-3 Façade Corrected Noise Contour Map with 1.8m High Noise Barriers $L_{10,\ 18hour}$ Modelled at Ground Floor Level. 79
Figure C-4 Façade Corrected Noise Contour Map with 1.8m High Noise Barriers $L_{10,\ 18hour}$ Modelled at First Floor Level. 80
Figure D-1 Predicted Construction Noise Levels for Clearing of Vegetation and Site Establishment 82
Figure D-2 Predicted Construction Noise Levels for Bulk Earthworks 83
Figure D-3 Predicted Construction Noise Levels for Drainage Infrastructure 84
Figure D-4 Predicted Construction Noise Levels for Road Surfacing Works 85

Technical Terms

Term	Definition
Adverse Weather	Weather effects that enhance noise (that is, wind and rain) that occur at a site for a significant period of time (that is, wind exceeding 5 m/s and rain exceeding 0.5 mm per hour during any measurement period.)
A-weighted Level	As per dB(A) defined below.
Ambient Sound	Of an environment: the all-encompassing sound associated with that environment, being a composite of sounds from many sources, near and far.
Background Sound Level	The average of the lowest levels of the sound levels measured in an affected area in the absence of noise from occupants and from unwanted external ambient noise sources.
CoRTN	Calculation of Road Traffic Noise, 1988
dB(A)	Unit of acoustic measurement electronically weighted to approximate the sensitivity of human hearing to sound frequency.
Decibel, dB	Unit of acoustic measurement. Measurements of power, pressure and intensity may be expressed in dB relative to standard reference levels.
L90, L10 etc.	A statistical measurement giving the sound pressure level which is exceeded for the given percentile of an observation period, i.e. L90 is the level which is exceeded for 90 percent of an observation period. L90 is commonly referred to as a basis for measuring the background sound level.
LAbg, T	The A-weighted background sound level measured over a time interval T.
LAeq, T	Equivalent continuous A-weighted sound pressure level. This is the value of the A-weighted sound pressure level of a continuous steady sound that, within a measurement time interval T, has the same A-weighted sound energy as the actual time-varying sound.
SEL	Sound Exposure Level (SEL) is the constant sound level which, if maintained for a period of 1 second would have the same acoustic energy as the measured noise event. SEL noise measurements are useful as they can be converted to obtain Leq sound levels over any period of time and can be used for predicting noise at various locations.
Sound Pressure Level, Lp, dB, of a sound	A measurement obtained directly obtained using a microphone and sound level meter. Sound pressure level varies with distance from a source and with changes to the measuring environment. Sound pressure level equals 20 times the logarithm to the base 10 of the ratio of the r.m.s. sound pressure to the reference sound pressure of 20 microPascals.
Sound Power Level, Lw, dB of a source	Sound power level is a measure of the sound energy emitted by a source, does not change with distance, and cannot be directly measured. Sound power level of a machine may vary depending on the actual operating load and is calculated from sound pressure level measurements with appropriate corrections for distance and/or environmental conditions. Sound power level is equal to 10 times the logarithm to the base 10 of the ratio of the sound power of the source to the reference sound power of 1 picoWatt.

1 Introduction

A noise impact assessment was undertaken for the proposed Muirhead North development located on the eastern side of Lee Point Road approximately 15 km northeast of Darwin. The assessment has been undertaken to determine the following

- Predicted construction noise impact upon neighbouring noise sensitive receivers as a result of clearing and construction of the development site.
- Predicted road traffic noise impacts on the development site as a result of traffic on Lee Point Road.

Noise mitigation measures were determined for both construction noise and for noise generated by traffic on Lee Point Road, where required.

This assessment considers the following policies and guidelines:

- NT Noise Guidelines for development sites In the Northern Territory (NTEPA January 2013)
- NT Road Traffic Noise on NT Government Controlled Roads (NT Department of Transport November 2014)
- QLD Road Traffic Noise Management Code of Practice 2013 Volume 1 (TMR CoP Vol 1)
- QLD Road Traffic Noise Management Code of Practice 2014 Volume 2 (Construction Noise) (TMR CoP Vol 2)

This assessment has used the UK "Calculation of Road Traffic Noise (CoRTN)" method to assess operational traffic noise in accordance with the Northern Territory's Department of Transport requirements. The Northern Territory's Department of Transport has indicated target road traffic noise objectives for land uses adjacent to arterial roads. It should be noted that Lee Point Road is not a state controlled road but a local council road. However due to the absence of road traffic noise criteria for roads operated by Darwin Council, the criteria outlined in the Northern Territory Government's Road Traffic Noise on NT Government Controlled Roads has been adopted.

Furthermore it should be noted that noise monitoring to determine existing background noise levels was not conducted as part of this assessment.

1.1 Assessment Objectives

The assessment objectives are:

1. To determine the predicted levels of noise and vibration impact on sensitive receivers located near to the project site during the construction period, and to determine the levels of mitigation that are likely to be required, if applicable, to enable compliance with the current Northern Territory legislation.
2. To determine the predicted levels of road traffic noise from Lee Point Road impacting on the Muirhead North project site, and determine the levels of mitigation that are likely to be required, if applicable, to enable compliance with the current Northern Territory legislation.

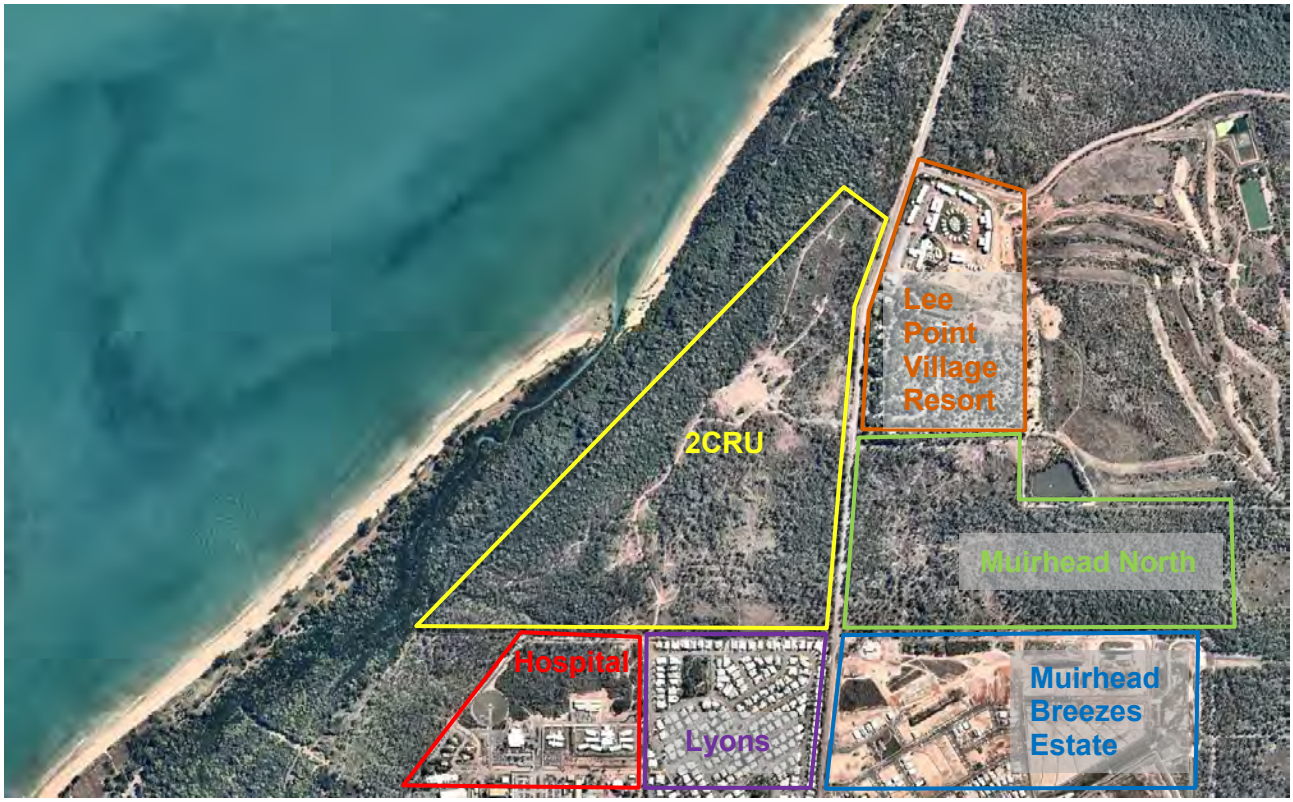
1.2 Project Description

1.2.1 Existing Site Description

The proposed development site is located 15 km northeast of Darwin in a currently rural area in nature but scheduled for several residential subdivisions and other developments in the future.

Figure 1-1 shows the location of the Muirhead North site as well as current and future developments adjacent to the site.

Figure 1-1 Site Location and Surrounding Land Uses



1.2.2 Proposed Project

Defence Housing Australia propose to develop the currently vacant land on lot 9370 denoted as Muirhead North. The development is proposed to accommodate residential dwellings, a community centre and a school.

The proposed plans indicate that the 2CRU site and the Muirhead Breezes Estate site will be developed before construction on the Muirhead North site is scheduled to commence.

The proposed plans for the Muirhead North site indicate that the community centre building(s) and some of the school buildings are proposed to be constructed adjacent to Lee Point Road.

Figure 1-2 shows the proposed zoning for the Muirhead North development.

Figure 1-2 Proposed Muirhead North Zoning

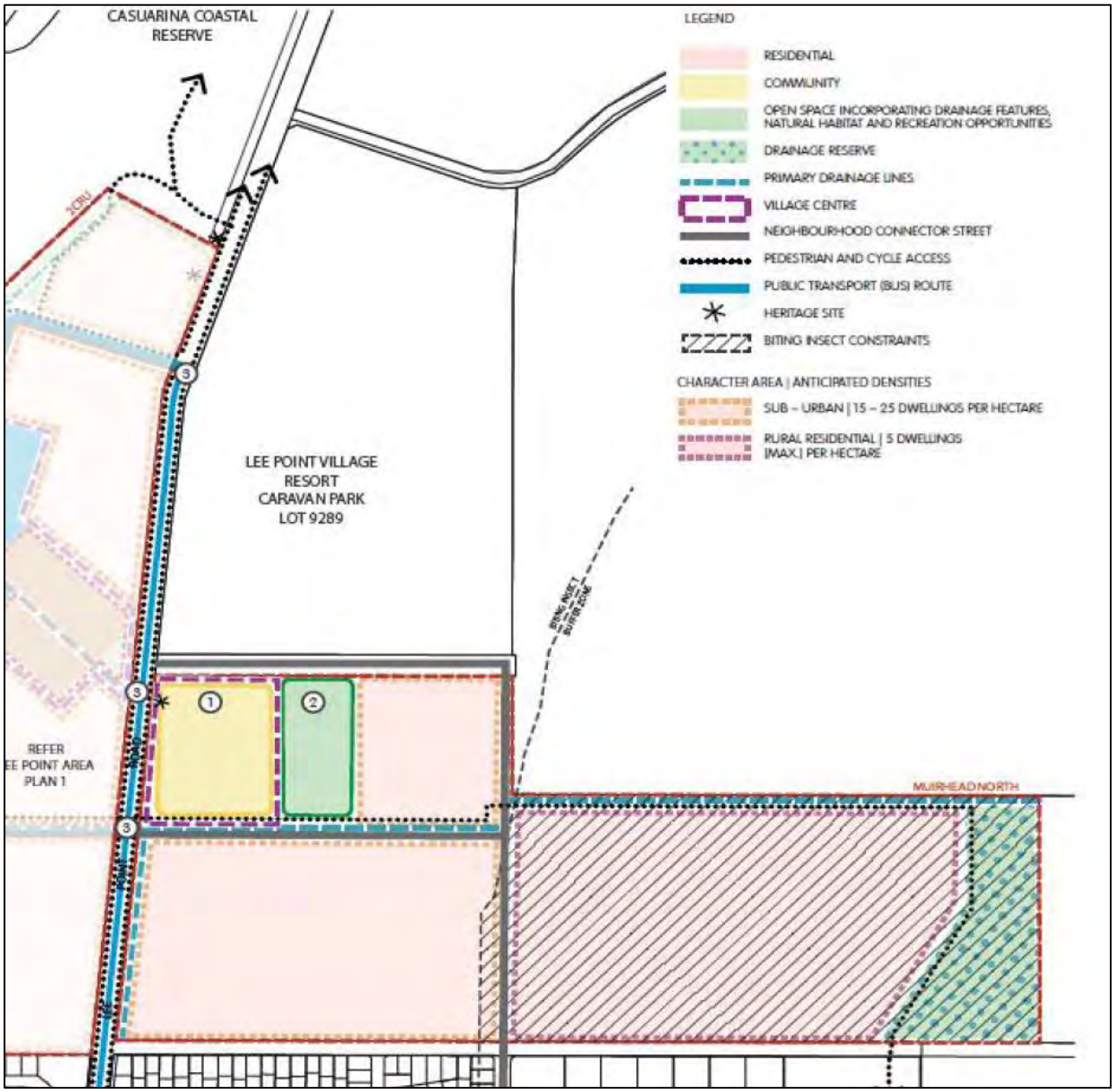


Figure 1-3 shows the proposed school and community hub within the Muirhead North development.

Figure 1-3 Proposed School and Community Hub in the Muirhead North Development

2 Existing Noise Environment

The existing ambient noise is likely to vary throughout the area. Ambient noise levels would be low in the middle of the site and increase closer to roads, the ocean or construction works at other development sites such as the Muirhead Breezes Estate. The existing ambient noise levels have not been measured, as the current site conditions will change as the development sites progress, and are not reflective of the finished or intermediate ambient conditions. On this basis, the ambient noise levels have been estimated in accordance with Australian Standard AS1055.2 – "Acoustics – Description & Measurement of Environmental Noise", to determine appropriate construction noise limits.

Table 2-1 is an extract from Appendix A of AS1055.2 which summarises the estimated average background A-weighted sound pressure levels ($L_{A90,T}$) for different areas containing residences in Australia.

Table 2-1 Estimated Average Background Noise Levels for Different Areas in Australia

Noise Area Category	Description of Neighbourhood	Average background A-weighted sound pressure level, $L_{A90,T}$					
		Monday to Saturday			Sunday and public holidays		
		0700-1800	1800-2200	2200-0700	0900-1800	1800-2200	2200-0900
R1	Areas with negligible transportation	40	35	30	40	35	30
R2	Areas with low density transportation	45	40	35	45	40	35
R3	Areas with medium density transportation or some commerce or industry	50	45	40	50	45	40
R4	Areas with dense transportation or some commerce or industry	55	50	45	55	50	45

The nature reserves and the residential areas surrounding the project site have been considered as: "Noise Area Category R2" and are described as: "Areas with low density transportation".

On this basis the ambient noise levels outlined in Table 2-2 have been adopted for each of the receiver areas located around the subject site:

Table 2-2 Adopted Assessment Background Noise Levels, dB(A)

Sensitive Receiver	Adopted AS 1055.2 Category	Assumed Background A-Weighted Sound Pressure Level, $L_{A90,T}$		
		0700-1800	1800-2200	2200-0700
Lyons	R2	40	35	30
Lee Point Village Resort	R2	40	35	30
Muirhead Breezes Estate	R2	40	35	30
2CRU	R2	40	35	30
Northern Reserve	R2	40	35	30
Eastern Reserve	R2	40	35	30

The established construction noise limits for the project are shown in Table 4-1.

3 Statutory Noise & Vibration Criteria

3.1 NT EPA Noise Guidelines for Development Sites in the Northern Territory

The Northern Territory Environmental Protection Authority's Noise Guidelines for Development Sites in the Northern Territory May 2014 outline acceptable construction times and noise levels that should not be exceeded during those times.

The guideline states that construction activities should be restricted to:

a. between the hours of 7am and 7pm Monday to Saturday; and

b. between the hours of 9am and 6pm on a Sunday or public holiday.

Table 3-1 outlines the specified construction noise limits for work undertaken during the acceptable construction times.

Table 3-1 NT EPA Construction Noise Criteria during Acceptable Construction Times

Designation Area	Construction Noise Limit $L_{Aeq, 15min}$
Residential	Ambient noise* plus 5 dB(A)
Mixed commercial/residential	60 dB(A)
Commercial	65 dB(A)
Industrial	70 dB(A)

* Ambient noise is not explained in the Noise Guidelines for Development Sites in the Northern Territory, it has therefore been assumed to be the background noise level typically described as the L_{A90} noise descriptor.

The levels specified in Table 3-1 apply within 15 metres of a Noise Sensitive Receptor (NSR) or at or on the boundary of the NSR (including when adjusted +5 dB each for for tonality or modulation, and +10 dB for impulsiveness).

Those responsible for development sites and construction activities are advised of their obligations under Part 3 of the Act, which stipulates their responsibility to notify of an incident, where there is reason to believe that the incident has caused or is threatening to cause pollution. The guideline further states that noise from a development site may be considered an environmental nuisance or pollution and may be considered an offence under the Act if:

a. the construction activity is conducted:
   i. outside the hours of 7am and 7pm Monday to Saturday; or
   ii. on a Sunday or public holiday outside the hours of 9am and 6pm;

b. the construction activity generates noise which exceeds the construction noise levels defined in these guidelines;

c. the construction activity was not carried out in accordance with „AS 2436 Guide to Noise and Vibration Control on Construction, Maintenance and Demolition Sites"; and

d. 48 hours' notice was not given to the occupiers of all noise-receiving premises where noise levels for the development site are likely to be of concern including;

   i. a description of proposed construction activity likely to cause a nuisance;
   ii. the date(s), time(s) and duration for the construction activity likely to cause a nuisance; and
   iii. the name and phone number of the person to whom a complaint may be made about noise emissions from the site;

OR

a. the activity was not carried out in accordance with a Noise Management Plan (NMP) registered with the NT EPA.

The guideline recommends community consultation in order to reduce the likelihood of complaints, where an isolated (i.e. one-off) activity is likely to occur which may cause environmental nuisance, the NT EPA recommends any NSRs (such as surrounding residential/commercial premises) in the area around the development site be given at least 48 notification about the noise activity and given the opportunity to provide feedback. Any feedback received should then be considered and accommodated. The guideline outlines that a NMP is required if noise resulting from a construction activity is to be emitted from a development site:

a. outside the times 7am to 7pm Monday to Saturday; or

b. outside the times 9am to 6pm on a Sunday or public holiday; or

c. is likely to exceed the construction noise levels defined in these guidelines; AND

d. the construction work is proposed, or taking place on, land within or directly adjacent to land zoned Commercial or Residential,

the party responsible for the development site must develop and register a NMP with the NT EPA. NMPs should comply with „AS 2436: Guide to Noise and Vibration Control on Construction, Maintenance and Demolition Sites".

A NMP must include management and mitigation strategies to prevent an environmental nuisance caused by construction noise. The NMP is to include, as a minimum:

a. justification for work on the development site, that is likely to be undertaken outside of the acceptable construction times (between the hours of 7am and 7pm Monday to Saturday and/or between the hours of 9am to 6pm on a Sunday or public holiday);

b. details and the duration of the activities on the development site likely to cause noise emissions that may exceed the construction noise levels defined in these guidelines;

c. details clearly demonstrating how site activity will comply with „AS 2436 Guide to Noise and Vibration Control on Construction, Maintenance and Demolition Sites";

d. documented complaint response procedures and how the procedures will be implemented;

e. documentation of the verifiable consultation and feedback program with occupants of all affected premises, demonstrating that all occupants were provided with advice on dates, times and nature of any potentially noisy and disruptive activity including measures proposed to mitigate such activity as well as noise complaint contact details;

f. a copy of any feedback received from any affected premises and an explanation on how the feedback was considered and accommodated in the NMP; and

g. name of the onsite person who will be responsible for implementing the NMP and the name and phone number of the person to whom a complaint may be made about noise emissions from the site.

3.2 QLD EPA EcoAccess Planning For Noise Control

In the absence of NT specific crteria for sleep disturbance relevant guidelines from the World Health Organiszation and the QLD EPA EcoAccess Planning for Noise Control Guideline have been refenced.

The World Health Organisation (WHO) issued its "Guidelines for Community Noise" in April 1999. The WHO guideline states the following in regard to sleep disturbance from continuous noise from activities such as mining operations:

"Where noise is continuous, the equivalent sound pressure level should not exceed 30 dB(A) indoors, if negative effects on sleep are to be avoided. When noise is composed of large proportion of low-frequency sounds a still lower guideline

value is recommended, because low-frequency noise (e.g. from a ventilation system) can disturb rest and sleep even at low sound pressure levels."

The EcoAccess Guideline "Planning for Noise Control", is referring to the World Health Organisation guideline, makes the following general recommendations regarding short term transient noise events:

"As a rule in planning for short-term or transient noise events, for good sleep over eight hours, the indoor sound pressure level measured as a maximum instantaneous value should not exceed approximately L_{Amax} *45 dB(A) more than 10 to 15 times per night."*

For less regular night events, the allowable internal noise level is higher, as follows:

- Approximately 3 events per night, L_{Amax} 50 dB(A)
- Approximately 1 event per night, L_{Amax} 65 dB(A)

In the EcoAccess Guideline it is proposed that the noise reduction provided by a typical residential building façade is 5 to 10 dB(A) assuming open windows. That is, with an external noise source, a 5 to 10 dB(A) reduction in noise levels from outside a house to inside a house is expected when windows are fully open. Thus the indoor noise levels noted above could be considered as the following external noise levels:

- Approximately 10-15 events per night, L_{Amax} 50 to 55 dB(A)
- Approximately 3 events per night L_{Amax} 55 to 60 dB(A)
- Approximately 1 event per night, L_{Amax} 70 to 75 dB(A)

3.3 NT Government - *Road Traffic Noise on NT Government Controlled Roads (RTNNTGCR)*

In the absence of road traffic noise criteria for roads operated by the City of Darwin the criteria outlined in the Northern Territory Government's Road Traffic Noise on NT Government Controlled Roads is adopted.

Table 3-2 outlines the target noise levels for particular types of road situations for residential and noise-sensitive land uses adjacent to arterial roads. The target levels outlined in Table 3-2 are not mandatory but are levels which the NT Department of Transport will consider for application within budgetary and physical constraints.

Table 3-2 Target Road Traffic Noise Objectives for Land Uses Adjacent to Arterial Roads

Project Type	Existing Residential Use	Existing Noise-Sensitive use	Future Residential or Noise-Sensitive Use
Existing Road Existing Road Upgrade Future Road Currently Planned	No target - no required action	No target - no required action	Responsibility rests with the proponent (private or government agency)
Future Road Not Currently Planned	Target 63 dB(A) $L_{10,18hr}$	Target 58 dB(A) $L_{10,18hr}$	

An Explanation of the terms shown in Table 3-2 is detailed below:

$L_{10,18hr}$ - unless otherwise stated, these values are measured at 1 metre from the façade of a building in accordance with Australian Standard 2702-1984 "Acoustics – Methods for the measurement of road traffic noise" and the method described above.

Existing road – an existing arterial road; includes a road subject to activities such as routine maintenance or minor development including new intersection turn lanes or other upgrading, traffic management measures such as a new roundabout or traffic signals, or normal traffic growth over time.

Existing Road Upgrade - a major upgrade to an existing arterial road such as the addition of new lane(s) or carriageway(s) or where the traffic mix or volume is significantly altered as a result of changes at the network level,

where the information has been available in the public domain for identification by way of publicly available government (i.e. Departmental) plans or documents at the time of development of the adjacent land.

Future Road Currently Planned - a new road or road corridor which has been identified in publicly available government plans or documents at the time of development of the adjacent land.

Future Road Not Currently Planned - any new roads or corridors which are not currently identified in publicly available government plans or documents at the time of release of this policy.

Existing Residential - residential land use immediately adjacent to arterial roads.

Existing Noise-Sensitive - includes aged care facilities, hospices and nursing homes and may include schools, libraries and hospitals. Commercial accommodation facilities relying on passing trade are not considered as noise sensitive developments under this policy.

Future Residential or Noise-Sensitive - any residential or noise sensitive land use adjacent to or in the vicinity of arterial roads which does not exist at the time of the release of this policy.

The Road Traffic Noise on NT Government Controlled Roads further states:

- Any noise management regimes and ameliorative measures for developments adjacent to planned or existing roads shall be in accordance with the requirements of the approval issued under the land use planning process, and shall be contained fully within the properties concerned; and
- New land development adjacent to an arterial road should be planned and developed in accordance with the provisions of the approval issued under the land use planning process stipulating an appropriate target $L_{10,18hr}$ noise level.

3.4 QLD TMR Road Traffic Noise Management Code of Practice 2014 Volume 2 – Construction Noise & Vibration

In the absence of NT Policies or guidelines with respect to construction vibration limits, relevant criteria has been referenced from the QLD TMR COP Volume 2 for both human comfort and building damage related vibration limits.

The CoP Volume 2 provides a section on the assessment of construction vibration form road projects. The criteria from this code of practice have been adopted for this assessment.

Vibration criteria for both human comfort and building damage due to ground borne vibration caused by construction activities (e.g. pile driving, compaction and blasting) are provided in this section. It should be noted that compliance in most cases with the human comfort criteria would also achieve the building damage criteria.

The British Standard BS 5228-2:2009 provides an alternative approach to those historically used to assess human comfort presented in the British Standard BS 6472-1:2008. While BS 6472-1 provides guidance on human response to vibration in buildings in terms of VDV, BS 5228-2 Table B.1 provides guidance on the use of PPV which is typically measured to determine potential building damage.

For human comfort in order to minimise annoyance due to ground borne construction vibration, this Code adopts vibration levels with lower and upper limits as presented in Table 4-2. The low limits are generally considered to be just perceptible if just exceeded. The upper limits are considered to cause significant annoyance if exceeded.

All reasonable and practicable measures should be implemented to achieve the lower limit. Exceedance of the upper limit requires immediate action and extensive community consultation to determine further mitigation measures.

The criteria associated with building damage are summarised in Section 4, in Table 4-3 and Table 4-4.

3.5 Australian & International Standards

Other relevant criteria and assessment methodologies are contained in Australian Standards. The following Australian Standards have been referenced in this assessment.

- Australian Standard AS1055: "Acoustics – Description and measurement of environmental noise"
- Australian Standard AS/NZS 2107:2000 "Recommended design sound levels and reverberation times for building interiors.
- Australian Standard AS 2702 – 1984, Methods for the Measurement of Road Traffic Noise.
- Australian Standard AS3671:1989, "Acoustics – Road Traffic Noise Intrusion – Building Siting & Construction"
- German Standard DIN 4150: "Structural Vibration – Effects of vibration on structures"
- British Standard BS 7385.2: 1993, "Evaluation and measurement for vibration in buildings" - Part 2.
- Australian Standard AS 2436:2010, "Acoustics – "Guide to Noise & Vibration Control on Construction, Demolition & Maintenance Sites"

3.5.1.1 AS/NZS 2107:2000

Table 3-3, referenced from the Australian Standard AS/NZS 2107:2000 states the following guidelines for internal sound levels, in a wide range of buildings and provides internal noise guidelines for residential buildings in areas that are located near major roads.

Table 3-3 Recommended design internal noise levels – AS/NZS 2107:2000

Type of Receiver	Acceptable Noise Level, L_{Aeq} dB(A)	Recommended Maximum L_{Aeq}, dB(A)
7. Residential Buildings		
Houses and Apartments near major roads-		
Sleeping Areas	30	40
Living Areas	35	45
Work Areas	35	45
Apartment common areas	45	55

3.5.1.2 AS3671:1989

AS 3671 provides methods to determine the required Traffic Noise Reduction and the types of construction required to achieve this reduction. The standard references the internal design sound levels listed in AS/NZS 2107. In accordance with Clause 3.2 of AS3671, the worst case Traffic Noise Reduction (TNR) can be calculated and associated category construction adopted. The required categories are defined as follows:

3.2.1 Category 1. Standard construction; openings, including open windows and doors may comprise up to 10% of the exposed facade. TNR of approximately 10 dB(A) is expected.

3.2.2 Category 2. Standard construction, except for lightweight elements, such as fibrous cement, or metal cladding, or all glass facades. Windows, doors and other openings must be closed. TNR of approximately 25 dB(A) is expected.

3.2.3 Category 3. Special construction, chosen in accordance with Clause 3.4. Windows, doors and other openings must be closed. TNR between 25 and 35 is expected.

4 Design Benchmarks

4.1 Construction Noise

The project area will at the time of construction be surrounded by nature reserves and residential areas. In the absence of specific relevant noise criteria for the nature reserves, the criteria for residential receivers has been adopted.

The existing ambient noise levels were not measured but estimated as outlined in Section 2. The estimated ambient noise levels have been referenced to establish the construction noise limits.

Works may have to be carried out, outside of standard hours due to the tropical climate. For this reason construction noise limits have been calculated for both standard and non-standard hours.

Taking into consideration the estimated ambient noise levels in Section 2 and the criteria from Section 3.1, the applicable construction noise limits for the project are shown in Table 4-1.

Table 4-1 Construction Noise Limits

Noise Area	Construction Noise Limit, $L_{Aeq,15\ min}$		Sleep Disturbance from 10pm to 7am, L_{Amax} Externally
	Monday to Saturday from 7am to 7pm	Sunday and public holidays from 9am to 6pm	
Residential	50	50	65
Nature Reserve	50	50	65

4.2 Construction Vibration

4.2.1 Human Comfort Criteria

The following vibration criteria for human comfort apply to this project.

Table 4-2 Preferred & Maximum Levels for Human Comfort

Building	Work Period	Examples	
		Lower Limit	Upper Limit
Dwellings (including hotels and motels)	Standard hours	1.0	2.0
	Non-Standard hours - evening	0.3	1.0
	Non-Standard hours - night-time		
Medical/health buildings (wards, surgeries, operating theatres, consulting rooms)	All	0.3	1.0
Educational facilities (rooms designated for teaching purposes)	While In Use		
Court of Law (Court rooms)			
Court of Law (Court reporting and transcript areas, Judges' chambers)			
Community buildings (Libraries, places of worship)	While In Use	1.0	2.0

4.2.2 Building Damage Criteria

The minimum 'safe limit' of vibration at low frequencies for commercial and industrial buildings are presented in DIN 4150.3 as follows:

Table 4-3 Structural Damage Criteria

Applicable Assessment Criteria	Assessment Criteria , mm/s	
	Day (7 AM–10 PM)	Night (10 PM–7 AM)
Dwellings (including hotels and motels)	5 (rms) at 1-10Hz 5 to 15 (rms) at 10-50Hz 15 to 20 (rms) at 50-100Hz	German Standard DIN 4150
	3 (rms) at 1-10Hz 3 (rms) to 8 at 10-50Hz 8 to 10 (rms) at 50-100Hz	German Standard DIN 4150

Table 4-4 Vibration Damage to Infrastructure & Assets – Transient Vibration

Type of Building	Resultant PPV in Frequency Range of Dominant Pulse, mm/s	
	4 to 15Hz	15Hz and above
Reinforced or framed structures. Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	-
Unreinforced or light framed structure. Residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

4.3 Road Traffic Noise

4.3.1 External Noise Objectives

In the absence of road traffic noise criteria for roads operated by the City of Darwin the criteria outlined in the Northern Territory Government's Road Traffic Noise on NT Government Controlled Roads is adopted. Table 4-5 below shows the applicable road traffic noise limits.

Table 4-5 Summary of External Road Traffic Noise Limits

Receiver Description	Applicable Road Traffic Noise Limits	
	Noise descriptor	External noise level in dB(A)
Residential, Hotels and Tourist Precincts	$L_{10,18hr}$	63
School, Day Care, Library and Community Building	$L_{10,18hr}$	58
Outdoor Educational and Passive Recreational Areas	$L_{10,18hr}$	58
Hospital, Aged Care Facility and Nursing Home	$L_{10,18hr}$	58

4.3.2 Internal Noise Objectives

The Northern Territory Government's Road Traffic Noise on NT Government Controlled Roads does not take night-time traffic volumes into consideration. To determine required façade noise reduction to achieve compliance with the recommendations outlined in AS 2107 we recommend that night time traffic noise levels be determined and assessed against the Acceptable Noise Levels as outlined in AS 2107. Table 4-6 shows the recommended internal noise levels for residential buildings adjacent to Lee Point Road. Previous noise measurements indicate that traffic noise levels typically are 3 dB(A) lower at night compared to the day time, this conversion factor has been used to determine night-time traffic noise levels.

Table 4-6 Recommended Internal Project Specific Noise Criteria

Area	Applicable Rooms	Recommended Internal Design Sound Objective, $L_{eq, (T),}$ dB(A)
7. Residential Buildings		
Houses and Apartments near major roads-		
Sleeping Areas	All bedrooms	30
Living Areas	Lounge rooms within dwellings	35
Work Areas		35
Apartment common areas		45

5 Operational Noise & Vibration Impacts

The prediction of road traffic noise was conducted with the 3D noise modelling software SoundPLAN 7.4. SoundPLAN software applies the algorithm from the Calculation of Road Traffic Noise, UK Department of Transport, Welsh Office 1988 (CoRTN). CoRTN methodology is commonly used for road traffic noise assessment throughout Australia. The modelling predicts expected road traffic noise impacts based on the following input data.

- Existing 3D topography of the site, surrounds and nearby road alignments.
- Proposed Site topography.
- Road traffic flows.
- Posted road traffic speeds, and % heavy vehicles.
- Pavement surface type

5.1 General Modelling Methodology

The traffic noise model was used to predict post-development road traffic noise impacts on the dwellings located within the proposed development in the year 2026. The predicted noise levels were compared to the relevant noise criteria and exceedances determined.

Recommendations relating to feasible and reasonable mitigation measures were then developed.

The CoRTN assessment methodology was adopted for this assessment. The CoRTN modelling methodology sets traffic sources at a height of 0.5 metres above the road.

5.1.1 Application of Correction Factors

The following correction factors have been applied to the modelling:

- Pavement surface corrections of 0 dB(A) for dense graded asphalt (DGAC)
- An AustRoads correction factor to convert standard CoRTN outputs to Australian Conditions of -1.7 dB(A) was applied to the modelling results for receivers associated with future buildings.
- An AustRoads correction factor to convert standard CoRTN outputs to Australian Conditions of -0.7 dB(A) was applied to the modelling results for free field receivers for the assessment of sports fields and playgrounds.
- The standard conversion (referenced from AS 3671) of $L_{A10,18hr} = L_{Aeq,\ day} + 3$ dB(A) was also applied.
- A conversion factor of $L_{Aeq,\ day} = L_{Aeq,\ night} + 3$ dB(A) was applied to determine night-time traffic noise levels.
- A façade correction factor of + 2.5 dB(A) was applied to modelled receivers to allow for façade correction once the buildings are located on each Lot.

5.1.2 Modelled Scenarios

Table 5-1 below, shows the modelled scenarios:

Table 5-1 Modelled Scenarios

Modelled Scenario	Description
Year 2026 – post-development road traffic noise	Traffic noise generated between 6am and midnight, based on predicted post-development road traffic volumes for year 2026
Year 2026 – post-development road traffic noise with noise barriers	Traffic noise generated between 6am and midnight, based on predicted post-development road traffic volumes for year 2026

5.2 Noise Modelling Inputs & Assumptions

5.2.1 General Modelling Input Data

Table 5-2 details the modelling input asumptions used for the modelling:

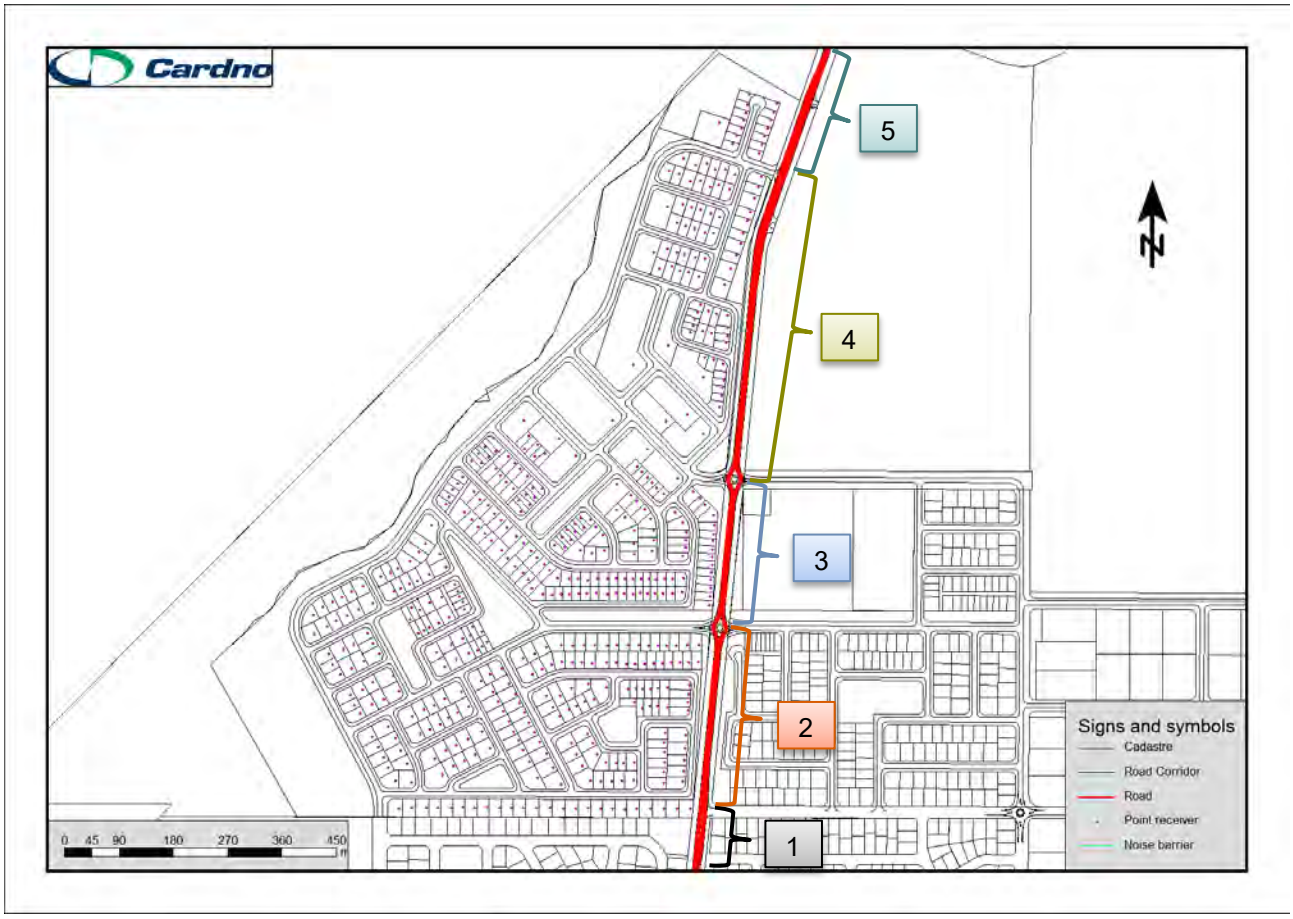
Table 5-2 Modelling Assumptions

Modelling Element	Input / Assumption. Source Reference
Ground Elevation Geometry	Provided by Cardno
Proposed Elevation Geometry	Provided by Cardno
Road Alignment	Provided by Cardno
Site Traffic Flow Data	Provided by SMEC & DHA detailed in Table 5-3.
Road Traffic Speed	Provided by Cardno detailed in Table 5-3.
Road pavement surfaces	Assumed to be DGA with no pavement correction factors added.
Ground Absorption	50% over soft ground
Methodology	Calculation of Road Traffic Noise, UK Department of Transport, 1988
Weather conditions	Calm Conditions
Façade Reflection	+2.5 dB(A) – applied to traffic prediction models, for receivers associated with future buildings.
L_{A10} and L_{Aeq} conversions	$L_{Aeq,day} = L_{A10,18hr} – 3$ dB(A)
Day time to night-time conversion	$L_{Aeq,night} = L_{A10,18hr} – 6$ dB(A)
AustRoads Correction to CoRTN for Façade Corrected Australian Conditions	-1.7 dB(A) CoRTN correction for Australian conditions (with reference to AustRoads.)
AustRoads Correction to CoRTN for Free Field Corrected Australian Conditions	-0.7 dB(A) CoRTN correction for Australian conditions (with reference to AustRoads.)
Receiver Height	Assumed to be 1.8 and 4.6 metres above ground level.

5.2.2 Modelled Road Segments

Figure 5-1 below shows the modelled road segments:

Figure 5-1 Modelled Road Segments



5.2.3 Traffic Volumes and Posted Speed

Projected (2026) traffic volumes within the project area were obtained from the traffic impact assessment for the Muirhead North Development & 2CRU prepared in July 2015 by SMEC and DHA. The traffic impact assessment report projected traffic volumes for year 2025 for the finished development of the greenfield sites north of Lions and Muirhead Breezes Estate. For this assessment it is assumed that traffic volumes for year 2026 is identical to year 2025 as no further developments are likely to occur as Lee Point Road is a dead end road north of the 2CRU development.

The percentage of heavy vehicles (HV) were stated as 0.0% in the traffic impact assessment report, the Cardno traffic engineers however, advised that 5% HV should be used as a conservative assumption, which is in line with previous noise impact assessments carried out for residential developments. Projected traffic volumes and traffic speeds, for the noise modelling are presented in Table 5-3.

Table 5-3 Projected (2025) Daily Traffic Volumes and Speeds

Road Segment	Projected Daily Vehicles (AADT)	Projected 18 Hour Traffic Volumes Between 6am and Midnight (94% of AADT)	% Heavy Vehicles	Proposed Speed
1	9128	8580	5 %	60 Km/h
2	8352	7851	5 %	60 Km/h
3	5459	5131	5 %	60 Km/h
4	1732	1628	5 %	60 Km/h
5	763	717	5 %	60 Km/h

5.3 Modelled Receivers

Locations of the modelled receivers and the modelled noise barriers are detailed in Appendix A.

5.4 Predicted Noise Levels

Modelled $L_{A10, 18hr}$ road traffic noise levels, without noise barriers, are presented for all modelled receivers in Appendix B The tables in Appendix B also include the required building envelope construction in accordance with AS 3671 for the "no barrier" scenario.

Appendix B also shows predicted $L_{A10, 18hr}$ road traffic noise levels with a 1.8 metre high noise barrier included as well as the associated building envelope construction in accordance with AS 3671.

Noise predictions in the form of noise contour maps are presented in Appendix C.

5.5 Result Overview

A review of the noise results outlined in Appendix B indicates that road traffic noise from Lee Point Road is not predicted to exceed the 58 dB(A) criteria at any of the modelled outdoor receivers whether the noise barriers are included or not. As such the predicted noise levels at the proposed sportsgrounds and playgrounds do not indicate that noise barriers are required for the Muirhead North development.

The predicted noise levels at the residential lots indicate that road traffic noise is not predicted to exceed the 63 dB(A) criteria at any of the receivers with or without the inclusion of noise barriers. As such the predicted noise levels at the proposed residential lots do not indicate that noise barriers are required for the Muirhead North development.

The results outlined in Appendix B indicate that road traffic noise at two of the proposed school buildings and the proposed community centre building is predicted to exceed the noise limit of 58 dB(A) for non-residential noise sensitive use. Without the provision of a 1.8 metre noise barrier between the school site and Lee Point Road 5 (2 ground floor and 3 first floor) exceedances are predicted. This number is reduced to 3 (1 ground floor and 2 first floor) with the inclusion of 1.8 metre high noise barriers located along the site boundary with Lee Point Road.

Noise modelling therefore indicates that the school buildings and the community centre building should be placed further away from Lee Point Road or that noise mitigation options, such as a noise barrier between the proposed school site and Lee Point Road, should be included in the design to allow compliance with the external noise limit of 58 dB(A) for non-residential noise sensitive use.

The noise contour maps show that noise levels of less than 58 dB(A) are predicted at distances in excess of approximately 50 metres from the Lee Point Road traffic corridor, without included noise amelioration. The noise contour maps also show that the inclusion of 1.8 metre high noise barriers provide a significant amount of noise reduction for ground floor levels. Therefore increased buffer distances between the proposed buildings and the road, or provision of a barrier, or both is recommended at this location.

The results indicate that all of the proposed residential lots will require building construction in accordance with either AS 3671 Category 1 or 2.The community centre building and the nearest school building will require building construction in accordance with AS 3671 Category 3 without the provision of a 1.8 metre high noise barrier. If a 1.8 metre high noise barrier is included along the site boundary, the Category 3 construction requirements are only applicable for the first floor levels of the two buildings.

6 Construction Noise Impact Assessment

6.1 Construction Noise Assessment Methodology

A preliminary assessment on the potential level of construction noise impact associated with construction of the development has been carried out to determine whether mitigation measures will be required, and to determine appropriate management controls.

Construction equipment requirements are not yet known. The type and number of plant and equipment associated with the proposed works was therefore assumed based upon experience from similar projects and the plant noise data provided in Australian Standard AS 2436:2010, "Acoustics – "Guide to Noise & Vibration Control on Construction, Demolition & Maintenance Sites". A more detailed assessment will be required as part of preparation of a Construction Noise & Vibration Management Plan once final construction staging detail becomes available during the next phase of the project.

The general construction phases for the project have been assumed based on similar previous projects. This has outlined that the following works, with the potential to generate significant noise, which are detailed below in Section 6.2.

6.2 Modelled Construction Phases

The following construction stages have been modelled:

Phase No.	Construction Phase Description
1	Clearing of Vegetation & Site Establishment
2	Bulk Earthworks
3	Drainage Infrastructure
4	Road Surfacing Works

To provide an indicative assessment of construction noise impact, a noise model was created for each of the above construction phases.

6.3 Noise Sensitive Areas

Noise modelling was conducted to determine the predicted level of noise impact at sensitive locations surrounding the project.

Works associated with the modelled stages will move around the project site, construction noise impacting on sensitive receivers will increase as the works is closer to them, and naturally decrease when works is far away. Construction works have therefore been modelled at four separate locations for each construction phase to provide a worst case predicted noise levels at four separate sensitive locations. Sensitive areas have been grouped into noise catchment areas as shown in Figure 1-1.

Noise contour maps showing the predicted noise levels for the modelled construction works are detailed in Appendix D.

6.4 Construction Timing

Some construction works are likely to be conducted outside of standard hours in addition to standard hours due to the tropical climate.

6.5 Construction Plant & Equipment

The construction plant included in the noise models are presented in Table 6-1. The equipment sound power levels were sourced from AS 2436 and Cardno's plant & equipment noise level library.

Table 6-1 Construction Plant Sound Power Levels

Plant	Number of Plant	Sound Power Level, L_{Aeq}, dB(A)
Scenario 1 – Clearing of Vegetation & Site Establishment	**Total L_{Aeq}** **Total L_{Amax}**	**121** **131**
Bulldozer D9	1	116
Excavator	2	110
Chainsaw	2	114
Tub Grinder / Mulcher	1	116
Dump Truck	4 per hour	110
Scenario 2 – Bulk Earthworks	**Total L_{Aeq}** **Total L_{Amax}**	**123** **133**
Bulldozer D9	1	116
Scraper 651	1	110
Excavator	1	110
Hydraulic Hammer	1	122
Grader	1	113
Dump Truck	8 per hour	110
Compactor	1	106
Roller	1	109
Water Cart	1	107
Scenario 3 – Drainage Infrastructure	**Total L_{Aeq}** **Total L_{Amax}**	**115** **116**
Backhoe	1	110
Franna Crane 20t	1	98
Excavator	1	110
Concrete Truck	4 per hour	109
Truck Compressor	1	75
Vibratory Roller	1	109
Road Truck	4 per hour	108
Scenario 4 – Road Surfacing Works	**Total L_{Aeq}** **Total L_{Amax}**	**118** **130**
Asphalt Paver	1	114
Concrete Truck	1	109
Kerb Extruder	1	107

Plant	Number of Plant	Sound Power Level, L_{Aeq}, dB(A)
Roller	1	107
Dump Truck	4 per hour	110
Asphalt Truck & Sprayer	1	103

6.6 Predicted Construction Noise Levels

The predicted noise impact from construction activities in the form of noise contour maps are presented in Appendix D. Predicted construction noise levels at each modelled receiver and scenario are shown below in Table 6-2 to Table 6-5.

The levels below represent the predicted noise impact when the construction plant is closest to each receiver and all plant is operating simultaneously thus providing a worst case scenario. A line Source has been used to model noise impact from works undertaken along Lee Point Road.

It should be noted that existing noise barriers as well as other natural noise screening topography has been included in the noise model, whereas proposed operational noise barriers and buildings have not been included. The predicted noise levels should therefore be considered as conservative. Noise levels as a result of construction activities are likely to be lower than these levels for most of the construction period.

Table 6-2 Predicted Construction Noise Levels – Clearing and Site Establishment

Receiver	Predicted Construction Noise Level, dB(A)	Predicted Maximum Construction Noise Level, dB(A)	Criteria, dB(A)		Predicted Worst Case Exceedance of Criteria, dB(A)	
	L_{Aeq}	L_{Amax}	L_{Aeq}	L_{Amax}	L_{Aeq}	L_{Amax}
Potential future dwellings at 2CRU	78	88	50	65	28	23
Lee Point Village Resort	94	104	50	65	44	39
Lyons Estate	63	71	50	65	13	6
Current dwellings at Muirhead Breezes Estate (June 2016)	64	73	50	65	14	8
Potential future dwellings at Muirhead Breezes Estate	94	104	50	65	44	39
Nature Reserve	79	89	50	65	29	24

Table 6-3 Predicted Construction Noise Levels – Bulk Earthworks

Receiver	Predicted Construction Noise Level, dB(A)	Predicted Maximum Construction Noise Level, dB(A)	Criteria, dB(A)		Predicted Worst Case Exceedance of Criteria, dB(A)	
	L_{Aeq}	L_{Amax}	L_{Aeq}	L_{Amax}	L_{Aeq}	L_{Amax}
Potential future dwellings at 2CRU	77	87	50	65	27	22
Lee Point Village Resort	89	99	50	65	39	34
Lyons Estate	73	83	50	65	23	18

Receiver	Predicted Construction Noise Level, dB(A)	Predicted Maximum Construction Noise Level, dB(A)	Criteria, dB(A)		Predicted Worst Case Exceedance of Criteria, dB(A)	
	L_{Aeq}	L_{Amax}	L_{Aeq}	L_{Amax}	L_{Aeq}	L_{Amax}
Current dwellings at Muirhead Breezes Estate (June 2016)	61	70	50	65	11	5
Potential future dwellings at Muirhead Breezes Estate	89	99	50	65	39	34
Nature Reserve	78	88	50	65	28	23

Table 6-4 Predicted Construction Noise Levels – Drainage Infrastructure

Receiver	Predicted Construction Noise Level, dB(A)	Predicted Maximum Construction Noise Level, dB(A)	Criteria, dB(A)		Predicted Worst Case Exceedance of Criteria, dB(A)	
	L_{Aeq}	L_{Amax}	L_{Aeq}	L_{Amax}	L_{Aeq}	L_{Amax}
Potential future dwellings at 2CRU	69	70	50	65	19	5
Lee Point Village Resort	84	84	50	65	34	19
Lyons Estate	65	66	50	65	15	1
Current dwellings at Muirhead Breezes Estate (June 2016)	53	53	50	65	3	-
Potential future dwellings at Muirhead Breezes Estate	84	84	50	65	34	19
Nature Reserve	72	73	50	65	22	8

Table 6-5 Predicted Construction Noise Levels – Road Surfacing Works

Receiver	Predicted Construction Noise Level, dB(A)	Predicted Maximum Construction Noise Level, dB(A)	Criteria, dB(A)		Predicted Worst Case Exceedance of Criteria, dB(A)	
	L_{Aeq}	L_{Amax}	L_{Aeq}	L_{Amax}	L_{Aeq}	L_{Amax}
Potential future dwellings at 2CRU	72	84	50	65	22	19
Lee Point Village Resort	83	95	50	65	33	30
Lyons Estate	68	80	50	65	18	15
Current dwellings at Muirhead Breezes Estate (June 2016)	56	67	50	65	6	2
Potential future dwellings at Muirhead Breezes Estate	83	95	50	65	33	30
Nature Reserve	74	86	50	65	24	21

6.7 Construction Noise Results Summary

6.7.1 Continuous Construction Noise

Construction noise levels are predicted to significantly exceed the design benchmark noise limits for worst case scenarios where work is conducted at the boundary of the development and during upgrade work of Lee Point Road. The exceedances are due to limited separation distance between the site and neighbouring receivers and the high noise levels typically generated by construction plant. However it is worth noting that the predicted construction noise levels only are applicable where work is conducted at locations in close vicinity to the affected receivers which will be for shorter durations only, as clearing of vegetation and general construction work will move around the development site as work progresses. The assessment also assumes that all the noisiest items of plant will be operating simultaneously which is not likely to occur often.

6.7.2 Sleep Disturbance

The most likely source of potential sleep disturbance from the night construction works will be from the use of pneumatic hammer/s or saw cutting during services relocation and/ or road pavement works or from truck movements on site, in particular the application of air brakes.

Maximum noise levels have been predicted to the nearest affected residential receivers to allow a review of the potential for sleep disturbance from construction activities at night. Noise levels have been calculated based on a worst case scenario when plant is located at the closest point to each receiver. On this basis, the results (L_{Amax}) summarised in Table 6-2 to Table 6-5 indicate that maximum construction noise levels at the nearest noise sensitive receivers are likely to exceed the sleep disturbance criteria, when construction works are located nearby. For this reason it is recommended that activities with potentially high maximum levels such as the use of pneumatic tools and truck air-braking are minimised or not operated at these locations during the night-time period.

If practical it is also recommended that the majority or road upgrade works occur before the neighbouring residential Lots are occupied.

7 Construction Vibration Assessment

7.1 Vibration Limits

Vibration from construction activities associated with the project could potentially impact on the amenity of the occupants of dwellings or buildings located close to the construction works. Generally, vibration impact can be summarised into two categories:

a Effect on human comfort; and

b Structural or cosmetic damage to buildings.

The CoP Volume 2 provides a section on the assessment of construction vibration from road projects. The criteria from this code of practice have been adopted for this assessment.

Vibration criteria for both human comfort and building damage due to ground borne vibration caused by construction activities (e.g. pile driving, compaction and blasting) are provided in section 4. It should be noted that compliance in most cases with the human comfort criteria would also achieve the building damage criteria.

The British Standard BS 5228-2:2009 provides an alternative approach to those historically used to assess human comfort presented in the British Standard BS 6472-1:2008. While BS 6472-1 provides guidance on human response to vibration in buildings in terms of VDV, BS 5228-2 Table B.1 provides guidance on the use of PPV which is typically measured to determine potential building damage.

For human comfort in order to minimise annoyance due to ground borne construction vibration, this Code adopts vibration levels with lower and upper limits as presented in Table 4-2. The low limits are generally considered to be just perceptible if just exceeded. The upper limits are considered to cause significant annoyance if exceeded.

All reasonable and practicable measures should be implemented to achieve the lower limit. Exceedance of the upper limit requires immediate action and extensive community consultation to determine further mitigation measures.

The criteria associated with building damage are summarised in Section 4, in Table 4-3 and Table 4-4.

7.1.1 Vibration Assessment

As proposed construction equipment and construction works has not been determined yet it is not possible to provide a specific minimum separation distance in metres. However Table 7-1 outlines recommended minimum separation distances between sensitive structures and typical vibration generating plant for probable construction areas.

Table 7-1 Recommended Minimum Working Distance

Receiver	Nearest Potential Construction Area	Distance to Nearest Sensitive Structure, metre	Maximum size of Vibratory Roller	Maximum size of Hydraulic Hammer
Potential future dwellings at 2CRU	Muirhead North Site and Lee Point Road Traffic Corridor	1.5	< 50 kN Typically 1-2 tonnes	300 kg - 5 to 12t excavator
Lee Point Village Resort	Muirhead North Site	1.5	< 50 kN Typically 1-2 tonnes	300 kg - 5 to 12t excavator
Lyons Estate	Muirhead North Site and Lee Point Road Traffic Corridor	15	< 300 kN Typically 7-13 tonnes	900 kg – 12 to 18t excavator
Current dwellings at Muirhead Breezes Estate (June 2016)	Muirhead North Site and Lee Point Road Traffic Corridor	50	> 300 kN > 18 tonnes	1600 kg – 18 to 34t excavator
Potential future dwellings at Muirhead Breezes Estate	Muirhead North Site and Lee Point Road Traffic Corridor	1.5	< 50 kN Typically 1-2 tonnes	300 kg - 5 to 12t excavator

8 Recommended Mitigation Measures

8.1 General Construction Noise & Vibration

The following best practice construction noise and vibration mitigation measures are based on recommendations provided within the QLD TMR CoP Volume 2 and Australian Standard AS 2436-1981: Guide to Noise Control on Construction, Maintenance and Demolition Sites. The following best practice measures apply to the proposed construction activities.

Construction noise and vibration should be minimised as far as is practically possible using methods such as:

- Development and implementation of all reasonable and feasible site specific mitigation measures to meet noise criteria applicable to the proposal in consultation with residents.
- Use of noise attenuating controls at the source, such as mufflers, acoustic screens, etc.
- Keeping plant and equipment well maintained.
- Locating static sources of noise such as the generators as remotely as possible from noise sensitive receivers.
- Developing proposed hours of operation in consultation with the residents / occupants of the affected receivers, and NT EPA with a view to minimising potential impacts as far as is practically feasible.
- Allowing construction to occur only during approved construction hours, unless otherwise required due to climatic conditions or safety requirements.
- Informing potentially affected receivers with adequate notice of the construction program and any planned activities that may exceed noise and vibration targets.
- Conducting noise monitoring during operations for the purposes of assisting in noise mitigation and to verify the findings of this noise assessment, if complaints are received or proposed activities and number of plant exceed those assumed in this assessment.
- Use of temporary noise barriers where practical.
- Application of respite periods for noisy activities.
- Use of broadband reversing alarms, or “quackers”, on mobile equipment in accordance with the relevant health and safety regulations.
- Modification of work activities where noise or vibration is found to cause unacceptable impact.
- Implementing a procedure for dealing with complaints to ensure that all complaints are registered and dealt with appropriately.

An operational Noise and Vibration Management Plan should be prepared for the project, to include, but not be limited to, the above measures.

8.2 Site Specific Measures

The following site specific mitigation measures are recommended:

8.2.1 Plant Controls

- Mulchers should be located away from noise sensitive receivers and used during daytime hours only, if practical.
- Reduce the number of plant operating at one time where works are required to be carried out outside of standard hours and close to existing sensitive receivers.
- Program the works to occur away from noise sensitive receivers and use temporary noise barriers, where night-works are required for climatic or safety reasons.

- Investigate whether “at plant” mitigation or muffled plant is available.
- Keep all plant and equipment well maintained.
- Use of broadband reversing alarms, or “quackers”, on mobile equipment in accordance with the relevant health and safety regulations.
- Preference should be for electric powered plant over combustion engine powered plant.
- Preference should be for hydraulic or electric powered plant over pneumatic powered plant.
- Avoid metal to metal contact on equipment to reduce impulsive or scraping noise.
- Avoid vibration intensive work at night to minimise the risk of sleep disturbance.

8.2.2 Manage of Hours of Operation

- Carrying out works within daytime hours as follows:
    - 7:00 am to 7:00 pm Monday to Saturday, 9:00 am to 6:00 pm on Sundays or public holidays.
- Do not carry out operations during evening or night-time hours, unless absolutely necessary due to climatic or safety reasons.
- Where evening or night-time hours cannot be avoided the following mitigation measures may be required;
    - Notification via letterbox or phone call
    - Provision of respite periods
    - Provision of alternative accommodation

8.2.3 Management and Behaviour Controls

- Ensure that managers effectively communicate acceptable and unacceptable work practices for the site, through staff site inductions, notice boards, and prestart meetings.
- Avoid the need for reversing in the construction area by creating a loop road or similar.
- Avoid dropping materials from height.
- Workers should avoid shouting, minimise talking loudly, and avoid slamming vehicle doors.

9 Conclusions

The following conclusions apply to this assessment:

9.1 Operational Road Traffic Noise Impacts

- Modelling indicates that the noise limit of $L_{A10, 18hour}$ 58 dB(A) is not predicted to be exceeded for outdoor free field receivers. As such, the predicted noise levels indicate that noise barriers between Lee Point Road and the development are not required to allow compliance with the noise limit for the proposed sportsgrounds and playgrounds.
- The predicted noise levels at the residential lots indicate that road traffic noise levels are not predicted to exceed the 63 dB(A) criteria, with no noise barriers. As such the predicted noise levels at the proposed residential lots indicate that noise barriers are not required for the Muirhead North development.
- The predicted noise levels at the proposed school buildings and proposed community centre indicate exceedances of the noise limit of $L_{A10, 18hour}$ 58 dB(A) for non-residential noise sensitive use. Without the provision of a 1.8 metre noise barrier between the school site and Lee Point Road 5 (2 ground floor and 3 first floor) exceedances are predicted. This number is reduced to 3 (1 ground floor and 2 first floor) with the inclusion of 1.8 metre high noise barriers located along the site boundary with Lee Point Road.
- Noise modelling therefore indicates that the school buildings and the community centre building should be placed further away from Lee Point Road or that noise mitigation options, such as provision of a noise barrier between the proposed school site and Lee Point Road, should be included in the design to allow compliance with the noise limit of 58 dB(A) for non-residential noise sensitive use.
- The noise contour maps show that noise levels of less than 58 dB(A) are predicted at distances in excess of approximately 50 metres from Lee Point Road, without included noise amelioration. The noise contour maps also show that the inclusion of 1.8 metre high noise barriers provide a significant amount of noise reduction for ground floor levels.
- The results indicate that all of the proposed residential lots will require building construction in accordance with either AS 3671 Category 1 or 2.
- The community centre building and the nearest school building will require building construction in accordance with AS 3671 Category 3 with no barriers. If the barrier is installed, the Category 3 construction requirements are only applicable for the first floor levels of the two buildings.
- Acoustic design principles should be taken into account during the final stage when considering overall layout and building orientation and shielding effects. Some principles to consider are listed below.
    - The building to be set back from the transport corridor as far as possible;
    - The building to shape away from the transport corridor;
    - The building to shield courtyards and open space areas from the corridor; and
- Noise sensitive spaces, such as bedrooms, should be shielded from noise by positioning less sensitive spaces, such as the garage, bathrooms and laundry, closer to the corridor.

9.2 Construction Noise Impacts

- Construction noise levels are predicted to exceed the design benchmark noise limits for worst case scenarios where work is conducted at the boundary of the development or where Lee Point Road is upgraded.
- The exceedances are due to limited separation distance between the site and neighbouring receivers and the high noise levels typically generated by construction plant. However it is worth noting that the predicted

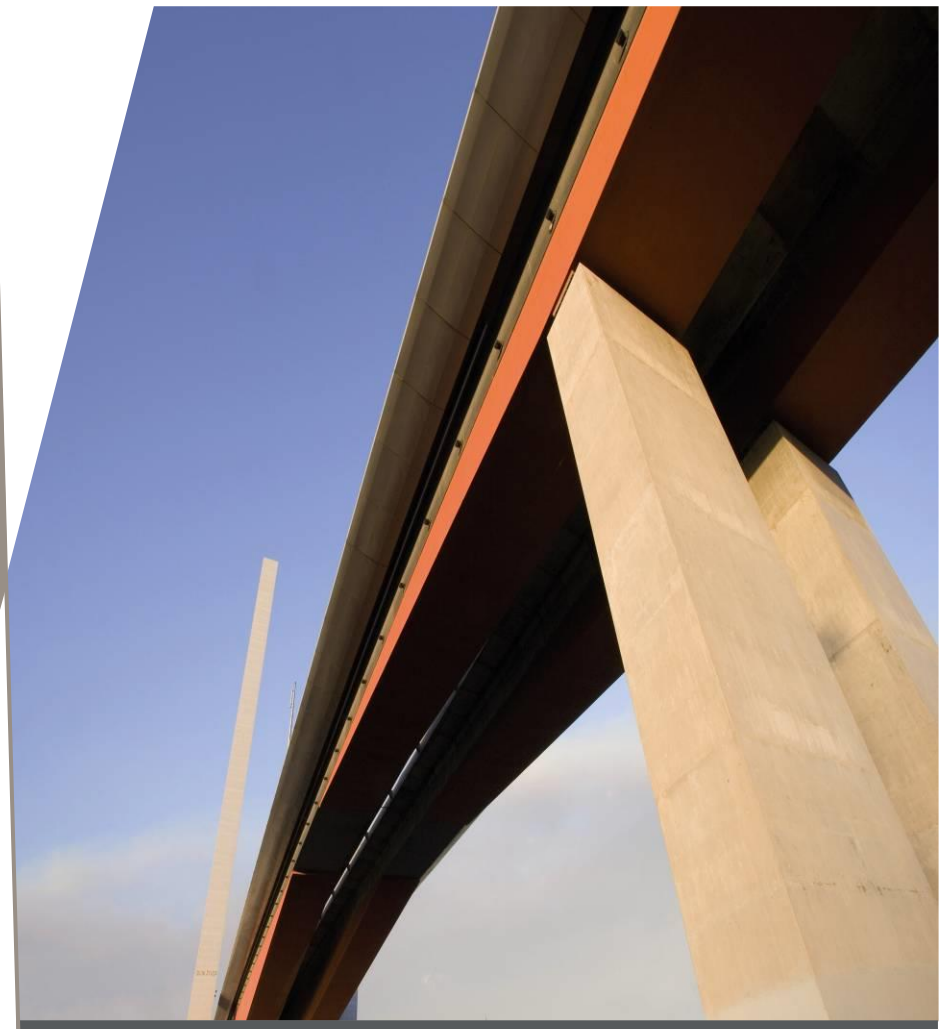
construction noise levels only are applicable where work is conducted at locations in close vicinity to the affected receivers which will be for shorter durations only, as clearing of vegetation and general construction work will move around the development site as work progresses.

- Maximum noise levels have been predicted to the nearest affected residential receivers to allow a review of the potential for sleep disturbance from construction activities at night. The results indicate that maximum construction noise levels at the nearest noise sensitive receivers are likely to exceed the sleep disturbance criteria, when construction works are located nearby. For this reason it is recommended that activities with potentially high maximum levels such as the use of pneumatic tools and truck air-braking are minimised or not carried out at these locations during the night-time period.
- It should be noted that this assessment has endeavoured to carry out "worst case" noise modelling, and noise levels are predicted based on a moving point source representative of the total construction noise level moving along the length of the project. Should the work sites or plant and equipment be relocated so that other receivers are located closer to the works, these receivers are likely to be affected more significantly than predicted in this report.
- The predicted exceedances are generally a result of works being located in close proximity to the adjacent receivers. This modelling has been carried out to provide a worst case scenario and it may be possible to reduce the number of plant operating simultaneously, particularly at night, once detailed construction schedules are known. This can be investigated further during preparation of the construction noise and vibration management plan for the project.
- Provision of temporary noise barriers is likely to be required between local construction sites and receivers, if night-time works are required near noise sensitive receivers.
- Best practice mitigation measures are recommended in Section 8 of this report.
- A detailed construction noise and vibration management plan should be prepared for the project prior to construction commencement to incorporate the recommendations detailed in Section 8 and updated to reflect the proposed staging and plant to be adopted for the project.

9.3 Construction Vibration Impacts

- Sensitive structures are located immediately adjacent to the Lee Point Road transport corridor indicating that consideration of vibration impacts will be required during the upgrade of the southern part of the transport corridor.
- Human discomfort may be felt should large vibratory rollers be used within 100 metres of nearby receivers. Therefore, vibratory rolling should only be carried out at night if the vibratory roller is rated less than 100 kN and the distance to vibration sensitive receivers is in excess of 20 metres to avoid the risk of human discomfort and sleep disturbance.
- A detailed construction noise and vibration management plan should be prepared for the project prior to construction commencement to incorporate the recommendations detailed in Section 8 and updated to reflect the proposed staging and plant to be adopted for the project.

Muirhead North Development, Darwin



APPENDIX A

MODELLED RECEIVERS AND NOISE BARRIERS WITHIN THE DEVELOPMENT

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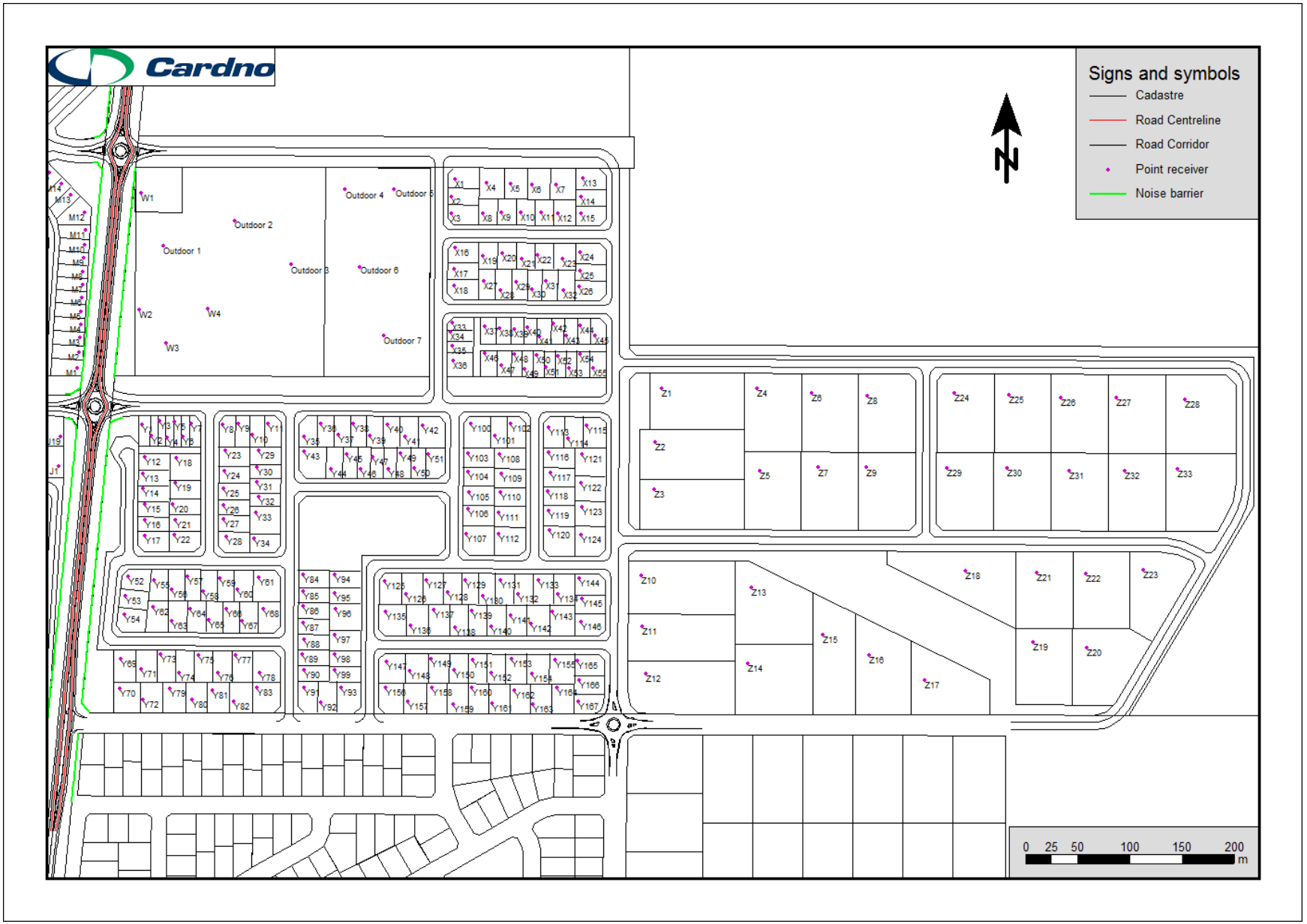
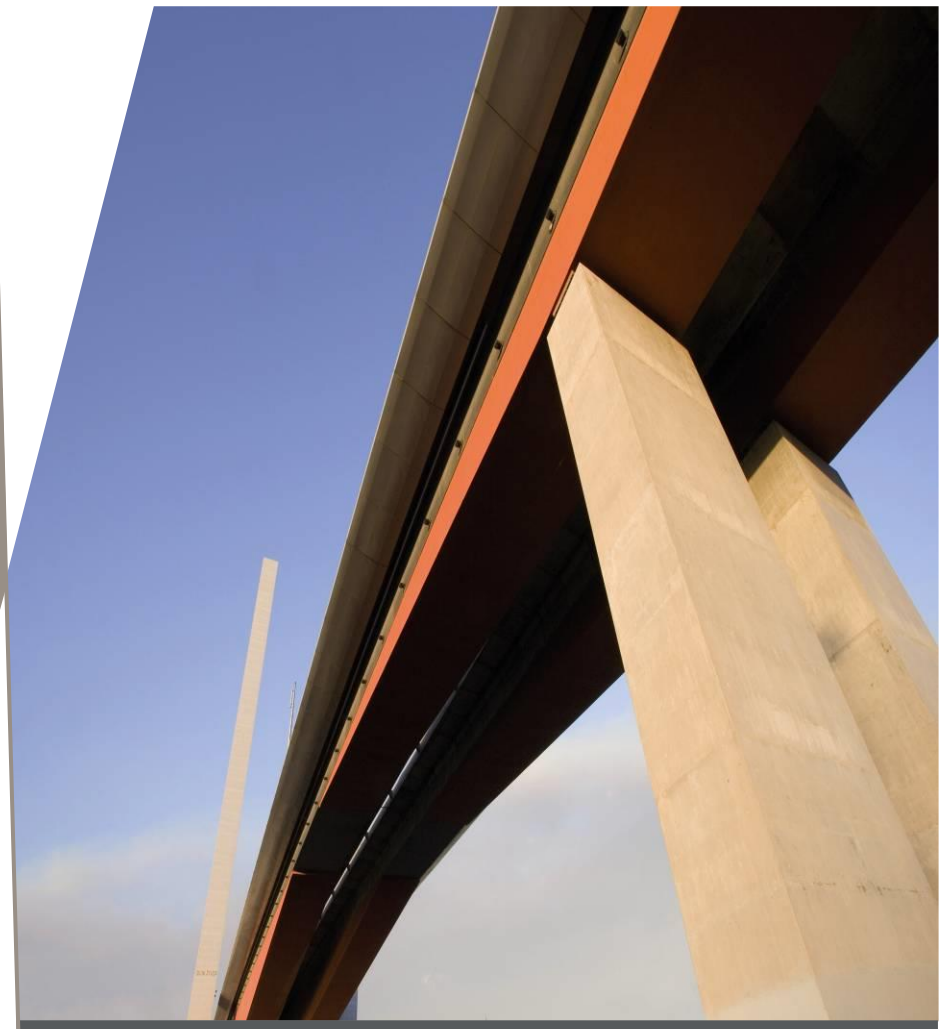
Figure A-1 Modelled Noise Sensitive Receivers and Modelled Noise Barrier Locations for Muirhead North.



Muirhead North Development, Darwin



APPENDIX B

PREDICTED NOISE LEVELS FOR MODELLED RECEIVERS IN THE DEVELOPMENT

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Table B-1 Predicted Noise Levels at the Facades of Potential Buildings for Year 2026 for the Muirhead North Development – with no Mitigation

Receiver	Floor	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance, $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance, $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq, 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq, 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
W1	Ground	63	63	-	58	5	57	30	27	3
W1	First	64	63	1	58	6	58	30	28	3
W2	Ground	61	63	-	58	3	55	30	25	2
W2	First	62	63	-	58	4	56	30	26	3
W3	Ground	57	63	-	58	-	51	30	21	2
W3	First	59	63	-	58	1	53	30	23	2
W4	Ground	54	63	-	58	-	48	30	18	2
W4	First	55	63	-	58	-	49	30	19	2
X1	Ground	47	63	-	58	-	41	30	11	2
X1	First	47	63	-	58	-	41	30	11	2
X2	Ground	47	63	-	58	-	41	30	11	2
X2	First	47	63	-	58	-	41	30	11	2
X3	Ground	47	63	-	58	-	41	30	11	2
X3	First	47	63	-	58	-	41	30	11	2
X4	Ground	46	63	-	58	-	40	30	10	1
X4	First	47	63	-	58	-	41	30	11	2
X5	Ground	45	63	-	58	-	39	30	9	1
X5	First	46	63	-	58	-	40	30	10	1
X6	Ground	45	63	-	58	-	39	30	9	1
X6	First	46	63	-	58	-	40	30	10	1
X7	Ground	45	63	-	58	-	39	30	9	1
X7	First	45	63	-	58	-	39	30	9	1
X8	Ground	46	63	-	58	-	40	30	10	1
X8	First	47	63	-	58	-	41	30	11	2
X9	Ground	46	63	-	58	-	40	30	10	1
X9	First	46	63	-	58	-	40	30	10	1
X10	Ground	45	63	-	58	-	39	30	9	1
X10	First	46	63	-	58	-	40	30	10	1
X11	Ground	45	63	-	58	-	39	30	9	1
X11	First	46	63	-	58	-	40	30	10	1
X12	Ground	45	63	-	58	-	39	30	9	1

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
X12	First	45	63	-	58	-	39	30	9	1
X13	Ground	45	63	-	58	-	39	30	9	1
X13	First	45	63	-	58	-	39	30	9	1
X14	Ground	45	63	-	58	-	39	30	9	1
X14	First	45	63	-	58	-	39	30	9	1
X15	Ground	45	63	-	58	-	39	30	9	1
X15	First	45	63	-	58	-	39	30	9	1
X16	Ground	47	63	-	58	-	41	30	11	2
X16	First	47	63	-	58	-	41	30	11	2
X17	Ground	47	63	-	58	-	41	30	11	2
X17	First	48	63	-	58	-	42	30	12	2
X18	Ground	47	63	-	58	-	41	30	11	2
X18	First	48	63	-	58	-	42	30	12	2
X19	Ground	46	63	-	58	-	40	30	10	1
X19	First	47	63	-	58	-	41	30	11	2
X20	Ground	46	63	-	58	-	40	30	10	1
X20	First	46	63	-	58	-	40	30	10	1
X21	Ground	46	63	-	58	-	40	30	10	1
X21	First	46	63	-	58	-	40	30	10	1
X22	Ground	45	63	-	58	-	39	30	9	1
X22	First	46	63	-	58	-	40	30	10	1
X23	Ground	45	63	-	58	-	39	30	9	1
X23	First	45	63	-	58	-	39	30	9	1
X24	Ground	45	63	-	58	-	39	30	9	1
X24	First	45	63	-	58	-	39	30	9	1
X25	Ground	45	63	-	58	-	39	30	9	1
X25	First	45	63	-	58	-	39	30	9	1
X26	Ground	45	63	-	58	-	39	30	9	1
X26	First	45	63	-	58	-	39	30	9	1
X27	Ground	46	63	-	58	-	40	30	10	1
X27	First	47	63	-	58	-	41	30	11	2
X28	Ground	46	63	-	58	-	40	30	10	1

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
X28	First	47	63	-	58	-	41	30	11	2
X29	Ground	46	63	-	58	-	40	30	10	1
X29	First	46	63	-	58	-	40	30	10	1
X30	Ground	45	63	-	58	-	39	30	9	1
X30	First	46	63	-	58	-	40	30	10	1
X31	Ground	45	63	-	58	-	39	30	9	1
X31	First	46	63	-	58	-	40	30	10	1
X32	Ground	45	63	-	58	-	39	30	9	1
X32	First	46	63	-	58	-	40	30	10	1
X33	Ground	47	63	-	58	-	41	30	11	2
X33	First	48	63	-	58	-	42	30	12	2
X34	Ground	47	63	-	58	-	41	30	11	2
X34	First	48	63	-	58	-	42	30	12	2
X35	Ground	47	63	-	58	-	41	30	11	2
X35	First	48	63	-	58	-	42	30	12	2
X36	Ground	47	63	-	58	-	41	30	11	2
X36	First	48	63	-	58	-	42	30	12	2
X37	Ground	47	63	-	58	-	41	30	11	2
X37	First	47	63	-	58	-	41	30	11	2
X38	Ground	46	63	-	58	-	40	30	10	1
X38	First	47	63	-	58	-	41	30	11	2
X39	Ground	46	63	-	58	-	40	30	10	1
X39	First	47	63	-	58	-	41	30	11	2
X40	Ground	46	63	-	58	-	40	30	10	1
X40	First	46	63	-	58	-	40	30	10	1
X41	Ground	46	63	-	58	-	40	30	10	1
X41	First	46	63	-	58	-	40	30	10	1
X42	Ground	45	63	-	58	-	39	30	9	1
X42	First	46	63	-	58	-	40	30	10	1
X43	Ground	45	63	-	58	-	39	30	9	1
X43	First	46	63	-	58	-	40	30	10	1
X44	Ground	45	63	-	58	-	39	30	9	1

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
X44	First	45	63	-	58	-	39	30	9	1
X45	Ground	45	63	-	58	-	39	30	9	1
X45	First	45	63	-	58	-	39	30	9	1
X46	Ground	46	63	-	58	-	40	30	10	1
X46	First	47	63	-	58	-	41	30	11	2
X47	Ground	46	63	-	58	-	40	30	10	1
X47	First	47	63	-	58	-	41	30	11	2
X48	Ground	46	63	-	58	-	40	30	10	1
X48	First	47	63	-	58	-	41	30	11	2
X49	Ground	46	63	-	58	-	40	30	10	1
X49	First	46	63	-	58	-	40	30	10	1
X50	Ground	46	63	-	58	-	40	30	10	1
X50	First	46	63	-	58	-	40	30	10	1
X51	Ground	45	63	-	58	-	39	30	9	1
X51	First	46	63	-	58	-	40	30	10	1
X52	Ground	45	63	-	58	-	39	30	9	1
X52	First	46	63	-	58	-	40	30	10	1
X53	Ground	45	63	-	58	-	39	30	9	1
X53	First	46	63	-	58	-	40	30	10	1
X54	Ground	45	63	-	58	-	39	30	9	1
X54	First	45	63	-	58	-	39	30	9	1
X55	Ground	45	63	-	58	-	39	30	9	1
X55	First	45	63	-	58	-	39	30	9	1
Y1	Ground	60	63	-	58	2	54	30	24	2
Y1	First	61	63	-	58	3	55	30	25	2
Y2	Ground	59	63	-	58	1	53	30	23	2
Y2	First	60	63	-	58	2	54	30	24	2
Y3	Ground	58	63	-	58	-	52	30	22	2
Y3	First	59	63	-	58	1	53	30	23	2
Y4	Ground	58	63	-	58	-	52	30	22	2
Y4	First	59	63	-	58	1	53	30	23	2
Y5	Ground	57	63	-	58	-	51	30	21	2

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y5	First	58	63	-	58	-	52	30	22	2
Y6	Ground	56	63	-	58	-	50	30	20	2
Y6	First	57	63	-	58	-	51	30	21	2
Y7	Ground	55	63	-	58	-	49	30	19	2
Y7	First	57	63	-	58	-	51	30	21	2
Y8	Ground	53	63	-	58	-	47	30	17	2
Y8	First	55	63	-	58	-	49	30	19	2
Y9	Ground	53	63	-	58	-	47	30	17	2
Y9	First	54	63	-	58	-	48	30	18	2
Y10	Ground	52	63	-	58	-	46	30	16	2
Y10	First	53	63	-	58	-	47	30	17	2
Y11	Ground	51	63	-	58	-	45	30	15	2
Y11	First	53	63	-	58	-	47	30	17	2
Y12	Ground	60	63	-	58	2	54	30	24	2
Y12	First	61	63	-	58	3	55	30	25	2
Y13	Ground	60	63	-	58	2	54	30	24	2
Y13	First	61	63	-	58	3	55	30	25	2
Y14	Ground	59	63	-	58	1	53	30	23	2
Y14	First	61	63	-	58	3	55	30	25	2
Y15	Ground	59	63	-	58	1	53	30	23	2
Y15	First	60	63	-	58	2	54	30	24	2
Y16	Ground	59	63	-	58	1	53	30	23	2
Y16	First	60	63	-	58	2	54	30	24	2
Y17	Ground	59	63	-	58	1	53	30	23	2
Y17	First	60	63	-	58	2	54	30	24	2
Y18	Ground	57	63	-	58	-	51	30	21	2
Y18	First	58	63	-	58	-	52	30	22	2
Y19	Ground	57	63	-	58	-	51	30	21	2
Y19	First	58	63	-	58	-	52	30	22	2
Y20	Ground	57	63	-	58	-	51	30	21	2
Y20	First	58	63	-	58	-	52	30	22	2
Y21	Ground	56	63	-	58	-	50	30	20	2

Receiver	Floor	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance, $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance, $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq, 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq, 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y21	First	58	63	-	58	-	52	30	22	2
Y22	Ground	56	63	-	58	-	50	30	20	2
Y22	First	57	63	-	58	-	51	30	21	2
Y23	Ground	53	63	-	58	-	47	30	17	2
Y23	First	55	63	-	58	-	49	30	19	2
Y24	Ground	54	63	-	58	-	48	30	18	2
Y24	First	55	63	-	58	-	49	30	19	2
Y25	Ground	54	63	-	58	-	48	30	18	2
Y25	First	55	63	-	58	-	49	30	19	2
Y26	Ground	54	63	-	58	-	48	30	18	2
Y26	First	55	63	-	58	-	49	30	19	2
Y27	Ground	53	63	-	58	-	47	30	17	2
Y27	First	55	63	-	58	-	49	30	19	2
Y28	Ground	53	63	-	58	-	47	30	17	2
Y28	First	54	63	-	58	-	48	30	18	2
Y29	Ground	52	63	-	58	-	46	30	16	2
Y29	First	53	63	-	58	-	47	30	17	2
Y30	Ground	52	63	-	58	-	46	30	16	2
Y30	First	53	63	-	58	-	47	30	17	2
Y31	Ground	52	63	-	58	-	46	30	16	2
Y31	First	53	63	-	58	-	47	30	17	2
Y32	Ground	52	63	-	58	-	46	30	16	2
Y32	First	53	63	-	58	-	47	30	17	2
Y33	Ground	52	63	-	58	-	46	30	16	2
Y33	First	53	63	-	58	-	47	30	17	2
Y34	Ground	52	63	-	58	-	46	30	16	2
Y34	First	53	63	-	58	-	47	30	17	2
Y35	Ground	50	63	-	58	-	44	30	14	2
Y35	First	51	63	-	58	-	45	30	15	2
Y36	Ground	50	63	-	58	-	44	30	14	2
Y36	First	51	63	-	58	-	45	30	15	2
Y37	Ground	50	63	-	58	-	44	30	14	2

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y37	First	50	63	-	58	-	44	30	14	2
Y38	Ground	49	63	-	58	-	43	30	13	2
Y38	First	50	63	-	58	-	44	30	14	2
Y39	Ground	49	63	-	58	-	43	30	13	2
Y39	First	50	63	-	58	-	44	30	14	2
Y40	Ground	49	63	-	58	-	43	30	13	2
Y40	First	49	63	-	58	-	43	30	13	2
Y41	Ground	48	63	-	58	-	42	30	12	2
Y41	First	49	63	-	58	-	43	30	13	2
Y42	Ground	48	63	-	58	-	42	30	12	2
Y42	First	48	63	-	58	-	42	30	12	2
Y43	Ground	51	63	-	58	-	45	30	15	2
Y43	First	52	63	-	58	-	46	30	16	2
Y44	Ground	50	63	-	58	-	44	30	14	2
Y44	First	51	63	-	58	-	45	30	15	2
Y45	Ground	49	63	-	58	-	43	30	13	2
Y45	First	50	63	-	58	-	44	30	14	2
Y46	Ground	49	63	-	58	-	43	30	13	2
Y46	First	50	63	-	58	-	44	30	14	2
Y47	Ground	49	63	-	58	-	43	30	13	2
Y47	First	50	63	-	58	-	44	30	14	2
Y48	Ground	49	63	-	58	-	43	30	13	2
Y48	First	49	63	-	58	-	43	30	13	2
Y49	Ground	48	63	-	58	-	42	30	12	2
Y49	First	49	63	-	58	-	43	30	13	2
Y50	Ground	48	63	-	58	-	42	30	12	2
Y50	First	49	63	-	58	-	43	30	13	2
Y51	Ground	48	63	-	58	-	42	30	12	2
Y51	First	48	63	-	58	-	42	30	12	2
Y52	Ground	60	63	-	58	2	54	30	24	2
Y52	First	61	63	-	58	3	55	30	25	2
Y53	Ground	60	63	-	58	2	54	30	24	2

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y53	First	61	63	-	58	3	55	30	25	2
Y54	Ground	60	63	-	58	2	54	30	24	2
Y54	First	61	63	-	58	3	55	30	25	2
Y55	Ground	57	63	-	58	-	51	30	21	2
Y55	First	59	63	-	58	1	53	30	23	2
Y56	Ground	56	63	-	58	-	50	30	20	2
Y56	First	57	63	-	58	-	51	30	21	2
Y57	Ground	55	63	-	58	-	49	30	19	2
Y57	First	56	63	-	58	-	50	30	20	2
Y58	Ground	54	63	-	58	-	48	30	18	2
Y58	First	55	63	-	58	-	49	30	19	2
Y59	Ground	53	63	-	58	-	47	30	17	2
Y59	First	55	63	-	58	-	49	30	19	2
Y60	Ground	53	63	-	58	-	47	30	17	2
Y60	First	54	63	-	58	-	48	30	18	2
Y61	Ground	52	63	-	58	-	46	30	16	2
Y61	First	53	63	-	58	-	47	30	17	2
Y62	Ground	56	63	-	58	-	50	30	20	2
Y62	First	58	63	-	58	-	52	30	22	2
Y63	Ground	55	63	-	58	-	49	30	19	2
Y63	First	57	63	-	58	-	51	30	21	2
Y64	Ground	55	63	-	58	-	49	30	19	2
Y64	First	56	63	-	58	-	50	30	20	2
Y65	Ground	54	63	-	58	-	48	30	18	2
Y65	First	55	63	-	58	-	49	30	19	2
Y66	Ground	53	63	-	58	-	47	30	17	2
Y66	First	54	63	-	58	-	48	30	18	2
Y67	Ground	52	63	-	58	-	46	30	16	2
Y67	First	53	63	-	58	-	47	30	17	2
Y68	Ground	52	63	-	58	-	46	30	16	2
Y68	First	53	63	-	58	-	47	30	17	2
Y69	Ground	59	63	-	58	1	53	30	23	2

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y69	First	61	63	-	58	3	55	30	25	2
Y70	Ground	59	63	-	58	1	53	30	23	2
Y70	First	61	63	-	58	3	55	30	25	2
Y71	Ground	57	63	-	58	-	51	30	21	2
Y71	First	59	63	-	58	1	53	30	23	2
Y72	Ground	57	63	-	58	-	51	30	21	2
Y72	First	58	63	-	58	-	52	30	22	2
Y73	Ground	56	63	-	58	-	50	30	20	2
Y73	First	57	63	-	58	-	51	30	21	2
Y74	Ground	55	63	-	58	-	49	30	19	2
Y74	First	56	63	-	58	-	50	30	20	2
Y75	Ground	54	63	-	58	-	48	30	18	2
Y75	First	55	63	-	58	-	49	30	19	2
Y76	Ground	52	63	-	58	-	46	30	16	2
Y76	First	54	63	-	58	-	48	30	18	2
Y77	Ground	52	63	-	58	-	46	30	16	2
Y77	First	53	63	-	58	-	47	30	17	2
Y78	Ground	51	63	-	58	-	45	30	15	2
Y78	First	52	63	-	58	-	46	30	16	2
Y79	Ground	55	63	-	58	-	49	30	19	2
Y79	First	56	63	-	58	-	50	30	20	2
Y80	Ground	53	63	-	58	-	47	30	17	2
Y80	First	54	63	-	58	-	48	30	18	2
Y81	Ground	53	63	-	58	-	47	30	17	2
Y81	First	54	63	-	58	-	48	30	18	2
Y82	Ground	52	63	-	58	-	46	30	16	2
Y82	First	53	63	-	58	-	47	30	17	2
Y83	Ground	51	63	-	58	-	45	30	15	2
Y83	First	52	63	-	58	-	46	30	16	2
Y84	Ground	51	63	-	58	-	45	30	15	2
Y84	First	51	63	-	58	-	45	30	15	2
Y85	Ground	51	63	-	58	-	45	30	15	2

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y85	First	51	63	-	58	-	45	30	15	2
Y86	Ground	51	63	-	58	-	45	30	15	2
Y86	First	51	63	-	58	-	45	30	15	2
Y87	Ground	51	63	-	58	-	45	30	15	2
Y87	First	51	63	-	58	-	45	30	15	2
Y88	Ground	50	63	-	58	-	44	30	14	2
Y88	First	51	63	-	58	-	45	30	15	2
Y89	Ground	50	63	-	58	-	44	30	14	2
Y89	First	51	63	-	58	-	45	30	15	2
Y90	Ground	50	63	-	58	-	44	30	14	2
Y90	First	51	63	-	58	-	45	30	15	2
Y91	Ground	50	63	-	58	-	44	30	14	2
Y91	First	51	63	-	58	-	45	30	15	2
Y92	Ground	50	63	-	58	-	44	30	14	2
Y92	First	50	63	-	58	-	44	30	14	2
Y93	Ground	49	63	-	58	-	43	30	13	2
Y93	First	50	63	-	58	-	44	30	14	2
Y94	Ground	50	63	-	58	-	44	30	14	2
Y94	First	51	63	-	58	-	45	30	15	2
Y95	Ground	50	63	-	58	-	44	30	14	2
Y95	First	51	63	-	58	-	45	30	15	2
Y96	Ground	50	63	-	58	-	44	30	14	2
Y96	First	51	63	-	58	-	45	30	15	2
Y97	Ground	50	63	-	58	-	44	30	14	2
Y97	First	50	63	-	58	-	44	30	14	2
Y98	Ground	50	63	-	58	-	44	30	14	2
Y98	First	50	63	-	58	-	44	30	14	2
Y99	Ground	50	63	-	58	-	44	30	14	2
Y99	First	50	63	-	58	-	44	30	14	2
Y100	Ground	47	63	-	58	-	41	30	11	2
Y100	First	48	63	-	58	-	42	30	12	2
Y101	Ground	46	63	-	58	-	40	30	10	1

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y101	First	47	63	-	58	-	41	30	11	2
Y102	Ground	46	63	-	58	-	40	30	10	1
Y102	First	47	63	-	58	-	41	30	11	2
Y103	Ground	47	63	-	58	-	41	30	11	2
Y103	First	47	63	-	58	-	41	30	11	2
Y104	Ground	47	63	-	58	-	41	30	11	2
Y104	First	47	63	-	58	-	41	30	11	2
Y105	Ground	46	63	-	58	-	40	30	10	1
Y105	First	47	63	-	58	-	41	30	11	2
Y106	Ground	47	63	-	58	-	41	30	11	2
Y106	First	47	63	-	58	-	41	30	11	2
Y107	Ground	47	63	-	58	-	41	30	11	2
Y107	First	47	63	-	58	-	41	30	11	2
Y108	Ground	46	63	-	58	-	40	30	10	1
Y108	First	47	63	-	58	-	41	30	11	2
Y109	Ground	46	63	-	58	-	40	30	10	1
Y109	First	47	63	-	58	-	41	30	11	2
Y110	Ground	46	63	-	58	-	40	30	10	1
Y110	First	47	63	-	58	-	41	30	11	2
Y111	Ground	46	63	-	58	-	40	30	10	1
Y111	First	47	63	-	58	-	41	30	11	2
Y112	Ground	46	63	-	58	-	40	30	10	1
Y112	First	47	63	-	58	-	41	30	11	2
Y113	Ground	45	63	-	58	-	39	30	9	1
Y113	First	46	63	-	58	-	40	30	10	1
Y114	Ground	45	63	-	58	-	39	30	9	1
Y114	First	46	63	-	58	-	40	30	10	1
Y115	Ground	45	63	-	58	-	39	30	9	1
Y115	First	45	63	-	58	-	39	30	9	1
Y116	Ground	45	63	-	58	-	39	30	9	1
Y116	First	46	63	-	58	-	40	30	10	1
Y117	Ground	45	63	-	58	-	39	30	9	1

Receiver	Floor	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance, $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance, $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq, 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq, 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y117	First	46	63	-	58	-	40	30	10	1
Y118	Ground	45	63	-	58	-	39	30	9	1
Y118	First	46	63	-	58	-	40	30	10	1
Y119	Ground	45	63	-	58	-	39	30	9	1
Y119	First	46	63	-	58	-	40	30	10	1
Y120	Ground	45	63	-	58	-	39	30	9	1
Y120	First	46	63	-	58	-	40	30	10	1
Y121	Ground	45	63	-	58	-	39	30	9	1
Y121	First	46	63	-	58	-	40	30	10	1
Y122	Ground	45	63	-	58	-	39	30	9	1
Y122	First	45	63	-	58	-	39	30	9	1
Y123	Ground	45	63	-	58	-	39	30	9	1
Y123	First	45	63	-	58	-	39	30	9	1
Y124	Ground	45	63	-	58	-	39	30	9	1
Y124	First	45	63	-	58	-	39	30	9	1
Y125	Ground	49	63	-	58	-	43	30	13	2
Y125	First	49	63	-	58	-	43	30	13	2
Y126	Ground	48	63	-	58	-	42	30	12	2
Y126	First	49	63	-	58	-	43	30	13	2
Y127	Ground	47	63	-	58	-	41	30	11	2
Y127	First	48	63	-	58	-	42	30	12	2
Y128	Ground	47	63	-	58	-	41	30	11	2
Y128	First	48	63	-	58	-	42	30	12	2
Y129	Ground	47	63	-	58	-	41	30	11	2
Y129	First	47	63	-	58	-	41	30	11	2
Y130	Ground	46	63	-	58	-	40	30	10	1
Y130	First	47	63	-	58	-	41	30	11	2
Y131	Ground	46	63	-	58	-	40	30	10	1
Y131	First	47	63	-	58	-	41	30	11	2
Y132	Ground	45	63	-	58	-	39	30	9	1
Y132	First	46	63	-	58	-	40	30	10	1
Y133	Ground	45	63	-	58	-	39	30	9	1

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y133	First	46	63	-	58	-	40	30	10	1
Y134	Ground	45	63	-	58	-	39	30	9	1
Y134	First	45	63	-	58	-	39	30	9	1
Y135	Ground	48	63	-	58	-	42	30	12	2
Y135	First	49	63	-	58	-	43	30	13	2
Y136	Ground	48	63	-	58	-	42	30	12	2
Y136	First	48	63	-	58	-	42	30	12	2
Y137	Ground	47	63	-	58	-	41	30	11	2
Y137	First	48	63	-	58	-	42	30	12	2
Y138	Ground	47	63	-	58	-	41	30	11	2
Y138	First	47	63	-	58	-	41	30	11	2
Y139	Ground	46	63	-	58	-	40	30	10	1
Y139	First	47	63	-	58	-	41	30	11	2
Y140	Ground	46	63	-	58	-	40	30	10	1
Y140	First	47	63	-	58	-	41	30	11	2
Y141	Ground	45	63	-	58	-	39	30	9	1
Y141	First	46	63	-	58	-	40	30	10	1
Y142	Ground	45	63	-	58	-	39	30	9	1
Y142	First	46	63	-	58	-	40	30	10	1
Y143	Ground	45	63	-	58	-	39	30	9	1
Y143	First	46	63	-	58	-	40	30	10	1
Y144	Ground	45	63	-	58	-	39	30	9	1
Y144	First	45	63	-	58	-	39	30	9	1
Y145	Ground	44	63	-	58	-	38	30	8	1
Y145	First	45	63	-	58	-	39	30	9	1
Y146	Ground	44	63	-	58	-	38	30	8	1
Y146	First	45	63	-	58	-	39	30	9	1
Y147	Ground	48	63	-	58	-	42	30	12	2
Y147	First	49	63	-	58	-	43	30	13	2
Y148	Ground	48	63	-	58	-	42	30	12	2
Y148	First	48	63	-	58	-	42	30	12	2
Y149	Ground	47	63	-	58	-	41	30	11	2

Receiver	Floor	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance, $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance, $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq, 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq, 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y149	First	48	63	-	58	-	42	30	12	2
Y150	Ground	46	63	-	58	-	40	30	10	1
Y150	First	47	63	-	58	-	41	30	11	2
Y151	Ground	46	63	-	58	-	40	30	10	1
Y151	First	47	63	-	58	-	41	30	11	2
Y152	Ground	46	63	-	58	-	40	30	10	1
Y152	First	46	63	-	58	-	40	30	10	1
Y153	Ground	45	63	-	58	-	39	30	9	1
Y153	First	46	63	-	58	-	40	30	10	1
Y154	Ground	45	63	-	58	-	39	30	9	1
Y154	First	45	63	-	58	-	39	30	9	1
Y155	Ground	44	63	-	58	-	38	30	8	1
Y155	First	45	63	-	58	-	39	30	9	1
Y156	Ground	48	63	-	58	-	42	30	12	2
Y156	First	49	63	-	58	-	43	30	13	2
Y157	Ground	48	63	-	58	-	42	30	12	2
Y157	First	48	63	-	58	-	42	30	12	2
Y158	Ground	47	63	-	58	-	41	30	11	2
Y158	First	48	63	-	58	-	42	30	12	2
Y159	Ground	46	63	-	58	-	40	30	10	1
Y159	First	47	63	-	58	-	41	30	11	2
Y160	Ground	46	63	-	58	-	40	30	10	1
Y160	First	47	63	-	58	-	41	30	11	2
Y161	Ground	45	63	-	58	-	39	30	9	1
Y161	First	46	63	-	58	-	40	30	10	1
Y162	Ground	45	63	-	58	-	39	30	9	1
Y162	First	46	63	-	58	-	40	30	10	1
Y163	Ground	45	63	-	58	-	39	30	9	1
Y163	First	45	63	-	58	-	39	30	9	1
Y164	Ground	44	63	-	58	-	38	30	8	1
Y164	First	45	63	-	58	-	39	30	9	1
Y165	Ground	44	63	-	58	-	38	30	8	1

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y165	First	45	63	-	58	-	39	30	9	1
Y166	Ground	44	63	-	58	-	38	30	8	1
Y166	First	45	63	-	58	-	39	30	9	1
Y167	Ground	44	63	-	58	-	38	30	8	1
Y167	First	45	63	-	58	-	39	30	9	1
Z1	Ground	44	63	-	58	-	38	30	8	1
Z1	First	44	63	-	58	-	38	30	8	1
Z2	Ground	44	63	-	58	-	38	30	8	1
Z2	First	44	63	-	58	-	38	30	8	1
Z3	Ground	44	63	-	58	-	38	30	8	1
Z3	First	44	63	-	58	-	38	30	8	1
Z4	Ground	42	63	-	58	-	36	30	6	1
Z4	First	43	63	-	58	-	37	30	7	1
Z5	Ground	42	63	-	58	-	36	30	6	1
Z5	First	43	63	-	58	-	37	30	7	1
Z6	Ground	42	63	-	58	-	36	30	6	1
Z6	First	42	63	-	58	-	36	30	6	1
Z7	Ground	42	63	-	58	-	36	30	6	1
Z7	First	42	63	-	58	-	36	30	6	1
Z8	Ground	41	63	-	58	-	35	30	5	1
Z8	First	42	63	-	58	-	36	30	6	1
Z9	Ground	41	63	-	58	-	35	30	5	1
Z9	First	42	63	-	58	-	36	30	6	1
Z10	Ground	44	63	-	58	-	38	30	8	1
Z10	First	44	63	-	58	-	38	30	8	1
Z11	Ground	44	63	-	58	-	38	30	8	1
Z11	First	44	63	-	58	-	38	30	8	1
Z12	Ground	43	63	-	58	-	37	30	7	1
Z12	First	44	63	-	58	-	38	30	8	1
Z13	Ground	42	63	-	58	-	36	30	6	1
Z13	First	43	63	-	58	-	37	30	7	1
Z14	Ground	42	63	-	58	-	36	30	6	1

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Z14	First	43	63	-	58	-	37	30	7	1
Z15	Ground	41	63	-	58	-	35	30	5	1
Z15	First	42	63	-	58	-	36	30	6	1
Z16	Ground	41	63	-	58	-	35	30	5	1
Z16	First	41	63	-	58	-	35	30	5	1
Z17	Ground	40	63	-	58	-	34	30	4	1
Z17	First	41	63	-	58	-	35	30	5	1
Z18	Ground	40	63	-	58	-	34	30	4	1
Z18	First	40	63	-	58	-	34	30	4	1
Z19	Ground	39	63	-	58	-	33	30	3	1
Z19	First	40	63	-	58	-	34	30	4	1
Z20	Ground	39	63	-	58	-	33	30	3	1
Z20	First	39	63	-	58	-	33	30	3	1
Z21	Ground	39	63	-	58	-	33	30	3	1
Z21	First	40	63	-	58	-	34	30	4	1
Z22	Ground	39	63	-	58	-	33	30	3	1
Z22	First	39	63	-	58	-	33	30	3	1
Z23	Ground	39	63	-	58	-	33	30	3	1
Z23	First	39	63	-	58	-	33	30	3	1
Z24	Ground	40	63	-	58	-	34	30	4	1
Z24	First	41	63	-	58	-	35	30	5	1
Z25	Ground	40	63	-	58	-	34	30	4	1
Z25	First	40	63	-	58	-	34	30	4	1
Z26	Ground	39	63	-	58	-	33	30	3	1
Z26	First	40	63	-	58	-	34	30	4	1
Z27	Ground	39	63	-	58	-	33	30	3	1
Z27	First	39	63	-	58	-	33	30	3	1
Z28	Ground	38	63	-	58	-	32	30	2	1
Z28	First	39	63	-	58	-	33	30	3	1
Z29	Ground	40	63	-	58	-	34	30	4	1
Z29	First	41	63	-	58	-	35	30	5	1
Z30	Ground	40	63	-	58	-	34	30	4	1

Receiver	Floor	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance, $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance, $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq, 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq, 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Z30	First	40	63	-	58	-	34	30	4	1
Z31	Ground	39	63	-	58	-	33	30	3	1
Z31	First	40	63	-	58	-	34	30	4	1
Z32	Ground	39	63	-	58	-	33	30	3	1
Z32	First	39	63	-	58	-	33	30	3	1
Z33	Ground	38	63	-	58	-	32	30	2	1
Z33	First	39	63	-	58	-	33	30	3	1

Number of Ground Floor exceedances	**-**	**15**	**Number of AS3671 Category 1 – Ground Floor**	**125**
Number of First Floor exceedances	**1**	**20**	**Number of AS3671 Category 1 – First Floor**	**99**
			Number of AS3671 Category 2 – Ground Floor	**133**
			Number of AS3671 Category 2 – First Floor	**158**
			Number of AS3671 Category 3 – Ground Floor	**1**
			Number of AS3671 Category 3 – First Floor	**2**

Table B-2 Predicted Noise Levels at the Facades of Potential Buildings for Year 2026 for the Muirhead North Development – with 1.8 Metre Barriers

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
W1	Ground	59	63	-	58	1	53	30	23	2
W1	First	64	63	1	58	6	58	30	28	3
W2	Ground	57	63	-	58	-	51	30	21	2
W2	First	62	63	-	58	4	56	30	26	3
W3	Ground	55	63	-	58	-	49	30	19	2
W3	First	57	63	-	58	-	51	30	21	2
W4	Ground	52	63	-	58	-	46	30	16	2
W4	First	53	63	-	58	-	47	30	17	2
X1	Ground	44	63	-	58	-	38	30	8	1
X1	First	45	63	-	58	-	39	30	9	1
X2	Ground	45	63	-	58	-	39	30	9	1
X2	First	45	63	-	58	-	39	30	9	1
X3	Ground	45	63	-	58	-	39	30	9	1
X3	First	45	63	-	58	-	39	30	9	1
X4	Ground	44	63	-	58	-	38	30	8	1
X4	First	44	63	-	58	-	38	30	8	1
X5	Ground	43	63	-	58	-	37	30	7	1
X5	First	44	63	-	58	-	38	30	8	1
X6	Ground	43	63	-	58	-	37	30	7	1
X6	First	44	63	-	58	-	38	30	8	1
X7	Ground	43	63	-	58	-	37	30	7	1
X7	First	43	63	-	58	-	37	30	7	1
X8	Ground	44	63	-	58	-	38	30	8	1
X8	First	44	63	-	58	-	38	30	8	1
X9	Ground	44	63	-	58	-	38	30	8	1
X9	First	44	63	-	58	-	38	30	8	1
X10	Ground	43	63	-	58	-	37	30	7	1
X10	First	44	63	-	58	-	38	30	8	1
X11	Ground	43	63	-	58	-	37	30	7	1
X11	First	43	63	-	58	-	37	30	7	1
X12	Ground	43	63	-	58	-	37	30	7	1

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
X12	First	43	63	-	58	-	37	30	7	1
X13	Ground	42	63	-	58	-	36	30	6	1
X13	First	43	63	-	58	-	37	30	7	1
X14	Ground	42	63	-	58	-	36	30	6	1
X14	First	43	63	-	58	-	37	30	7	1
X15	Ground	42	63	-	58	-	36	30	6	1
X15	First	43	63	-	58	-	37	30	7	1
X16	Ground	45	63	-	58	-	39	30	9	1
X16	First	45	63	-	58	-	39	30	9	1
X17	Ground	45	63	-	58	-	39	30	9	1
X17	First	45	63	-	58	-	39	30	9	1
X18	Ground	45	63	-	58	-	39	30	9	1
X18	First	45	63	-	58	-	39	30	9	1
X19	Ground	44	63	-	58	-	38	30	8	1
X19	First	45	63	-	58	-	39	30	9	1
X20	Ground	44	63	-	58	-	38	30	8	1
X20	First	44	63	-	58	-	38	30	8	1
X21	Ground	43	63	-	58	-	37	30	7	1
X21	First	44	63	-	58	-	38	30	8	1
X22	Ground	43	63	-	58	-	37	30	7	1
X22	First	44	63	-	58	-	38	30	8	1
X23	Ground	43	63	-	58	-	37	30	7	1
X23	First	43	63	-	58	-	37	30	7	1
X24	Ground	43	63	-	58	-	37	30	7	1
X24	First	43	63	-	58	-	37	30	7	1
X25	Ground	43	63	-	58	-	37	30	7	1
X25	First	43	63	-	58	-	37	30	7	1
X26	Ground	43	63	-	58	-	37	30	7	1
X26	First	43	63	-	58	-	37	30	7	1
X27	Ground	44	63	-	58	-	38	30	8	1
X27	First	45	63	-	58	-	39	30	9	1
X28	Ground	44	63	-	58	-	38	30	8	1

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
X28	First	44	63	-	58	-	38	30	8	1
X29	Ground	44	63	-	58	-	38	30	8	1
X29	First	44	63	-	58	-	38	30	8	1
X30	Ground	43	63	-	58	-	37	30	7	1
X30	First	44	63	-	58	-	38	30	8	1
X31	Ground	43	63	-	58	-	37	30	7	1
X31	First	43	63	-	58	-	37	30	7	1
X32	Ground	43	63	-	58	-	37	30	7	1
X32	First	43	63	-	58	-	37	30	7	1
X33	Ground	45	63	-	58	-	39	30	9	1
X33	First	45	63	-	58	-	39	30	9	1
X34	Ground	45	63	-	58	-	39	30	9	1
X34	First	45	63	-	58	-	39	30	9	1
X35	Ground	45	63	-	58	-	39	30	9	1
X35	First	45	63	-	58	-	39	30	9	1
X36	Ground	45	63	-	58	-	39	30	9	1
X36	First	45	63	-	58	-	39	30	9	1
X37	Ground	44	63	-	58	-	38	30	8	1
X37	First	44	63	-	58	-	38	30	8	1
X38	Ground	44	63	-	58	-	38	30	8	1
X38	First	44	63	-	58	-	38	30	8	1
X39	Ground	44	63	-	58	-	38	30	8	1
X39	First	44	63	-	58	-	38	30	8	1
X40	Ground	43	63	-	58	-	37	30	7	1
X40	First	44	63	-	58	-	38	30	8	1
X41	Ground	43	63	-	58	-	37	30	7	1
X41	First	44	63	-	58	-	38	30	8	1
X42	Ground	43	63	-	58	-	37	30	7	1
X42	First	43	63	-	58	-	37	30	7	1
X43	Ground	43	63	-	58	-	37	30	7	1
X43	First	43	63	-	58	-	37	30	7	1
X44	Ground	43	63	-	58	-	37	30	7	1

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
X44	First	43	63	-	58	-	37	30	7	1
X45	Ground	42	63	-	58	-	36	30	6	1
X45	First	43	63	-	58	-	37	30	7	1
X46	Ground	44	63	-	58	-	38	30	8	1
X46	First	44	63	-	58	-	38	30	8	1
X47	Ground	44	63	-	58	-	38	30	8	1
X47	First	44	63	-	58	-	38	30	8	1
X48	Ground	44	63	-	58	-	38	30	8	1
X48	First	44	63	-	58	-	38	30	8	1
X49	Ground	44	63	-	58	-	38	30	8	1
X49	First	44	63	-	58	-	38	30	8	1
X50	Ground	43	63	-	58	-	37	30	7	1
X50	First	44	63	-	58	-	38	30	8	1
X51	Ground	43	63	-	58	-	37	30	7	1
X51	First	44	63	-	58	-	38	30	8	1
X52	Ground	43	63	-	58	-	37	30	7	1
X52	First	43	63	-	58	-	37	30	7	1
X53	Ground	43	63	-	58	-	37	30	7	1
X53	First	43	63	-	58	-	37	30	7	1
X54	Ground	43	63	-	58	-	37	30	7	1
X54	First	43	63	-	58	-	37	30	7	1
X55	Ground	42	63	-	58	-	36	30	6	1
X55	First	43	63	-	58	-	37	30	7	1
Y1	Ground	57	63	-	58	-	51	30	21	2
Y1	First	60	63	-	58	2	54	30	24	2
Y2	Ground	56	63	-	58	-	50	30	20	2
Y2	First	58	63	-	58	-	52	30	22	2
Y3	Ground	56	63	-	58	-	50	30	20	2
Y3	First	57	63	-	58	-	51	30	21	2
Y4	Ground	55	63	-	58	-	49	30	19	2
Y4	First	56	63	-	58	-	50	30	20	2
Y5	Ground	54	63	-	58	-	48	30	18	2

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y5	First	56	63	-	58	-	50	30	20	2
Y6	Ground	53	63	-	58	-	47	30	17	2
Y6	First	55	63	-	58	-	49	30	19	2
Y7	Ground	53	63	-	58	-	47	30	17	2
Y7	First	54	63	-	58	-	48	30	18	2
Y8	Ground	51	63	-	58	-	45	30	15	2
Y8	First	52	63	-	58	-	46	30	16	2
Y9	Ground	51	63	-	58	-	45	30	15	2
Y9	First	51	63	-	58	-	45	30	15	2
Y10	Ground	50	63	-	58	-	44	30	14	2
Y10	First	51	63	-	58	-	45	30	15	2
Y11	Ground	49	63	-	58	-	43	30	13	2
Y11	First	50	63	-	58	-	44	30	14	2
Y12	Ground	56	63	-	58	-	50	30	20	2
Y12	First	59	63	-	58	1	53	30	23	2
Y13	Ground	56	63	-	58	-	50	30	20	2
Y13	First	59	63	-	58	1	53	30	23	2
Y14	Ground	55	63	-	58	-	49	30	19	2
Y14	First	58	63	-	58	-	52	30	22	2
Y15	Ground	55	63	-	58	-	49	30	19	2
Y15	First	58	63	-	58	-	52	30	22	2
Y16	Ground	55	63	-	58	-	49	30	19	2
Y16	First	58	63	-	58	-	52	30	22	2
Y17	Ground	55	63	-	58	-	49	30	19	2
Y17	First	57	63	-	58	-	51	30	21	2
Y18	Ground	54	63	-	58	-	48	30	18	2
Y18	First	55	63	-	58	-	49	30	19	2
Y19	Ground	53	63	-	58	-	47	30	17	2
Y19	First	55	63	-	58	-	49	30	19	2
Y20	Ground	53	63	-	58	-	47	30	17	2
Y20	First	55	63	-	58	-	49	30	19	2
Y21	Ground	53	63	-	58	-	47	30	17	2

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y21	First	55	63	-	58	-	49	30	19	2
Y22	Ground	53	63	-	58	-	47	30	17	2
Y22	First	54	63	-	58	-	48	30	18	2
Y23	Ground	51	63	-	58	-	45	30	15	2
Y23	First	52	63	-	58	-	46	30	16	2
Y24	Ground	51	63	-	58	-	45	30	15	2
Y24	First	52	63	-	58	-	46	30	16	2
Y25	Ground	51	63	-	58	-	45	30	15	2
Y25	First	52	63	-	58	-	46	30	16	2
Y26	Ground	51	63	-	58	-	45	30	15	2
Y26	First	52	63	-	58	-	46	30	16	2
Y27	Ground	51	63	-	58	-	45	30	15	2
Y27	First	52	63	-	58	-	46	30	16	2
Y28	Ground	51	63	-	58	-	45	30	15	2
Y28	First	52	63	-	58	-	46	30	16	2
Y29	Ground	50	63	-	58	-	44	30	14	2
Y29	First	50	63	-	58	-	44	30	14	2
Y30	Ground	50	63	-	58	-	44	30	14	2
Y30	First	51	63	-	58	-	45	30	15	2
Y31	Ground	50	63	-	58	-	44	30	14	2
Y31	First	50	63	-	58	-	44	30	14	2
Y32	Ground	50	63	-	58	-	44	30	14	2
Y32	First	50	63	-	58	-	44	30	14	2
Y33	Ground	50	63	-	58	-	44	30	14	2
Y33	First	50	63	-	58	-	44	30	14	2
Y34	Ground	50	63	-	58	-	44	30	14	2
Y34	First	50	63	-	58	-	44	30	14	2
Y35	Ground	48	63	-	58	-	42	30	12	2
Y35	First	49	63	-	58	-	43	30	13	2
Y36	Ground	48	63	-	58	-	42	30	12	2
Y36	First	49	63	-	58	-	43	30	13	2
Y37	Ground	47	63	-	58	-	41	30	11	2

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y37	First	48	63	-	58	-	42	30	12	2
Y38	Ground	47	63	-	58	-	41	30	11	2
Y38	First	48	63	-	58	-	42	30	12	2
Y39	Ground	47	63	-	58	-	41	30	11	2
Y39	First	47	63	-	58	-	41	30	11	2
Y40	Ground	46	63	-	58	-	40	30	10	1
Y40	First	47	63	-	58	-	41	30	11	2
Y41	Ground	46	63	-	58	-	40	30	10	1
Y41	First	47	63	-	58	-	41	30	11	2
Y42	Ground	45	63	-	58	-	39	30	9	1
Y42	First	46	63	-	58	-	40	30	10	1
Y43	Ground	48	63	-	58	-	42	30	12	2
Y43	First	49	63	-	58	-	43	30	13	2
Y44	Ground	48	63	-	58	-	42	30	12	2
Y44	First	48	63	-	58	-	42	30	12	2
Y45	Ground	47	63	-	58	-	41	30	11	2
Y45	First	48	63	-	58	-	42	30	12	2
Y46	Ground	47	63	-	58	-	41	30	11	2
Y46	First	48	63	-	58	-	42	30	12	2
Y47	Ground	47	63	-	58	-	41	30	11	2
Y47	First	47	63	-	58	-	41	30	11	2
Y48	Ground	47	63	-	58	-	41	30	11	2
Y48	First	47	63	-	58	-	41	30	11	2
Y49	Ground	46	63	-	58	-	40	30	10	1
Y49	First	47	63	-	58	-	41	30	11	2
Y50	Ground	46	63	-	58	-	40	30	10	1
Y50	First	46	63	-	58	-	40	30	10	1
Y51	Ground	45	63	-	58	-	39	30	9	1
Y51	First	46	63	-	58	-	40	30	10	1
Y52	Ground	56	63	-	58	-	50	30	20	2
Y52	First	59	63	-	58	1	53	30	23	2
Y53	Ground	56	63	-	58	-	50	30	20	2

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y53	First	59	63	-	58	1	53	30	23	2
Y54	Ground	56	63	-	58	-	50	30	20	2
Y54	First	59	63	-	58	1	53	30	23	2
Y55	Ground	54	63	-	58	-	48	30	18	2
Y55	First	56	63	-	58	-	50	30	20	2
Y56	Ground	53	63	-	58	-	47	30	17	2
Y56	First	54	63	-	58	-	48	30	18	2
Y57	Ground	52	63	-	58	-	46	30	16	2
Y57	First	53	63	-	58	-	47	30	17	2
Y58	Ground	51	63	-	58	-	45	30	15	2
Y58	First	52	63	-	58	-	46	30	16	2
Y59	Ground	51	63	-	58	-	45	30	15	2
Y59	First	52	63	-	58	-	46	30	16	2
Y60	Ground	50	63	-	58	-	44	30	14	2
Y60	First	51	63	-	58	-	45	30	15	2
Y61	Ground	50	63	-	58	-	44	30	14	2
Y61	First	50	63	-	58	-	44	30	14	2
Y62	Ground	53	63	-	58	-	47	30	17	2
Y62	First	55	63	-	58	-	49	30	19	2
Y63	Ground	52	63	-	58	-	46	30	16	2
Y63	First	54	63	-	58	-	48	30	18	2
Y64	Ground	52	63	-	58	-	46	30	16	2
Y64	First	53	63	-	58	-	47	30	17	2
Y65	Ground	51	63	-	58	-	45	30	15	2
Y65	First	52	63	-	58	-	46	30	16	2
Y66	Ground	50	63	-	58	-	44	30	14	2
Y66	First	51	63	-	58	-	45	30	15	2
Y67	Ground	50	63	-	58	-	44	30	14	2
Y67	First	50	63	-	58	-	44	30	14	2
Y68	Ground	49	63	-	58	-	43	30	13	2
Y68	First	50	63	-	58	-	44	30	14	2
Y69	Ground	55	63	-	58	-	49	30	19	2

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y69	First	58	63	-	58	-	52	30	22	2
Y70	Ground	56	63	-	58	-	50	30	20	2
Y70	First	58	63	-	58	-	52	30	22	2
Y71	Ground	54	63	-	58	-	48	30	18	2
Y71	First	55	63	-	58	-	49	30	19	2
Y72	Ground	54	63	-	58	-	48	30	18	2
Y72	First	55	63	-	58	-	49	30	19	2
Y73	Ground	53	63	-	58	-	47	30	17	2
Y73	First	54	63	-	58	-	48	30	18	2
Y74	Ground	52	63	-	58	-	46	30	16	2
Y74	First	53	63	-	58	-	47	30	17	2
Y75	Ground	51	63	-	58	-	45	30	15	2
Y75	First	52	63	-	58	-	46	30	16	2
Y76	Ground	50	63	-	58	-	44	30	14	2
Y76	First	51	63	-	58	-	45	30	15	2
Y77	Ground	50	63	-	58	-	44	30	14	2
Y77	First	50	63	-	58	-	44	30	14	2
Y78	Ground	49	63	-	58	-	43	30	13	2
Y78	First	50	63	-	58	-	44	30	14	2
Y79	Ground	52	63	-	58	-	46	30	16	2
Y79	First	54	63	-	58	-	48	30	18	2
Y80	Ground	51	63	-	58	-	45	30	15	2
Y80	First	52	63	-	58	-	46	30	16	2
Y81	Ground	50	63	-	58	-	44	30	14	2
Y81	First	51	63	-	58	-	45	30	15	2
Y82	Ground	50	63	-	58	-	44	30	14	2
Y82	First	50	63	-	58	-	44	30	14	2
Y83	Ground	49	63	-	58	-	43	30	13	2
Y83	First	50	63	-	58	-	44	30	14	2
Y84	Ground	48	63	-	58	-	42	30	12	2
Y84	First	49	63	-	58	-	43	30	13	2
Y85	Ground	48	63	-	58	-	42	30	12	2

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y85	First	49	63	-	58	-	43	30	13	2
Y86	Ground	48	63	-	58	-	42	30	12	2
Y86	First	49	63	-	58	-	43	30	13	2
Y87	Ground	48	63	-	58	-	42	30	12	2
Y87	First	49	63	-	58	-	43	30	13	2
Y88	Ground	48	63	-	58	-	42	30	12	2
Y88	First	49	63	-	58	-	43	30	13	2
Y89	Ground	48	63	-	58	-	42	30	12	2
Y89	First	49	63	-	58	-	43	30	13	2
Y90	Ground	48	63	-	58	-	42	30	12	2
Y90	First	48	63	-	58	-	42	30	12	2
Y91	Ground	48	63	-	58	-	42	30	12	2
Y91	First	48	63	-	58	-	42	30	12	2
Y92	Ground	47	63	-	58	-	41	30	11	2
Y92	First	48	63	-	58	-	42	30	12	2
Y93	Ground	47	63	-	58	-	41	30	11	2
Y93	First	48	63	-	58	-	42	30	12	2
Y94	Ground	48	63	-	58	-	42	30	12	2
Y94	First	48	63	-	58	-	42	30	12	2
Y95	Ground	48	63	-	58	-	42	30	12	2
Y95	First	48	63	-	58	-	42	30	12	2
Y96	Ground	48	63	-	58	-	42	30	12	2
Y96	First	48	63	-	58	-	42	30	12	2
Y97	Ground	47	63	-	58	-	41	30	11	2
Y97	First	48	63	-	58	-	42	30	12	2
Y98	Ground	47	63	-	58	-	41	30	11	2
Y98	First	48	63	-	58	-	42	30	12	2
Y99	Ground	47	63	-	58	-	41	30	11	2
Y99	First	48	63	-	58	-	42	30	12	2
Y100	Ground	44	63	-	58	-	38	30	8	1
Y100	First	45	63	-	58	-	39	30	9	1
Y101	Ground	44	63	-	58	-	38	30	8	1

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y101	First	44	63	-	58	-	38	30	8	1
Y102	Ground	44	63	-	58	-	38	30	8	1
Y102	First	44	63	-	58	-	38	30	8	1
Y103	Ground	44	63	-	58	-	38	30	8	1
Y103	First	45	63	-	58	-	39	30	9	1
Y104	Ground	44	63	-	58	-	38	30	8	1
Y104	First	45	63	-	58	-	39	30	9	1
Y105	Ground	44	63	-	58	-	38	30	8	1
Y105	First	45	63	-	58	-	39	30	9	1
Y106	Ground	44	63	-	58	-	38	30	8	1
Y106	First	45	63	-	58	-	39	30	9	1
Y107	Ground	45	63	-	58	-	39	30	9	1
Y107	First	45	63	-	58	-	39	30	9	1
Y108	Ground	44	63	-	58	-	38	30	8	1
Y108	First	44	63	-	58	-	38	30	8	1
Y109	Ground	44	63	-	58	-	38	30	8	1
Y109	First	44	63	-	58	-	38	30	8	1
Y110	Ground	44	63	-	58	-	38	30	8	1
Y110	First	44	63	-	58	-	38	30	8	1
Y111	Ground	44	63	-	58	-	38	30	8	1
Y111	First	44	63	-	58	-	38	30	8	1
Y112	Ground	44	63	-	58	-	38	30	8	1
Y112	First	44	63	-	58	-	38	30	8	1
Y113	Ground	43	63	-	58	-	37	30	7	1
Y113	First	44	63	-	58	-	38	30	8	1
Y114	Ground	43	63	-	58	-	37	30	7	1
Y114	First	43	63	-	58	-	37	30	7	1
Y115	Ground	43	63	-	58	-	37	30	7	1
Y115	First	43	63	-	58	-	37	30	7	1
Y116	Ground	43	63	-	58	-	37	30	7	1
Y116	First	44	63	-	58	-	38	30	8	1
Y117	Ground	43	63	-	58	-	37	30	7	1

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y117	First	43	63	-	58	-	37	30	7	1
Y118	Ground	43	63	-	58	-	37	30	7	1
Y118	First	44	63	-	58	-	38	30	8	1
Y119	Ground	43	63	-	58	-	37	30	7	1
Y119	First	44	63	-	58	-	38	30	8	1
Y120	Ground	43	63	-	58	-	37	30	7	1
Y120	First	44	63	-	58	-	38	30	8	1
Y121	Ground	43	63	-	58	-	37	30	7	1
Y121	First	43	63	-	58	-	37	30	7	1
Y122	Ground	43	63	-	58	-	37	30	7	1
Y122	First	43	63	-	58	-	37	30	7	1
Y123	Ground	43	63	-	58	-	37	30	7	1
Y123	First	43	63	-	58	-	37	30	7	1
Y124	Ground	43	63	-	58	-	37	30	7	1
Y124	First	43	63	-	58	-	37	30	7	1
Y125	Ground	47	63	-	58	-	41	30	11	2
Y125	First	47	63	-	58	-	41	30	11	2
Y126	Ground	46	63	-	58	-	40	30	10	1
Y126	First	46	63	-	58	-	40	30	10	1
Y127	Ground	45	63	-	58	-	39	30	9	1
Y127	First	46	63	-	58	-	40	30	10	1
Y128	Ground	45	63	-	58	-	39	30	9	1
Y128	First	45	63	-	58	-	39	30	9	1
Y129	Ground	44	63	-	58	-	38	30	8	1
Y129	First	45	63	-	58	-	39	30	9	1
Y130	Ground	44	63	-	58	-	38	30	8	1
Y130	First	44	63	-	58	-	38	30	8	1
Y131	Ground	44	63	-	58	-	38	30	8	1
Y131	First	44	63	-	58	-	38	30	8	1
Y132	Ground	43	63	-	58	-	37	30	7	1
Y132	First	44	63	-	58	-	38	30	8	1
Y133	Ground	43	63	-	58	-	37	30	7	1

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y133	First	43	63	-	58	-	37	30	7	1
Y134	Ground	43	63	-	58	-	37	30	7	1
Y134	First	43	63	-	58	-	37	30	7	1
Y135	Ground	46	63	-	58	-	40	30	10	1
Y135	First	47	63	-	58	-	41	30	11	2
Y136	Ground	45	63	-	58	-	39	30	9	1
Y136	First	46	63	-	58	-	40	30	10	1
Y137	Ground	45	63	-	58	-	39	30	9	1
Y137	First	45	63	-	58	-	39	30	9	1
Y138	Ground	44	63	-	58	-	38	30	8	1
Y138	First	45	63	-	58	-	39	30	9	1
Y139	Ground	44	63	-	58	-	38	30	8	1
Y139	First	45	63	-	58	-	39	30	9	1
Y140	Ground	44	63	-	58	-	38	30	8	1
Y140	First	44	63	-	58	-	38	30	8	1
Y141	Ground	43	63	-	58	-	37	30	7	1
Y141	First	44	63	-	58	-	38	30	8	1
Y142	Ground	43	63	-	58	-	37	30	7	1
Y142	First	43	63	-	58	-	37	30	7	1
Y143	Ground	43	63	-	58	-	37	30	7	1
Y143	First	43	63	-	58	-	37	30	7	1
Y144	Ground	43	63	-	58	-	37	30	7	1
Y144	First	43	63	-	58	-	37	30	7	1
Y145	Ground	43	63	-	58	-	37	30	7	1
Y145	First	43	63	-	58	-	37	30	7	1
Y146	Ground	42	63	-	58	-	36	30	6	1
Y146	First	43	63	-	58	-	37	30	7	1
Y147	Ground	46	63	-	58	-	40	30	10	1
Y147	First	46	63	-	58	-	40	30	10	1
Y148	Ground	45	63	-	58	-	39	30	9	1
Y148	First	46	63	-	58	-	40	30	10	1
Y149	Ground	45	63	-	58	-	39	30	9	1

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y149	First	45	63	-	58	-	39	30	9	1
Y150	Ground	44	63	-	58	-	38	30	8	1
Y150	First	45	63	-	58	-	39	30	9	1
Y151	Ground	44	63	-	58	-	38	30	8	1
Y151	First	45	63	-	58	-	39	30	9	1
Y152	Ground	44	63	-	58	-	38	30	8	1
Y152	First	44	63	-	58	-	38	30	8	1
Y153	Ground	43	63	-	58	-	37	30	7	1
Y153	First	44	63	-	58	-	38	30	8	1
Y154	Ground	43	63	-	58	-	37	30	7	1
Y154	First	43	63	-	58	-	37	30	7	1
Y155	Ground	43	63	-	58	-	37	30	7	1
Y155	First	43	63	-	58	-	37	30	7	1
Y156	Ground	46	63	-	58	-	40	30	10	1
Y156	First	46	63	-	58	-	40	30	10	1
Y157	Ground	45	63	-	58	-	39	30	9	1
Y157	First	46	63	-	58	-	40	30	10	1
Y158	Ground	45	63	-	58	-	39	30	9	1
Y158	First	45	63	-	58	-	39	30	9	1
Y159	Ground	44	63	-	58	-	38	30	8	1
Y159	First	45	63	-	58	-	39	30	9	1
Y160	Ground	44	63	-	58	-	38	30	8	1
Y160	First	44	63	-	58	-	38	30	8	1
Y161	Ground	43	63	-	58	-	37	30	7	1
Y161	First	44	63	-	58	-	38	30	8	1
Y162	Ground	43	63	-	58	-	37	30	7	1
Y162	First	44	63	-	58	-	38	30	8	1
Y163	Ground	43	63	-	58	-	37	30	7	1
Y163	First	43	63	-	58	-	37	30	7	1
Y164	Ground	43	63	-	58	-	37	30	7	1
Y164	First	43	63	-	58	-	37	30	7	1
Y165	Ground	42	63	-	58	-	36	30	6	1

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Y165	First	43	63	-	58	-	37	30	7	1
Y166	Ground	42	63	-	58	-	36	30	6	1
Y166	First	43	63	-	58	-	37	30	7	1
Y167	Ground	42	63	-	58	-	36	30	6	1
Y167	First	43	63	-	58	-	37	30	7	1
Z1	Ground	42	63	-	58	-	36	30	6	1
Z1	First	42	63	-	58	-	36	30	6	1
Z2	Ground	42	63	-	58	-	36	30	6	1
Z2	First	42	63	-	58	-	36	30	6	1
Z3	Ground	42	63	-	58	-	36	30	6	1
Z3	First	42	63	-	58	-	36	30	6	1
Z4	Ground	40	63	-	58	-	34	30	4	1
Z4	First	41	63	-	58	-	35	30	5	1
Z5	Ground	40	63	-	58	-	34	30	4	1
Z5	First	41	63	-	58	-	35	30	5	1
Z6	Ground	40	63	-	58	-	34	30	4	1
Z6	First	40	63	-	58	-	34	30	4	1
Z7	Ground	40	63	-	58	-	34	30	4	1
Z7	First	40	63	-	58	-	34	30	4	1
Z8	Ground	39	63	-	58	-	33	30	3	1
Z8	First	40	63	-	58	-	34	30	4	1
Z9	Ground	39	63	-	58	-	33	30	3	1
Z9	First	39	63	-	58	-	33	30	3	1
Z10	Ground	42	63	-	58	-	36	30	6	1
Z10	First	42	63	-	58	-	36	30	6	1
Z11	Ground	42	63	-	58	-	36	30	6	1
Z11	First	42	63	-	58	-	36	30	6	1
Z12	Ground	41	63	-	58	-	35	30	5	1
Z12	First	42	63	-	58	-	36	30	6	1
Z13	Ground	40	63	-	58	-	34	30	4	1
Z13	First	41	63	-	58	-	35	30	5	1
Z14	Ground	40	63	-	58	-	34	30	4	1

Receiver	Floor	Predicted Noise Level, $L_{A10,\ 18hr}$ dB(A)	Residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance, $L_{A10,\ 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq,\ 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq,\ 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Z14	First	41	63	-	58	-	35	30	5	1
Z15	Ground	39	63	-	58	-	33	30	3	1
Z15	First	40	63	-	58	-	34	30	4	1
Z16	Ground	39	63	-	58	-	33	30	3	1
Z16	First	39	63	-	58	-	33	30	3	1
Z17	Ground	39	63	-	58	-	33	30	3	1
Z17	First	39	63	-	58	-	33	30	3	1
Z18	Ground	38	63	-	58	-	32	30	2	1
Z18	First	39	63	-	58	-	33	30	3	1
Z19	Ground	38	63	-	58	-	32	30	2	1
Z19	First	38	63	-	58	-	32	30	2	1
Z20	Ground	37	63	-	58	-	31	30	1	1
Z20	First	37	63	-	58	-	31	30	1	1
Z21	Ground	38	63	-	58	-	32	30	2	1
Z21	First	38	63	-	58	-	32	30	2	1
Z22	Ground	37	63	-	58	-	31	30	1	1
Z22	First	38	63	-	58	-	32	30	2	1
Z23	Ground	37	63	-	58	-	31	30	1	1
Z23	First	37	63	-	58	-	31	30	1	1
Z24	Ground	38	63	-	58	-	32	30	2	1
Z24	First	39	63	-	58	-	33	30	3	1
Z25	Ground	38	63	-	58	-	32	30	2	1
Z25	First	38	63	-	58	-	32	30	2	1
Z26	Ground	38	63	-	58	-	32	30	2	1
Z26	First	38	63	-	58	-	32	30	2	1
Z27	Ground	37	63	-	58	-	31	30	1	1
Z27	First	37	63	-	58	-	31	30	1	1
Z28	Ground	37	63	-	58	-	31	30	1	1
Z28	First	37	63	-	58	-	31	30	1	1
Z29	Ground	38	63	-	58	-	32	30	2	1
Z29	First	39	63	-	58	-	33	30	3	1
Z30	Ground	38	63	-	58	-	32	30	2	1

Receiver	Floor	Predicted Noise Level, $L_{A10, 18hr}$ dB(A)	Residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance, $L_{A10, 18hr}$ dB(A)	Non-residential Noise Limit, $L_{A10, 18hr}$ dB(A)	Predicted Exceedance, $L_{A10, 18hr}$ dB(A)	Predicted External Night-time Noise Level, $L_{Aeq, 9hr}$ dB(A)	Internal Noise Limit in Bedrooms, $L_{Aeq, 9hr}$ dB(A)	Required Façade Reduction, dB(A)	Required AS 3671 Category
Z30	First	38	63	-	58	-	32	30	2	1
Z31	Ground	37	63	-	58	-	31	30	1	1
Z31	First	38	63	-	58	-	32	30	2	1
Z32	Ground	37	63	-	58	-	31	30	1	1
Z32	First	37	63	-	58	-	31	30	1	1
Z33	Ground	37	63	-	58	-	31	30	1	1
Z33	First	37	63	-	58	-	31	30	1	1
Number of Ground Floor exceedances				**-**		**1**	**Number of AS3671 Category 1 – Ground Floor**			**161**
Number of First Floor exceedances				**1**		**8**	**Number of AS3671 Category 1 – First Floor**			**157**
							Number of AS3671 Category 2 – Ground Floor			**98**
							Number of AS3671 Category 2 – First Floor			**100**
							Number of AS3671 Category 3 – Ground Floor			**-**
							Number of AS3671 Category 3 – First Floor			**2**

Table B-3 Predicted Noise Levels for Free Field Receivers for Year 2026 for the Muirhead North Development – with no Mitigation

Receiver	Floor	Predicted Noise Level $L_{A10,\ 18hr}$ dB(A)	Outdoor Educational and Passive Recreational Areas $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance $L_{A10,\ 18hr}$ dB(A)
Outdoor 1	Ground	57	58	-
Outdoor 2	Ground	51	58	-
Outdoor 3	Ground	49	58	-
Outdoor 4	Ground	47	58	-
Outdoor 5	Ground	47	58	-
Outdoor 6	Ground	48	58	-
Outdoor 7	Ground	47	58	-

Table B-4 Predicted Noise Levels for Free Field Receivers for Year 2026 for the Muirhead North Development – with 1.8 Metre Barriers

Receiver	Floor	Predicted Noise Level $L_{A10,\ 18hr}$ dB(A)	Outdoor Educational and Passive Recreational Areas $L_{A10,\ 18hr}$ dB(A)	Predicted Exceedance $L_{A10,\ 18hr}$ dB(A)
Outdoor 1	Ground	53	58	-
Outdoor 2	Ground	49	58	-
Outdoor 3	Ground	47	58	-
Outdoor 4	Ground	46	58	-
Outdoor 5	Ground	45	58	-
Outdoor 6	Ground	46	58	-
Outdoor 7	Ground	45	58	-

Muirhead North Development, Darwin

APPENDIX C

NOISE CONTOUR MAPS – ROAD TRAFFIC NOISE IMPACT

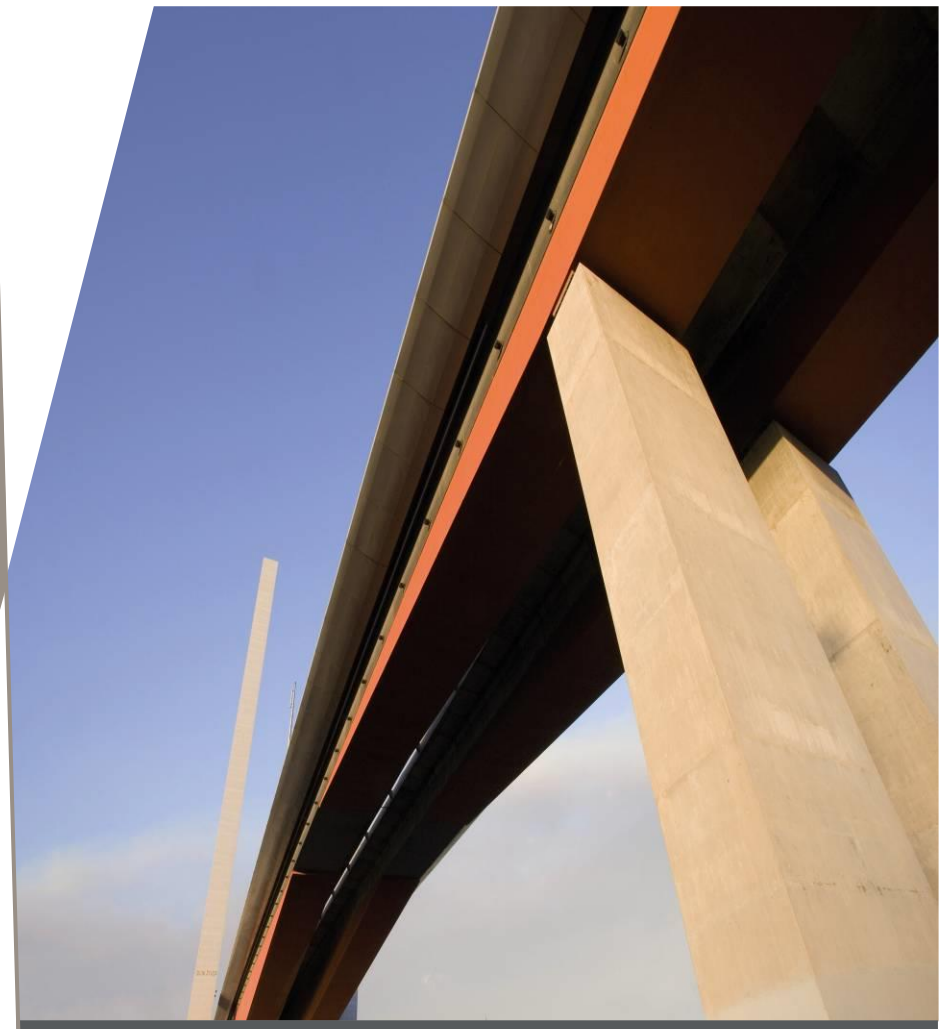

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Figure C-1 Façade Corrected Noise Contour Map without Noise Barriers $L_{10, 18hour}$ Modelled at Ground Floor Level.

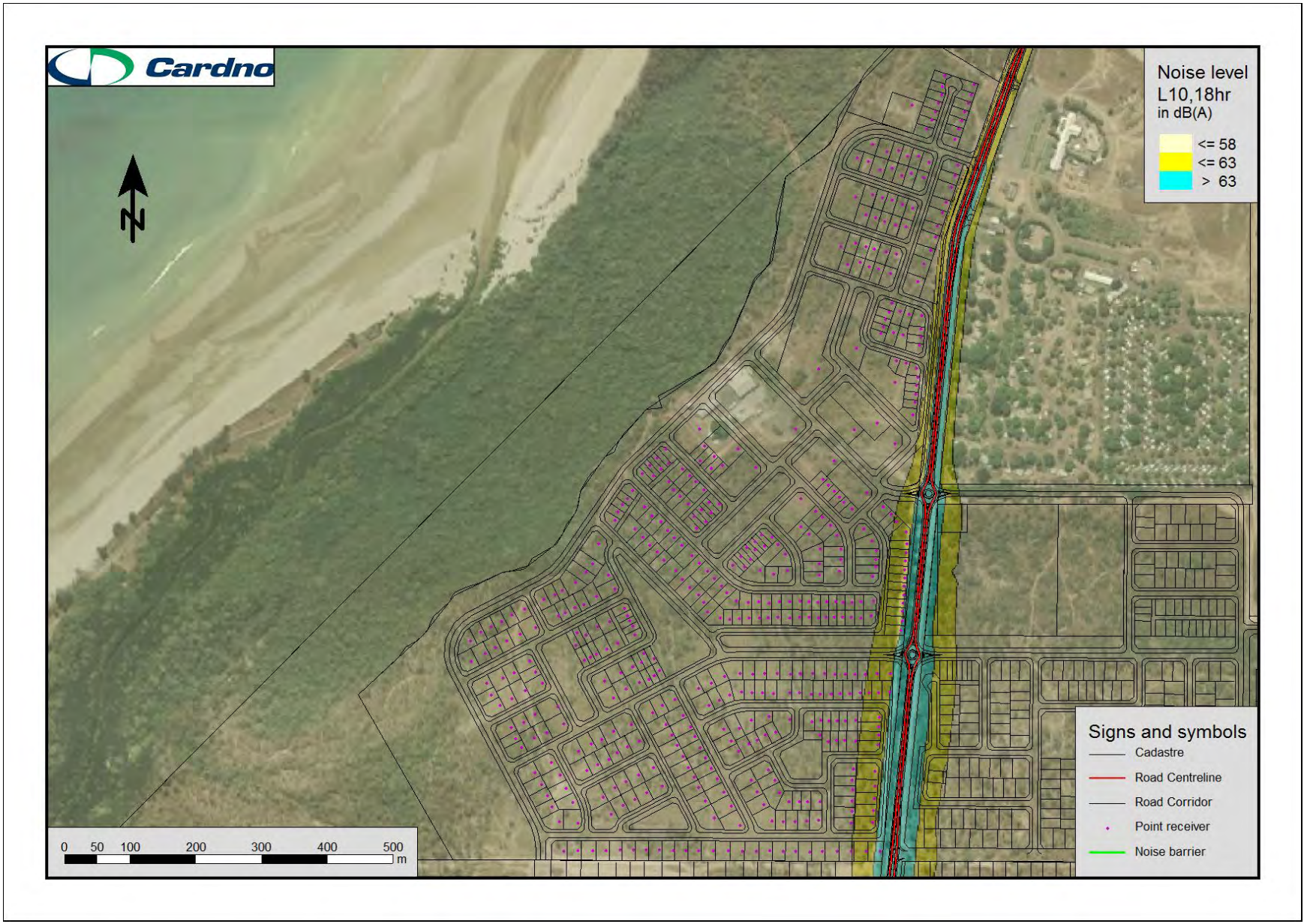


Figure C-2 Façade Corrected Noise Contour Map without Noise Barriers $L_{10, 18hour}$ Modelled at First Floor Level.

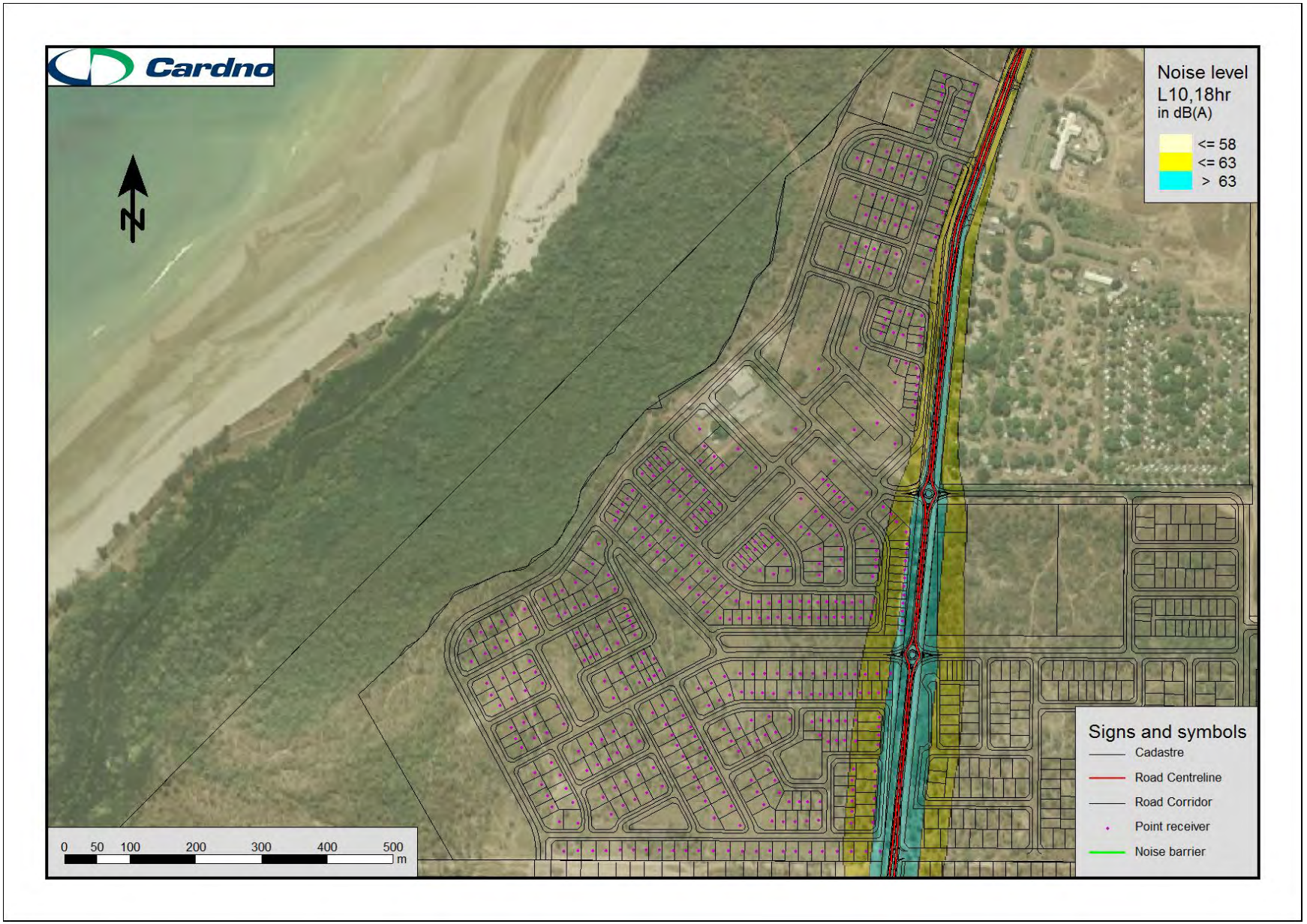


Figure C-3 Façade Corrected Noise Contour Map with 1.8m High Noise Barriers $L_{10, 18hour}$ Modelled at Ground Floor Level.

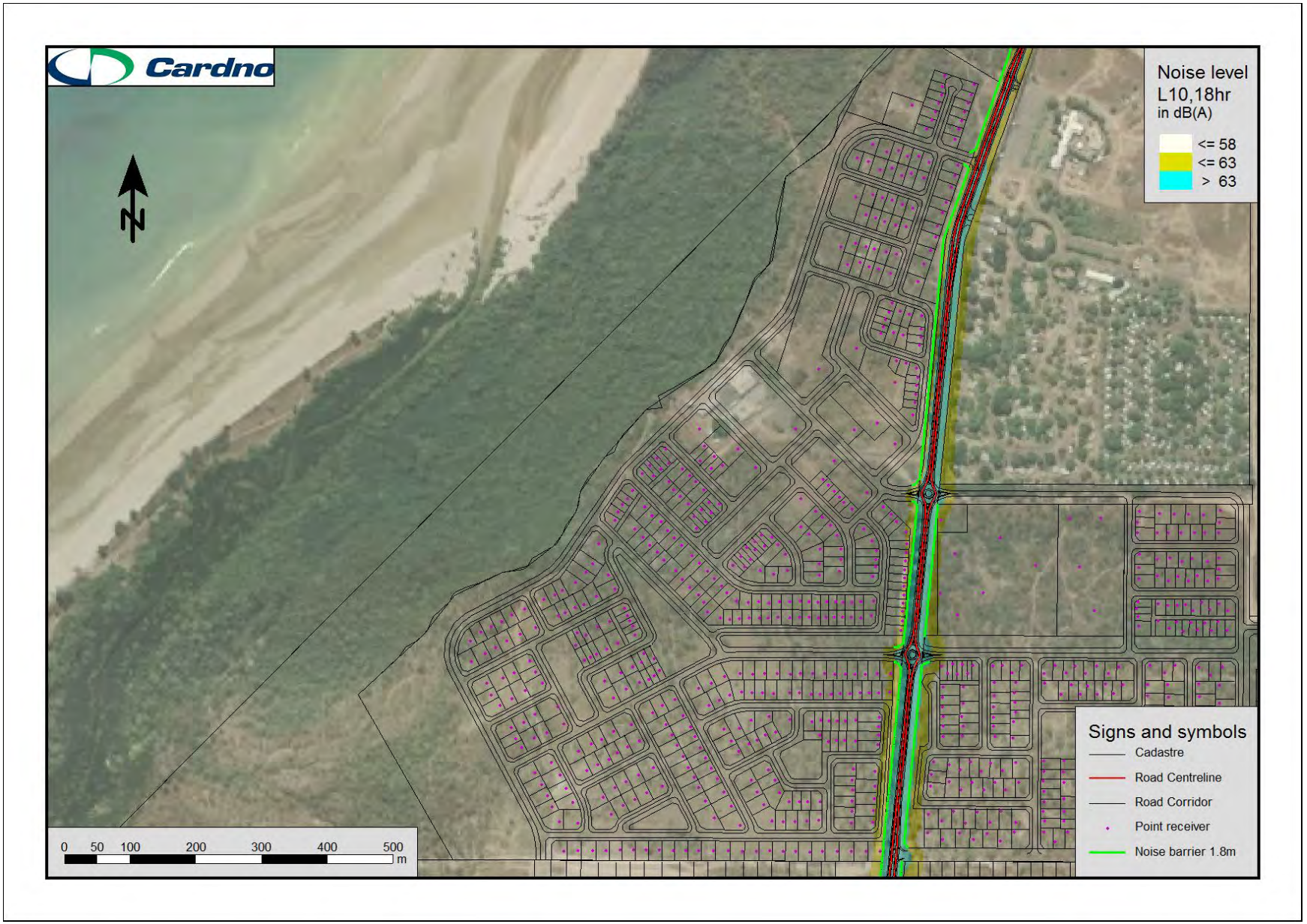
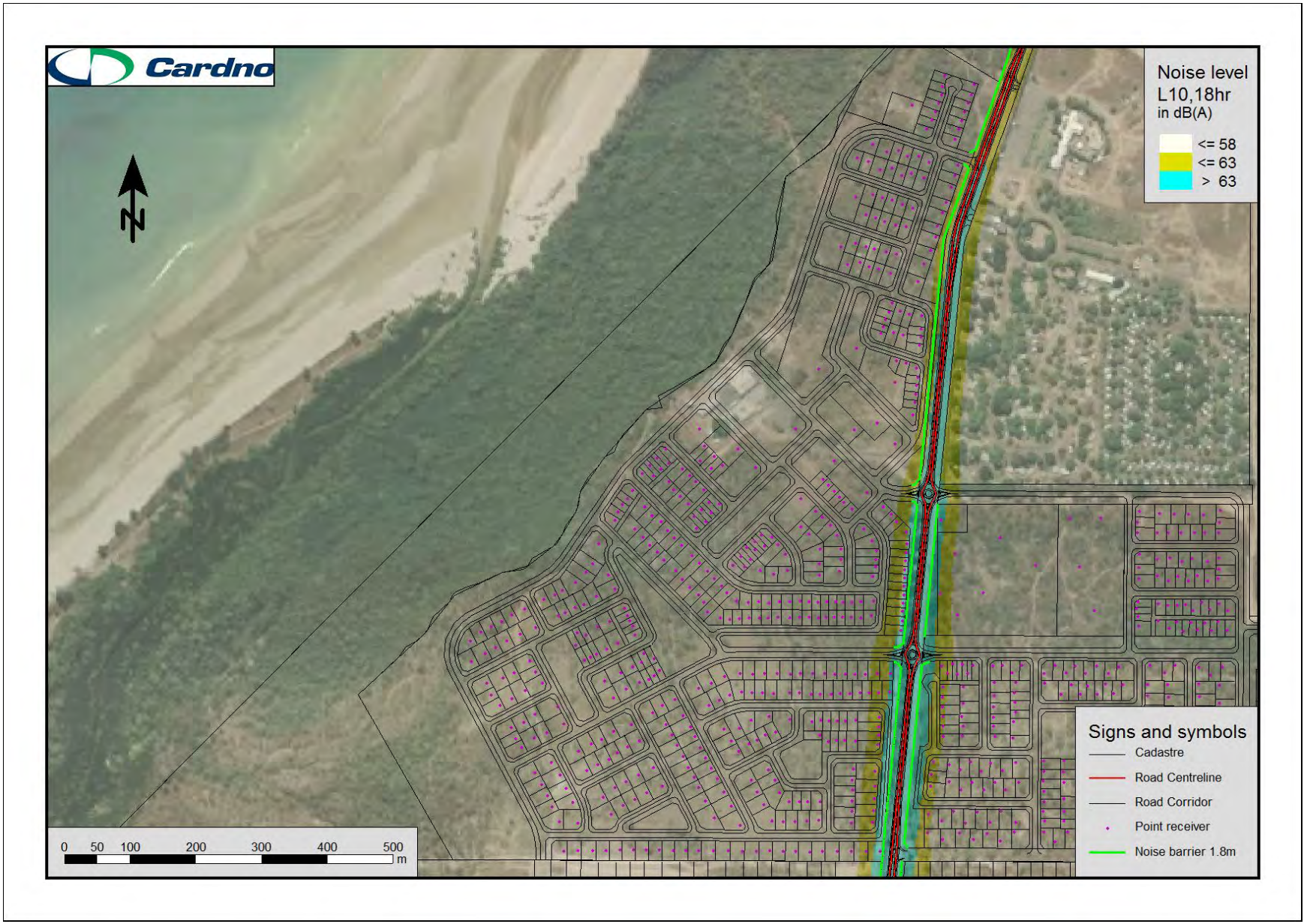


Figure C-4 Façade Corrected Noise Contour Map with 1.8m High Noise Barriers $L_{10, 18hour}$ Modelled at First Floor Level.



Muirhead North Development, Darwin

APPENDIX D

NOISE CONTOUR MAPS – CONSTRUCTION NOISE IMPACT

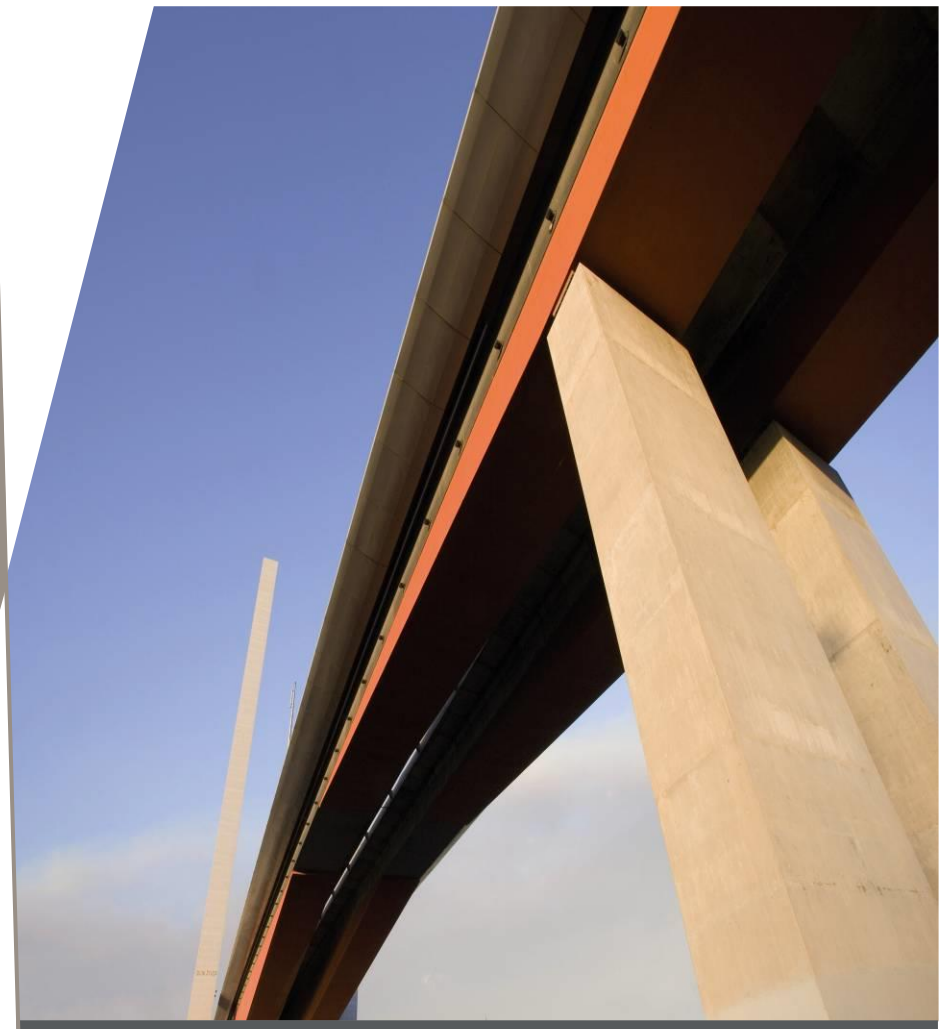


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Figure D-1 Predicted Construction Noise Levels for Clearing of Vegetation and Site Establishment

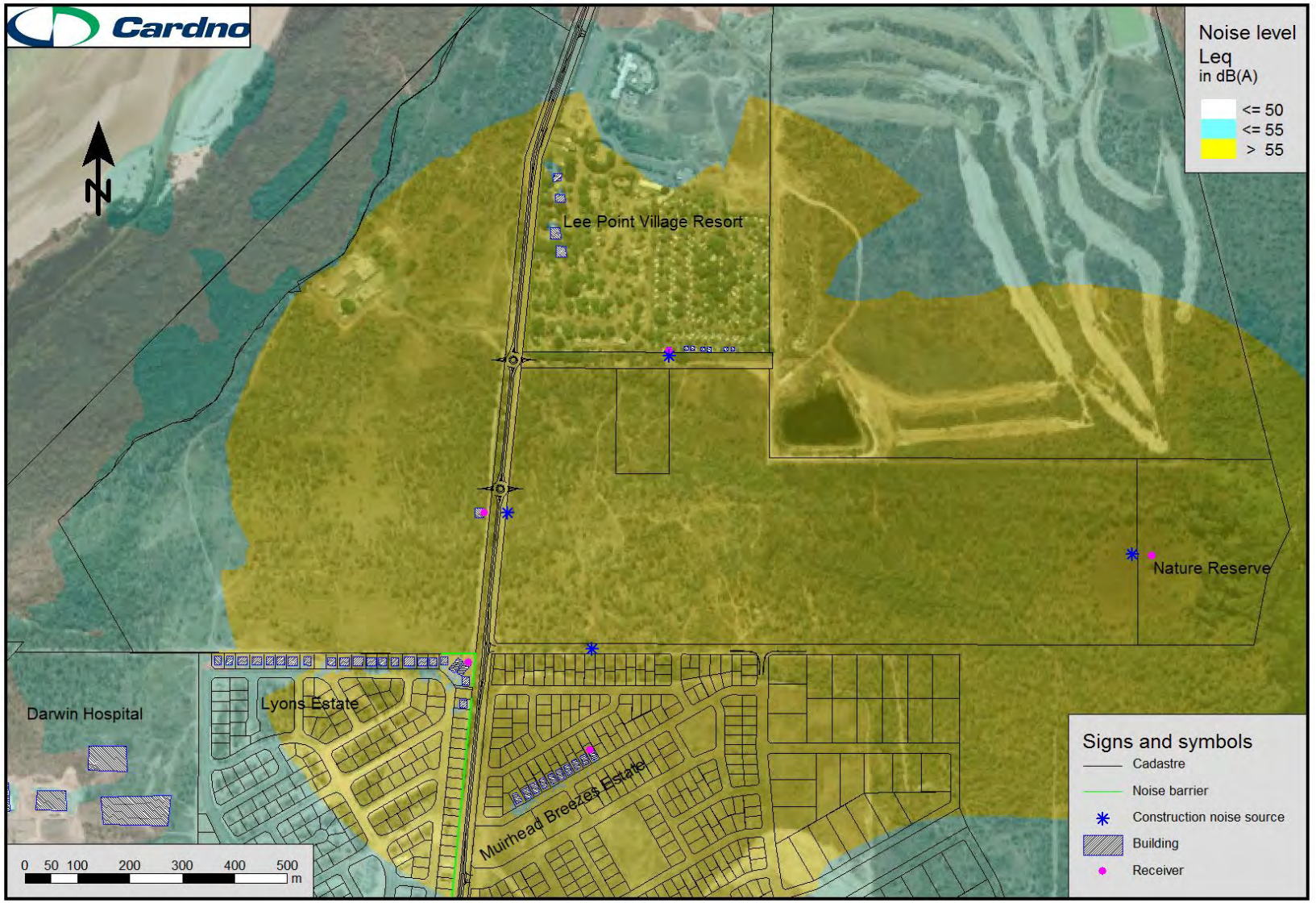


Figure D-2 Predicted Construction Noise Levels for Bulk Earthworks

Figure D-3 Predicted Construction Noise Levels for Drainage Infrastructure

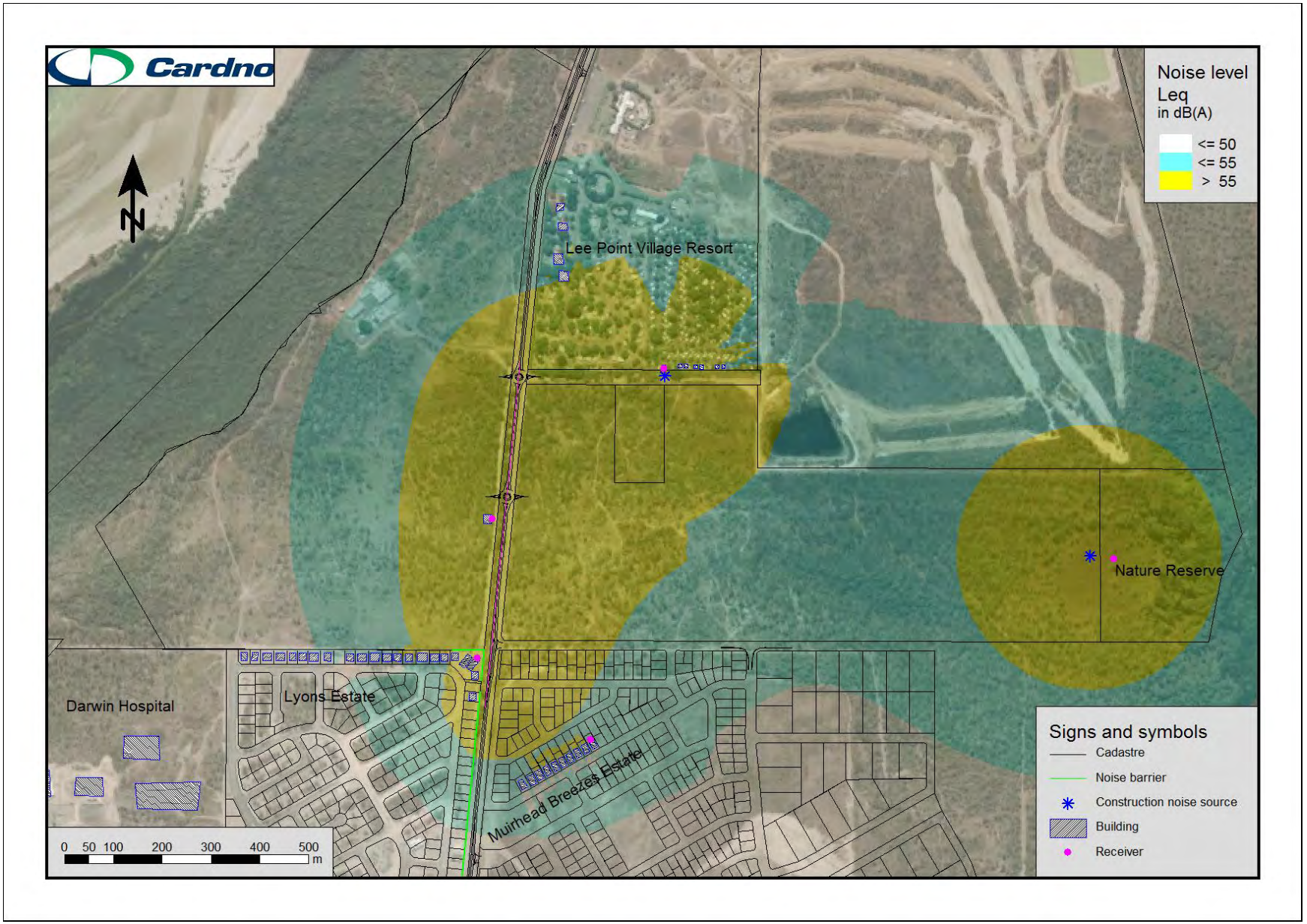
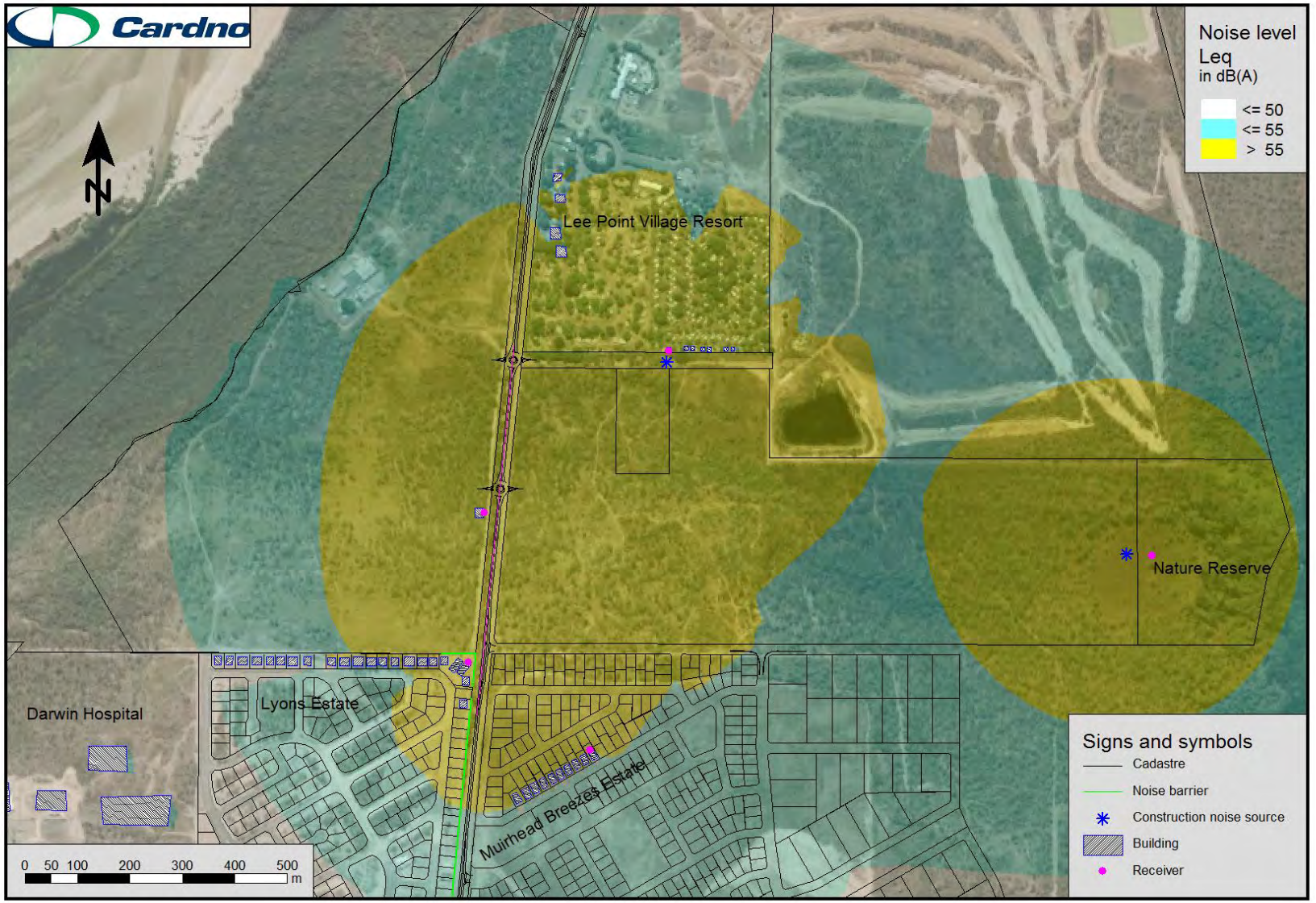


Figure D-4 Predicted Construction Noise Levels for Road Surfacing Works



APPENDIX J

Odour Impact Assessment report

Defence Housing Australia
Odour Impact Assessment

Field Odour Inspection of
Leanyer-Sanderson WWTP, Darwin NT

Final Report

March 2017

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DOCUMENT CONTROL

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Report Preparation		
Report Prepared By: J. Hurley		Approved By: T. Schulz
Report Title: Odour Impact Assessment - Field Odour Inspection of Leanyer-Sanderson WWTP		

TABLE OF CONTENTS

EXECUTIVE SUMMARY 6

1 PROJECT BACKGROUND 7

2 TERMS & DEFINITIONS 9

3 ODOUR ASSESSMENT METHODS 12

3.1 Determination of Plume Extent (European Standard: EN 16841-2:2016) 13
3.1.1 Dynamic Plume Method 16

3.2 Determination of Odour Intensity (German Standard: VDI 3940; 3882 Part 1) 17

3.3 Selection of Assessors and Odour Panel 19

3.4 Accompanying Meteorological Measurements 19

4 SCOPE OF WORKS SUMMARY & ASSESSMENT AREA 20

4.1 Odour Assessment Area 21

5 PRELIMINARY ODOUR PLUME DETERMINATION 24

6 LOCATIONS OF FIELD INSPECTION POINTS 26

7 FIELD INSPECTION MEASUREMENT DAYS & WEATHER CONDITIONS 30

8 FIELD INSPECTION RESULTS 32

8.1 Determination of Plume Extent (European Standard: EN 16841-2:2016) 33

8.2 Determination of Odour Intensity (German Standard: VDI 3940; 3882 Part 1) 34

9 RESULTS & CONCLUSIONS 42

REFERENCES 45

FIGURES

Figure 1: Schematic diagrams of an example of dynamic plume measurement; in the first drawing the measurement commences moving towards the source; in the second drawing the measurement commences from the source……..…..15

Figure 2: Layout of Leanyer-Sanderson WWTP (green polygon), adjacent Residential development (blue polygon) and primary Assessment Areas (yellow dashed polygons) ……..……22

Figure 3: Layout of Existing and Under Construction adjacent Residential Area (Fitzmaurice Drive southern road and dotted line)……..……23

Figure 4: Preliminary Odour Plume Determination & Variation on Saturday, 25th February ……..……25

Figure 5: Position of Main Field Inspection Locations surrounding the WWTP (yellow numbers) as well as other locations for inspection (yellow dots)……..……29

TABLES

Table 1: VDI 3882 (Part 1) Odour Intensity Categories……..……18

Table 2: Field Inspection Locations……..26

Table 3: Rainfall statistics for February 2017 (Darwin AP AWS)……..33

EXECUTIVE SUMMARY

The Odour Unit WA Pty Limited (TOU) was commissioned by Defence Housing Australia (DHA) to undertake an odour impact assessment (OIA) of the Leanyer-Sanderson Wastewater Treatment Plant (WWTP) in Darwin, NT and determine if odour emissions from the WWTP would impact on DHA's land holdings to the north-west which reside at a minimal distance of 1.3kms downwind. The OIA involved the field odour inspection of the downwind surrounds between the land holdings and the WWTP to determine the extent (length and width) of the odour plume (if any) from the WWTP whilst also collecting statistical data for the presence, intensity and frequency of odour observations within those downwind surrounds.

TOU found that the odour emanating from the WWTP resembled typically well maintained WWTP pond configurations. Early morning field odour inspections attempted to observe odour during peak inflow periods at the WWTP. TOU believes it observed inflow peaks during those field inspections where odour was observed. TOU found that odour impacts were observable up to a distance of approximately 600m downwind and that those odours were of a low frequency, low intensity and would therefore not be considered a nuisance. Spot odour was observed along Barratt Road; however, the incidence of up, or downwind odours around that spot location failed to find any contributing odour suggesting the odour observations at that location may be a localised and not necessarily from the WWTP.

TOU further considered the assessment and findings of the Masterplan NT report (2015), specifically the contribution by GHD where a site-specific odour sampling and testing assessment was undertaken at the WWTP. GHD found that the risk of odour impacts beyond typically 500m was Low. TOU supported this conclusion based on its own inspection and assessment.

It is the opinion of TOU that the findings of the odour impact field inspection within the north-west assessment area surrounding the Leanyer-Sanderson WWTP support the judgement that odour impacts on the DHA land holdings, Muirhead North and 2CRU, would be negligible and in all likelihood nil. This conclusion is based on the standard daily operations of the WWTP without upset/breakdown conditions.

1 PROJECT BACKGROUND

The Odour Unit WA Pty Limited (TOU) was commissioned by Defence Housing Australia (DHA) in February 2017 to undertake a field-based odour impact assessment (OIA) of the Leanyer-Sander Waste Water Treatment plant (WWTP), Darwin NT, specifically DHA land holdings downwind of the WWTP in a north-westerly direction.

The purpose of this assessment was two-fold; the first being an attempt to determine the length and width of the odour plume (if any) from the WWTP whilst also making observations of odour intensity and frequency downwind, and the second being a review and consideration of the findings and recommendations of the Planning Report: "Proposal to Amend the NT Planning Scheme - Lots 6959, 6960 and 6961 Town of Sanderson (54 Fitzmaurice Drive, 4 Timor Court and, 7 Glyde Court, Leanyer)" prepared by Masterplan NT, February 2015, specifically Attachment C of the Masterplan report where an odour impact assessment of the WWTP was undertaken by GHD in 2015.

DHA has two land holdings (the ***"land holdings"***) to the north-west of the WWTP, designated as 2CRU and Muirhead North. Muirhead North is the closest to the WWTP at a nominal distance of 1.3kms, with 2CRU residing at approximately 1.9kms north-west of the WWTP.

Between the DHA land holdings is an existing development currently under construction (Stage 7) as well as completed and occupied residential areas.

TOU undertook the assessment by the undertaking of an offsite field inspection methodology that determines the extent of the odour plume emitted, and its perceived impact from the WWTP using field methods based on the standard known as *"Measurement of Odour Impact by Field Inspection"* defined by the German Standard VDI 3940, and where the system by which those observed odours are ranked according to the strength of the odour sensation experienced is based on the German Standard VDI 3882 Part 1; and, the most recent European Methodology (BS EN 16841-2:2016) *"Ambient air – Determination of odour in ambient air by using field inspection".*

Reference to these methods hereinafter is referred to as the **field inspection method**. The field inspection method assessed odour impacts offsite from the WWTP under preferential weather conditions directly affecting the landholdings locale as well as other wind conditions during each day of inspection.

These field inspection methods utilise field data observations by 'ground-truthing' detectable odours from a pre-defined odour source to assess the plume extent (and derived plume impact area), odour intensity of an observed odour at measurement points within the plume, and its frequency of observation at those measurement points. These odours are detected by field technicians (*panel members*) that have been calibrated for their olfactory sensitivity according to the Australian/New Zealand Standard AS/NZS4323.3:2001.

The odour impact assessment was undertaken during the period Thursday 23rd February – Tuesday 28th February inclusive. The weather conditions during the assessment were fine, clear skies with some overcast conditions.

2 TERMS & DEFINITIONS

"TOU" refers to The Odour Unit (WA) Pty Limited who are the commissioned consultant undertaking the method;

"sensory adaptation" temporary modification of the sensitivity of a sense organ due to continued and/or repeated stimulation. Note 1: Adaptation can also occur as a result of a gradually increasing stimulation;

"assessor" somebody who participates in odour testing;

"crossing" series of single measurements by a panel member starting at an odour absence point, crossing the plume direction more or less at a right angle towards an odour absence point on the other side of the plume direction. Note 1: The crossing shall cover similar distances at each side of the plume direction. Note 2: When a crossing does not yield odour presence points it shall start at a distance similar to the estimated maximum plume width;

"experienced panel member" panel member with the necessary experience to make valid observations for the dynamic method according to Australian Standard AS/NZS4323.3:2001 for Dynamic Olfactometry. Note 1: To become an experienced panel member a panel member shall participate at least five times in a measurement cycle with at least three different odour types;

"European odour unit" amount of odorant(s) that, when evaporated into 1 cubic metre of neutral gas at standard conditions, elicits a physiological response from a panel (detection threshold) equivalent to that elicited by one European Reference Odour Mass (EROM), evaporated in one cubic metre of neutral gas at standard conditions;

"field inspection" measuring odours in ambient air using panel members;

"field observations coordinator" individual responsible for the correct execution of the field measurement procedure'

"**field survey"** total of measurement sessions (cycles) required to characterize an exposure level (see part 1 grid method) or plume extent (see part 2 plume method) in an area under study affected by one or more sources or emitting facilities;

"**intersection line'** intersection line is a line perpendicular to the plume direction along which panel members are placed for the stationary plume method;

"method" refers to the methodology to be undertaken;

"methodology" means the system of all individual tasks, techniques, tools and measurements undertaken to collect the desired dataset of information or solve the problem;

"measurement day" refers to the day on which a measurement cycle, or cycles was undertaken;

"maximum plume reach" maximum distance downwind where an odour type can be perceived and recognized (under defined meteorological conditions);

"**measurement cycle"** procedure of consecutive field observations required to determine the odour plume extent once, conducted by a panel under defined meteorological conditions;

"measurement point" location where single measurement(s) are carried out;

"**odorant"** substance whose volatiles can be perceived by the olfactory organ (including nerves);

"odour" sensation perceived by means of the olfactory organ in sniffing certain volatile substances;

"odour absence point" measurement point at which the odour under study is not perceived and recognized as a result of a single measurement;

"**odour detection"** to become aware of the sensation resulting from adequate stimulation of the olfactory system;

"**odour hour"** odour hour is obtained by a single measurement when the percentage odour time reaches or exceeds 10 % by convention. Note 1: Only relevant for the stationary method. Note 2: A test result of one single measurement can be positive for more than one distinct odour type;

"odour presence point" measurement point at which the odour under study is perceived and recognized as a result of a single measurement;

"**odour recognition (in ambient air)"** odour sensation in ambient air that allows positive identification of the odour type**;**

"odour type" odour that can be recognized and assigned to a certain installation or source. Note 1: Odour types are defined specifically for one survey. One installation can emit more than one odour type. Several facilities can emit the same odour type;

"odour quality" means the comparative description of an odour with olfactory experience, e.g. "there is a smell of…", "it smells burnt, rotten…" etc;

"panel member" assessor who is qualified to perform field inspections according to Section 6.2 of the Standard "Assessors and panel members";

"**panel selection"** procedure to determine which assessors are qualified as panel members;

"plume extent" shape of the plume delineated by a smoothed interpolation polyline through the transition points, the source location and the location determined by the maximum plume reach estimate;

"**plume extent area"** surface area enclosed by a smoothed interpolation polyline through the transition points, the source location and the location determined by the maximum plume reach estimate;

"recognition threshold" as it relates to the German Standard VDI 3940 means the odorant concentration at which a detectable odour within a facility's impact range can be clearly assigned to a facility for the first time;

"percentage odour time" refers to the total times/intervals which the odour is recognizable during a measurement cycle at a single measurement point;

"**single measurement"** procedure to obtain recorded observations at a given moment at a given measurement point necessary to determine absence or presence of recognizable odour. Note 1: For the stationary plume method one single measurement results in the test result 'odour hour' or 'non-odour hour'. Note 2: For the stationary plume method the absence or presence is determined based on the observed percentage odour time over a defined single measurement duration. For the dynamic plume method the absence or presence is based on the direct and instantaneous observation of recognizable odour or the lack of it;

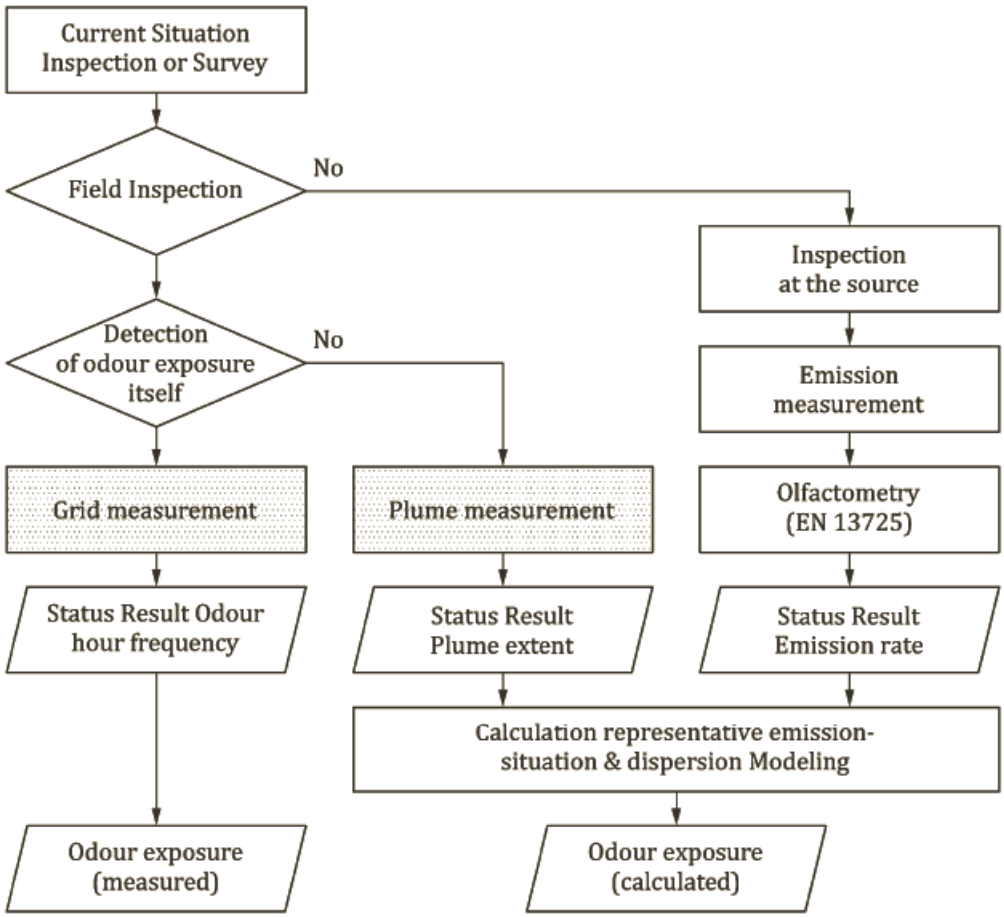
"**single measurement duration"** time required to conduct a single measurement. Note 1: The single measurement duration is 10 min (60 observations) for a stationary plume method. A single measurement duration of at least ten minutes is required in order to obtain a representative statement with at least 80 % certainty on the odour situation within an hour. The single measurement duration for the dynamic plume method is the duration of one inhalation (one observation);

"**sniffing unit"** minimal amount of odorant(s), present into 1 cubic meter of air, that generates a response of recognition of a certain odour type by an experienced panel member, under field conditions;

"transition point" point halfway between the last absence point and the first presence point at the limit of the recognizable odour plume under investigation.

3 ODOUR ASSESSMENT METHODS

The European Standard (EN 16841-2:2016) process flow for determining the appropriate field inspection method follows as:



For the purpose of this assessment, the Plume Measurement method was chosen to determine the plume extent in the direction of the landholdings under preferential wind conditions. The Plume measurement allows the observers to move around in order to define the plume extents. Given the residential area, housing structures, local natural changes in topography and the dense bushland dividing the landholdings from the WWTP, a stationary method was not suited.

The plume method involves the determination of the presence or absence (YES/NO) of recognizable odours in and around the plume originating from a specific odorant emission source, for a specific emission situation and under specific meteorological conditions (specific wind direction, wind speed and boundary layer turbulence). The unit of measurement is the presence or absence of recognizable odours at a particular location downwind of a source.

The extent of the plume is assessed as the transition of absence to presence of recognizable odour. The results are typically used to determine a plausible extent of potential exposure to recognizable odours, or to estimate the total emission rate based on the plume extent, using reverse dispersion modelling. The plume extent measurement is particularly useful as a starting point for estimating emission rates for diffuse odorant sources where sampling at source is impracticable.

Further assessment of the plumes' odour impact was undertaken by reference to the VDI Standard where the intensity and frequency of odour observations was determined at the plume extents (length and width). This provided further insight as to the plumes' potential for odour decay as assessors move further away from the odour source.

3.1 Determination of Plume Extent (European Standard: EN 16841-2:2016)

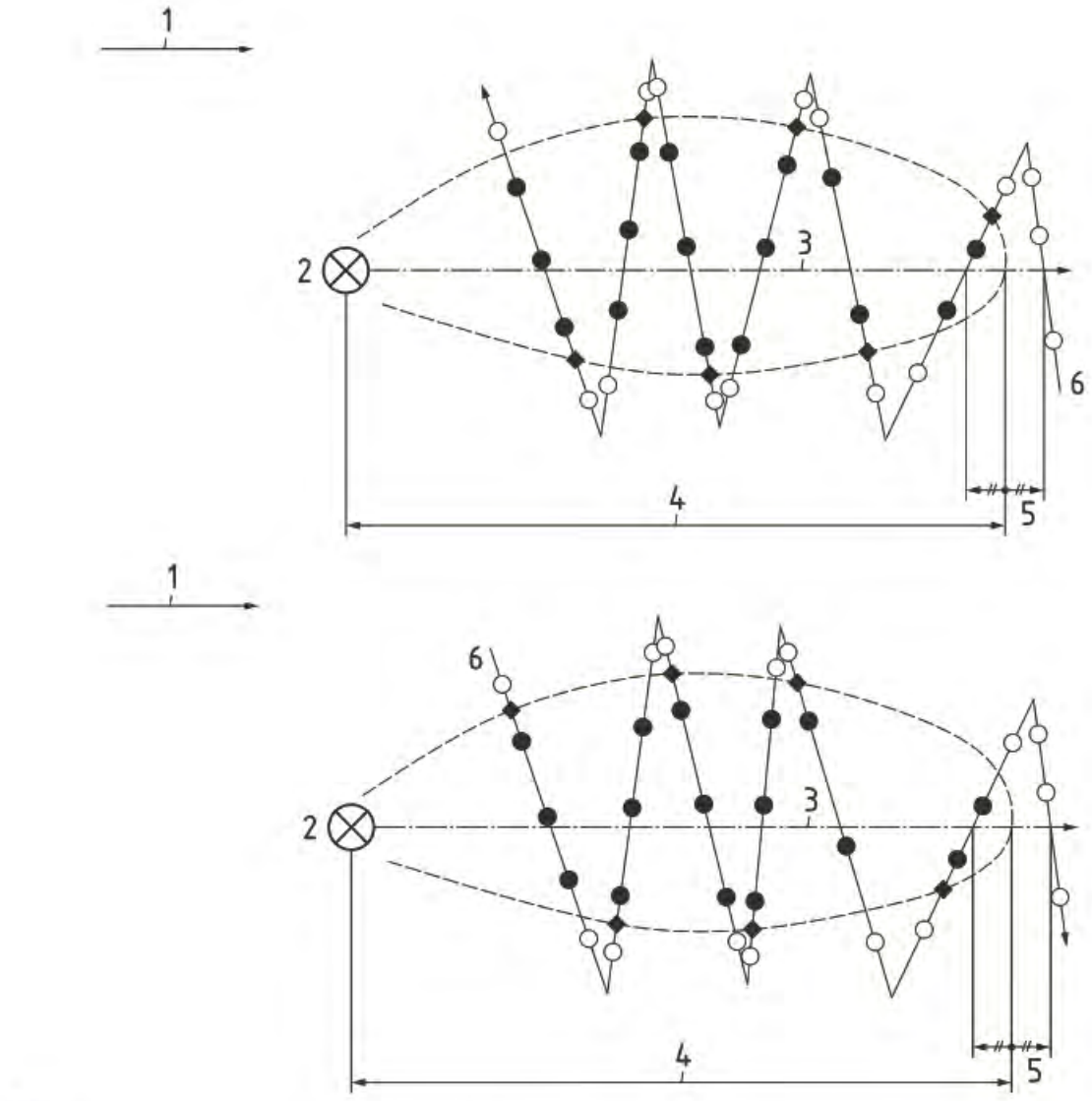
Panel members are used to determine the presence or absence of the specific odour under investigation at different points downwind of a source under well-defined meteorological conditions. These conditions are chosen to ensure that the extent of the plume is well defined. The meteorological conditions during the field observations are measured and recorded.

Typically, the measurement is repeated to reduce uncertainty to an acceptable level. In this way variability due to random variations in meteorological conditions, panel member performance and odorant emission is averaged out. There are two versions of observation methods for plume extent measurement; stationary plume measurement, and dynamic plume measurement.

Using the dynamic method, the panel members cross the plume, while conducting single measurements at frequent intervals. By successively entering and exiting the plume and in this way determining the transition between absence and presence of recognizable odour, the extent of the plume is defined. This approach helps to avoid adaptation.

The plume direction is crossed at different distances from the source. This includes crossings at distances where no recognizable odour is detected. The maximum plume reach estimate is defined as the distance along the plume direction between the source and the point halfway from the furthest intersection line or crossing where odour presence points were recorded, and the first intersection line or crossing where only odour absence points were recorded. This equal distance between the two intersection lines/crossings is indicated as point 5 on the schematic **Figure 1 below**.

The plume extent is defined by the transition points. A transition point is the point halfway between adjacent odour absence point and odour presence point for the odour type under study. In order to prevent possible adaptation effects causing incorrect observations, the transition points in the dynamic plume method are only determined whilst entering the plume, and not while exiting.



Key

●	single measurement: odour presence point
○	single measurement: odour absence point
◆	transition point
	Crossings
	plume extent
1	wind direction
2	source
3	plume direction
4	maximum odour plume reach estimate
5	equal distance between the furthest crossing with and the one without recognizable odour
6	start of measurement

Figure 1: Schematic diagrams of an example of dynamic plume measurement; in the first drawing the measurement commences moving towards the source; in the second drawing the measurement commences from the source.

3.1.1 Dynamic Plume Method

A measurement cycle consists of at least 20 single measurements at different distances from the source by at least two experienced panel members in order to define at least 6 transition points and finally the odour plume extent. These observations (single measurements) are to be done on foot or by bike.

It is advisable to estimate the plume direction and the rough plume extent beforehand, e.g. by car, as a guide for the measurement. Before starting the observations, timing devices shall be synchronized.

The experienced panel members begin a measurement cycle by starting observations either close to the source or at a certain distance downwind. In case of a complex source situation emitting different odour types, it is advisable to start at a distance downwind where the different odours can be clearly discerned. The objective of these initial observations is to familiarize the experienced panel members with the odour type(s) under investigation. The decision of where to start and which direction to go is to be made by the field observations coordinator.

In order to prevent adaptation to the odour under investigation, panel members regularly go in and out the plume preferably by crossing the plume axis in a zigzag pattern as shown in **Figure 1**. In certain circumstances it is however allowed to cross only the edge of the plume in a zigzag way, e.g. when the complete crossing of the plume is not possible due to geographical restrictions.

The plume is then repeatedly crossed at different distances from the source in order to cover the whole estimated plume extent. The observations should include crossings at distances downwind where no odour is recognized, in order to ensure that the maximum odour plume reach can be determined.

Each measurement point is chosen by the experienced panel member and is indicated on a topographical map or on a portable GPS-system by adding a waypoint. For each measurement point, the exact time is registered, and also whether or not the odour under

investigation is recognized. Information about other odour types should also be registered.

3.2 Determination of Odour Intensity (German Standard: VDI 3940; 3882 Part 1)

Following the determination of the Plume extent, the assessors then refer to VDI for determining odour intensity at incremental plume extents downwind of the odour source.

With this method, a panel of calibrated and experienced panel members conduct a single measurement(s) at discrete measurement points (defined within the determined odour plume) downwind of the site. Each measurement cycle comprises 60 grab measurements every 10 seconds for a single measurement cycle of 10 minutes. Each grab measurement results in a single Odour Sample. For every single measurement the panel assesses the presence, character and intensity of any observed odours.

The measurement cycle is often reflective of worst-case meteorological conditions. The result of each measurement cycle determines the odour intensity at each measurement point, incremental spaced along the plume extents, and thus determines the resultant odour intensity decay of the plume downwind of the odour source. In general, the objective of a survey is to determine the decay of odours observed downwind of the odour source/s thus defining the odour impact and impact range.

Within the impact range the magnitude of the odour impact can be defined by determining the maximum distance to which the clearly recognizable odour is considered problematic. This is done by firstly assigning a level of odour intensity (the quantitative scale) considered problematic for a given odour source, which would be considered equal to or greater than a nuisance odour intensity. *For example; an intensity of 3 (distinct) may be considered the upper limit to which an observed odour is acceptable in the community. Once a 3 is observed, or greater, the odour is clearly recognizable at that measurement point and hence the observed odour can be assigned to the facility being assessed (the recognition threshold). Multiple measurement points within the assessment area impacted by an observed odour intensity of 3 or greater would then make up the impact range. However, the frequency of the odour observations must also be considered.*

The observed odour intensities are quantified according to the German Standard VDI 3882 Part 1. The category scale for judging odour intensity in the field is a quantitative reference scale where panel members award one of the attributes in the **Table 1** (below) to his or her odour impression.

Table 1: VDI 3882 (Part 1) Odour Intensity Categories

Odour Strength	Intensity Rank (code)	TOU Interpretation (meaning)
Not detectable	0	No odour detected
Very Weak	1	Odour recognised and assigned to the odour source (recognition)
Weak	2	Odour is weak but not yet distinct
Distinct	3	Odour is clearly distinct
Strong	4	Strong odour detectable
Very Strong	5	If offensive, observer may consider moving from the area
Extremely Strong	6	Odour is sufficiently over-powering that assessor moves from area

An odour is clearly recognised (category of intensity 1) when the odour quality and hence an origin of the odour source can be clearly assigned.

The use of VDI 3940 will allow additional interpretation of the odour plume to determine of the entire odour plume elicits an odour impact, or if the farthest downwind extents of the plume exhibit sufficiently low odour intensities and frequency of observations thus demonstrating that the entire plume is not necessarily constrained as an odour impact. In other words, the Plume method can be further refined using observations of odour intensity along the extents and within the plume.

3.3 Selection of Assessors and Odour Panel

- The initial selection of assessors is carried out according to AS/NZS4323.3:2001 Dynamic Olfactometry;
- The panel selection is carried out before the field observations are conducted. The assessment of compliance with the panel selection criteria shall not be dated more than 6 months before the date of field observations;
- Valid observations shall only be carried out by panel members;
- To become an experienced panel member for the dynamic method a panel member shall participate at least five times in a measurement cycle with at least three distinct odour types;
- The size of panel to be used in one measurement cycle shall be;
    - For the dynamic plume method a minimum of two experienced panel members is required, to make measurements simultaneously.

3.4 Accompanying Meteorological Measurements

Representative meteorological measurements of the area were carried out during the measurement cycle for the following parameters:

- Wind speed;
- Wind direction; and
- Temperature.

Additional visual observations should also be made for unusual features, e.g. precipitation, mist, snow, during each measurement cycle.

4 SCOPE OF WORKS SUMMARY & ASSESSMENT AREA

TOU deployed two personnel to Darwin to undertake the Plume Measurement field inspection method and supporting odour intensity and frequency method. The logistics and project steps are summarised as follows:

(i) Deploy to Darwin on Thursday 23rd February 2017;

(ii) Undertake a reconnaissance of the WWTP and surrounding primary assessment area and determine the odour type, plume extent and constraints to the assessment methods;

(iii) Starting around 5-6AM each day, undertake the first of multiple measurement cycles prescribed by the Dynamic Plume Method for one complete field survey, with an expectation that a minimum of two (2) cycles will be completed each day to determine the odour plume reach and width;

a. each measurement cycle will consist of at least 20 single measurement points;

b. the length of each measurement cycle will depend upon the clear observation of an odour plume; however, the expectation is that one measurement cycle will take up to 2 hours to complete including Odour Intensity determination;

c. Depending on local weather conditions, TOU may undertake the method in the early AM and possibly in the PM hours to achieve a representative dataset;

(iv) During each measurement cycle assessors will undertake odour intensity determination at incremental locations along the plume extent, or at locations it deems of relevance during the measurement cycle;

(v) scrutiny of field observations and subsequent mapping of findings;

(vi) determination of plume reach, width and derived impact area for each measurement cycle;

(vii) overlay of all measurement cycles to determine the maximal plume reach, width and derived impact area; and

(viii) determination of overall plume odour impact by consideration of odour intensity observations along the plume extents.

4.1 Odour Assessment Area

The odour source that is the subject of this assessment is the Leanyer-Sanderson WWTP, Darwin NT. The odour assessment area is primarily focused within the north-west quadrant adjacent to the WWTP. Other assessment areas under differing wind conditions were decided upon at the time of each daily assessment.

The primary assessment area is designated by the two yellow-dashed polygons to the north-west of the WWTP **(refer Figure 2 below).** Also designated is the newly developed and under construction residential area (blue polygon). The WWTP itself consists of a Ponds system with inlet chambers and other infrastructure. It should be noted that the treated effluent is discharged into Buffalo Creek directly north of the WWTP ponds.

The assessment area focused primarily on the residential area within the blue polygon. Line of sight to the ponds was only achieved along Fitzmaurice Drive **(refer Figure 3)**.
TOU undertook the dynamic plume method along Fitzmaurice Drive and within the residential area where odour was detectable.

During easterly wind conditions TOU observed the odour directly along the Fenceline of the WWTP and compared that odour character to the observable odour downwind of the WWTP. Under differing wind conditions TOU attempted to traverse the dense bushland as much as possible.

Figure 2: Layout of Leanyer-Sanderson WWTP (green polygon), adjacent Residential development (blue polygon) and primary Assessment Areas (yellow dashed polygons)

Figure 3: Layout of Existing and Under Construction adjacent Residential Area (Fitzmaurice Drive southern road and dotted line)

5 PRELIMINARY ODOUR PLUME DETERMINATION

TOU undertook a preliminary odour plume reconnaissance on Thursday, February 23rd from approximately 3PM onward, unfortunately the winds were from the west and line of sight was not achievable on that day.

Traversing the southern downwind surrounds was possible only up to a distance of approximately 1.2kms via access off Vanderlin Drive. No odour was detected.

On Saturday, 25th February the winds were originating from the east in the early AM periods. TOU was then able to better determine an odour plume determination following observations of the pond odours made from the ponds fenceline along the western boundary of the WWTP.

The odour plume was observable along Fitzmaurice Drive only, and during the observations was narrow and intermittent with low odour intensity. The plume barely extended beyond the Power and Water boundary with intermittent low intensity odours at the extent; moreover, the plume width was difficult to observe since local terrain effects provided buffering of the odour; however, TOU estimated the width to be approximately 150m. **Figure 4** to follow shows the pre-determined odour plume length and width observations between 6AM – 9AM.

Replicating the odour plume proved difficult thereafter due primarily to wind conditions, but also due to local obstacles such as terrain and building structures. Spot odour observations were made further within the residential area. These observations along with all assessment observations are detailed in **Section 8.**

Figure 4: Preliminary Odour Plume Determination on Saturday, 25th February

6 LOCATIONS OF FIELD INSPECTION POINTS

The positions of the main field inspection locations are listed below. The numbering of the inspection points don't reflect the order in which they were assessed, the numbering is purely for I.D purposes. The field inspection locations can be viewed on **Figure 5**.

Other locations were also inspected for the purposes of determining other odour sources and to establish areas where field inspections could take place. These locations are depicted as yellow dots on Figure 5.

Table 2: Field Inspection Locations

I.D	Location Address	Location Characteristics	Downwind Compass Bearing
1	Fitzmaurice Drive @ Power & Water Gate	At the outer boundary of the WWTP	ENE
2	Fitzmaurice Drive adjacent to Withnall Circuit	Along Fitzmaurice Drive	ENE
3	Withnall Circuit	Adjacent to open space; No line of sight to WWTP	E
4	Withnall Circuit	Adjacent to open space; No line of sight to WWTP	E
5	Spargo Street	Middle of Street length; No line of sight to WWTP	E
6	Ward Crescent	Adjacent to open space; No line of sight to WWTP	E
7	Ward Crescent	Adjacent to open space; No line of sight to WWTP	E

I.D	Location Address	Location Characteristics	Downwind Compass Bearing
8	Withnall Circuit / Barratt Street Corner	Within Residential area; No line of sight to WWTP	E
9	Mahoney Street	Adjacent to open space; No line of sight to WWTP	E
10	Mahoney Street / Hannan Street Corner	Adjacent to open space; No line of sight to WWTP	E
11	Mahoney Street / Lemke Street Corner	Adjacent to open space; No line of sight to WWTP	E
12	Mahoney Street / Hargrave Street Corner	Adjacent to open space; No line of sight to WWTP	ESE
13	Hargrave Street	Adjacent to open space; No line of sight to WWTP	SE
14	Street Drainage Runoff	Adjacent to open space; No line of sight to WWTP	SE
15	Newmarch Street Corner	Adjacent to Park within Residential area; No line of sight to WWTP	E
16	Lee Point Road / Asche Street Corner	Main Road & within Residential area	SE
17	Lee Point Road / Fitzmaurice Corner	Main Road & within Residential area; general line of sight to WWTP ponds	ENE
18	Lemke Street / Coleman Street Intersect	Adjacent to Park within Residential area; No line of sight to WWTP	E
19	Fenceline of Power & Water	Adjacent to Creek; No line of sight to WWTP	E

I.D	Location Address	Location Characteristics	Downwind Compass Bearing
20	Fenceline of WWTP Ponds	Clear line of sight to WWTP Ponds	E
21	Fenceline of WWTP Ponds	Clear line of sight to WWTP Ponds	E
22	Fenceline of WWTP Ponds	Clear line of sight to WWTP Ponds	E
23	Fenceline of WWTP Ponds	Clear line of sight to WWTP Ponds	E
24	Hodgson Drive	Adjacent to bushland; No line of sight to WWTP	N
25	Buffalo Creek Road	Adjacent to bushland & Caravan Park waste ponds; No line of sight to WWTP	S

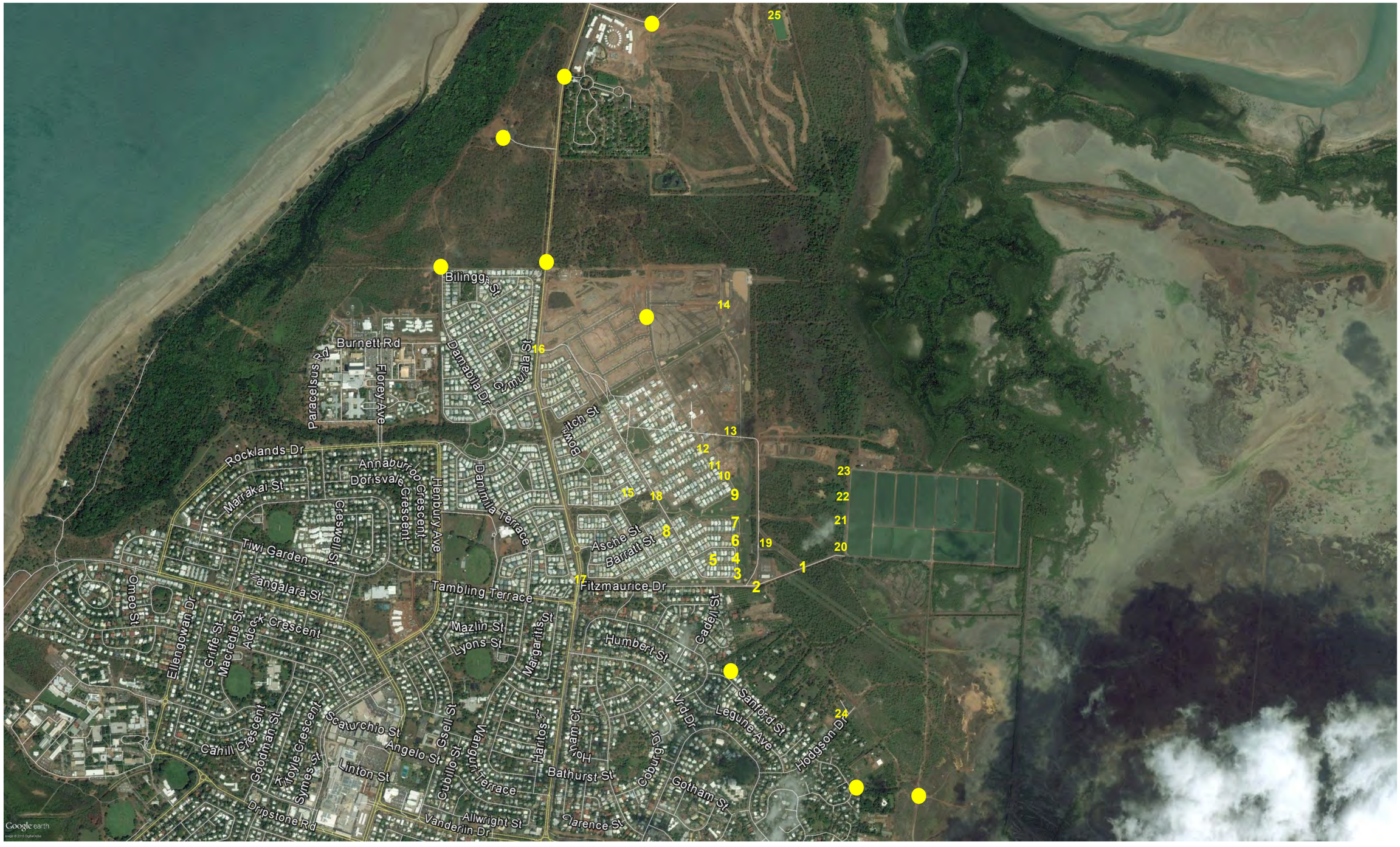
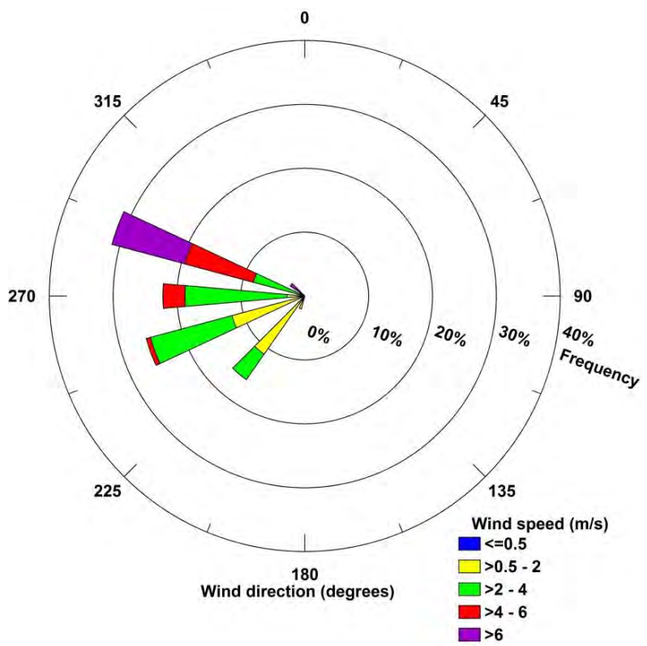


Figure 5: Position of Main Field Inspection Locations surrounding the WWTP (yellow numbers) as well as other locations for inspection (yellow dots)

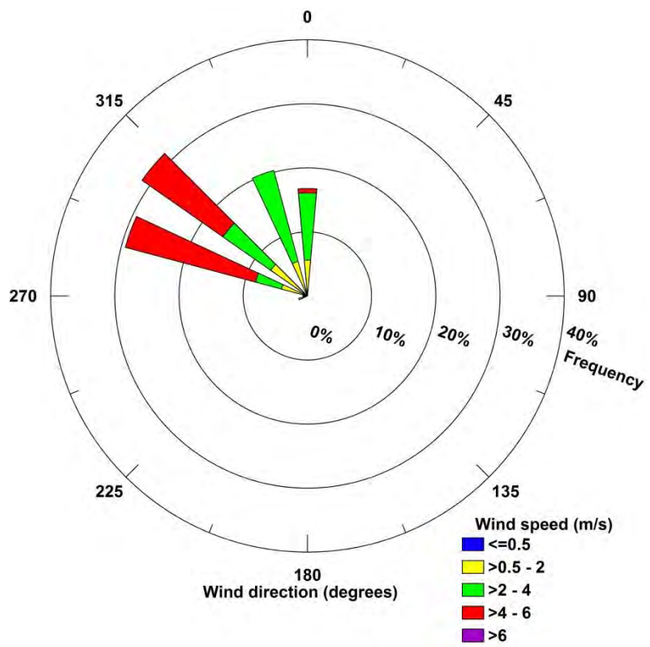
7 FIELD INSPECTION MEASUREMENT DAYS & WEATHER CONDITIONS

Date & Day	Time of Field Inspections	Darwin AP AWS 0630hrs Observations			Darwin AP AWS 1400hrs Observations			Temp. (min)	Temp. (max)	Rain	Relative Humidity @ 0630hrs	Cloud @ 0900hrs
		Wind Direction	Wind Speed	Temp.	Wind Direction	Wind Speed	Temp.					
		Origin	km/hr	^{0}C	Origin	km/hr	^{0}C	^{0}C	^{0}C	mm	%	8th
Thursday, 23rd February	1500 - 1800	SSW	7	26.2	WNW	20	33.6	26.0	34.7	0	89	1
Friday, 24th February	0630 – 1100; 1200 – 1400	WNW	13	28.4	NNW	11	30.8	28.3	32.1	0	83	7
Saturday, 25th February	0630 – 1100; 1200 – 1400	ENE	2	25.3	ESE	7	29.6	25.3	31.3	0	96	6
Sunday, 26th February	0630 – 1100; 1200 – 1400	SSW	7	26.2	WNW	19	32.2	25.7	33.3	15.4	91	5
Monday, 27th February	0630 – 1100; 1200 – 1400	S	6	25	NNW	15	33.4	24.2	33.7	49.8	96	2
Tuesday, 28th February	0630 - 1100	WSW	7	25.2	NNW	15	32.7	23.9	33.1	21.8	93	6

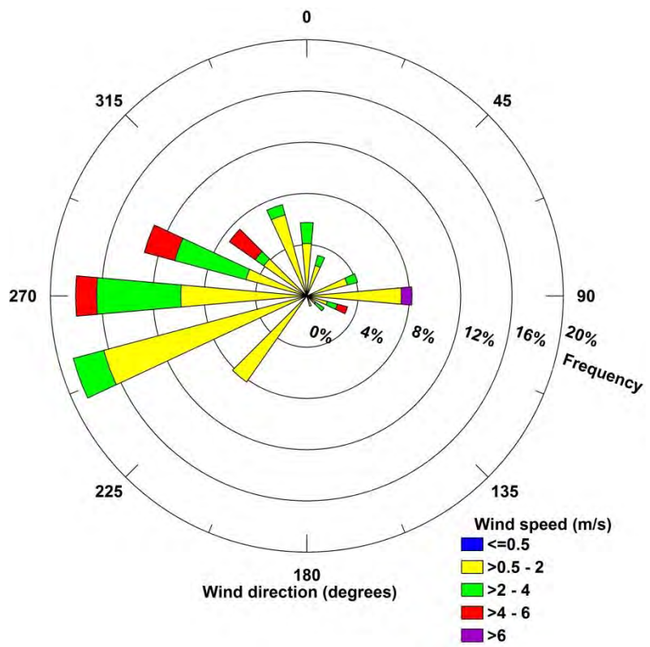
The daily 10 minute Darwin Airport AWS observation, for each full day are presented below as Windroses.



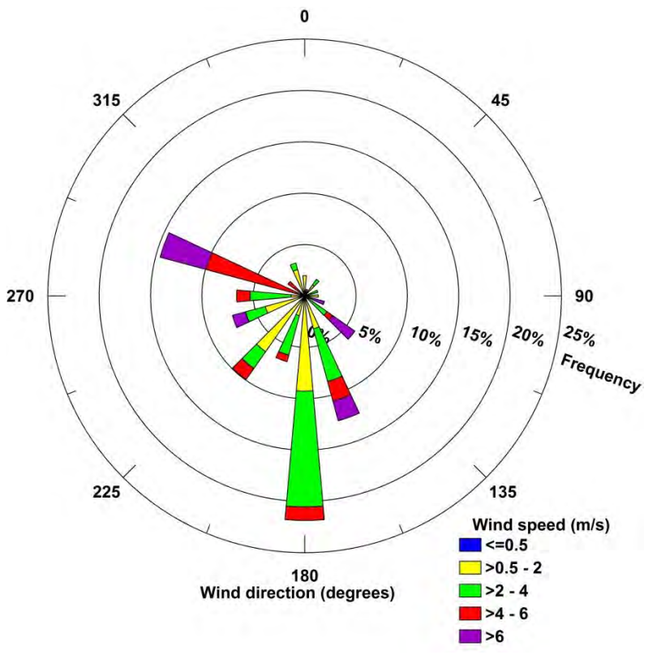
Thursday, 23rd February



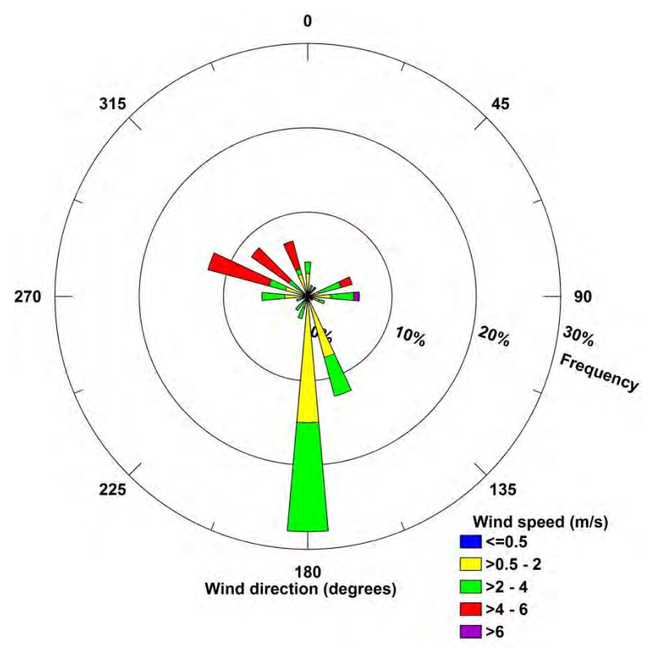
Friday, 24th February



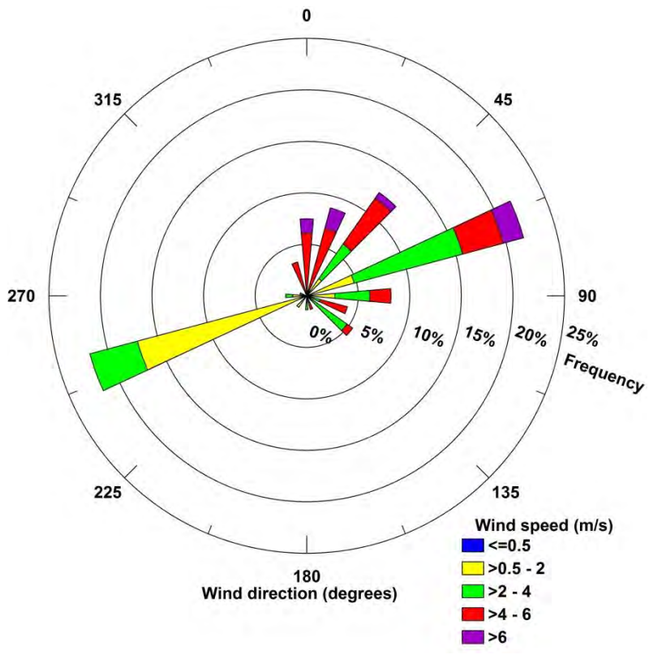
Saturday, 25th February



Sunday, 26th February



Monday, 27th February



Tuesday, 28th February

8 FIELD INSPECTION RESULTS

During the assessment period TOU was able to make direct observations of the WWTP odours at the fence line (**refer Figure 6: positions 20, 21-23**). The odour character was typically characteristic of WWTP ponds, namely slight H_2S, stagnant and sour with a slight faecal (toilet) character. The odour character was not observed to be a strong odour at the fence line, that is, the odour intensity according to VDI 3882 Part 1 (**refer Table 1**) was less than a 4, and rarely observed as a 3. Although the character was clearly discernible, the intensity was not high.

It would appear that the ponds were operating well and that upset conditions such as inlet chamber malfunctions, or dried beds etc were not prevalent. Given TOU's observations on the fence line took in the entire breadth of the ponds, the observations were highly repeatable at the fence line.

When TOU moved away from the fence line and down Fitzmaurice Drive, still on the WWTP access road, the odour became far less observable and was lost within the dense bushlands. The character then became a dilute, slight wastewater odour which was observed offsite (away from the ponds) on few occasions.

There are a large amount of drainage ways and runoff catchments in the area, together with runoff creeks and the encroaching Buffalo Creek toward the WWTP. The existence of large accumulations of water, both flowing and stagnant, may be a source of low level odour in localised areas.

The Darwin area was in the wet season during the assessment period; however, the month of February had very low to nil rainfall (mm) in the second half of the month. This made for a suitable time to do the assessment in the wet season because high rain events that would purge and dilute the WWTP ponds were not prevalent in the lead up to the assessment period. It can be seen from **Table 3 below** that the week of the 15th – 21st February had only 12.4mm of rain, whilst during the week of the assessment rainfall was 87mm toward the end of February and those rainfall events were in the evening.

Table 3: Rainfall statistics for February 2017 (Darwin AP AWS)							
Date	1	2	3	4	5	6	7
Day	Wed	Thurs	Friday	Sat	Sun	Mon	Tues
Rainfall (mm)	10.8	9.2	6.2	4.2	201.8	56	5.6
Date	8	9	10	11	12	13	14
Day	Wed	Thurs	Friday	Sat	Sun	Mon	Tues
Rainfall (mm)	1	58.4	70.8	6.8	57	14	5.4
Date	15	16	17	18	19	20	21
Day	Wed	Thurs	Friday	Sat	Sun	Mon	Tues
Rainfall (mm)	0	0	0	0	0.2	12.2	0
Date	22	23	24	25	26	27	28
Day	Wed	Thurs	Friday	Sat	Sun	Mon	Tues
Rainfall (mm)	0	0	0	0	15.4	49.8	21.8

8.1 Determination of Plume Extent (European Standard: EN 16841-2:2016)

The determination of the plume length and width was unable to be successfully completed due to the local topographical features (dense bush, tall grasses, dense housing etc) and the inability to achieve a clear line of sight to the WWTP. This was expected to some degree, although TOU was not previously aware of the obstructions between the WWTP and the assessment area.

Determining an odour plume, using the dynamic method, within a built up residential area, is often a difficult task because the stagnation and movement of the odour plume under very low wind conditions means that the plume often stalls.

Nonetheless, TOU was successful on Saturday, 25th February in determining the odour plume length and width in the early morning hours under a direct line of sight (easterly winds) and with winds in the typical range of 0.5 – 2.0m/s. the odour plume was determined to be approximately 5-600m long x 150m wide. The plume was observed on two occasions at those approximate dimensions when winds began to shift around the easterly bearing **(Refer Figure 4)**.

Given the early time of day in observing the odour plume, it is likely that the WWTP was receiving waste during a peak AM period.

There were other observations of odour within the residential area; these were considered as “spot” locations where odour was observable but only in the immediate vicinity. Further investigation both up, and downwind of those spot locations showed no observable odour. Barratt Street on two occasions had an observable spot odour location. The odour did resemble a stagnant water/wastewater character, but given the lack of observations upwind of the location, the origin of the odour was not readily identified.

Overcoming this required TOU to make odour intensity observations at set locations (**refer Figure 6**) and record the presence, intensity and frequency of odour observations over discrete 10-minute periods.

8.2 Determination of Odour Intensity (German Standard: VDI 3940; 3882 Part 1)

TOU undertook field inspections for odour on each day of the project duration with the scope of undertaking a minimum of ten (10) discrete field inspection surveys.

The wind characteristics during each field inspection were largely stable in direction with typical intermittent lateral flux, although fluxing winds were very low and consequently odour plumes were largely directionally fixed during these field inspections with multiple periods of calm winds, or stalls in wind speed.

Observing odour beyond typically 5-600m was nil. The odour plumes tended to be localised along Fitzmaurice Drive, close to the Power and Water gate, due to a line of sight. There were no odour observations within the landholdings of 2CRU and Muirhead North. The density of the natural bushland and long grasses meant that ground level odours were trapped in periods of calms or stalls.

Breeze conditions following stalls failed to show plume stagnation and meander within the residential area beyond the intermittent plume extent; although spot odour along Barratt

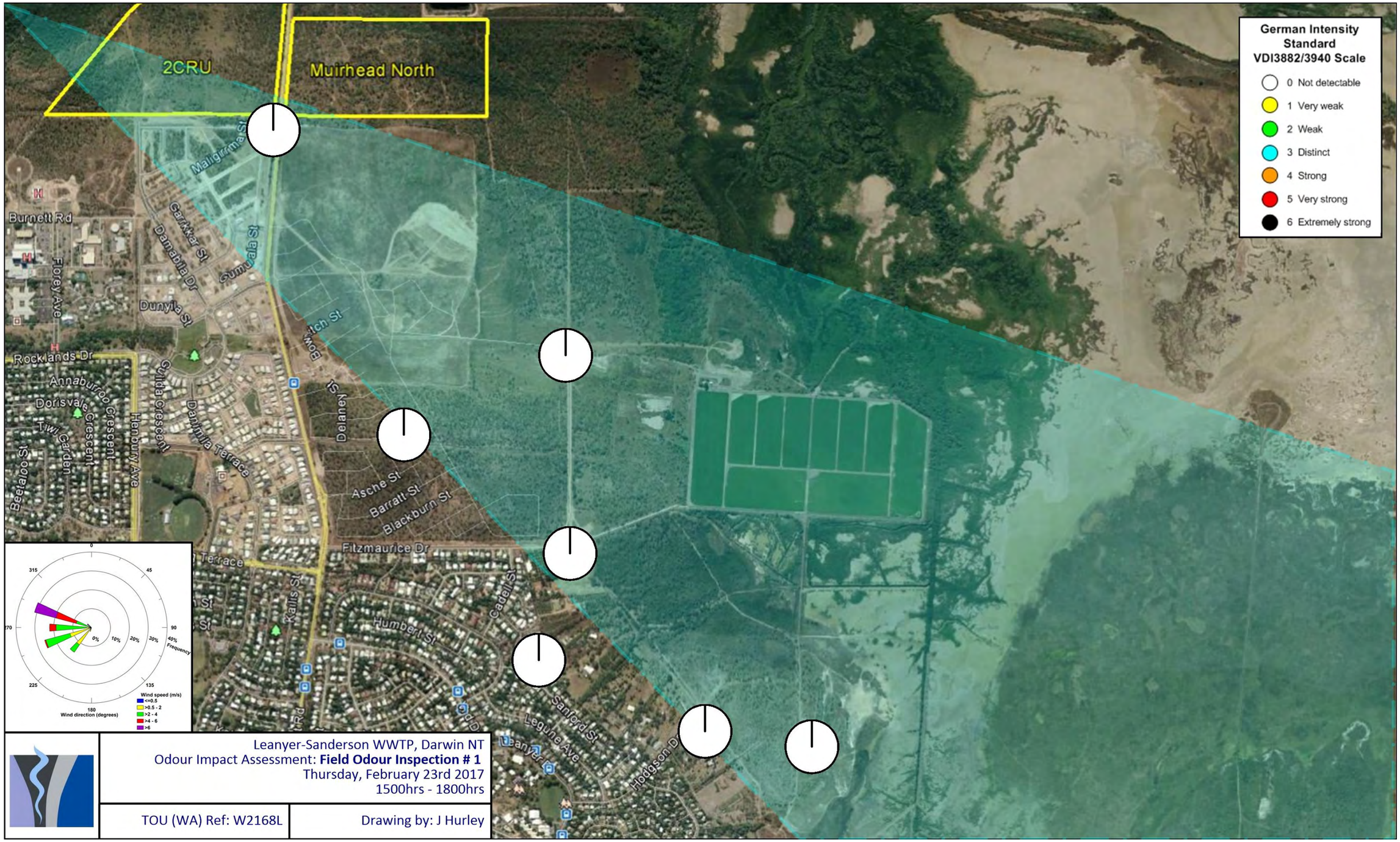
Street was observed without successful determination of its origin. This spot odour was localised between two houses only and suggest that a local issue may be the origin.

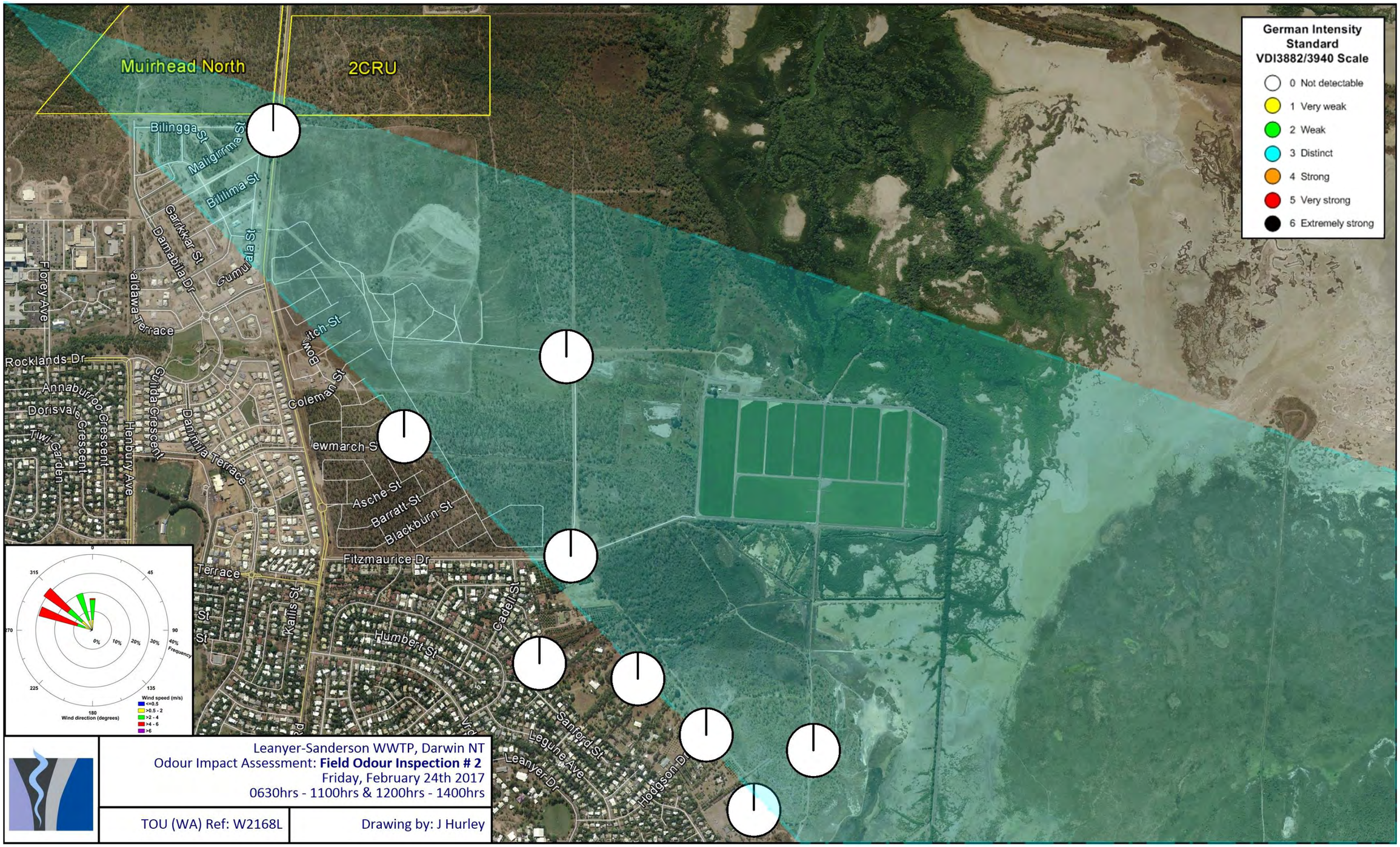
The individual field inspections on each day are presented below as illustrations of the recorded odour intensity and frequency (pie charts) at each field inspection location on an assessment map. The maps are illustrative and do not specifically represent the exact locations down to the nearest metre, they do however show the relative position of observations and the wind vector within which observations are made.

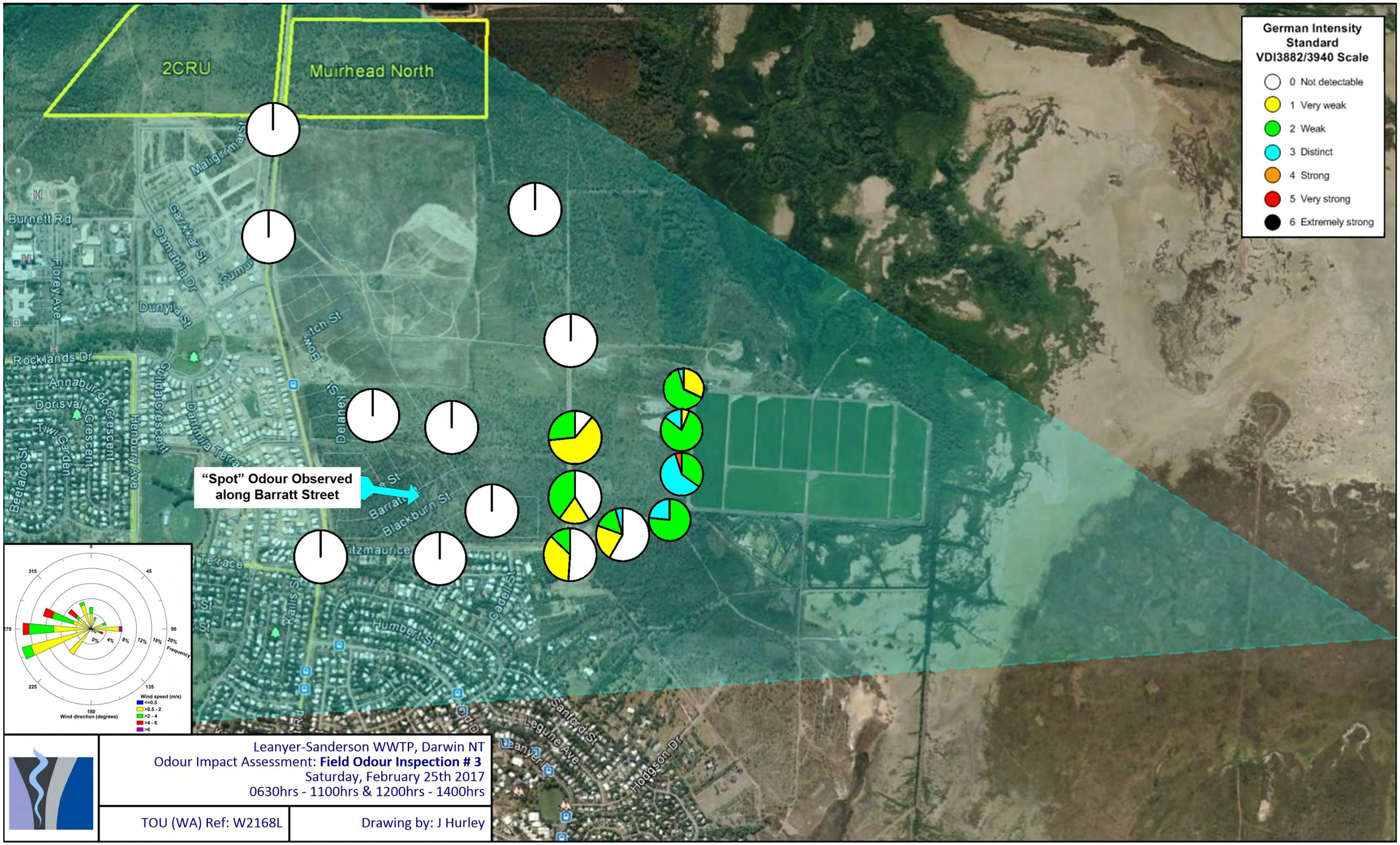
Of the assessment days there were only two (2) days that observable odour was detected. The wind conditions made observing odour difficult due to topographical constraints under westerly and northerly conditions; as such the field inspections on these days was focused on finding other sources of upwind odour whilst also venturing as far deep, toward the WWTP, as local conditions would allow and accounting for personnel safety.

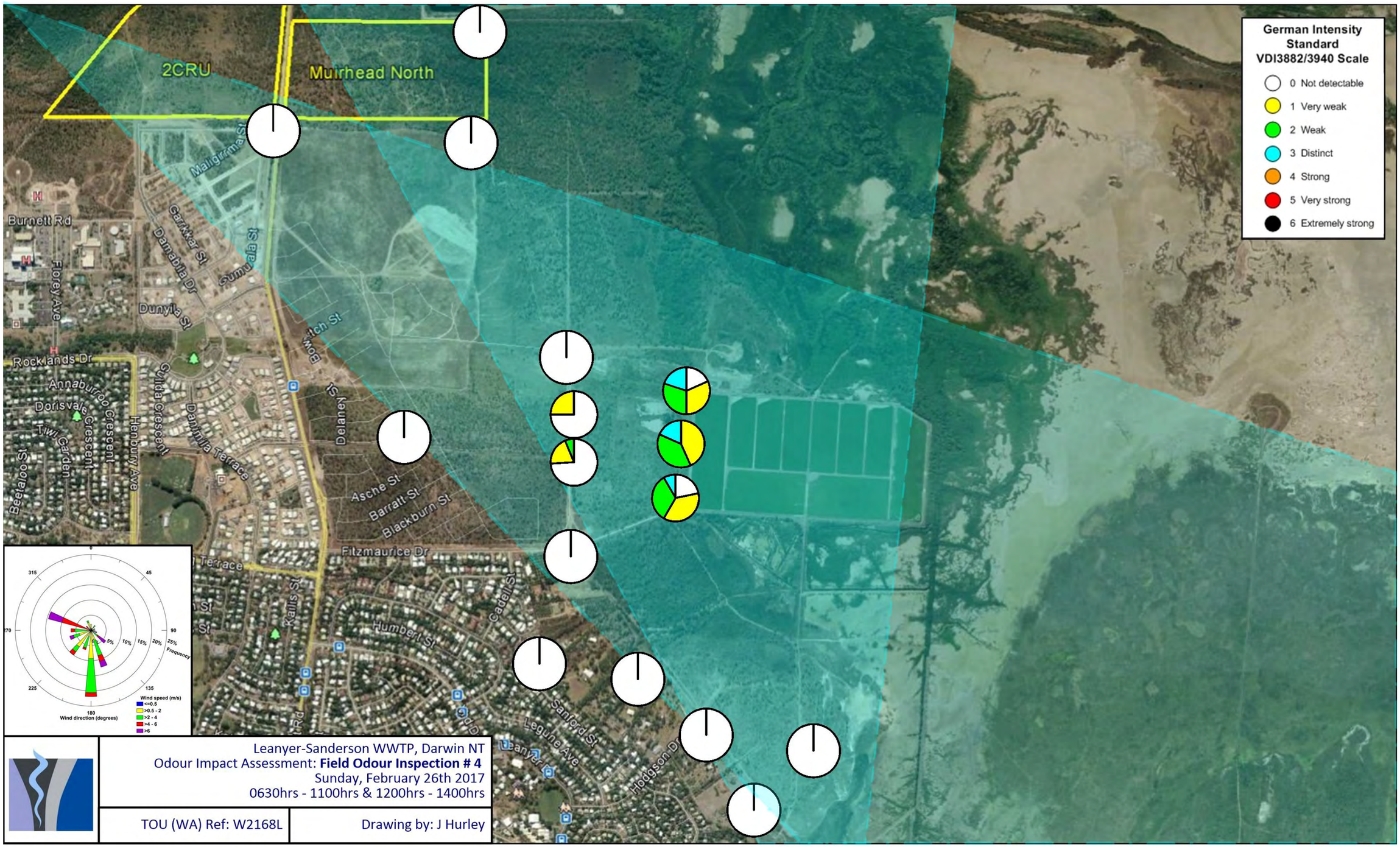
White pie charts indicate no odour was detected.

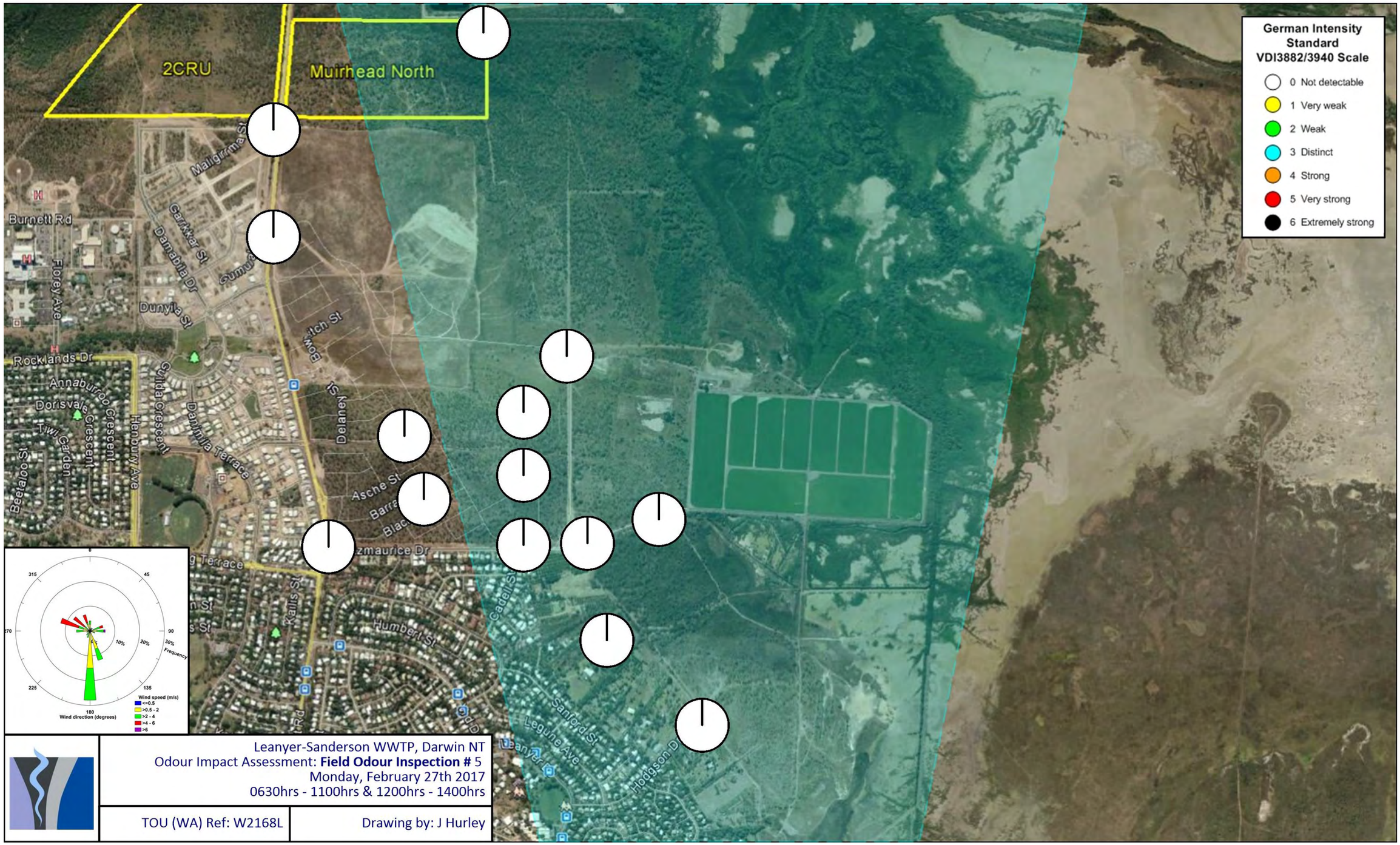
The light blue polygon represents the average wind direction for the duration of the field inspection/s where odour observations were made.

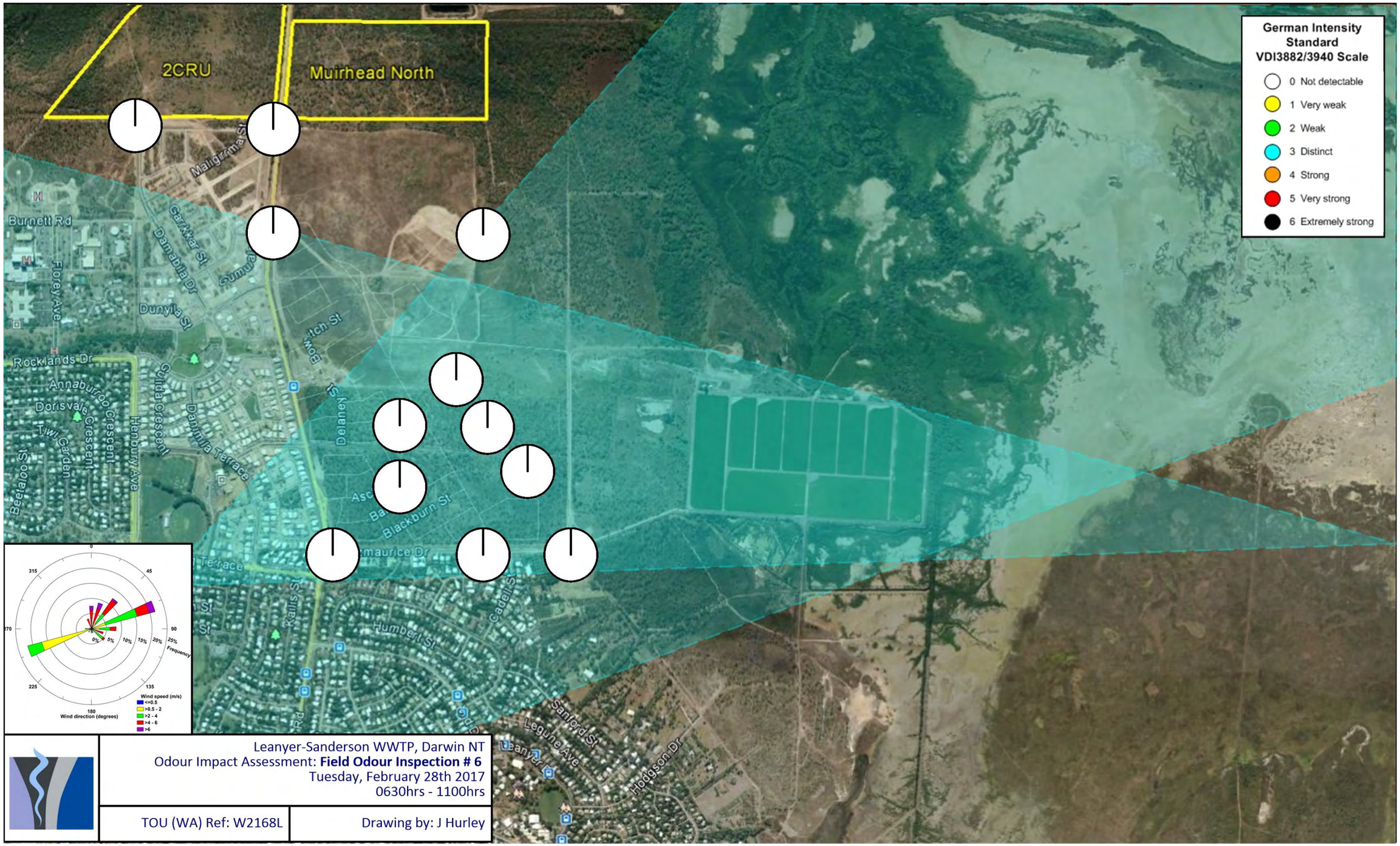

2CRU
Muirhead North
German Intensity Standard VDI3882/3940 Scale
0 Not detectable
1 Very weak
2 Weak
3 Distinct
4 Strong
5 Very strong
6 Extremely strong
Burnett Rd
Florey Ave
Rocklands Dr
Annaburroo Crescent
Dorisvale Crescent
Tiwi Garden
Beelaloo St
Henbury Ave
Guilda Crescent
Dantmila Terrace
Delaney St
Asche St
Barratt St
Blackburn St
Fitzmaurice Dr
Cadell St
Humbert St
Sanford St
Legune Ave
Hodgson D
Ralfe St
Malgirma St
Carlwar St
Damabila Dr
Gumurala St
Dunyila St
Wind direction (degrees)
Wind speed (m/s)
<=0.5
>0.5 - 2
>2 - 4
>4 - 6
>6
Frequency
Leanyer-Sanderson WWTP, Darwin NT
Odour Impact Assessment: Field Odour Inspection # 1
Thursday, February 23rd 2017
1500hrs - 1800hrs
TOU (WA) Ref: W2168L
Drawing by: J Hurley


Muirhead North
2CRU
German Intensity Standard VDI3882/3940 Scale
0 Not detectable
1 Very weak
2 Weak
3 Distinct
4 Strong
5 Very strong
6 Extremely strong
Bilingga St
Maligirrma St
Billima St
Garnkkar St
Damabila Dr
Florey Ave
Rocklands Dr
Annaburroo Crescent
Dorisvale Crescent
Tiwi Garden
Henbury Ave
Danmila Terrace
Coleman St
Ewmarch St
Asche St
Barratt St
Blackburn St
Fitzmaurice Dr
Humbert St
Cadell St
Sanford St
Leguna Ave
Leanyer Dr
Hodgson Dr
Wind speed (m/s)
<=0.5
>0.5 - 2
>2 - 4
>4 - 6
>6
Wind direction (degrees)
Frequency
Leanyer-Sanderson WWTP, Darwin NT
Odour Impact Assessment: Field Odour Inspection # 2
Friday, February 24th 2017
0630hrs - 1100hrs & 1200hrs - 1400hrs
TOU (WA) Ref: W2168L
Drawing by: J Hurley


2CRU
Muirhead North
German Intensity Standard VDI3882/3940 Scale
0 Not detectable
1 Very weak
2 Weak
3 Distinct
4 Strong
5 Very strong
6 Extremely strong
"Spot" Odour Observed along Barratt Street
Burnett Rd
Florey Ave
Dunyila St
Rocklands Dr
Annaburroo Crescent
Dorisvale Crescent
Tiwi Garden
Henbury Ave
Danjimla Terrace
Delaney St
Barratt St
Blackburn St
Itzmaurice
Terrace
Humbert St
Cadell St
Sanford St
Leguhe Ave
Hodgson Dr
Wind speed (m/s)
<=0.5
>0.5 - 2
>2 - 4
>4 - 6
>6
Wind direction (degrees)
Frequency
Leanyer-Sanderson WWTP, Darwin NT
Odour Impact Assessment: Field Odour Inspection # 3
Saturday, February 25th 2017
0630hrs - 1100hrs & 1200hrs - 1400hrs
TOU (WA) Ref: W2168L
Drawing by: J Hurley


2CRU
Muirhead North
German Intensity Standard VDI3882/3940 Scale
0 Not detectable
1 Very weak
2 Weak
3 Distinct
4 Strong
5 Very strong
6 Extremely strong
Burnett Rd
Florey Ave
Rocklands Dr
Annaburroo Crescent
Dorisvale Crescent
Beeroo St
Henbury Ave
Danninga Terrace
Delaney St
Asche St
Barratt St
Blackburn St
Fitzmaurice Dr
Humbert St
Cadell St
Sanford St
Legune Ave
Hodgson Dr
Kalis St
Dunyila St
Gumurdul St
Wind direction (degrees)
Wind speed (m/s)
<=0.5
>0.5 - 2
>2 - 4
>4 - 6
>6
Frequency
Leanyer-Sanderson WWTP, Darwin NT
Odour Impact Assessment: Field Odour Inspection # 4
Sunday, February 26th 2017
0630hrs - 1100hrs & 1200hrs - 1400hrs
TOU (WA) Ref: W2168L
Drawing by: J Hurley


2CRU
Muirhead North
German Intensity Standard VDI3882/3940 Scale
0 Not detectable
1 Very weak
2 Weak
3 Distinct
4 Strong
5 Very strong
6 Extremely strong
Burnett Rd
Florey Ave
Rocklands Dr
Annaburroo Crescent
Dorisvale Crescent
Twi Garden
Henbury Ave
Danmilla Terrace
Delaney St
Asche St
Humbert St
Sanford St
Leguna Ave
Hodgson D
Wind direction (degrees)
Wind speed (m/s)
<=0.5
>0.5 - 2
>2 - 4
>4 - 6
>6
Frequency
Leanyer-Sanderson WWTP, Darwin NT
Odour Impact Assessment: **Field Odour Inspection #** 5
Monday, February 27th 2017
0630hrs - 1100hrs & 1200hrs - 1400hrs
TOU (WA) Ref: W2168L
Drawing by: J Hurley


2CRU
Muirhead North
German Intensity Standard VDI3882/3940 Scale
0 Not detectable
1 Very weak
2 Weak
3 Distinct
4 Strong
5 Very strong
6 Extremely strong
Burnett Rd
Florey Ave
Rocklands Dr
Annaburroo Crescent
Dorisvale Crescent
Tiwi Garden
Henbury Ave
Danjimla Terrace
Dunyila St
Delaney St
Blackburn St
Humbert St
Cadell St
Sanford St
Leguna Ave
Hodgson Dr
Wind direction (degrees)
Wind speed (m/s)
<=0.5
>0.5 - 2
>2 - 4
>4 - 6
>6
Frequency
Leanyer-Sanderson WWTP, Darwin NT
Odour Impact Assessment: Field Odour Inspection # 6
Tuesday, February 28th 2017
0630hrs - 1100hrs
TOU (WA) Ref: W2168L
Drawing by: J Hurley

9 RESULTS & CONCLUSIONS

The field inspection odour impact assessment resulted in low intensity and frequency of odour impacts being detected up to nominally 5-600m downwind of the nearest WWTP pond with intermittent observations. These observations were under easterly wind conditions with the least amount of physical obstructions between the observation locations and the WWTP ponds.

There were no additional odour sources in and around the assessment area other than natural accumulations of water in creeks, as well as rainfall runoff levees. At times these water sources exhibited very low stagnant water odours, but not characteristic of WWTP odours.

During observable odour events, the plume was narrow and rarely meandered, in particular after calm periods where stagnation and subsequent meander would occur. The lack of observable odour during preferential wind conditions suggests a number of reasoning's, such as:

1. Good performance of process at the WWTP;
2. Lack of upset conditions such as inlet works breakdowns;
3. Lack of drying out of ponds where sludge may be exposed;
4. Control of sludge;
5. Lack of anaerobic conditions where algal blooms may occur;
6. Lack of cleared lands to sufficiently allow low intensity odour to carry large distances offsite.

However; the contrary to any of the above points 1-5 would in all likelihood generate odour impacts at distances greater than the observed. These types of odour impacts under those upset conditions would be the responsibility of the WWTP and its process operations rather than a typical event in the daily running and maintenance of modern WWTP's and associated secondary and infiltration/evaporation ponds.

TOU did not find any conditions, nor reason to suggest that odour impacts would be of a sufficient strength, frequency and intensity to impact on the Muirhead North and 2CRU land holdings. Moreover, the dense residential development that separates the land

holdings from the WWTP are already heavily populated and thus local complaints would be a more meaningful representation of odour impacts from the WWTP.

If odour impacts are recorded, the process conditions at the WWTP must be investigated to determine if upset conditions prevail. In TOU's extensive experience with WWTP's across Australia, the incidence of upset conditions, in particularly related to control of the inlet works and algal bloom events, can lead to increased odour impacts offsite; however, once an upset condition is known it can be communicated and remedied.

The Masterplan NT report, specifically the GHD contribution where an odour impact assessment was undertaken at the Leanyer-Sanderson WWTP, found that peak offsite odour impacts may occur under specific wind conditions, but that they also would arise under non-standard conditions such as:

a) Odour impacts from sludge exposure in lagoons (ponds) where supernatant falls to levels allowing exposure;
    a. can be managed and mitigated by ensuring supernatant levels are above the sludge layer,
b) Continued use of uncovered inlet chambers;
    a. can be managed by installing covers with an expected decrease in the primary odour source emissions of 25%.

GHD also discussed the management of sludge which requires partial desludging of the ponds every 4-6 years, although typically on an as-needs basis and may extent out to ten years. An event such as desludging has the potential to create far reaching odour impacts offsite; however, the planning of this and communication with the residents allows for an upset condition to be prepared for and managed accordingly.

The GHD report found that the existing odour emissions under standard operating conditions, coupled with the planned increase in capacity at the WWTP over coming years would result in a Low risk for a subdivision application at approximately 500m downwind of the WWTP. The subdivision boundary is in line (generally) with the main gate at the Power and Water entry to site. In consideration of a refurbished WWTP the risk of nuisance odours at this distance is Low according to the GHD report.

It is the opinion of TOU that the findings of the odour impact field inspection within the north-west assessment area surrounding the Leanyer-Sanderson WWTP support the judgement that odour impacts on the DHA land holdings 2CRU and Muirhead North would be negligible and in all likelihood nil. This conclusion is based on the standard operations of the WWTP.

The separation distance for Muirhead North, (at least 1.3kms) is a considerable separation distance as is that for the 2CRU land holding where the separation distance is 1.9kms. There is also no line of sight to the WWTP.

In the event of upset conditions at the WWTP the incidence of far reaching odour impacts may prevail; however as discussed, upset conditions are non-standard practice and can be managed, mitigated, and in some instances planned for. The existence of high-density residential areas between the DHA land holdings and the WWTP further suggests that the WWTP is under more scrutiny to improve and maintain its performance given the encroachment of potential complainants. Approvals to develop these areas also suggest that confidence in the running of the WWTP is high or improving, and communication between the WWTP operators and local regulators is apparent.

The GHD report further solidifies TOU's position given the extent to which the GHD report sampled and assessed the WWTP. The report showed at peak times and under proposed operations (i.e. expansion) a ground level concentration of 2ou would not reach the DHA land holdings. GHD referred to the Victorian EPA odour performance criterion of 1ou at the boundary, 3-minute averaging times at 99.9th percentile. This criterion is in TOU's opinion excessive and largely untenable for a ponds configuration WWTP i.e. without covered inlets, extraction and bio-scrubber/bio-trickling filtration and subsequent exhaust via chemical treated stacks (or similar best-practices). If the predictions from the GHD report were realised then there would be significant odour complaints within the existing residential areas.

TOU holds the opinion that the Leanyer-Sanderson WWTP, operating at standard practices with all care taken to mitigate upset conditions would not have an odour impact on the DHA land holdings to the north-west of the WWTP.

REFERENCES

- BS EN 16841-2:2016. Ambient air. Determination of odour in ambient air by using field inspection. Plume method
- BS EN 16841-1:2016. Ambient air. Determination of odour in ambient air by using field inspection. Grid method
- VDI 3940-2:2006. Measurement Of Odour Impact By Field Inspection - Measurement Of The Impact Frequency Of Recognizable Odours - Plume Measurement
- VDI 3940-1:2006. Measurement Of Odour Impact By Field Inspection - Measurement Of The Impact Frequency Of Recognizable Odours - Grid Measurement
- VDI 3882-1:1992. Olfactometry; Determination Of Odour Intensity
- NT, M., 2015. *Planning Report: Proposal to Amend the NT Planning Scheme,* Northern Territory: Masterplan NT

APPENDIX K

Traffic Impact Assessment report - 2CRU

Transport Impact Assessment

2CRU Subdivision, Lee Point

Prepared for
Defence Housing Australia

13 September 2016

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Shaping the Future

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Table of Contents

1 Introduction and Summary 1
1.1 Purpose of Report and Study Objectives 1
1.2 Summary 1
1.2.1 Site Location and Study Area 1
1.2.2 Development Description 2
1.2.3 Types of Studies Undertaken 2
1.2.4 Principle Findings 2
1.2.5 Conclusions 3
1.2.6 Recommendations 3
2 Proposed Development 4
2.1 Off-site Development 4
2.2 Description of On-Site Development 4
2.2.1 Land Use and Intensity 4
2.2.2 Location 5
2.2.3 Site Plan 5
2.2.4 Zoning 6
2.2.5 Phasing and Timing 6
3 Existing Area Conditions 8
3.1 Study Area 8
3.1.1 Area of Influence 8
3.1.2 Area of Significant Transport Impact 8
3.2 Study Area Land Use 8
3.2.1 Existing Land Uses 8
3.2.2 Existing Zoning 9
3.2.3 Anticipated Future Development 10
3.3 Site Accessibility 10
3.3.1 Area Roadway System 10
3.3.2 Traffic Volumes and Conditions 11
3.3.3 Transit Service 11
3.3.4 Pedestrians and Bicyclists 13
3.3.5 Existing Relevant Transportation System Management Programs 13
4 Projected Traffic 14
4.1 Site Traffic (Each Horizon Year) 14
4.1.1 Trip Generation 14
4.1.2 Trip Distribution 15
4.1.3 Modal Split 16
4.1.4 Trip Assignment 16
4.2 Through Traffic (Each Horizon Year) 16
4.2.1 Method Projection 16
4.2.2 Non-Site Traffic for Anticipated Development in Study Area 16
4.2.3 Through Traffic 16
4.2.4 Estimated Volumes 16
5 Transportation Analysis 21
5.1 Summary of Assumptions 21
5.2 Site Access and Existing Intersections 21

5.3 Capacity and Level of Service (2017 Base Scenario, Without Development) 23
5.3.1 Lee Point Road / Buffalo Creek Road Intersection 23
5.3.2 Lee Point Road / Lee Point Village Resort 24
5.4 Capacity and Level of Service (2027 Base Scenario, Without Development) 26
5.4.1 Lee Point Road / Buffalo Creek Road Intersection 26
5.4.2 Lee Point Road / Lee Point Village Resort 27
5.5 Capacity and Level of Service (2017 Base Scenario, With Development) 28
5.5.1 Lee Point Road / Buffalo Creek Road Intersection 28
5.5.2 Lee Point Road / Lee Point Village Resort 29
5.5.3 Lee Point Road / Access Road 1 Intersection 31
5.5.4 Lee Point Road / Access Road 2 Intersection 32
5.5.5 Lee Point Road / Access Road 3 Intersection 33
5.6 Capacity and Level of Service (2027 Base Scenario, With Development) 35
5.6.1 Lee Point Road / Buffalo Creek Road Intersection 35
5.6.2 Lee Point Road / Lee Point Village Resort 36
5.6.3 Lee Point Road / Access Road 1 Intersection 37
5.6.4 Lee Point Road / Access Road 2 Intersection 37
5.6.5 Lee Point Road / Access Road 3 Intersection 38
5.7 Transportation Safety 39
5.7.1 Operating Speeds 39
5.7.2 Guidance and Delineation 39
5.8 Traffic Signals 39
5.9 Site Circulation and Parking 39

6 Improvement Analysis 40
6.1 Improvements to Accommodate Existing Traffic 40
6.2 Improvements to Accommodate Background Traffic 40
6.3 Additional Improvements to Total Traffic (with Development) 40
6.4 Alternative Improvements 40
6.5 Status of Improvements Already Funded, Programmed, or Planned 40
6.6 Evaluation 40

7 Findings 41
7.1 Site Accessibility 41
7.2 Transportation Impacts 41
7.3 Needs for Any Improvements 41
7.4 Compliance with Applicable Local Codes 41

8 Recommendation 42
8.1 Site Access / Circulation Plan 42
8.2 Roadway Improvements 42
8.2.1 On-Site 42
8.2.2 Off-Site 42
8.3 Transit, Pedestrians and Bicycles 42
8.4 Transportation System Management / Transportation Demand Management Actions 42
8.4.1 Off-Site 42
8.4.2 On-Site Operational 42
8.4.3 On-Site 42

Appendices

Appendix A Site Plan

Tables

Table 2-1	Land Use Summary	4
Table 3-1	Existing Traffic Volumes (two-way)	11
Table 4-1	Trip Generation Rates (From RTA Guide to Traffic Generating Developments)	14
Table 4-2	Trip Directional Distribution	14
Table 4-3	Trip Generation and Distribution Estimation	14
Table 5-1	Lee Point Road / Buffalo Creek Road Intersection AM Performance – 2017 Without Development	24
Table 5-2	Lee Point Road / Buffalo Creek Road Intersection PM Performance – 2017 Without Development	24
Table 5-3	Lee Point Road / Lee Point Village Resort Intersection AM Performance – 2017 Without Development	25
Table 5-4	Lee Point Road / Lee Point Village Resort Intersection PM Performance – 2017 Without Development	26
Table 5-5	Lee Point Road / Buffalo Creek Road Intersection AM Performance – 2027 Without Development	26
Table 5-6	Lee Point Road / Buffalo Creek Road Intersection PM Performance – 2027 Without Development	27
Table 5-7	Lee Point Road / Lee Point Village Resort Intersection AM Performance – 2027 Without Development	27
Table 5-8	Lee Point Road / Lee Point Village Resort Intersection PM Performance – 2027 Without Development	27
Table 5-9	Lee Point Road / Buffalo Creek Road Intersection AM Performance – 2017 With Development	28
Table 5-10	Lee Point Road / Buffalo Creek Road Intersection PM Performance – 2017 With Development	29
Table 5-11	Lee Point Road / Lee Point Village Resort Intersection AM Performance – 2017 With Development	30
Table 5-12	Lee Point Road / Lee Point Village Resort Intersection PM Performance – 2017 With Development	30
Table 5-13	Lee Point Road / Access Road 1 Intersection AM Performance – 2017 With Development	31
Table 5-14	Lee Point Road / Access Road 1 Intersection PM Performance – 2017 With Development	32
Table 5-15	Lee Point Road / Access Road 2 Intersection AM Performance – 2017 With Development	33
Table 5-16	Lee Point Road / Access Road 2 Intersection PM Performance – 2017 With Development	33
Table 5-17	Lee Point Road / Access Road 3 Intersection AM Performance – 2017 With Development	34
Table 5-18	Lee Point Road / Access Road 3 Intersection PM Performance – 2017 With Development	35
Table 5-19	Lee Point Road / Buffalo Creek Road Intersection AM Performance – 2027 With Development	35
Table 5-20	Lee Point Road / Buffalo Creek Road Intersection PM Performance – 2027 With Development	36
Table 5-21	Lee Point Road / Lee Point Village Resort Intersection AM Performance – 2027 With Development	36

Table 5-22 Lee Point Road / Lee Point Village Resort Intersection PM Performance – 2027 With Development 36
Table 5-23 Lee Point Road / Access Road 1 Intersection AM Performance – 2027 With Development 37
Table 5-24 Lee Point Road / Access Road 1 Intersection PM Performance – 2027 With Development 37
Table 5-25 Lee Point Road / Access Road 2 Intersection AM Performance – 2027 With Development 38
Table 5-26 Lee Point Road / Access Road 2 Intersection PM Performance – 2027 With Development 38
Table 5-27 Lee Point Road / Access Road 3 Intersection AM Performance – 2027 With Development 38
Table 5-28 Lee Point Road / Access Road 3 Intersection PM Performance – 2027 With Development 39

Figures

Figure 1-1 Site Location and Study Area 1
Figure 1-2 Development Plan 2
Figure 2-1 Muirhead North Development Plan 4
Figure 2-2 Site Location 5
Figure 2-3 Site Plan for 2CRU Site. 6
Figure 2-4 Preliminary Staging Plan 7
Figure 3-1 Lee Point Road, Lee Point – Area of Influence and Existing Intersections 8
Figure 3-2 Land Zoning 9
Figure 3-3 Site Access Arrangements 10
Figure 3-4 Existing Public Transport Service 12
Figure 3-5 Existing Pedestrian/Cycling Facilities in the Area Surrounding the Site 13
Figure 4-1 Peak Trip Distribution 15
Figure 4-2 Estimated Background Conditions Traffic Volume in the Year 2017 17
Figure 4-3 Estimated Background Conditions Traffic Volume in the Year 2027 18
Figure 4-4 Estimated Total Traffic Volume in the Year 2017 with Development 19
Figure 4-5 Estimated Total Traffic Volume in the Year 2027 with Development 20
Figure 5-1 Site Access and Existing Intersection 22
Figure 5-2 Lee Point Road / Buffalo Creek Road Intersection Layout 23
Figure 5-3 Lee Point Road / Lee Point Village Resort Intersection Layout 25
Figure 5-4 Lee Point Road / Buffalo Creek Road Intersection Layout 28
Figure 5-5 Lee Point Road / Lee Point Village Resort Intersection Layout 29
Figure 5-6 Lee Point Road / Access Road 1 Intersection Layout 31
Figure 5-7 Lee Point Road / Access Road 2 Intersection Layout 32
Figure 5-8 Lee Point Road / Access Road 3 Intersection Layout 34

1 Introduction and Summary

1.1 Purpose of Report and Study Objectives

Cardno has been commissioned by Defence Housing Australia to prepare a *Transport Impact Assessment* (TIA) for the 2CRU site located at Lot 4873 Lee Point Road, Lee Point, City of Darwin.

The Site will primarily consist of residential development along with areas of mixed use. The development plan is enclosed in **Appendix A**.

This report has been prepared in accordance with the Austroads *Guide to Traffic Management Part 12: Traffic Impacts of Development*.

The purpose of this report is to determine the overall impact of the development on the surrounding road network along with the performance of nearby intersections and the overall amenity of the area.

1.2 Summary

1.2.1 Site Location and Study Area

The study area and existing intersections within the study area are shown in **Figure 1-1**.

Figure 1-1 Site Location and Study Area

Source: Nearmap

1.2.2 Development Description

The proposed development area for the Site is shown in **Figure 1-2** and will comprise of residential dwellings, serviced apartments, hotels, private apartments and a commercial and retail area. For the purpose of this report, it is anticipated that the development will open in 2017.

Figure 1-2 Development Plan

Source: Defence Housing Australia (DHA)

1.2.3 Types of Studies Undertaken

As the primary access location for the Site is proposed via Lee Point Road, a TIA has been undertaken to determine the effect of the development to the nearby existing intersections (Lee Point Road/Lee Point Village Resort and Lee Point Road/Buffalo Creek Road) and if necessary, any improvement to the intersection that will provide adequate access, while maintaining an acceptable Level Of Service (LOS) for road intersections.

1.2.4 Principle Findings

This Transport Impact Assessment has found that all intersections along Lee Point Road will perform satisfactorily for the year 2017 and 2027 in their currently proposed form and no improvement to the intersections are necessary to accommodate the expected increase in traffic.

1.2.5 Conclusions

The development is expected to have minimal impact on the surrounding road network and the overall amenity of the area, therefore no upgrades are necessary to Lee Point Road, as well as the surrounding road network.

1.2.6 Recommendations

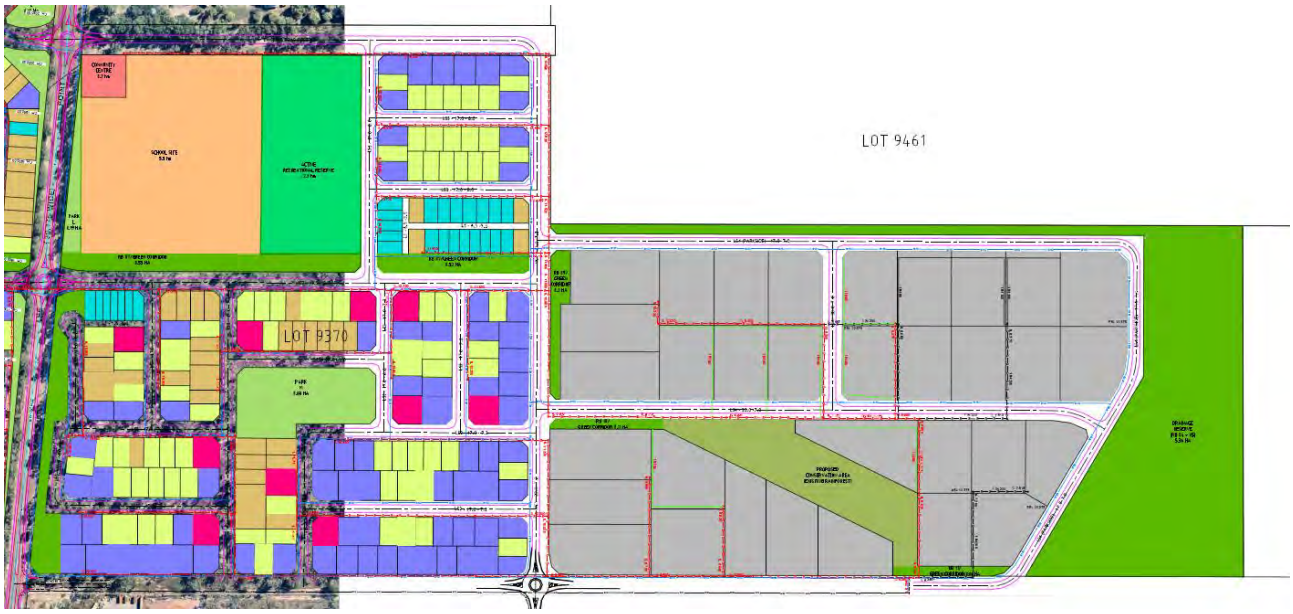
No roadway improvements have been proposed for Lee Point Road and the surrounding road network (other than what has been proposed in the Site plans) as it is expected that the Site will have minimal impact on the surrounding area.

2 Proposed Development

2.1 Off-site Development

To the east of the proposed 2CRU development, is the proposed Muirhead North development. The Muirhead development site is described as Lot 9370 and is located to the east of Lee Point Road to the north of Muirhead Breezes estate in the Northern Territory. The development has a total site area of approximately 49.32ha and is proposed to be developed into 220 residential single dwellings lots, 37 rural residential lots, a primary school and a community hub. The Muirhead North development plan is shown in **Figure 2-1**.

Figure 2-1 Muirhead North Development Plan



Source: Defence Housing Australian (DHA)

2.2 Description of On-Site Development

2.2.1 Land Use and Intensity

The 2CRU developments are proposed to accommodate residential dwellings, along with serviced apartments, hotels, private apartments and a commercial and retail area. The proposed site plan is shown in **Figure 2-3** and a summary of the land uses is shown in **Table 2-1**.

Table 2-1 Land Use Summary

Land Use	Traffic Generation Category and % Splits	Provision
Single Dwelling Residential	Residential	340 dwellings
Multiple Dwelling Residential (duplex)	Small units and flats	40 dwellings
Medium Density Residential	Large units and town houses	92 dwellings
Tourism (serviced apartments and hotel units)	50% serviced apartments 50% hotel units	300 dwellings
Mixed Use (commercial, retail and restaurant	40% commercial 40% retail 20% restaurant	60 units
General Urban	70% small units and flats 30% large units and town houses	160 units

2.2.2 Location

The location of the proposed subdivision (the Site) is shown in **Figure 2-2**.

Figure 2-2 Site Location

Source: Nearmap

2.2.3 Site Plan

A site plan for the proposed subdivision is shown in **Figure 2-3.** High resolution plans of the Site have been provided in **Appendix A.**

Figure 2-3 Site Plan for 2CRU Site.

Source: Defence Housing Australia

2.2.4 Zoning

The subdivision is zoned 'Future Development' under the Northern Territory Planning Scheme.

2.2.5 Phasing and Timing

The preliminary staging plan is shown in **Figure 2-4**. The timing for construction is intended commence in the 2017 dry season and nominally one stage per year to be released. The staging and timing are subject to change due to the environmental approvals process and commercial assessment.

Figure 2-4 Preliminary Staging Plan

Source: Defence Housing Australia

3 Existing Area Conditions

3.1 Study Area

3.1.1 Area of Influence

The study area along with surrounding roads and intersections within this area are shown in **Figure 3-1.**

Figure 3-1 Lee Point Road, Lee Point – Area of Influence and Existing Intersections

Source: Nearmap

3.1.2 Area of Significant Transport Impact

The area of significant transportation impact is shown in **Figure 3-1** as this includes the intersections serving the study area.

3.2 Study Area Land Use

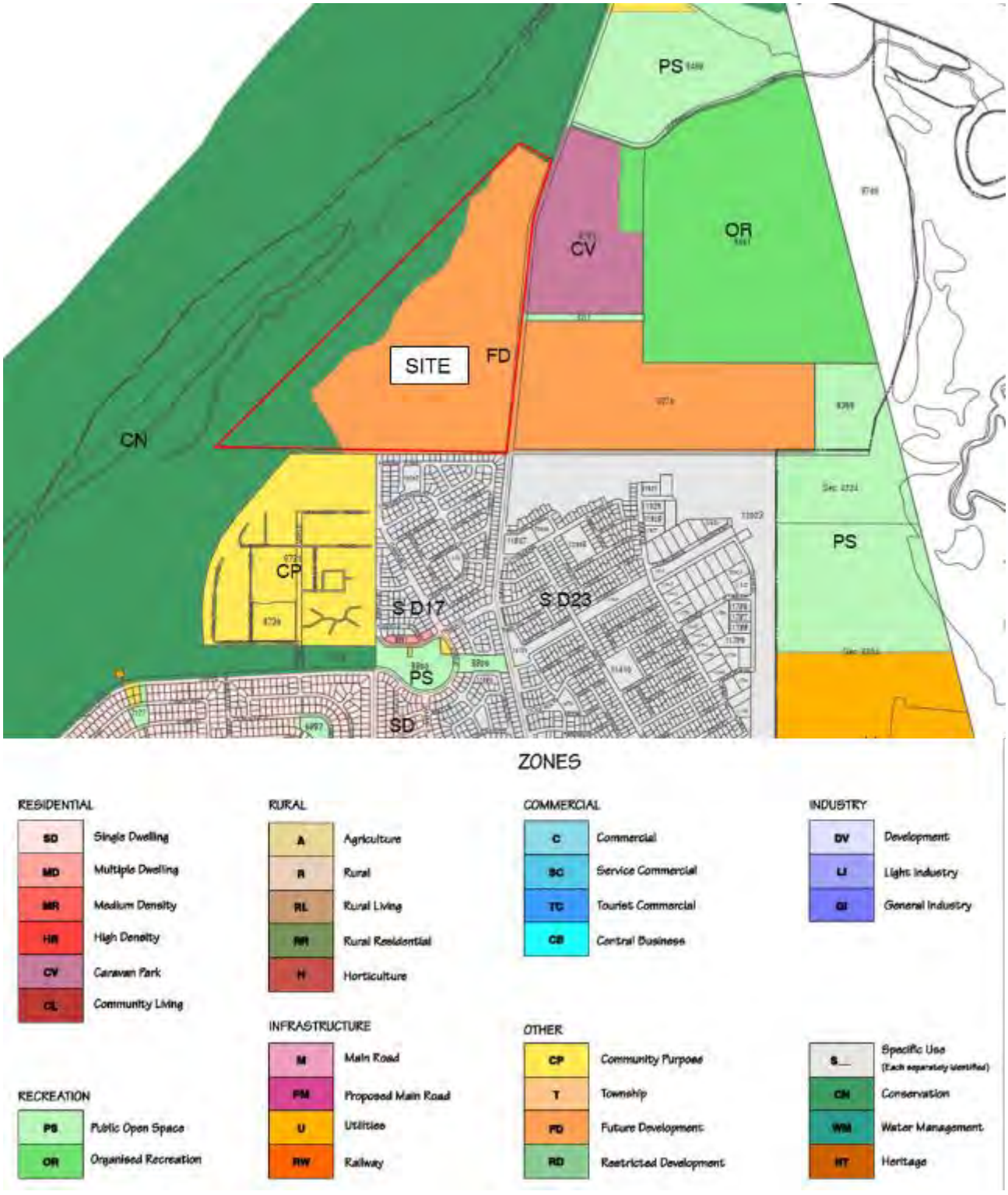
3.2.1 Existing Land Uses

Land use surrounding the Site includes a caravan park and future development to the east, conservation land to the west and community purpose and residential to the south.

3.2.2 Existing Zoning

As shown in **Figure 3-2**, the land within the Site is zoned as 'Future Development' under the Northern Territory Planning Scheme.

Figure 3-2 Land Zoning



Source: Northern Territory Planning Scheme

3.2.3 Anticipated Future Development

It is anticipated that the area will consist of single dwelling and medium density residential developments along with commercial/retail mixed use development.

3.3 Site Accessibility

3.3.1 Area Roadway System

3.3.1.1 Existing

There is currently one existing access to the Site located approximately 370m south of Lee Point Village Resort. Public access is currently prohibited along this road.

3.3.1.2 Future

The proposed vehicular access for the development is shown in **Figure 3-3**. A total of three access roads have been proposed:

- **Access 1** – Located on Lee Point Road, full movement stop priority controlled access
- **Access 2** – Located on Lee Point Road, full movement roundabout access
- **Access 3** – Located on Lee Point Road, full movement roundabout access

Figure 3-3 Site Access Arrangements

Source: Nearmap

3.3.2 Traffic Volumes and Conditions

A traffic survey for the access to Lee Point Village Resort was conducted in March 2015. The traffic surveys indicated that the AM and PM peak hours for the Lee Point Village Resort access road occurred from 7:30am – 8:30am and 5:45pm – 6:45pm, respectively. Traffic volumes at the Lee Point Road/Buffalo Creek Road intersection were estimated using the volumes collected for the Lee Point Village Resort access. **Table 3-1** provides a summary of the existing traffic volumes.

Table 3-1 Existing Traffic Volumes (two-way)

Road Name	Date	Average Two-way Traffic Volumes	
		Vehicles per AM Peak Hour	**Vehicles Per PM Peak Hour**
Lee Point Village Resort	March 2015	16	15
Buffalo Creek Road	March 2015	28	58
Lee Point Road (At Lee Point Village Resort)	March 2015	35	94
Lee Point Road (At Buffalo Creek Road)	March 2015	18	48

3.3.3 Transit Service

The Northern Territory's public transport services are managed by the Department of Transport (DoT) and operated by a range of contractors. There are currently no public transport services along the section of Lee Point Road fronted by the 2CRU development

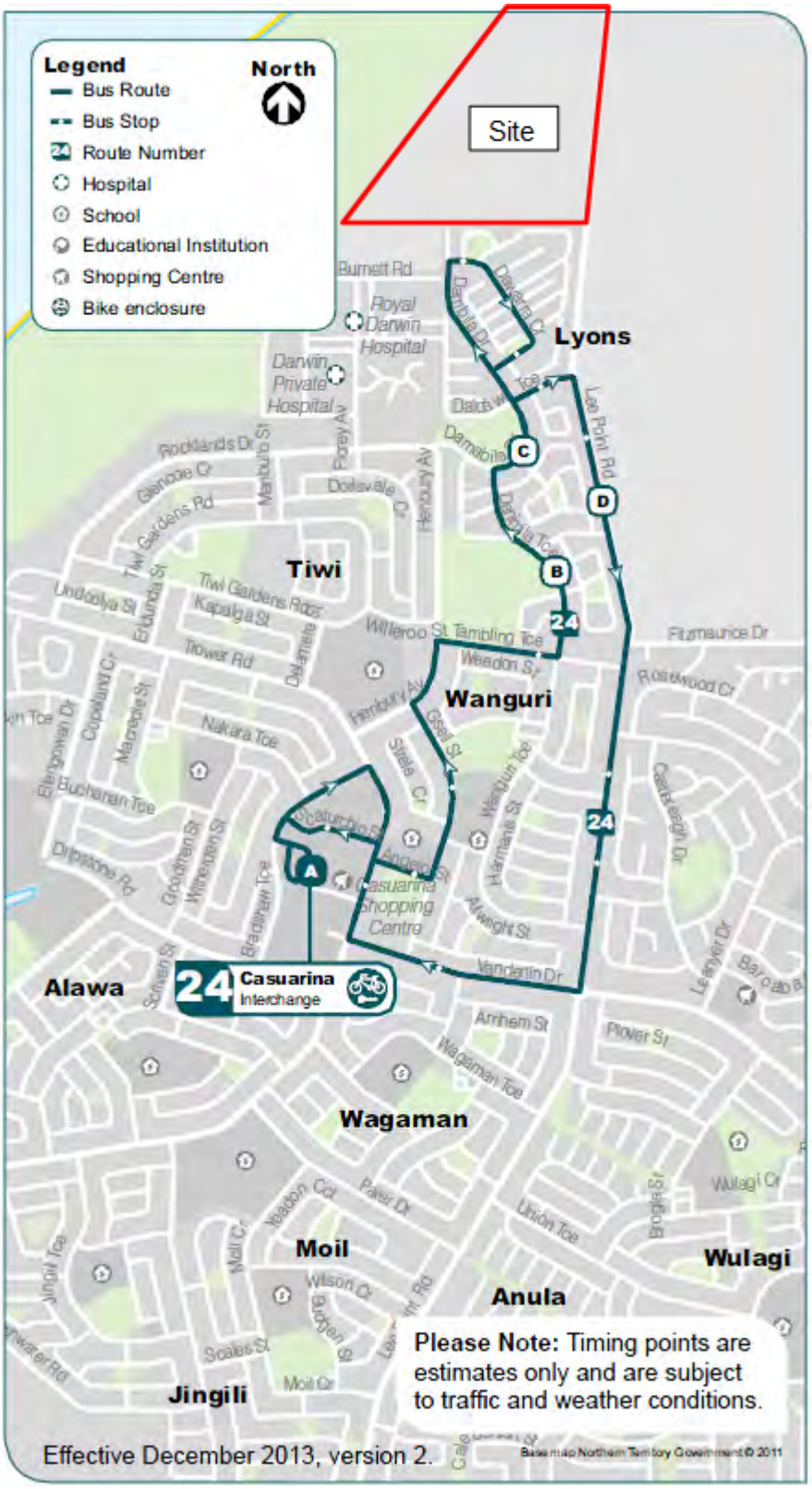
However, bus services do operate along Lee Point Road to the south of the site. Bus route 24 loops from Casuarina to Lyons and travels south along Lee Point Road from Daladawa Terrace to Vanderlin Drive. The closest bus stop from the development for this route is on Lee Point Road, approximately 1km south of the Site. The route has been illustrated in **Figure 3-4** and the frequency of service are as follows:

> Weekdays: Every 30 – 60 minutes

> Weekends and Public Holidays: Every 35 – 70 minutes

Though public transport services do not operate near the Site, future development within the area may create opportunities for new services or extensions of existing services towards the area of the Site.

Figure 3-4 Existing Public Transport Service



Source: Department of Transport NT

3.3.4 Pedestrians and Bicyclists

According to the map provided by Department of Transport, shown in **Figure 3-5**, there are 2.5m shared paths along the eastern side of Damabila Drive and Lee Point Road. Both shared paths end just before the southern border of the Site.

As the area surrounding the Site is undeveloped there is currently a lack of pedestrian and cycling paths, though future development will create new opportunities for path construction.

Figure 3-5 Existing Pedestrian/Cycling Facilities in the Area Surrounding the Site

Source: Department of Transport NT

3.3.5 Existing Relevant Transportation System Management Programs

There are no known existing relevant transportation system management programs that impact on the nominated study area.

4 Projected Traffic

4.1 Site Traffic (Each Horizon Year)

4.1.1 Trip Generation

The trip generation rates for the Site were sourced from the RTA Guide to Traffic Generating Developments (October 2002) and are summarised in **Table 4-1**. The assumed trip directional distribution for the peak-hour trip rates have been summarised in **Table 4-2**. **Table 4-3** summarises the total estimated traffic generated by the development and the distribution.

Table 4-1 Trip Generation Rates (From RTA Guide to Traffic Generating Developments)

Land Use	Weekday Peak Hour (AM and PM)	Daily
Residential	0.85 per dwelling	9 per dwelling
Serviced Apartments	0.45	4.5
Hotel Units	0.4	3
Smaller Units and Flats	0.45	4.5
Larger Units and Town Houses	0.6	6
Commercial	2 per 100m^2 GFA	10 per 100m^2 GFA
Retail	12.5 per 100m^2 GLFA	121 per 100m^2 GLFA
Restaurant	5 per 100m^2 GFA	60 per 100m^2 GFA

Table 4-2 Trip Directional Distribution

Land Use	AM Peak		PM Peak	
	In	Out	In	Out
Residential	30%	70%	60%	40%
Serviced Apartments	30%	70%	60%	40%
Hotel Units	30%	70%	60%	40%
Smaller Units and Flats	30%	70%	60%	40%
Larger Units and Town Houses	30%	70%	60%	40%
Commercial	85%	15%	15%	85%
Retail	50%	50%	50%	50%
Restaurant	50%	50%	50%	50%

Table 4-3 Trip Generation and Distribution Estimation

Land Use	AM Peak		PM Peak	
	In	Out	In	Out
Residential	87	202	173	116
Serviced Apartments	20	47	41	27
Hotel Units	18	42	36	24
Smaller Units and Flats	21	48	41	27
Larger Units and Town Houses	25	59	50	34
Commercial	27	5	5	27
Retail	56	56	56	56
Restaurant	20	20	20	20
Total	**274**	**479**	**422**	**331**

4.1.2 Trip Distribution

The distribution of traffic to/from the Site has been determined based on the location of the Site in relation to the location of nearby employment/commercial areas and attractions. As the Site is located on the northern fringe of Darwin, it is assumed that the majority of traffic generated from the Site will likely travel south towards the Darwin Town Centre. A small percentage of traffic is expected to travel north to the Casuarina Coastal Reserve and Buffalo Creek boat ramp. It is therefore assumed that the residents would access the Site as follows:

> 5% of trips travel north along Lee Point Road

> 95% of trips travel south along Lee Point Road

The trip distribution for the peak periods are presented in **Figure 4-1**. It is assumed that the distribution is the same for both AM and PM peaks.

Figure 4-1 Peak Trip Distribution

Source: Defence Housing Australia (DHA)

The trips generated by the site onto Lee Point Road will be assigned as follows:

> 20% using Access 1;

> 45% using Access 2;

> 35% using Access 3.

4.1.3 Modal Split

An allowance for typical modal split is incorporated in the *ITE* trip generation rates.

4.1.4 Trip Assignment

It is assumed that all traffic going in and out of the Site will be via Lee Point Road, as it is the only access point of the Site.

4.2 Through Traffic (Each Horizon Year)

4.2.1 Method Projection

Due to the limited development opportunities to the north of the proposed development, a conservative growth rate has been determined to reflect this scenario. This rate has been applied to the traffic counts provided for 2015 to reflect the estimated traffic volumes for 2017.

4.2.2 Non-Site Traffic for Anticipated Development in Study Area

For the purpose of this assessment, the Muirhead North Development has been excluded.

4.2.2.1 Method of Projections

This is not applicable as there are no known additional anticipated developments within the study area.

4.2.2.2 Trip Generation

This is not applicable as there are no known additional anticipated developments within the study area.

4.2.2.3 Trip Distribution

This is not applicable as there are no known additional anticipated developments within the study area.

4.2.2.4 Modal Split

This is not applicable as there are no known additional anticipated developments within the study area.

4.2.2.5 Trip Assignment

This is not applicable as there are no known additional anticipated developments within the study area.

4.2.3 Through Traffic

TMR's Guideline for Assessment of Road Impacts of Development (GARID) recommends that intersection and accesses are designed to accommodate up to 10 years of traffic growth after opening. The opening year for this intersection is assumed to be 2017 and the design year has been selected as 2027.

A linear growth rate of 3% p.a has been adopted to establish the 2025 base (no development) traffic volumes.

4.2.4 Estimated Volumes

4.2.4.1 Background Conditions

Estimated traffic for the background conditions scenario is shown in **Figure 4-2** and **Figure 4-3.**

Figure 4-2 Estimated Background Conditions Traffic Volume in the Year 2017

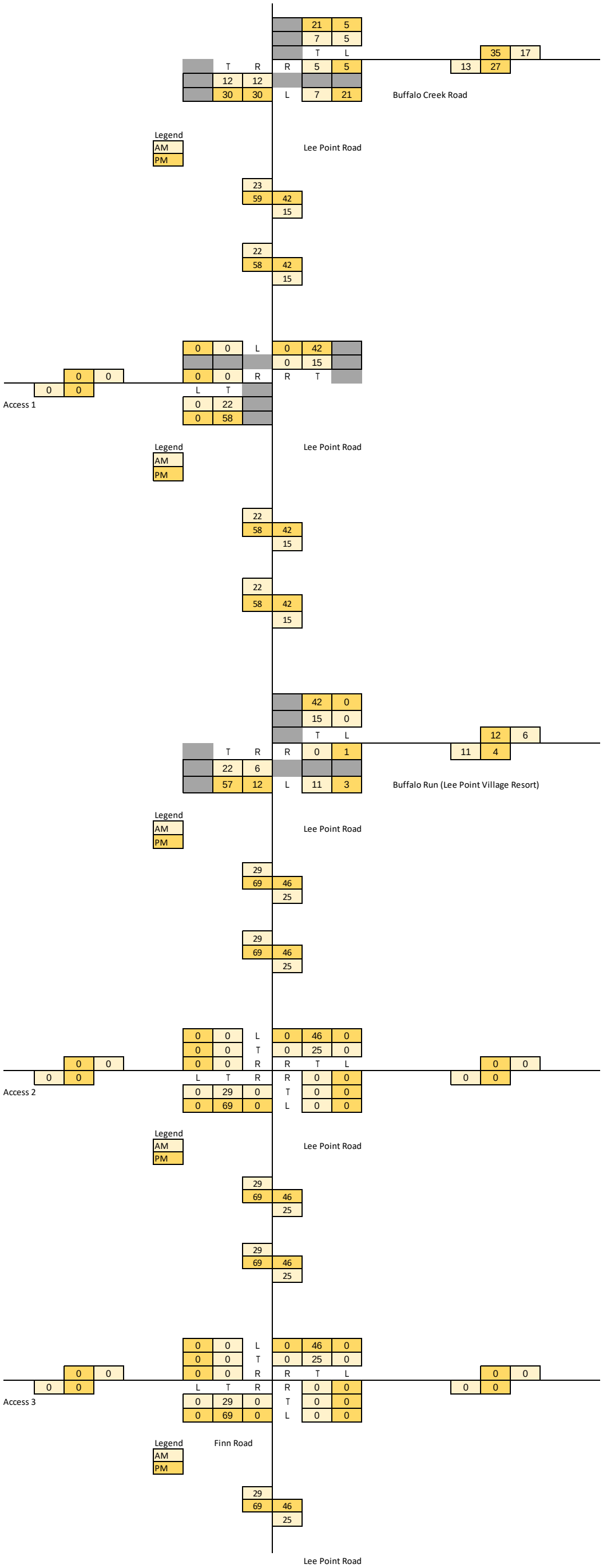
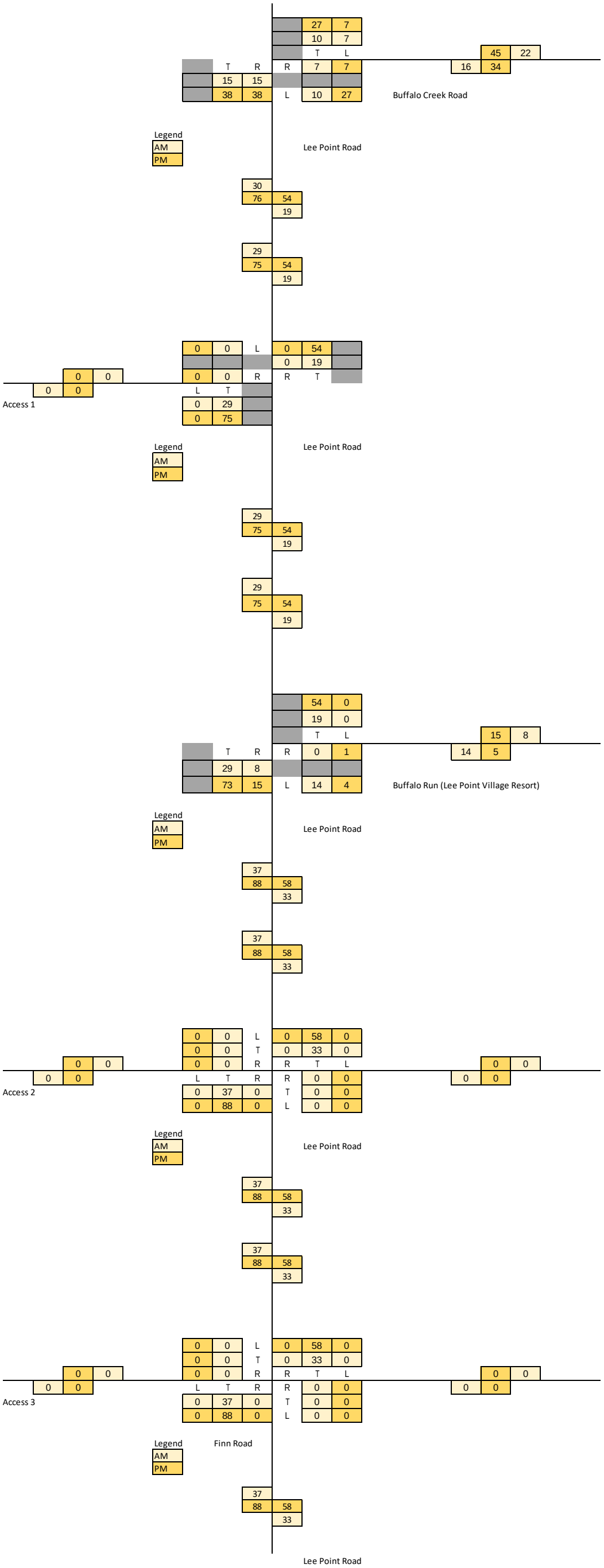


Figure 4-3 Estimated Background Conditions Traffic Volume in the Year 2027



4.2.4.2 Total Traffic (with development)

Estimated traffic for the background conditions scenario is shown in **Figure 4-4** and **Figure 4-5.**

Figure 4-4 Estimated Total Traffic Volume in the Year 2017 with Development

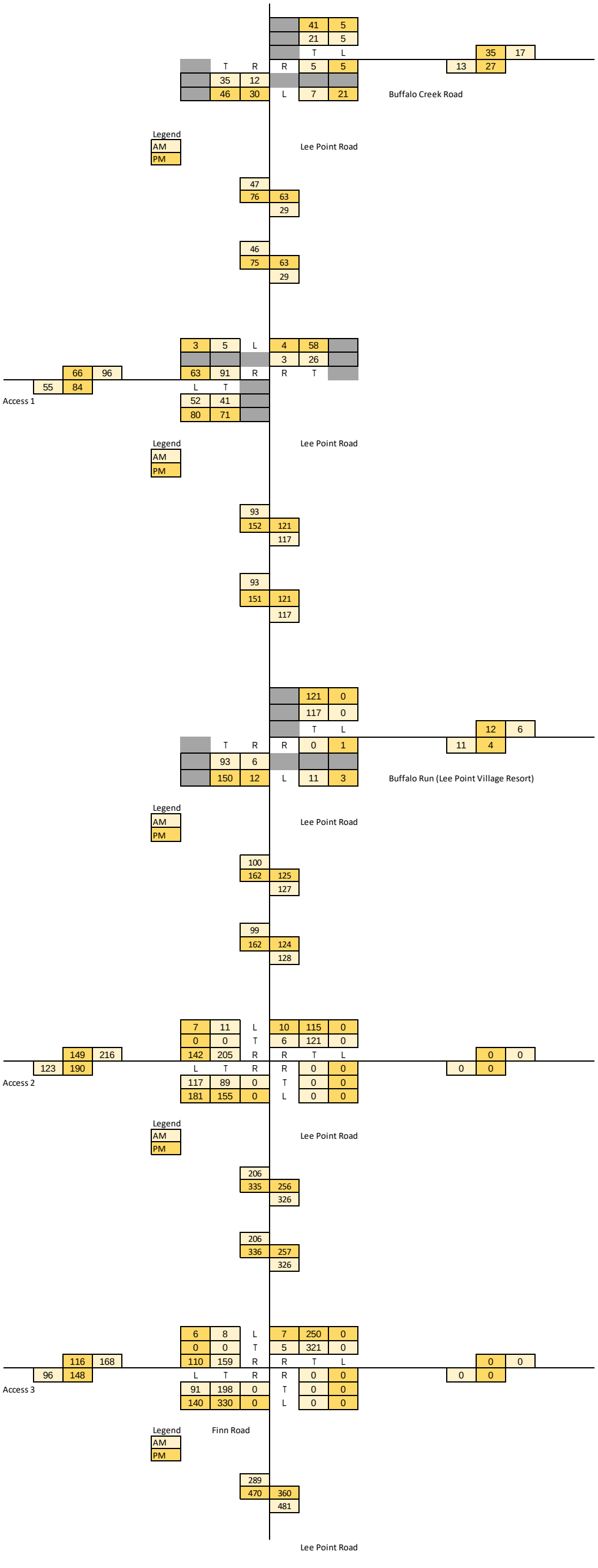
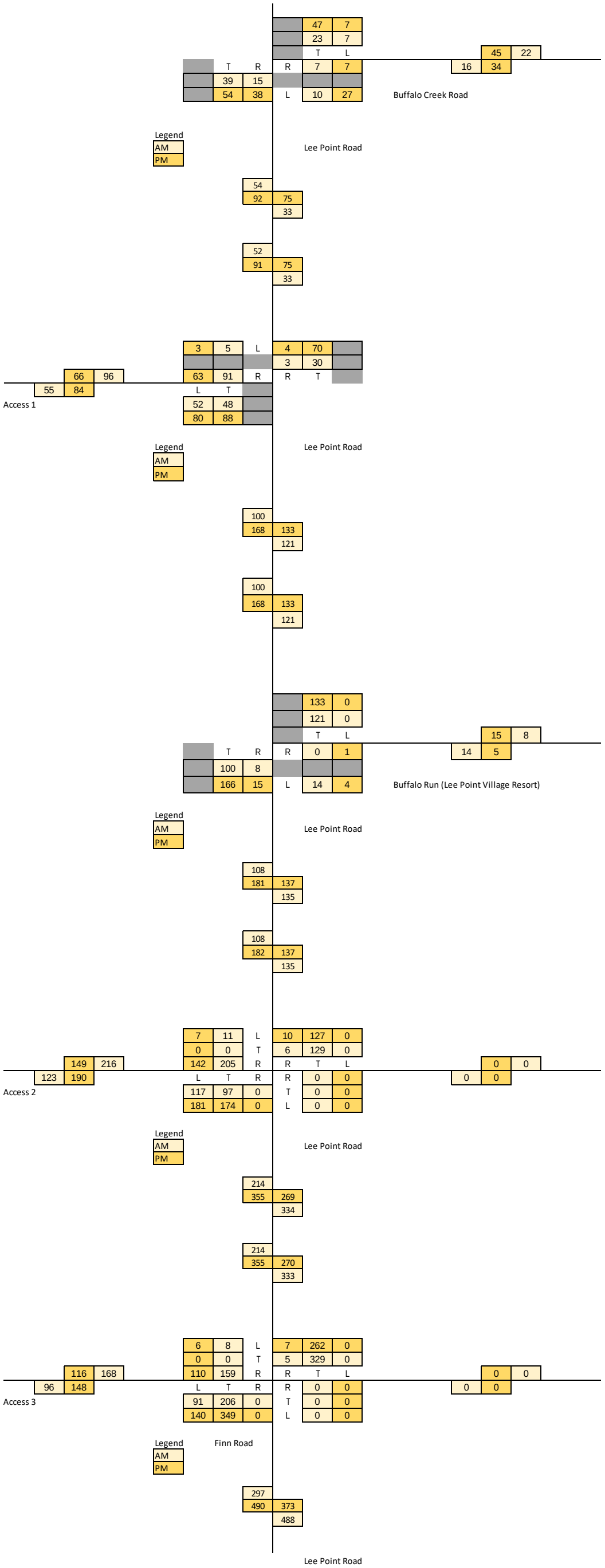


Figure 4-5 Estimated Total Traffic Volume in the Year 2027 with Development



5 Transportation Analysis

5.1 Summary of Assumptions

A summary of the assumptions used for this analysis are as follows:

Land use:

> A 50:50 split of serviced apartments and hotel rooms within the tourism precinct accommodation

> A 70:30 split of two bedroom and three bedroom private apartments (general urban)

> 75% of the mixed use area is gross floor area (GFA) for the buildings

> 50% of the mixed use buildings GFA is designated as retail, commercial and restaurants

> The retail, commercial and restaurants as part of the mixed use buildings are 40%, 40% and 20% respectively

Trip generation:

> No reduction rates have been applied (for internal or multi-purpose trips) to provide a robust assessment.

Trip distribution:

> It is assumed that residents would access the site as follows:

- 5% of trips travel north along Lee Point Road
- 95% of trips travel south along Lee Point Road

> The trips generated by the site onto Lee Point Road will be assigned as follows:

- 20% using Access 1;
- 45% using Access 2;
- 35% using Access 3.

Transportation analysis:

> As there is no traffic along the eastern legs of Access 2 and 3 roundabouts (due to the exclusion of Muirhead North), the eastern leg will be removed for the purpose of this assessment

> A conservative figure of 5% has been assumed for heavy vehicles

> A linear growth rate of 3% p.a has been adopted to establish the 2017 and 2027 base (no development) traffic volumes

5.2 Site Access and Existing Intersections

As shown in **Figure 5-1**, the only access into the Site is at the three access points along Lee Point Road. All traffic is expected to exit the Site via these access roads then onto Lee Point Road where it distributes to the north or south.

Figure 5-1 Site Access and Existing Intersection

The assessment scenarios are as follows:

> 2017 Base Scenario, Without Development for the following intersections
  - Lee Point Road / Buffalo Creek Road Intersection
  - Lee Point Road / Lee Point Village Intersection
> 2027 Base Scenario, Without Development for the following intersections
  - Lee Point Road / Buffalo Creek Road Intersection
  - Lee Point Road / Lee Point Village Intersection
> 2017 Base Scenario, With Development for the following intersections
  - Lee Point Road / Buffalo Creek Road Intersection
  - Lee Point Road / Lee Point Village Intersection
  - Lee Point Road / Access Point 1
  - Lee Point Road / Access Point 2
  - Lee Point Road / Access Point 3

> 2027 Base Scenario, With Development for the following intersections

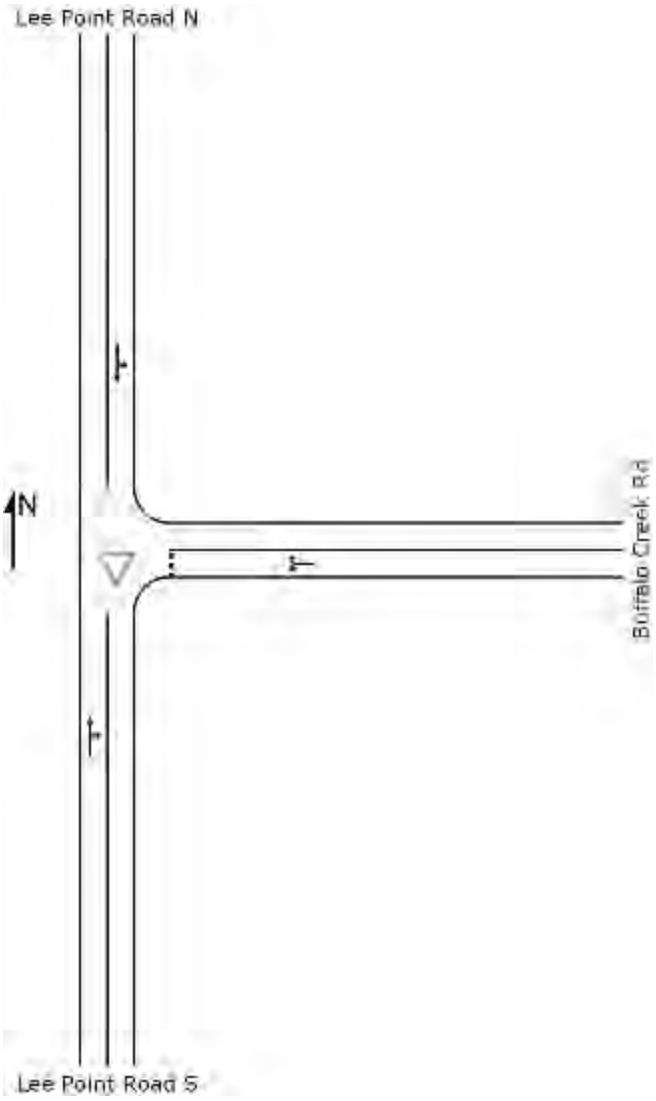
- Lee Point Road / Buffalo Creek Road Intersection
- Lee Point Road / Lee Point Village Intersection
- Lee Point Road / Access Point 1
- Lee Point Road / Access Point 2
- Lee Point Road / Access Point 3

5.3 Capacity and Level of Service (2017 Base Scenario, Without Development)

5.3.1 Lee Point Road / Buffalo Creek Road Intersection

As shown in **Figure 5-1**, the Lee Point Road / Buffalo Creek Road intersection is located to the north of the Site. This intersection is a priority controlled intersection with Lee Point Road having priority over Buffalo Creek Road. The intersection layout of Lee Point Road and Buffalo Creek Road used for all of the analysis scenarios is shown in **Figure 5-2**.

Figure 5-2 Lee Point Road / Buffalo Creek Road Intersection Layout



The results of the SIDRA for the existing condition in the year 2017 without development is shown in **Table 5-1** and **Table 5-2.** The results shows that the intersection performed satisfactorily in the AM and PM peak background condition in the year 2017.

Table 5-1 Lee Point Road / Buffalo Creek Road Intersection AM Performance – 2017 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
2	T1	12	5.0	0.013	0.0	LOS A	0.1	0.4	0.05	0.29	57.2
3	R2	12	5.0	0.013	5.5	LOS A	0.1	0.4	0.05	0.29	54.9
Approach		24	5.0	0.013	2.8	NA	0.1	0.4	0.05	0.29	56.1
East: Buffalo Creek Rd											
4	L2	7	5.0	0.009	5.6	LOS A	0.0	0.2	0.04	0.57	53.3
6	R2	5	5.0	0.009	5.6	LOS A	0.0	0.2	0.04	0.57	52.8
Approach		12	5.0	0.009	5.6	LOS A	0.0	0.2	0.04	0.57	53.1
North: Lee Point Road N											
7	L2	5	5.0	0.006	5.6	LOS A	0.0	0.0	0.00	0.25	56.0
8	T1	7	5.0	0.006	0.0	LOS A	0.0	0.0	0.00	0.25	57.8
Approach		12	5.0	0.006	2.3	NA	0.0	0.0	0.00	0.25	57.1
All Vehicles		48	5.0	0.013	3.4	NA	0.1	0.4	0.03	0.35	55.5

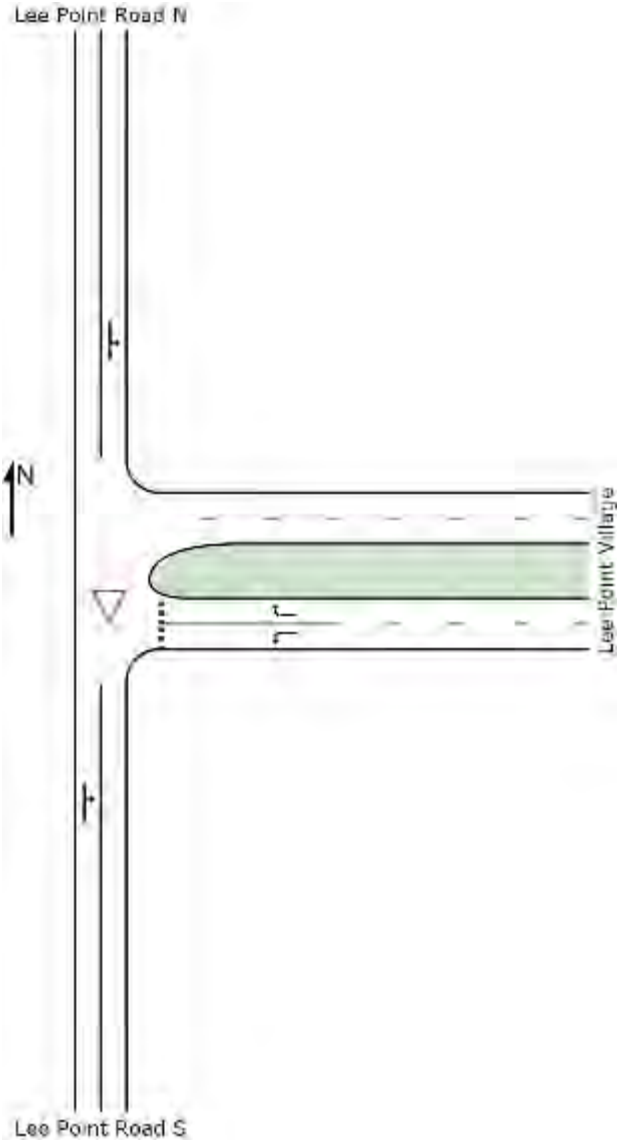
Table 5-2 Lee Point Road / Buffalo Creek Road Intersection PM Performance – 2017 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
2	T1	30	5.0	0.034	0.1	LOS A	0.1	1.0	0.08	0.29	57.1
3	R2	30	5.0	0.034	5.6	LOS A	0.1	1.0	0.08	0.29	54.8
Approach		60	5.0	0.034	2.8	NA	0.1	1.0	0.08	0.29	56.0
East: Buffalo Creek Rd											
4	L2	21	5.0	0.018	5.7	LOS A	0.1	0.5	0.07	0.56	53.2
6	R2	5	5.0	0.018	5.8	LOS A	0.1	0.5	0.07	0.56	52.7
Approach		26	5.0	0.018	5.7	LOS A	0.1	0.5	0.07	0.56	53.1
North: Lee Point Road N											
7	L2	5	5.0	0.014	5.6	LOS A	0.0	0.0	0.00	0.11	57.1
8	T1	21	5.0	0.014	0.0	LOS A	0.0	0.0	0.00	0.11	59.0
Approach		26	5.0	0.014	1.1	NA	0.0	0.0	0.00	0.11	58.6
All Vehicles		112	5.0	0.034	3.1	NA	0.1	1.0	0.06	0.31	55.8

5.3.2 Lee Point Road / Lee Point Village Resort

As shown in **Figure 5-1**, the Lee Point Road / Lee Point Village Resort intersection is located to the east of the Site. This intersection is a priority controlled intersection with Lee Point Road having priority. The intersection layout of Lee Point Road and Lee Point Village Resort used for all of the analysis scenarios is shown in **Figure 5-3**.

Figure 5-3 Lee Point Road / Lee Point Village Resort Intersection Layout



The results of the SIDRA for the existing condition in the year 2017 without development is shown in **Table 5-3** and **Table 5-4.** The results shows that the intersection performed satisfactorily in the AM and PM peak background condition in the year 2017.

Table 5-3 Lee Point Road / Lee Point Village Resort Intersection AM Performance – 2017 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
2	T1	22	5.0	0.015	0.0	LOS A	0.0	0.2	0.03	0.13	58.7
3	R2	6	5.0	0.015	5.6	LOS A	0.0	0.2	0.03	0.13	53.8
Approach		28	5.0	0.015	1.2	NA	0.0	0.2	0.03	0.13	58.0
East: Lee Point Village											
4	L2	11	5.0	0.007	5.6	LOS A	0.0	0.2	0.06	0.55	49.6
6	R2	1	5.0	0.001	5.7	LOS A	0.0	0.0	0.10	0.55	49.1
Approach		12	5.0	0.007	5.6	LOS A	0.0	0.2	0.06	0.55	49.5
North: Lee Point Road N											
7	L2	1	5.0	0.008	5.6	LOS A	0.0	0.0	0.00	0.04	31.6
8	T1	15	5.0	0.008	0.0	LOS A	0.0	0.0	0.00	0.04	59.7
Approach		16	5.0	0.008	0.4	NA	0.0	0.0	0.00	0.04	57.7
All Vehicles		56	5.0	0.015	1.9	NA	0.0	0.2	0.03	0.19	56.4

Table 5-4 Lee Point Road / Lee Point Village Resort Intersection PM Performance – 2017 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
2	T1	57	5.0	0.038	0.0	LOS A	0.1	0.5	0.05	0.10	58.9
3	R2	12	5.0	0.038	5.7	LOS A	0.1	0.5	0.05	0.10	54.0
Approach		69	5.0	0.038	1.0	NA	0.1	0.5	0.05	0.10	58.3
East: Lee Point Village											
4	L2	3	5.0	0.002	5.7	LOS A	0.0	0.1	0.11	0.53	49.3
6	R2	1	5.0	0.001	5.9	LOS A	0.0	0.0	0.18	0.54	48.7
Approach		4	5.0	0.002	5.7	LOS A	0.0	0.1	0.13	0.53	49.2
North: Lee Point Road N											
7	L2	1	5.0	0.023	5.6	LOS A	0.0	0.0	0.00	0.01	31.7
8	T1	42	5.0	0.023	0.0	LOS A	0.0	0.0	0.00	0.01	59.9
Approach		43	5.0	0.023	0.1	NA	0.0	0.0	0.00	0.01	59.1
All Vehicles		116	5.0	0.038	0.9	NA	0.1	0.5	0.03	0.08	58.4

5.4 Capacity and Level of Service (2027 Base Scenario, Without Development)

5.4.1 Lee Point Road / Buffalo Creek Road Intersection

The results of the SIDRA for the future scenario in the year 2027 without development is shown in **Table 5-5** and **Table 5-6.** The results shows that the intersection performed satisfactorily in the AM and PM peak background condition in the year 2027.

Table 5-5 Lee Point Road / Buffalo Creek Road Intersection AM Performance – 2027 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
2	T1	15	5.0	0.017	0.0	LOS A	0.1	0.5	0.06	0.29	57.2
3	R2	15	5.0	0.017	5.6	LOS A	0.1	0.5	0.06	0.29	54.9
Approach		30	5.0	0.017	2.8	NA	0.1	0.5	0.06	0.29	56.0
East: Buffalo Creek Rd											
4	L2	10	5.0	0.012	5.6	LOS A	0.0	0.3	0.05	0.57	53.3
6	R2	7	5.0	0.012	5.6	LOS A	0.0	0.3	0.05	0.57	52.7
Approach		17	5.0	0.012	5.6	LOS A	0.0	0.3	0.05	0.57	53.1
North: Lee Point Road N											
7	L2	7	5.0	0.009	5.6	LOS A	0.0	0.0	0.00	0.24	56.1
8	T1	10	5.0	0.009	0.0	LOS A	0.0	0.0	0.00	0.24	57.8
Approach		17	5.0	0.009	2.3	NA	0.0	0.0	0.00	0.24	57.1
All Vehicles		64	5.0	0.017	3.4	NA	0.1	0.5	0.04	0.35	55.5

Table 5-6 Lee Point Road / Buffalo Creek Road Intersection PM Performance – 2027 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
2	T1	38	5.0	0.043	0.1	LOS A	0.2	1.3	0.10	0.29	57.1
3	R2	38	5.0	0.043	5.6	LOS A	0.2	1.3	0.10	0.29	54.8
Approach		76	5.0	0.043	2.8	NA	0.2	1.3	0.10	0.29	55.9
East: Buffalo Creek Rd											
4	L2	27	5.0	0.023	5.7	LOS A	0.1	0.6	0.08	0.55	53.2
6	R2	7	5.0	0.023	5.9	LOS A	0.1	0.6	0.08	0.55	52.6
Approach		34	5.0	0.023	5.7	LOS A	0.1	0.6	0.08	0.55	53.1
North: Lee Point Road N											
7	L2	7	5.0	0.018	5.6	LOS A	0.0	0.0	0.00	0.12	57.1
8	T1	27	5.0	0.018	0.0	LOS A	0.0	0.0	0.00	0.12	58.9
Approach		34	5.0	0.018	1.2	NA	0.0	0.0	0.00	0.12	58.5
All Vehicles		144	5.0	0.043	3.1	NA	0.2	1.3	0.07	0.31	55.8

5.4.2 Lee Point Road / Lee Point Village Resort

The results of the SIDRA for the future scenario in the year 2027 without development is shown in **Table 5-7** and **Table 5-8.** The results shows that the intersection performed satisfactorily in the AM and PM peak background condition in the year 2027.

Table 5-7 Lee Point Road / Lee Point Village Resort Intersection AM Performance – 2027 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
2	T1	29	5.0	0.020	0.0	LOS A	0.0	0.3	0.04	0.13	58.7
3	R2	8	5.0	0.020	5.6	LOS A	0.0	0.3	0.04	0.13	53.7
Approach		37	5.0	0.020	1.2	NA	0.0	0.3	0.04	0.13	57.9
East: Lee Point Village											
4	L2	14	5.0	0.009	5.6	LOS A	0.0	0.3	0.07	0.55	49.5
6	R2	1	5.0	0.001	5.7	LOS A	0.0	0.0	0.12	0.54	49.0
Approach		15	5.0	0.009	5.6	LOS A	0.0	0.3	0.07	0.55	49.5
North: Lee Point Road N											
7	L2	1	5.0	0.011	5.6	LOS A	0.0	0.0	0.00	0.03	31.7
8	T1	19	5.0	0.011	0.0	LOS A	0.0	0.0	0.00	0.03	59.7
Approach		20	5.0	0.011	0.3	NA	0.0	0.0	0.00	0.03	58.1
All Vehicles		72	5.0	0.020	1.9	NA	0.0	0.3	0.03	0.19	56.6

Table 5-8 Lee Point Road / Lee Point Village Resort Intersection PM Performance – 2027 Without Development

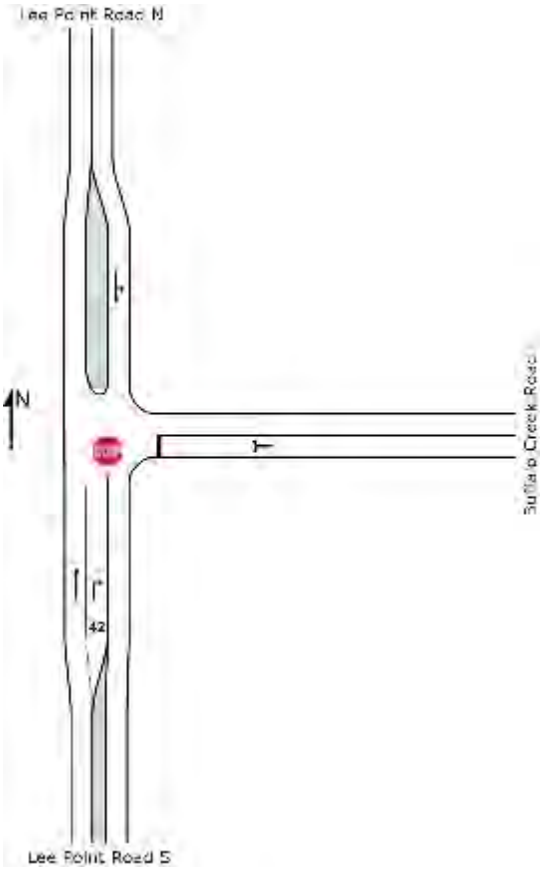
Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
2	T1	73	5.0	0.048	0.0	LOS A	0.1	0.7	0.05	0.10	58.9
3	R2	15	5.0	0.048	5.7	LOS A	0.1	0.7	0.05	0.10	53.9
Approach		88	5.0	0.048	1.0	NA	0.1	0.7	0.05	0.10	58.3
East: Lee Point Village											
4	L2	4	5.0	0.003	5.7	LOS A	0.0	0.1	0.13	0.53	49.3
6	R2	1	5.0	0.001	6.0	LOS A	0.0	0.0	0.21	0.53	48.6
Approach		5	5.0	0.003	5.8	LOS A	0.0	0.1	0.15	0.53	49.1
North: Lee Point Road N											
7	L2	1	5.0	0.029	5.6	LOS A	0.0	0.0	0.00	0.01	31.8
8	T1	54	5.0	0.029	0.0	LOS A	0.0	0.0	0.00	0.01	59.9
Approach		55	5.0	0.029	0.1	NA	0.0	0.0	0.00	0.01	59.3
All Vehicles		148	5.0	0.048	0.8	NA	0.1	0.7	0.04	0.08	58.4

5.5 Capacity and Level of Service (2017 Base Scenario, With Development)

5.5.1 Lee Point Road / Buffalo Creek Road Intersection

As shown in **Figure 5-1**, the Lee Point Road / Buffalo Creek Road Intersection is located to the east of the Site. This intersection is a priority controlled intersection with Lee Point Road having priority. The intersection layout of Lee Point Road and Buffalo Creek Road Intersection used for all of the analysis scenarios is shown in **Figure 5-4**.

Figure 5-4 Lee Point Road / Buffalo Creek Road Intersection Layout



The results of the SIDRA for the existing condition in the year 2017 with development is shown in **Table 5-9** and **Table 5-10.** The results shows that the intersection performed satisfactorily in the AM and PM peak background condition in the year 2017.

Table 5-9 Lee Point Road / Buffalo Creek Road Intersection AM Performance – 2017 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
2	T1	35	5.0	0.019	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	12	5.0	0.007	5.6	LOS A	0.0	0.2	0.09	0.56	52.7
Approach		47	5.0	0.019	1.4	NA	0.0	0.2	0.02	0.14	57.9
East: Buffalo Creek Road											
4	L2	7	5.0	0.010	8.3	LOS A	0.0	0.3	0.09	0.94	51.7
6	R2	5	5.0	0.010	8.1	LOS A	0.0	0.3	0.09	0.94	51.2
Approach		12	5.0	0.010	8.2	LOS A	0.0	0.3	0.09	0.94	51.5
North: Lee Point Road N											
7	L2	5	5.0	0.014	5.6	LOS A	0.0	0.0	0.00	0.11	57.1
8	T1	21	5.0	0.014	0.0	LOS A	0.0	0.0	0.00	0.11	59.0
Approach		26	5.0	0.014	1.1	NA	0.0	0.0	0.00	0.11	58.6
All Vehicles		85	5.0	0.019	2.3	NA	0.0	0.3	0.03	0.25	57.1

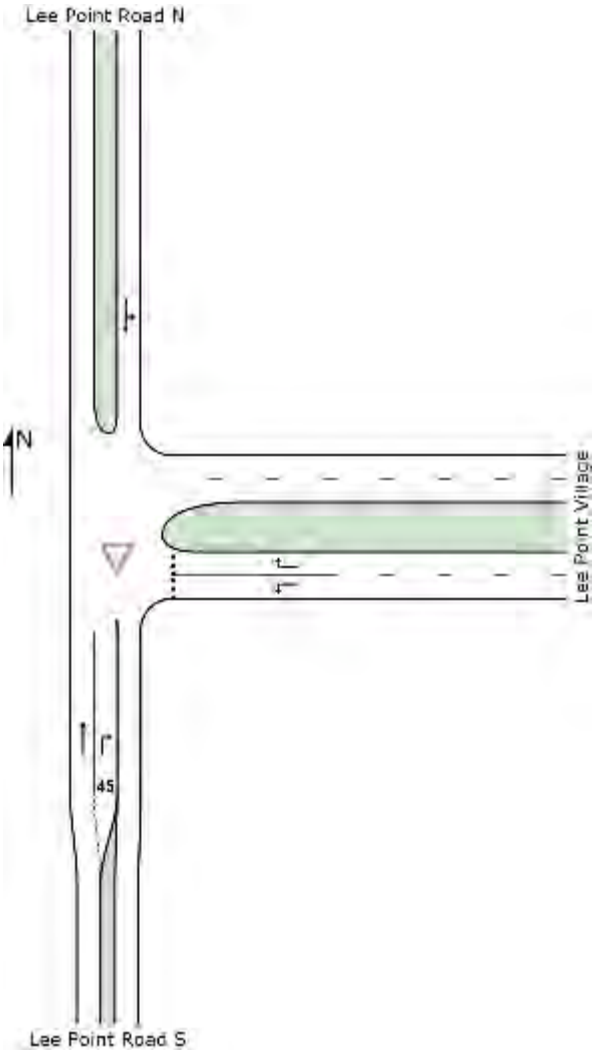
Table 5-10 Lee Point Road / Buffalo Creek Road Intersection PM Performance – 2017 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
2	T1	46	5.0	0.024	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	30	5.0	0.018	5.6	LOS A	0.1	0.6	0.13	0.56	52.6
Approach		76	5.0	0.024	2.2	NA	0.1	0.6	0.05	0.22	56.8
East: Buffalo Creek Road											
4	L2	21	5.0	0.021	8.4	LOS A	0.1	0.6	0.12	0.92	51.6
6	R2	5	5.0	0.021	8.4	LOS A	0.1	0.6	0.12	0.92	51.1
Approach		26	5.0	0.021	8.4	LOS A	0.1	0.6	0.12	0.92	51.5
North: Lee Point Road N											
7	L2	5	5.0	0.024	5.6	LOS A	0.0	0.0	0.00	0.06	57.6
8	T1	41	5.0	0.024	0.0	LOS A	0.0	0.0	0.00	0.06	59.4
Approach		46	5.0	0.024	0.6	NA	0.0	0.0	0.00	0.06	59.2
All Vehicles		148	5.0	0.024	2.8	NA	0.1	0.6	0.05	0.30	56.5

5.5.2 Lee Point Road / Lee Point Village Resort

As shown in **Figure 5-1**, the Lee Point Road / Lee Point Village Resort Intersection is located to the east of the Site. This intersection is a priority controlled intersection with Lee Point Road having priority. The intersection layout of Lee Point Road and Lee Point Village Resort Intersection used for all of the analysis scenarios is shown in **Figure 5-5**.

Figure 5-5 Lee Point Road / Lee Point Village Resort Intersection Layout



The results of the SIDRA for the existing condition in the year 2017 with development is shown in **Table 5-11** and **Table 5-12.** The results shows that the intersection performed satisfactorily in the AM and PM peak background condition in the year 2017.

Table 5-11 Lee Point Road / Lee Point Village Resort Intersection AM Performance – 2017 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
2	T1	93	5.0	0.049	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	6	5.0	0.004	5.9	LOS A	0.0	0.1	0.22	0.53	47.9
Approach		99	5.0	0.049	0.4	NA	0.0	0.1	0.01	0.03	59.4
East: Lee Point Village											
4	L2	11	5.0	0.008	5.9	LOS A	0.0	0.2	0.21	0.53	48.9
6	R2	1	5.0	0.001	6.7	LOS A	0.0	0.0	0.33	0.53	48.1
Approach		12	5.0	0.008	6.0	LOS A	0.0	0.2	0.22	0.53	48.9
North: Lee Point Road N											
7	L2	1	5.0	0.063	5.6	LOS A	0.0	0.0	0.00	0.01	31.8
8	T1	117	5.0	0.063	0.0	LOS A	0.0	0.0	0.00	0.01	59.9
Approach		118	5.0	0.063	0.1	NA	0.0	0.0	0.00	0.01	59.7
All Vehicles		229	5.0	0.063	0.5	NA	0.0	0.2	0.02	0.04	59.1

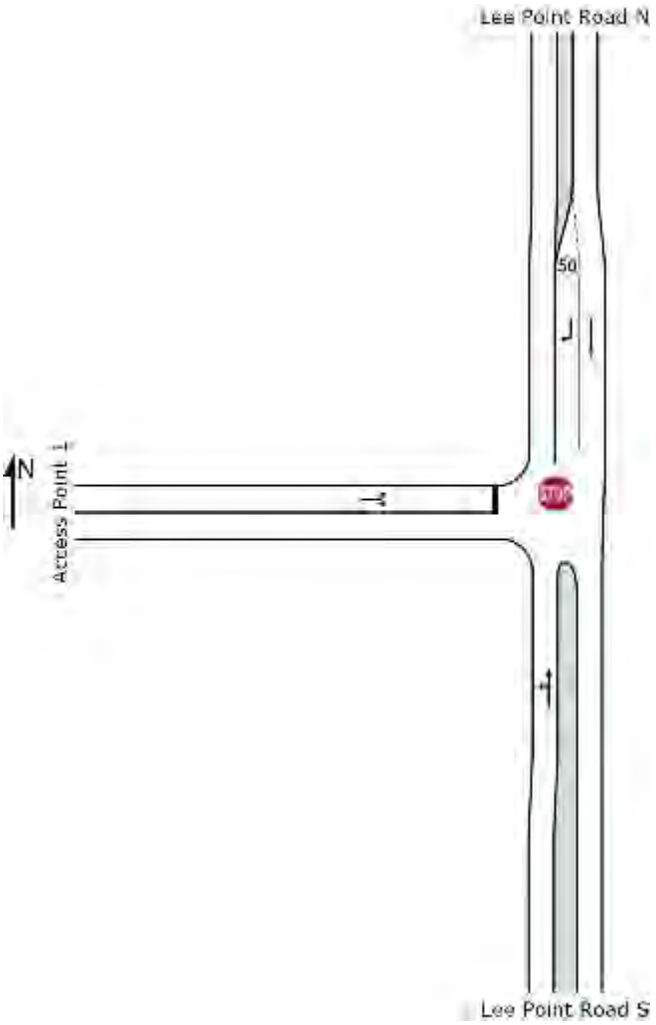
Table 5-12 Lee Point Road / Lee Point Village Resort Intersection PM Performance – 2017 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
2	T1	150	5.0	0.079	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	12	5.0	0.008	5.9	LOS A	0.0	0.2	0.23	0.53	47.8
Approach		162	5.0	0.079	0.4	NA	0.0	0.2	0.02	0.04	59.3
East: Lee Point Village											
4	L2	3	5.0	0.002	5.9	LOS A	0.0	0.1	0.21	0.52	48.9
6	R2	1	5.0	0.001	7.1	LOS A	0.0	0.0	0.39	0.54	47.8
Approach		4	5.0	0.002	6.2	LOS A	0.0	0.1	0.26	0.53	48.6
North: Lee Point Road N											
7	L2	1	5.0	0.065	5.6	LOS A	0.0	0.0	0.00	0.00	31.8
8	T1	121	5.0	0.065	0.0	LOS A	0.0	0.0	0.00	0.00	59.9
Approach		122	5.0	0.065	0.1	NA	0.0	0.0	0.00	0.00	59.7
All Vehicles		288	5.0	0.079	0.4	NA	0.0	0.2	0.01	0.03	59.3

5.5.3 Lee Point Road / Access Road 1 Intersection

As shown in **Figure 5-1**, the Lee Point Road / Access Road 1 intersection is located to the east of the Site. This intersection is a priority controlled intersection with Lee Point Road having priority. The intersection layout of Lee Point Road and Access Road 1 used for all of the analysis scenarios is shown in **Figure 5-6**.

Figure 5-6 Lee Point Road / Access Road 1 Intersection Layout



The results of the SIDRA for the existing condition in the year 2017 with development is shown in **Table 5-13** and **Table 5-14.** The results shows that the intersection performed satisfactorily in the AM and PM peak background condition in the year 2017.

Table 5-13 Lee Point Road / Access Road 1 Intersection AM Performance – 2017 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	52	5.0	0.051	5.6	LOS A	0.0	0.0	0.00	0.33	55.4
2	T1	41	5.0	0.051	0.0	LOS A	0.0	0.0	0.00	0.33	57.1
Approach		93	5.0	0.051	3.1	NA	0.0	0.0	0.00	0.33	56.1
North: Lee Point Road N											
8	T1	26	5.0	0.014	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
9	R2	3	5.0	0.002	5.8	LOS A	0.0	0.1	0.19	0.54	52.4
Approach		29	5.0	0.014	0.6	NA	0.0	0.1	0.02	0.06	59.1
West: Access Point 1											
10	L2	5	5.0	0.100	8.4	LOS A	0.4	3.0	0.23	0.89	51.7
12	R2	91	5.0	0.100	8.4	LOS A	0.4	3.0	0.23	0.89	51.2
Approach		96	5.0	0.100	8.4	LOS A	0.4	3.0	0.23	0.89	51.3
All Vehicles		218	5.0	0.100	5.1	NA	0.4	3.0	0.10	0.54	54.2

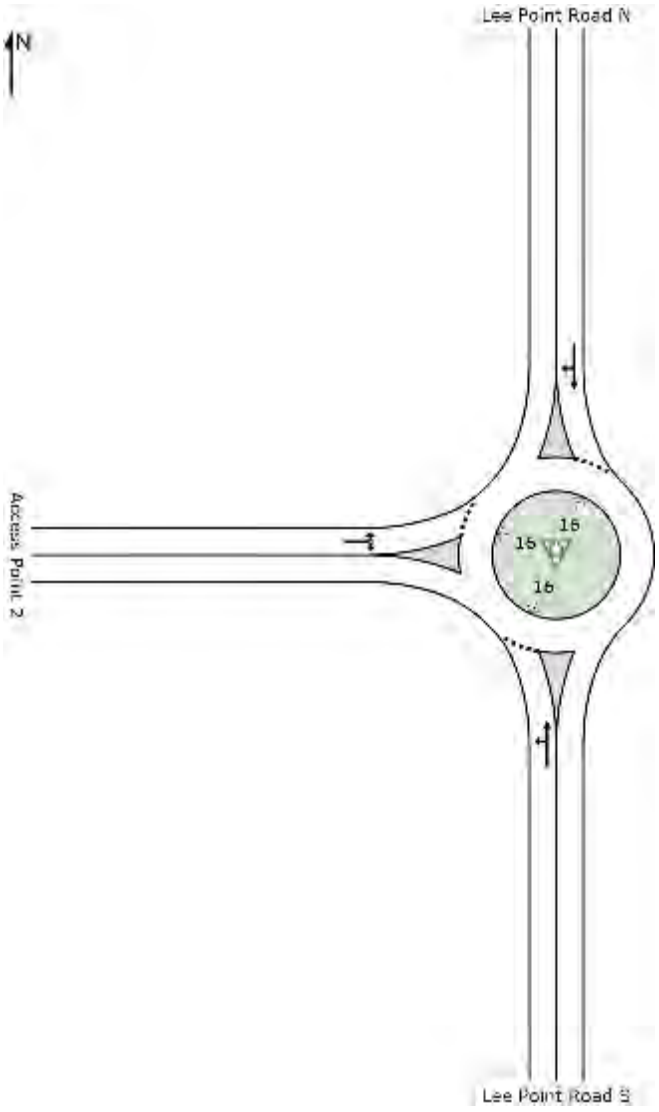
Table 5-14 Lee Point Road / Access Road 1 Intersection PM Performance – 2017 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	80	5.0	0.082	5.6	LOS A	0.0	0.0	0.00	0.31	55.5
2	T1	71	5.0	0.082	0.0	LOS A	0.0	0.0	0.00	0.31	57.2
Approach		151	5.0	0.082	3.0	NA	0.0	0.0	0.00	0.31	56.3
North: Lee Point Road N											
8	T1	58	5.0	0.031	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
9	R2	4	5.0	0.003	6.0	LOS A	0.0	0.1	0.26	0.54	52.2
Approach		62	5.0	0.031	0.4	NA	0.0	0.1	0.02	0.03	59.4
West: Access Point 1											
10	L2	3	5.0	0.076	8.5	LOS A	0.3	2.2	0.31	0.88	51.4
12	R2	63	5.0	0.076	8.9	LOS A	0.3	2.2	0.31	0.88	51.0
Approach		66	5.0	0.076	8.9	LOS A	0.3	2.2	0.31	0.88	51.0
All Vehicles		279	5.0	0.082	3.8	NA	0.3	2.2	0.08	0.39	55.6

5.5.4 Lee Point Road / Access Road 2 Intersection

As shown in **Figure 5-1**, the Lee Point Road / Access Road 2 intersection is located to the east of the Site. This intersection is proposed to be a 4 leg approach roundabout. As there is no traffic along the eastern leg of the roundabout, it has been removed for the purposed of this assessment. The intersection layout of Lee Point Road and Access Road 2 used for all of the analysis scenarios is shown in **Figure 5-7**.

Figure 5-7 Lee Point Road / Access Road 2 Intersection Layout



The results of the SIDRA for the existing condition in the year 2017 with development is shown in **Table 5-15** and **Table 5-16.** The results shows that the intersection performed satisfactorily in the AM and PM peak background condition in the year 2017.

Table 5-15 Lee Point Road / Access Road 2 Intersection AM Performance – 2017 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	117	5.0	0.131	4.1	LOS A	0.7	5.4	0.05	0.46	54.7
2	T1	89	5.0	0.131	4.4	LOS A	0.7	5.4	0.05	0.46	55.9
Approach		206	5.0	0.131	4.2	LOS A	0.7	5.4	0.05	0.46	55.2
North: Lee Point Road N											
8	T1	121	5.0	0.118	5.5	LOS A	0.6	4.4	0.39	0.51	54.2
9	R2	6	5.0	0.118	9.6	LOS A	0.6	4.4	0.39	0.51	53.9
Approach		127	5.0	0.118	5.7	LOS A	0.6	4.4	0.39	0.51	54.2
West: Access Point 2											
10	L2	11	5.0	0.171	4.6	LOS A	0.9	6.5	0.25	0.61	51.2
12	R2	205	5.0	0.171	9.0	LOS A	0.9	6.5	0.25	0.61	52.0
Approach		216	5.0	0.171	8.7	LOS A	0.9	6.5	0.25	0.61	52.0
All Vehicles		549	5.0	0.171	6.3	LOS A	0.9	6.5	0.21	0.53	53.6

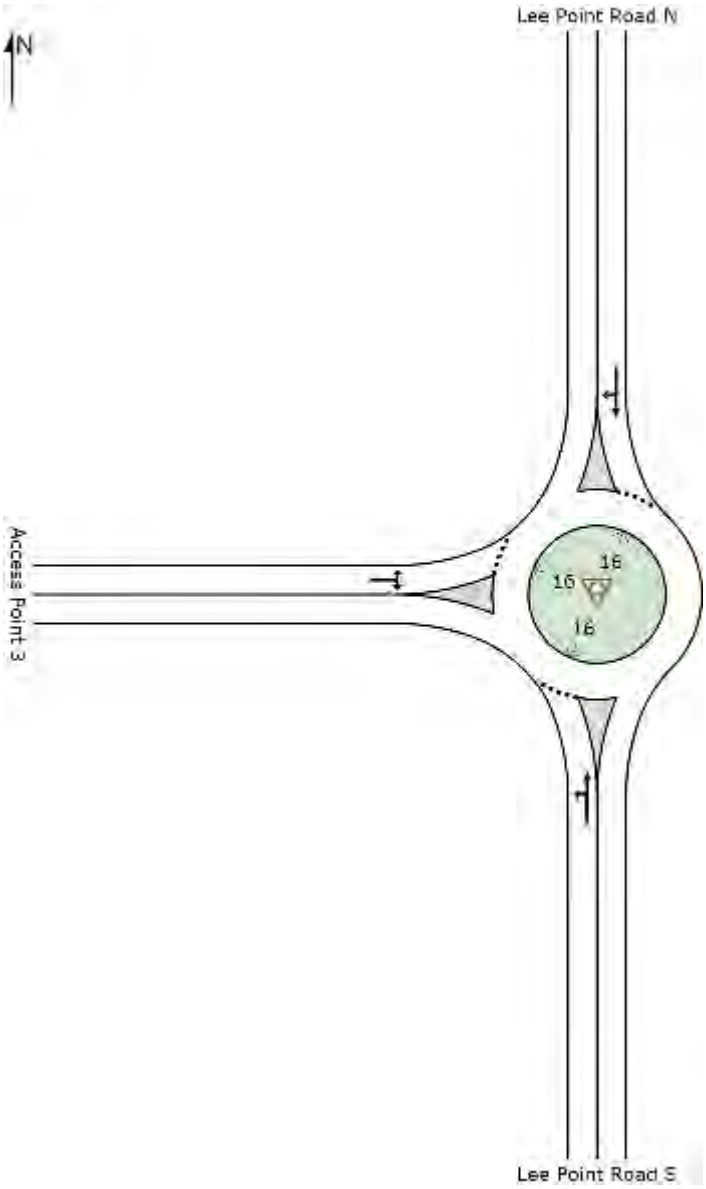
Table 5-16 Lee Point Road / Access Road 2 Intersection PM Performance – 2017 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	181	5.0	0.214	4.2	LOS A	1.3	9.5	0.08	0.46	54.6
2	T1	155	5.0	0.214	4.4	LOS A	1.3	9.5	0.08	0.46	55.8
Approach		336	5.0	0.214	4.3	LOS A	1.3	9.5	0.08	0.46	55.2
North: Lee Point Road N											
8	T1	115	5.0	0.110	5.1	LOS A	0.6	4.2	0.33	0.49	54.4
9	R2	10	5.0	0.110	9.2	LOS A	0.6	4.2	0.33	0.49	54.1
Approach		125	5.0	0.110	5.4	LOS A	0.6	4.2	0.33	0.49	54.3
West: Access Point 2											
10	L2	7	5.0	0.131	5.0	LOS A	0.7	4.8	0.33	0.63	50.9
12	R2	142	5.0	0.131	9.3	LOS A	0.7	4.8	0.33	0.63	51.8
Approach		149	5.0	0.131	9.1	LOS A	0.7	4.8	0.33	0.63	51.7
All Vehicles		610	5.0	0.214	5.7	LOS A	1.3	9.5	0.19	0.51	54.1

5.5.5 Lee Point Road / Access Road 3 Intersection

As shown in **Figure 5-1**, the Lee Point Road / Access Road 3 intersection is located to the east of the Site. This intersection is proposed to be a 4 leg approach roundabout. The intersection layout of Lee Point Road and Access Road 3 used for all of the analysis scenarios is shown in **Figure 5-8**.

Figure 5-8 Lee Point Road / Access Road 3 Intersection Layout



The results of the SIDRA for the existing condition in the year 2017 with development is shown in **Table 5-17** and **Table 5-18.** The results shows that the intersection performed satisfactorily in the AM and PM peak background condition in the year 2017.

Table 5-17 Lee Point Road / Access Road 3 Intersection AM Performance – 2017 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	91	5.0	0.179	4.1	LOS A	1.1	7.9	0.05	0.45	54.7
2	T1	198	5.0	0.179	4.4	LOS A	1.1	7.9	0.05	0.45	55.9
Approach		289	5.0	0.179	4.3	LOS A	1.1	7.9	0.05	0.45	55.5
North: Lee Point Road N											
8	T1	321	5.0	0.282	5.3	LOS A	1.7	12.7	0.41	0.51	54.2
9	R2	5	5.0	0.282	9.5	LOS A	1.7	12.7	0.41	0.51	53.9
Approach		326	5.0	0.282	5.4	LOS A	1.7	12.7	0.41	0.51	54.2
West: Access Point 3											
10	L2	8	5.0	0.152	5.3	LOS A	0.8	5.6	0.38	0.65	50.8
12	R2	159	5.0	0.152	9.6	LOS A	0.8	5.6	0.38	0.65	51.6
Approach		167	5.0	0.152	9.4	LOS A	0.8	5.6	0.38	0.65	51.6
All Vehicles		782	5.0	0.282	5.8	LOS A	1.7	12.7	0.27	0.51	54.1

Table 5-18 Lee Point Road / Access Road 3 Intersection PM Performance – 2017 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	140	5.0	0.290	4.2	LOS A	1.9	14.1	0.07	0.44	54.6
2	T1	330	5.0	0.290	4.4	LOS A	1.9	14.1	0.07	0.44	55.8
Approach		470	5.0	0.290	4.3	LOS A	1.9	14.1	0.07	0.44	55.4
North: Lee Point Road N											
8	T1	250	5.0	0.211	5.0	LOS A	1.3	9.2	0.32	0.47	54.5
9	R2	7	5.0	0.211	9.1	LOS A	1.3	9.2	0.32	0.47	54.3
Approach		257	5.0	0.211	5.1	LOS A	1.3	9.2	0.32	0.47	54.5
West: Access Point 3											
10	L2	6	5.0	0.117	6.0	LOS A	0.6	4.3	0.47	0.68	50.6
12	R2	110	5.0	0.117	10.3	LOS B	0.6	4.3	0.47	0.68	51.4
Approach		116	5.0	0.117	10.1	LOS B	0.6	4.3	0.47	0.68	51.3
All Vehicles		843	5.0	0.290	5.3	LOS A	1.9	14.1	0.20	0.48	54.5

5.6 Capacity and Level of Service (2027 Base Scenario, With Development)

5.6.1 Lee Point Road / Buffalo Creek Road Intersection

The results of the SIDRA for the existing condition in the year 2027 with development is shown in **Table 5-19** and **Table 5-20.** The results shows that the intersection performed satisfactorily in the AM and PM peak background condition in the year 2027.

Table 5-19 Lee Point Road / Buffalo Creek Road Intersection AM Performance – 2027 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
2	T1	39	5.0	0.021	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	15	5.0	0.009	5.6	LOS A	0.0	0.3	0.10	0.56	52.6
Approach		54	5.0	0.021	1.6	NA	0.0	0.3	0.03	0.16	57.8
East: Buffalo Creek Road											
4	L2	10	5.0	0.015	8.3	LOS A	0.1	0.4	0.10	0.94	51.7
6	R2	7	5.0	0.015	8.1	LOS A	0.1	0.4	0.10	0.94	51.2
Approach		17	5.0	0.015	8.2	LOS A	0.1	0.4	0.10	0.94	51.5
North: Lee Point Road N											
7	L2	7	5.0	0.016	5.6	LOS A	0.0	0.0	0.00	0.14	56.9
8	T1	23	5.0	0.016	0.0	LOS A	0.0	0.0	0.00	0.14	58.7
Approach		30	5.0	0.016	1.3	NA	0.0	0.0	0.00	0.14	58.3
All Vehicles		101	5.0	0.021	2.6	NA	0.1	0.4	0.03	0.28	56.7

Table 5-20 Lee Point Road / Buffalo Creek Road Intersection PM Performance – 2027 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
2	T1	54	5.0	0.029	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	38	5.0	0.023	5.7	LOS A	0.1	0.7	0.14	0.56	52.5
Approach		92	5.0	0.029	2.3	NA	0.1	0.7	0.06	0.23	56.7
East: Buffalo Creek Road											
4	L2	27	5.0	0.028	8.4	LOS A	0.1	0.8	0.14	0.92	51.6
6	R2	7	5.0	0.028	8.6	LOS A	0.1	0.8	0.14	0.92	51.1
Approach		34	5.0	0.028	8.4	LOS A	0.1	0.8	0.14	0.92	51.5
North: Lee Point Road N											
7	L2	7	5.0	0.029	5.6	LOS A	0.0	0.0	0.00	0.08	57.4
8	T1	47	5.0	0.029	0.0	LOS A	0.0	0.0	0.00	0.08	59.3
Approach		54	5.0	0.029	0.7	NA	0.0	0.0	0.00	0.08	59.0
All Vehicles		180	5.0	0.029	3.0	NA	0.1	0.8	0.06	0.31	56.3

5.6.2 Lee Point Road / Lee Point Village Resort

The results of the SIDRA for the existing condition in the year 2027 with development is shown in **Table 5-21** and **Table 5-22.** The results shows that the intersection performed satisfactorily in the AM and PM peak background condition in the year 2027.

Table 5-21 Lee Point Road / Lee Point Village Resort Intersection AM Performance – 2027 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
2	T1	100	5.0	0.053	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	8	5.0	0.005	5.9	LOS A	0.0	0.2	0.23	0.53	47.8
Approach		108	5.0	0.053	0.4	NA	0.0	0.2	0.02	0.04	59.3
East: Lee Point Village											
4	L2	14	5.0	0.010	5.9	LOS A	0.0	0.3	0.21	0.53	48.9
6	R2	1	5.0	0.001	6.7	LOS A	0.0	0.0	0.35	0.53	48.1
Approach		15	5.0	0.010	6.0	LOS A	0.0	0.3	0.22	0.53	48.8
North: Lee Point Road N											
7	L2	1	5.0	0.065	5.6	LOS A	0.0	0.0	0.00	0.00	31.8
8	T1	121	5.0	0.065	0.0	LOS A	0.0	0.0	0.00	0.00	59.9
Approach		122	5.0	0.065	0.1	NA	0.0	0.0	0.00	0.00	59.7
All Vehicles		245	5.0	0.065	0.6	NA	0.0	0.3	0.02	0.05	59.0

Table 5-22 Lee Point Road / Lee Point Village Resort Intersection PM Performance – 2027 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
2	T1	166	5.0	0.088	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	15	5.0	0.010	6.0	LOS A	0.0	0.3	0.24	0.54	47.8
Approach		181	5.0	0.088	0.5	NA	0.0	0.3	0.02	0.04	59.2
East: Lee Point Village											
4	L2	4	5.0	0.003	5.9	LOS A	0.0	0.1	0.22	0.52	48.9
6	R2	1	5.0	0.001	7.3	LOS A	0.0	0.0	0.41	0.55	47.6
Approach		5	5.0	0.003	6.2	LOS A	0.0	0.1	0.26	0.53	48.6
North: Lee Point Road N											
7	L2	1	5.0	0.071	5.6	LOS A	0.0	0.0	0.00	0.00	31.8
8	T1	133	5.0	0.071	0.0	LOS A	0.0	0.0	0.00	0.00	59.9
Approach		134	5.0	0.071	0.0	NA	0.0	0.0	0.00	0.00	59.7
All Vehicles		320	5.0	0.088	0.4	NA	0.0	0.3	0.02	0.04	59.3

5.6.3 Lee Point Road / Access Road 1 Intersection

The results of the SIDRA for the existing condition in the year 2027 with development is shown in **Table 5-23** and **Table 5-24.** The results shows that the intersection performed satisfactorily in the AM and PM peak background condition in the year 2027.

Table 5-23 Lee Point Road / Access Road 1 Intersection AM Performance – 2027 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
1	L2	52	5.0	0.054	5.6	LOS A	0.0	0.0	0.00	0.31	55.6
2	T1	48	5.0	0.054	0.0	LOS A	0.0	0.0	0.00	0.31	57.3
Approach		100	5.0	0.054	2.9	NA	0.0	0.0	0.00	0.31	56.4
North: Lee Point Road N											
8	T1	30	5.0	0.016	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
9	R2	3	5.0	0.002	5.8	LOS A	0.0	0.1	0.20	0.54	52.4
Approach		33	5.0	0.016	0.5	NA	0.0	0.1	0.02	0.05	59.2
West: Access Point 1											
10	L2	5	5.0	0.101	8.4	LOS A	0.4	3.0	0.24	0.89	51.7
12	R2	91	5.0	0.101	8.5	LOS A	0.4	3.0	0.24	0.89	51.2
Approach		96	5.0	0.101	8.5	LOS A	0.4	3.0	0.24	0.89	51.2
All Vehicles		229	5.0	0.101	4.9	NA	0.4	3.0	0.10	0.51	54.5

Table 5-24 Lee Point Road / Access Road 1 Intersection PM Performance – 2027 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
1	L2	80	5.0	0.091	5.6	LOS A	0.0	0.0	0.00	0.28	55.8
2	T1	88	5.0	0.091	0.0	LOS A	0.0	0.0	0.00	0.28	57.5
Approach		168	5.0	0.091	2.7	NA	0.0	0.0	0.00	0.28	56.6
North: Lee Point Road N											
8	T1	70	5.0	0.037	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
9	R2	4	5.0	0.003	6.0	LOS A	0.0	0.1	0.27	0.54	52.2
Approach		74	5.0	0.037	0.3	NA	0.0	0.1	0.01	0.03	59.5
West: Access Point 1											
10	L2	3	5.0	0.079	8.6	LOS A	0.3	2.3	0.34	0.88	51.3
12	R2	63	5.0	0.079	9.2	LOS A	0.3	2.3	0.34	0.88	50.8
Approach		66	5.0	0.079	9.2	LOS A	0.3	2.3	0.34	0.88	50.9
All Vehicles		308	5.0	0.091	3.5	NA	0.3	2.3	0.08	0.35	55.9

5.6.4 Lee Point Road / Access Road 2 Intersection

The results of the SIDRA for the existing condition in the year 2027 with development is shown in **Table 5-25** and **Table 5-26.** The results shows that the intersection performed satisfactorily in the AM and PM peak background condition in the year 2027.

Table 5-25 Lee Point Road / Access Road 2 Intersection AM Performance – 2027 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	117	5.0	0.135	4.1	LOS A	0.8	5.7	0.05	0.46	54.7
2	T1	97	5.0	0.135	4.4	LOS A	0.8	5.7	0.05	0.46	55.9
Approach		214	5.0	0.135	4.2	LOS A	0.8	5.7	0.05	0.46	55.2
North: Lee Point Road N											
8	T1	129	5.0	0.125	5.5	LOS A	0.7	4.8	0.40	0.52	54.2
9	R2	6	5.0	0.125	9.6	LOS A	0.7	4.8	0.40	0.52	53.9
Approach		135	5.0	0.125	5.7	LOS A	0.7	4.8	0.40	0.52	54.1
West: Access Point 2											
10	L2	11	5.0	0.173	4.7	LOS A	0.9	6.6	0.26	0.62	51.2
12	R2	205	5.0	0.173	9.0	LOS A	0.9	6.6	0.26	0.62	52.0
Approach		216	5.0	0.173	8.8	LOS A	0.9	6.6	0.26	0.62	51.9
All Vehicles		565	5.0	0.173	6.3	LOS A	0.9	6.6	0.22	0.53	53.7

Table 5-26 Lee Point Road / Access Road 2 Intersection PM Performance – 2027 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	181	5.0	0.226	4.2	LOS A	1.4	10.2	0.08	0.46	54.6
2	T1	174	5.0	0.226	4.4	LOS A	1.4	10.2	0.08	0.46	55.8
Approach		355	5.0	0.226	4.3	LOS A	1.4	10.2	0.08	0.46	55.2
North: Lee Point Road N											
8	T1	127	5.0	0.120	5.1	LOS A	0.6	4.7	0.34	0.49	54.3
9	R2	10	5.0	0.120	9.3	LOS A	0.6	4.7	0.34	0.49	54.1
Approach		137	5.0	0.120	5.4	LOS A	0.6	4.7	0.34	0.49	54.3
West: Access Point 2											
10	L2	7	5.0	0.133	5.1	LOS A	0.7	4.9	0.35	0.63	50.9
12	R2	142	5.0	0.133	9.4	LOS A	0.7	4.9	0.35	0.63	51.7
Approach		149	5.0	0.133	9.2	LOS A	0.7	4.9	0.35	0.63	51.7
All Vehicles		641	5.0	0.226	5.7	LOS A	1.4	10.2	0.20	0.50	54.1

5.6.5 Lee Point Road / Access Road 3 Intersection

The results of the SIDRA for the existing condition in the year 2027 with development is shown in **Table 5-27** and **0.** The results shows that the intersection performed satisfactorily in the AM and PM peak background condition in the year 2027.

Table 5-27 Lee Point Road / Access Road 3 Intersection AM Performance – 2027 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	91	5.0	0.184	4.1	LOS A	1.1	8.2	0.05	0.45	54.7
2	T1	206	5.0	0.184	4.4	LOS A	1.1	8.2	0.05	0.45	55.9
Approach		297	5.0	0.184	4.3	LOS A	1.1	8.2	0.05	0.45	55.5
North: Lee Point Road N											
8	T1	329	5.0	0.288	5.3	LOS A	1.8	13.1	0.41	0.51	54.2
9	R2	5	5.0	0.288	9.5	LOS A	1.8	13.1	0.41	0.51	53.9
Approach		334	5.0	0.288	5.4	LOS A	1.8	13.1	0.41	0.51	54.2
West: Access Point 2											
10	L2	8	5.0	0.153	5.3	LOS A	0.8	5.7	0.39	0.65	50.8
12	R2	159	5.0	0.153	9.7	LOS A	0.8	5.7	0.39	0.65	51.6
Approach		167	5.0	0.153	9.4	LOS A	0.8	5.7	0.39	0.65	51.6
All Vehicles		798	5.0	0.288	5.8	LOS A	1.8	13.1	0.27	0.51	54.1

Table 5-28 Lee Point Road / Access Road 3 Intersection PM Performance – 2027 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	140	5.0	0.302	4.2	LOS A	2.0	14.8	0.07	0.44	54.6
2	T1	349	5.0	0.302	4.4	LOS A	2.0	14.8	0.07	0.44	55.8
Approach		489	5.0	0.302	4.3	LOS A	2.0	14.8	0.07	0.44	55.5
North: Lee Point Road N											
8	T1	262	5.0	0.220	5.0	LOS A	1.3	9.8	0.33	0.47	54.5
9	R2	7	5.0	0.220	9.1	LOS A	1.3	9.8	0.33	0.47	54.2
Approach		269	5.0	0.220	5.1	LOS A	1.3	9.8	0.33	0.47	54.5
West: Access Point 2											
10	L2	6	5.0	0.119	6.1	LOS A	0.6	4.4	0.48	0.69	50.5
12	R2	110	5.0	0.119	10.4	LOS B	0.6	4.4	0.48	0.69	51.3
Approach		116	5.0	0.119	10.2	LOS B	0.6	4.4	0.48	0.69	51.3
All Vehicles		874	5.0	0.302	5.3	LOS A	2.0	14.8	0.20	0.48	54.6

5.7 Transportation Safety

5.7.1 Operating Speeds

The posted speed limit for Lee Point Road is 70km/h. As it currently operates, there is some degree of hooning which occurs at the northern section of Lee Point Road. Its location along the outskirts of Darwin and away from built up areas may attribute to hooning along Lee Point Road. However, as development into the northern areas increase, hooning would likely decrease as the road is modified and upgraded to accommodate developments and complaints against this behaviour increases.

5.7.2 Guidance and Delineation

The Site plans show that Lee Point Road is likely to be upgraded to improve amenity and accessibility for residents and visitors to and from the Site. Improvements include:

> Access to the site via three new intersections described as follows:
  - Access 1, stop priority intersection
  - Access 2, roundabout intersection
  - Access 3, roundabout intersection
> Cycling lanes along both sides of the road. This includes roundabouts designed to accommodate cyclist movement.
> A median strip to accommodate right turn movements at intersections.

In addition to these measures, the following should be implemented to improve guidance and delineation:

> Advance warning signs to indicate upcoming intersections
> Appropriate linemarking to delineate road lanes and stop/give way lines
> Wayfinding signage such as street name signs
> Regulatory signage such as stop or give way signs

5.8 Traffic Signals

This is not applicable as there are no signalised intersection in the vicinity of the Site.

5.9 Site Circulation and Parking

The proposed road circulation network is shown on the Site plan in **Appendix A**. Note that these plans are not final and the road network layout may change in future iterations.

Parking is expected to be provided within individual lots.

6 Improvement Analysis

6.1 Improvements to Accommodate Existing Traffic

The SIDRA analysis indicate that all intersections performed satisfactorily with LoS of A for all legs, therefore no improvements are necessary to accommodate existing traffic.

6.2 Improvements to Accommodate Background Traffic

The SIDRA analysis indicate that all intersections performed satisfactorily with LoS of A for all legs, therefore no improvements are necessary to accommodate background traffic.

6.3 Additional Improvements to Total Traffic (with Development)

The SIDRA analysis indicate that all intersections performed satisfactorily with LoS of A for all legs, therefore no improvements are necessary to accommodate total traffic.

6.4 Alternative Improvements

No additional alternative improvements have been evaluated.

6.5 Status of Improvements Already Funded, Programmed, or Planned

To the best of Cardno's knowledge, there are no improvements that have been funded or programmed.

6.6 Evaluation

No potential mitigation measures have been evaluated as the current intersection form is adequate to accommodate all traffic scenarios analysed in this report.

7 Findings

7.1 Site Accessibility

SIDRA analysis has shown that the main accesses into the Site, i.e. Access 1, Access 2 and Access 3 will perform satisfactorily with the background and development traffic in the year 2027.

7.2 Transportation Impacts

As the Site generates very low traffic volume, it is expected that the Site will have negligible impact on the surrounding road network.

7.3 Needs for Any Improvements

No improvements are recommended at this stage as the Lee Point Road/Lee Point Village Resort and Lee Point Road/Buffalo Creek Road intersections are expected to perform satisfactorily in its current form. The development will have minimal impact on the surrounding road network.

7.4 Compliance with Applicable Local Codes

No applicable local standards have been relevant to this assessment, however any future modifications to the proposed site plans may require the need for additional assessment to meet the required standards.

8 Recommendation

8.1 Site Access / Circulation Plan

No recommendations or mitigation measures are proposed for the Site.

8.2 Roadway Improvements

8.2.1 On-Site

No recommendations for roadway improvement are proposed for the Site.

8.2.2 Off-Site

No recommendations for roadway improvement are proposed for the Site.

8.3 Transit, Pedestrians and Bicycles

No improvements to transit, pedestrian or bicycle infrastructure or services are recommended.

8.4 Transportation System Management / Transportation Demand Management Actions

8.4.1 Off-Site

Not applicable due to the nature and location of the Site.

8.4.2 On-Site Operational

Not applicable due to the nature and location of the Site.

8.4.3 On-Site

Not applicable due to the nature and location of the Site.

2CRU Development, Lee Point

APPENDIX A

SITE PLAN

Cardno
Shaping the Future

LEGEND

- SUBJECT SITE
- PROPOSED STAGING BOUNDARY
- COMMUNITY USE
- OPEN SPACE
- ENCUMBERED OPEN SPACE
- PROPOSED COASTAL RESERVE
- PROPOSED CONSERVATION RESERVE
- PARKING (WITHIN BASEMENT)
- PARKING (WITHIN CARCOURT)

DWELLING YIELD SUMMARY TABLE

LOT YIELD	TOTAL AREA (Ha)	NO. LOTS	AVERAGE LOT SIZE (m2)
Standard Residential Lots	35.30	704	494
Rural Lots	14.19	32	4305

STANDARD LOT TYPES	TOTAL AREA (m2)	NO. LOTS	% (TOTAL STANDARD RES. LOTS)
240 - 360 m 2 (Medium Density)	30,000	100	14%
360 - 450 m 2 (Small Lot)	63,990	158	22%
450 - 550 m 2 (Medium Lot)	85,000	170	24%
550 - 650 m 2 (Large Lot)	114,600	191	27%
650 - 750 m 2 (Duplex)	59,500	85	12%
TOTAL STANDARD LOTS	353,090	704	100%

SPECIAL SITES - APARTMENTS	SITE AREA (m2)	DWELLINGS	TYPE
TOURISM PRECINCT - ACCOMMODATION	2.70	300	
TP1 - Height Limit 12 Storeys	1.12	180	Hotel/ serviced apartments
TP2 - Height Limit 12 Storeys	0.51	80	Hotel/ serviced apartments
TP3 - Height Limit 8 Storeys	0.42	40	Hotel/ serviced apartments
TP4 - No Residential Included	0.65	0	
MIXED USE - HEIGHT LIMIT 4 STOREYS	1.00	60	Private apartments
GENERAL URBAN - HEIGHT LIMIT 3 STOREYS	3.00	160	Private apartments
TOTAL APARTMENTS		520	

BEAGLE GULF
CASUARINA COASTAL RESERVE
2CRU BOUNDARY 82.03HA
PARK A 0.75Ha
RB 03 0.26 Ha
HERITAGE RESERVE 0.18Ha
STAGE 5
RB 02 0.62 Ha
TOURISM ACTIVITY AREA
LINEAR RESERVE A 0.29 Ha
LEE POINT VILLAGE RESORT CARAVAN PARK LOT 9289
GREEN CORRIDOR
CREEK
TP 4
TP 1
PARK B 0.52 Ha
TP 2
TP 3
SANDY
PROPOSED COASTAL RESERVE
PROPOSED PRIMARY SCHOOL + COMMUNITY HUB
PROPOSED COMMUNITY CENTRE 0.2Ha
PARK C 0.59 Ha
PARK F 1.43 Ha
LINEAR RESERVE B 0.16 Ha
STAGE 2A
PARK E 0.52 Ha
STAGE 1A
PARK D 0.31 Ha
ROYAL DARWIN GOLF COURSE
ROYAL DARWIN HOSPITAL
LINEAR RESERVE C 0.10Ha
PARK G 0.92 Ha
RB 06/ GREEN CORRIDOR 0.51Ha
PROPOSED COASTAL RESERVE 21.13 Ha
PARK H 0.51 Ha
STAGE 3
STAGE 4
RB 01 3.74 Ha
PARK K 0.34Ha
PARK I 0.3 Ha
PARK J 0.11 Ha
2CRU BOUNDARY [82.03HA]
ROYAL DARWIN GOLF COURSE
CASUARINA SQUARE SHOPPING CENTRE
BREEZES HOTEL
ROYAL DARWIN HOSPITAL
LEE POINT ROAD
PROPOSED PRIMARY SCHOOL + COMMUNITY HUB 3.5Ha
ACTIVE RECREATIONAL RESERVE 2 Ha
PARK L 0.19 Ha
RB 07/ GREEN CORRIDOR 1.04 Ha
STAGE 1B
RB 08 0.56 Ha
PARK M 0.59 Ha
GREEN CORRIDOR
MUIRHEAD NORTH
MUIRHEAD NORTH 49.32HA
RB 09/ GREEN CORRIDOR 0.28 Ha
STAGE 2B
RURAL LOTS 14.19 Ha
DRAINAGE RESERVE [RB 04 +RB 05] 6.15Ha
RB 10/ GREEN CORRIDOR 0.26 Ha
CONSERVATION AREA 1.57 Ha
RB 11/ GREEN CORRIDOR 0.13 Ha

Lee Point | Master Plan
Lee Point Road, Lee Point
City of Darwin, Northern Territory

REF NO	DRAW NO	REV
DHA LEE	RD 3102	C

NOTES:
MP reference:
RD3003F Lee Point_Illustrative Master Plan_170215

Land budget reference:
RD4501E DHA LEE_ Preliminary_Land Budget_170215

REV	DESCRIPTION	DDMMYY	DRAWN	APPR'D
C	per SB 16.02.15 - RD3003F	170215	KT	EP
B	per SB 02.02.15 - RD3003E	110215	KT	EP
A	per SB 081214	101214	KT	EP

SCALE 1:2,500 SIZE A0
50 100 150 200 250 300m

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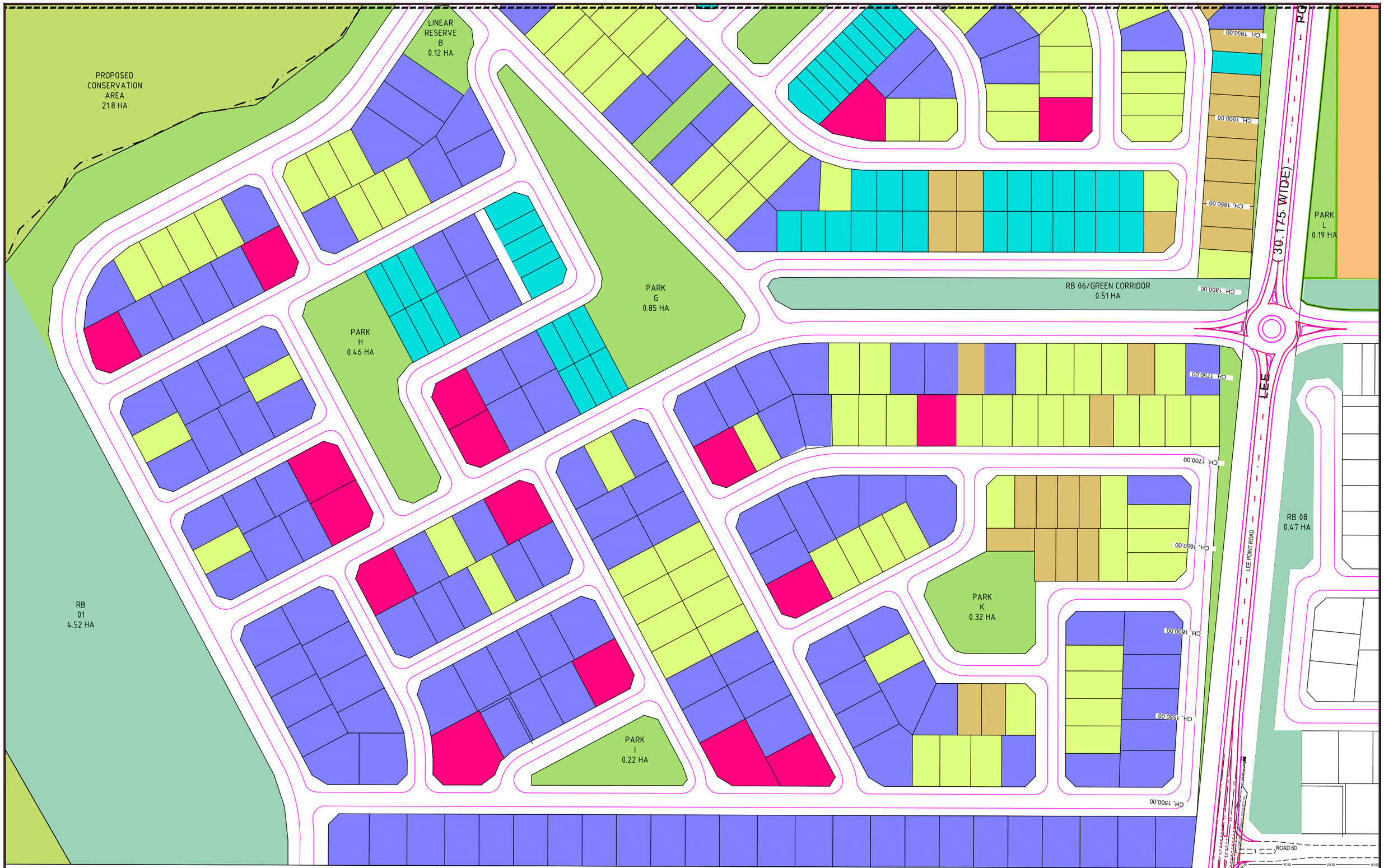

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REVISION		DATE	DES/DFT	APP'D

DHA Defence Housing Australia

Principal
Defence Housing Authority

Project Leader TFR
Designed CH
Drawn CH
Checked DB
Authorised TFR
Date April 2016

NORTH

Scale @ A1
1:1000

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Lee Point Road, Muirhead 2CRU

Master Planning - Stages
City of Darwin
Lot Layout Plan

Sheet 1 of 2
Drawing No. -
Rev A
Dev. App. No. -
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REVISION		DATE	DES/DFT	APP'D

DHA Defence Housing Australia

Principal
Defence Housing Authority

Project Leader
TFR
Designed
CH
Drawn
CH
Checked
DB
Authorised
TFR
Date
April 2016

NORTH

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1:1000

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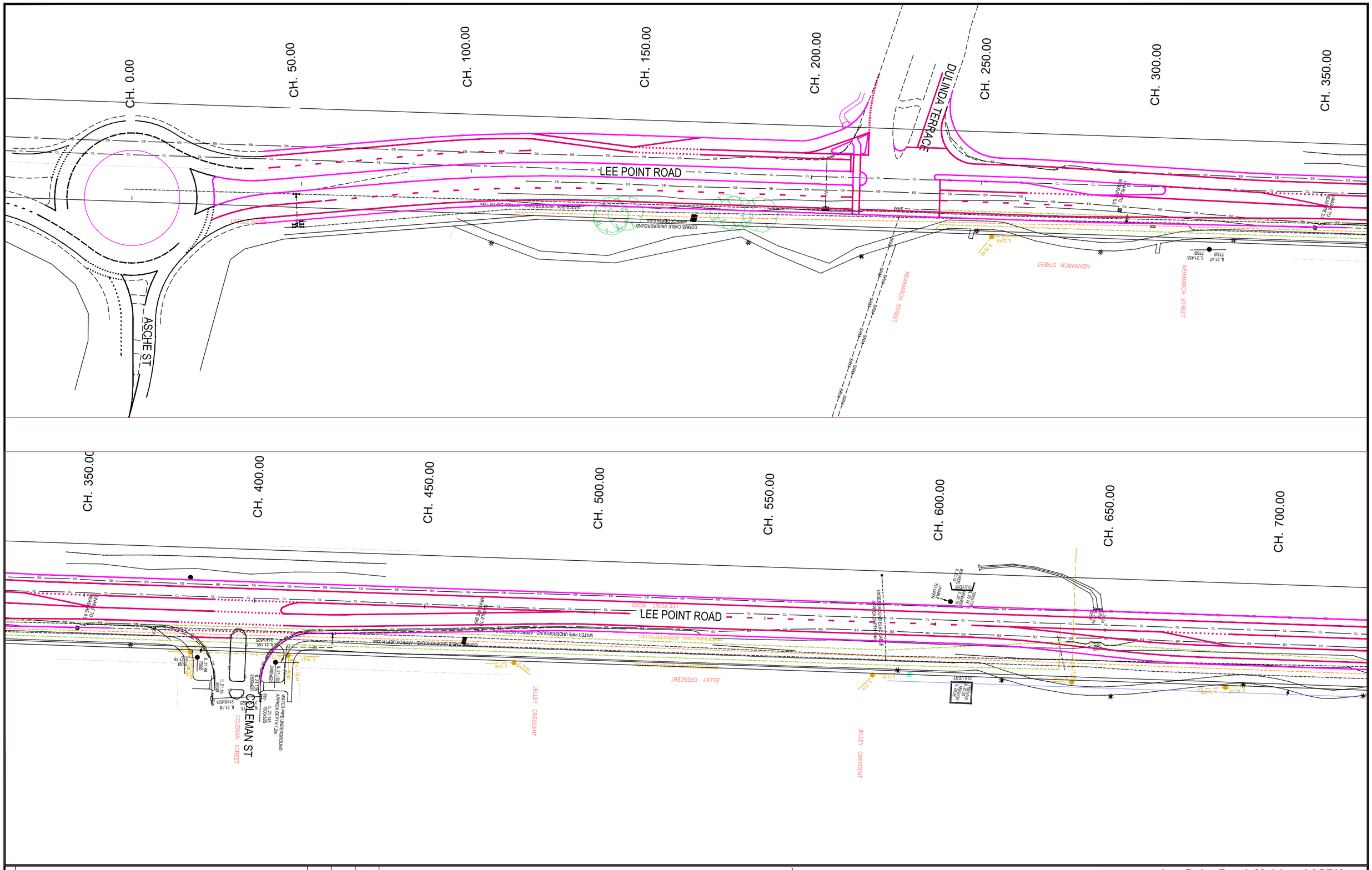

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Principal
Defence Housing Authority

Project Leader
TFR
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CH
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NORTH

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Lee Point Road, Muirhead 2CRU

Master Planning - Stages
City of Darwin
Roadworks Layout Plan

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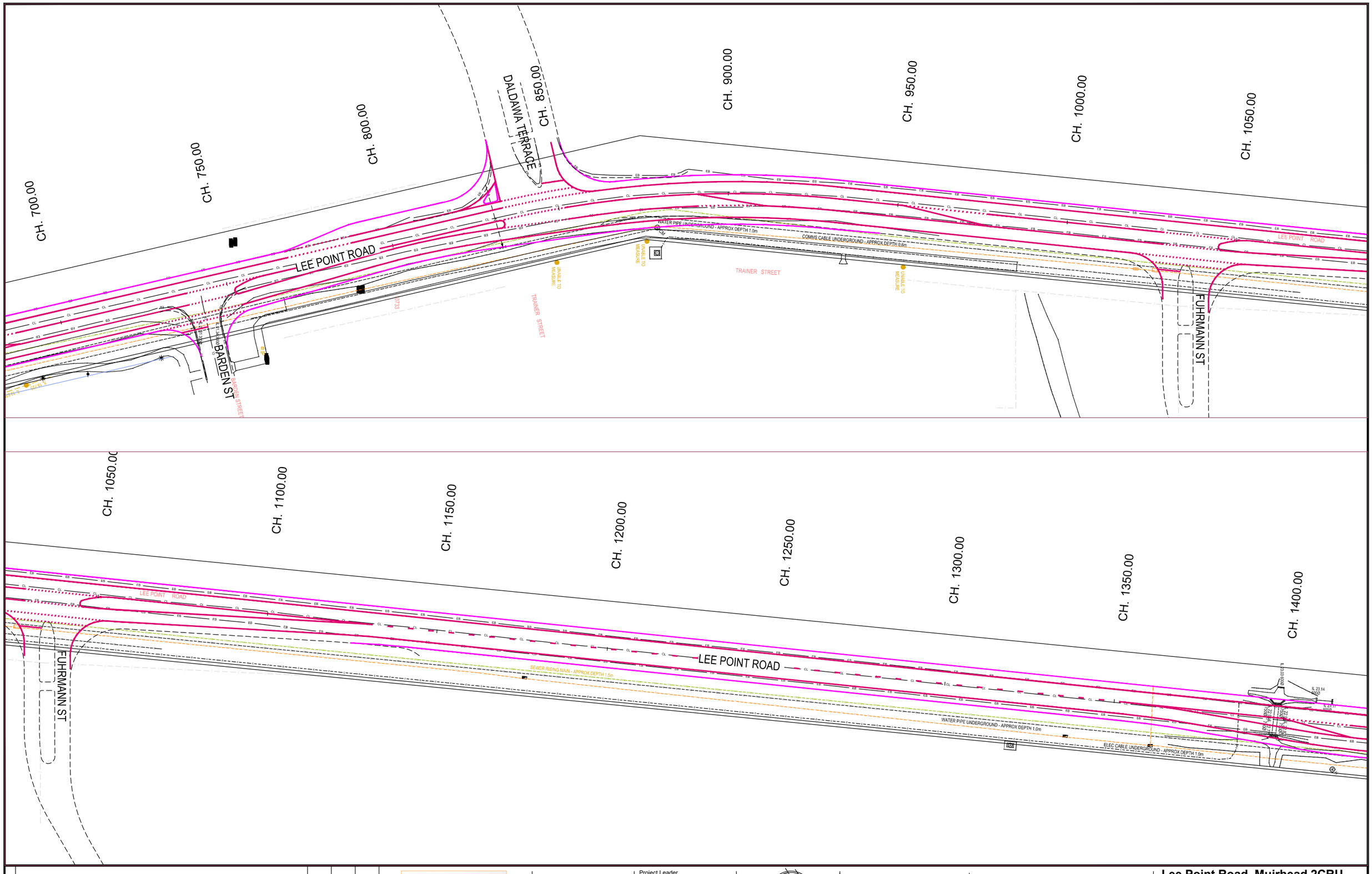

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Defence Housing Authority

Project Leader
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April 2016

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Sheet 2 of 5
Drawing No. -
Rev A
Dev. App. No. -
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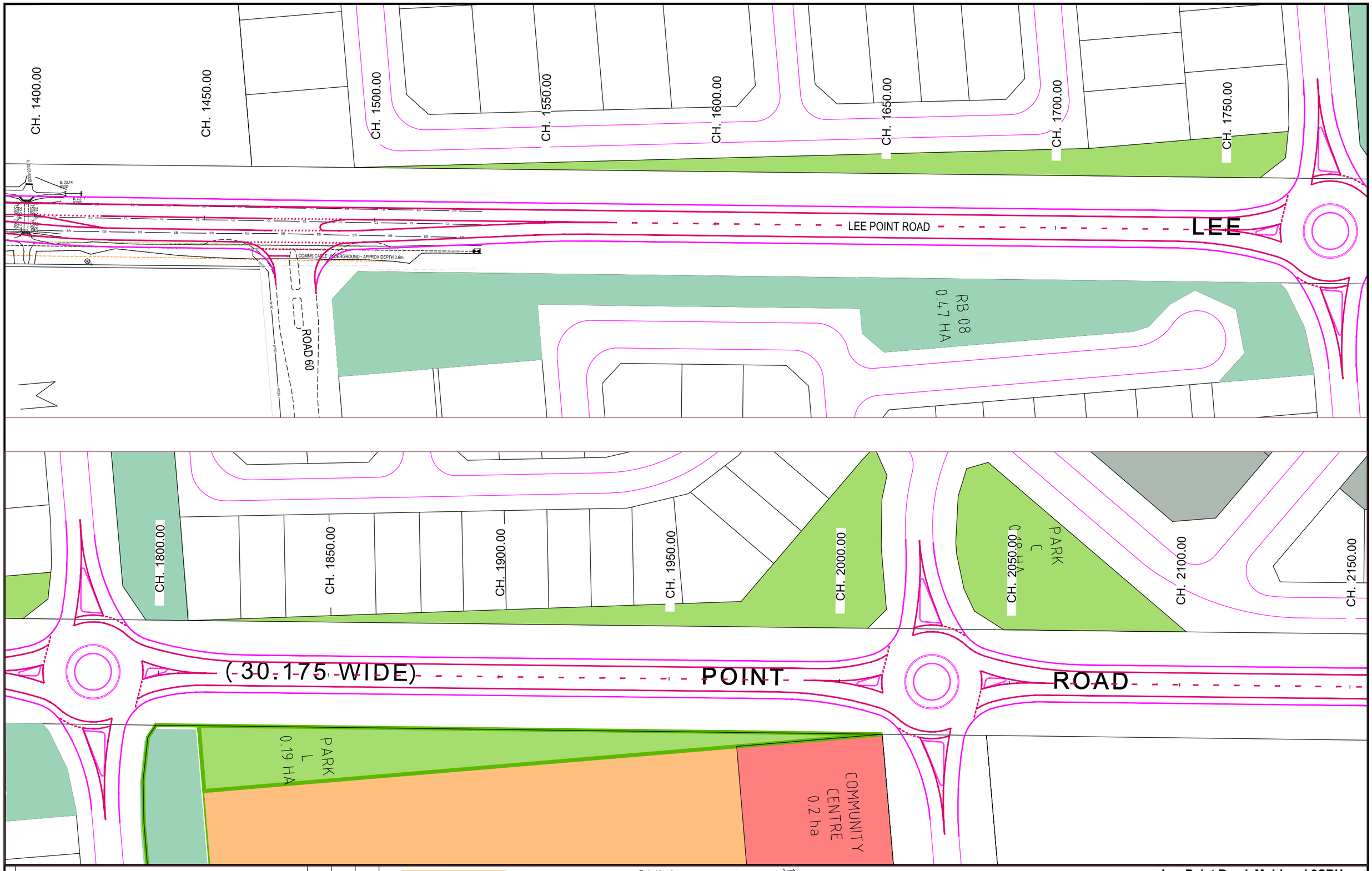

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Lee Point Road, Muirhead 2CRU

Master Planning - Stages
City of Darwin
Roadworks Layout Plan

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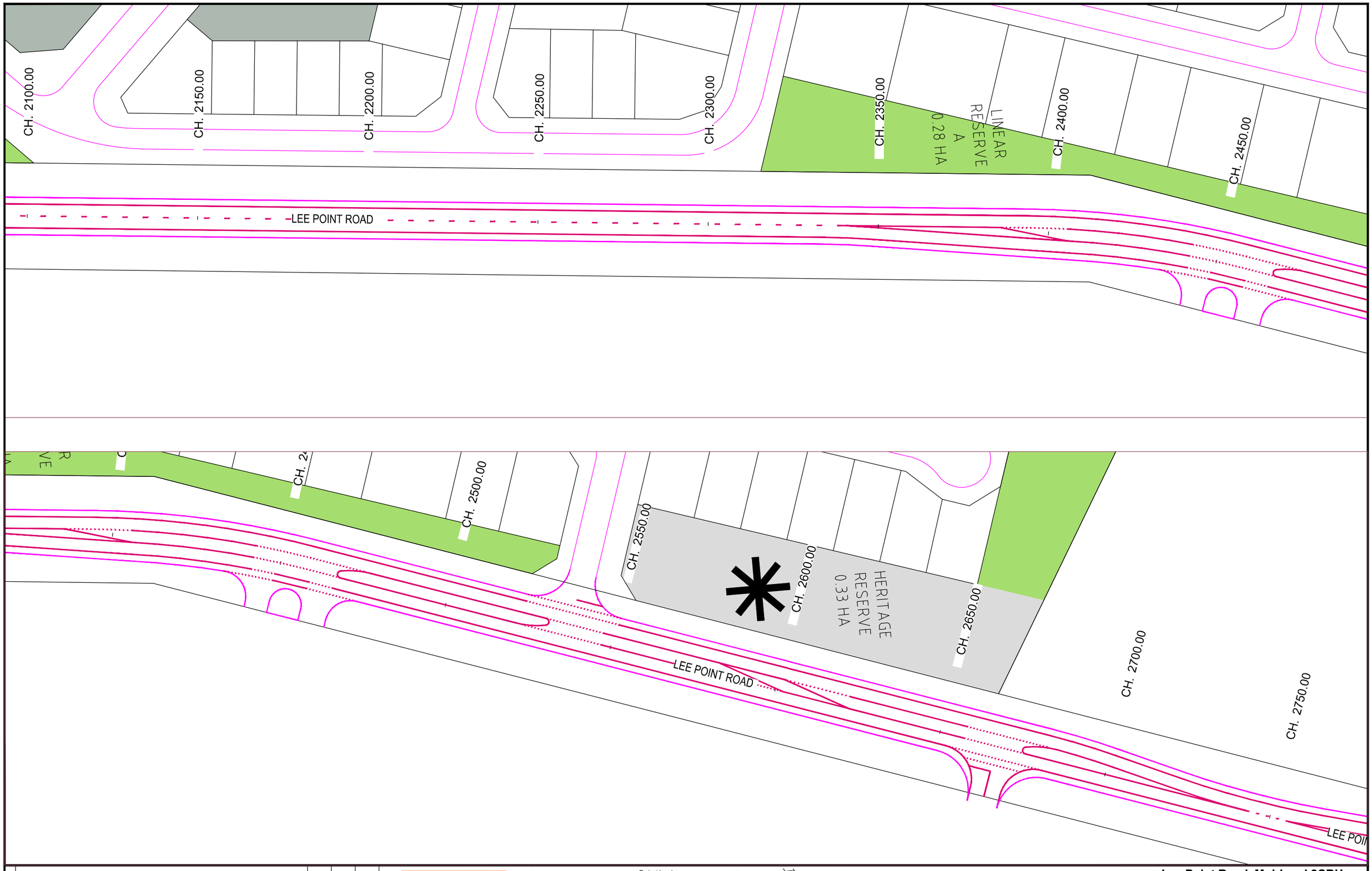

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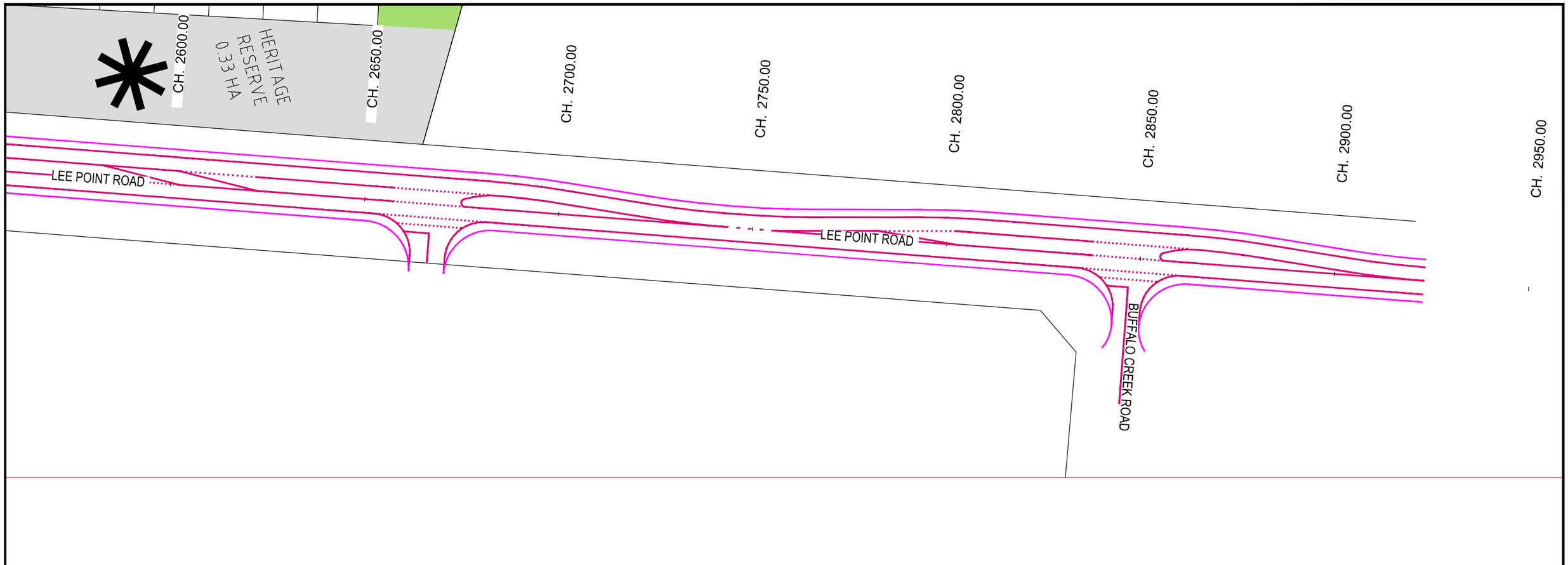

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APPENDIX L

Traffic Impact Assessment report – Muirhead North

Transport Impact Assessment

Muirhead Subdivision, Lee Point

Prepared for
Defence Housing Australia

22 December 2016

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Shaping the Future

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Table of Contents

1 Introduction and Summary 1
1.1 Purpose of Report and Study Objectives 1
1.2 Summary 1
1.2.1 Site Location and Study Area 1
1.2.2 Development Description 2
1.2.3 Types of Studies Undertaken 2
1.2.4 Principle Findings 2
1.2.5 Conclusions 2
1.2.6 Recommendations 2
2 Proposed Development 3
2.1 Off-site Development 3
2.2 Description of On-Site Development 3
2.2.1 Land Use and Intensity 3
2.2.2 Location 4
2.2.3 Site Plan 4
2.2.4 Zoning 5
2.2.5 Phasing and Timing 5
3 Existing Area Conditions 7
3.1 Study Area 7
3.1.1 Area of Influence 7
3.1.2 Area of Significant Transport Impact 7
3.2 Study Area Land Use 7
3.2.1 Existing Land Uses 7
3.2.2 Existing Zoning 8
3.2.3 Anticipated Future Development 9
3.3 Site Accessibility 9
3.3.1 Area Roadway System 9
3.3.2 Traffic Volumes and Conditions 10
3.3.3 Transit Service 10
3.3.4 Pedestrians and Bicyclists 12
3.3.5 Existing Relevant Transportation System Management Programs 12
4 Projected Traffic 13
4.1 Site Traffic (Each Horizon Year) 13
4.1.1 Trip Generation 13
4.1.2 Trip Distribution 14
4.1.3 Modal Split 15
4.1.4 Trip Assignment 15
4.2 Through Traffic (Each Horizon Year) 15
4.2.1 Method Projection 15
4.2.2 Non-Site Traffic for Anticipated Development in Study Area 15
4.2.3 Through Traffic 17
4.2.4 Estimated Volumes 17
5 Transportation Analysis 22
5.1 Summary of Assumptions 22
5.2 Site Access and Existing Intersections 22

5.3 Capacity and Level of Service (2019 Base Scenario, Without Development) 24
5.3.1 Lee Point Road / Buffalo Creek Road Intersection 24
5.3.2 Lee Point Road / Lee Point Village Resort 25
5.3.3 Lee Point Road / Access Road 1 Intersection 27
5.3.4 Lee Point Road / Access Road 2 Intersection 28
5.3.5 Lee Point Road / Access Road 3 Intersection 30
5.4 Capacity and Level of Service (2029 Base Scenario, Without Development) 31
5.4.1 Lee Point Road / Buffalo Creek Road Intersection 31
5.4.2 Lee Point Road / Lee Point Village Resort 32
5.4.3 Lee Point Road / Access Road 1 Intersection 33
5.4.4 Lee Point Road / Access Road 2 Intersection 34
5.4.5 Lee Point Road / Access Road 3 Intersection 34
5.5 Capacity and Level of Service (2019 Base Scenario, With Development) 36
5.5.1 Lee Point Road / Buffalo Creek Road Intersection 36
5.5.2 Lee Point Road / Lee Point Village Resort 36
5.5.3 Lee Point Road / Access Road 1 Intersection 37
5.5.4 Lee Point Road / Access Road 2 Intersection 38
5.5.5 Lee Point Road / Access Road 3 Intersection 39
5.5.6 Lee Point Road / Access Road 4 Intersection 41
5.6 Capacity and Level of Service (2029 Base Scenario, With Development) 43
5.6.1 Lee Point Road / Buffalo Creek Road Intersection 43
5.6.2 Lee Point Road / Lee Point Village Resort 44
5.6.3 Lee Point Road / Access Road 1 Intersection 45
5.6.4 Lee Point Road / Access Road 2 Intersection 45
5.6.5 Lee Point Road / Access Road 3 Intersection 46
5.6.6 Lee Point Road / Access Road 4 Intersection 47
5.7 Transportation Safety 48
5.7.1 Operating Speeds 48
5.7.2 Guidance and Delineation 48
5.8 Traffic Signals 49
5.9 Site Circulation and Parking 49
6 Improvement Analysis 50
6.1 Improvements to Accommodate Existing Traffic 50
6.2 Improvements to Accommodate Background Traffic 50
6.3 Additional Improvements to Total Traffic (with Development) 50
6.4 Alternative Improvements 50
6.5 Status of Improvements Already Funded, Programmed, or Planned 50
6.6 Evaluation 50
7 Findings 51
7.1 Site Accessibility 51
7.2 Transportation Impacts 51
7.3 Needs for Any Improvements 51
7.4 Compliance with Applicable Local Codes 51
8 Recommendation 52
8.1 Site Access / Circulation Plan 52
8.2 Roadway Improvements 52
8.2.1 On-Site 52
8.2.2 Off-Site 52

8.3 Transit, Pedestrians and Bicycles 52
8.4 Transportation System Management / Transportation Demand Management Actions 52
8.4.1 Off-Site 52
8.4.2 On-Site Operational 52
8.4.3 On-Site 52

Appendices

Appendix A Site Plan

Tables

Table 2-1 Land Use Summary – Muirhead Subdivision 4
Table 3-1 Existing Traffic Volumes (two-way) 10
Table 4-1 Trip Generation Rates (From RTA Guide to Traffic Generating Developments) 13
Table 4-2 Trip Directional Distribution 13
Table 4-3 Trip Generation and Distribution Estimation 13
Table 4-4 Trip Generation and Distribution Estimation 15
Table 5-1 Lee Point Road / Buffalo Creek Road Intersection AM Performance – 2019 Without Development 25
Table 5-2 Lee Point Road / Buffalo Creek Road Intersection PM Performance – 2019 Without Development 25
Table 5-3 Lee Point Road / Lee Point Village Resort Intersection AM Performance – 2019 Without Development 26
Table 5-4 Lee Point Road / Lee Point Village Resort Intersection PM Performance – 2019 Without Development 27
Table 5-5 Lee Point Road / Access Road 1 Intersection AM Performance – 2019 Without Development 28
Table 5-6 Lee Point Road / Access Road 1 Intersection PM Performance – 2019 Without Development 28
Table 5-7 Lee Point Road / Access Road 2 Intersection AM Performance – 2019 Without Development 29
Table 5-8 Lee Point Road / Access Road 2 Intersection PM Performance – 2019 Without Development 30
Table 5-9 Lee Point Road / Access Road 3 Intersection AM Performance – 2019 Without Development 31
Table 5-10 Lee Point Road / Access Road 3 Intersection PM Performance – 2019 Without Development 31
Table 5-11 Lee Point Road / Buffalo Creek Road Intersection AM Performance – 2029 Without Development 32
Table 5-12 Lee Point Road / Buffalo Creek Road Intersection PM Performance – 2029 Without Development 32
Table 5-13 Lee Point Road / Lee Point Village Resort Intersection AM Performance – 2029 Without Development 32
Table 5-14 Lee Point Road / Lee Point Village Resort Intersection PM Performance – 2029 Without Development 33
Table 5-15 Lee Point Road / Access Road 1 Intersection AM Performance – 2029 Without Development 33
Table 5-16 Lee Point Road / Access Road 1 Intersection PM Performance – 2029 Without Development 33
Table 5-17 Lee Point Road / Access Road 2 Intersection AM Performance – 2029 Without Development 34
Table 5-18 Lee Point Road / Access Road 2 Intersection PM Performance – 2029 Without Development 34
Table 5-19 Lee Point Road / Access Road 3 Intersection AM Performance – 2029 Without Development 35
Table 5-20 Lee Point Road / Access Road 3 Intersection PM Performance – 2029 Without Development 35

Table 5-21 Lee Point Road / Buffalo Creek Road Intersection AM Performance – 2019 With Development 36
Table 5-22 Lee Point Road / Buffalo Creek Road Intersection PM Performance – 2019 With Development 36
Table 5-23 Lee Point Road / Lee Point Village Resort Intersection AM Performance – 2019 With Development 37
Table 5-24 Lee Point Road / Lee Point Village Resort Intersection PM Performance – 2019 With Development 37
Table 5-25 Lee Point Road / Access Road 1 Intersection AM Performance – 2019 With Development 37
Table 5-26 Lee Point Road / Access Road 1 Intersection PM Performance – 2019 With Development 38
Table 5-27 Lee Point Road / Access Road 2 Intersection AM Performance – 2019 With Development 39
Table 5-28 Lee Point Road / Access Road 2 Intersection PM Performance – 2019 With Development 39
Table 5-29 Lee Point Road / Access Road 3 Intersection AM Performance – 2019 With Development 41
Table 5-30 Lee Point Road / Access Road 3 Intersection PM Performance – 2019 With Development 41
Table 5-31 Lee Point Road / Access Road 4 Intersection AM Performance – 2019 With Development 42
Table 5-32 Lee Point Road / Access Road 4 Intersection PM Performance – 2019 With Development 43
Table 5-33 Lee Point Road / Buffalo Creek Road Intersection AM Performance – 2029 With Development 43
Table 5-34 Lee Point Road / Buffalo Creek Road Intersection PM Performance – 2029 With Development 44
Table 5-35 Lee Point Road / Lee Point Village Resort Intersection AM Performance – 2029 With Development 44
Table 5-36 Lee Point Road / Lee Point Village Resort Intersection PM Performance – 2029 With Development 44
Table 5-37 Lee Point Road / Access Road 1 Intersection AM Performance – 2029 With Development 45
Table 5-38 Lee Point Road / Access Road 1 Intersection PM Performance – 2029 With Development 45
Table 5-39 Lee Point Road / Access Road 2 Intersection AM Performance – 2029 With Development 46
Table 5-40 Lee Point Road / Access Road 2 Intersection PM Performance – 2029 With Development 46
Table 5-41 Lee Point Road / Access Road 3 Intersection AM Performance – 2029 With Development 47
Table 5-42 Lee Point Road / Access Road 3 Intersection PM Performance – 2029 With Development 47
Table 5-43 Lee Point Road / Access Road 4 Intersection AM Performance – 2029 With Development 48
Table 5-44 Lee Point Road / Access Road 4 Intersection PM Performance – 2029 With Development 48

Figures

Figure 1-1 Site Location and Existing Intersections 1
Figure 1-2 Development Plan 2
Figure 2-1 2CRU North Development Plan 3
Figure 2-2 Site Location 4
Figure 2-3 Site Plan for Muirhead Site. 5
Figure 2-4 Preliminary Staging Plan – Muirhead Subdivision 6
Figure 3-1 Lee Point Road, Lee Point – Area of Influence and Existing Intersections 7
Figure 3-2 Land Zoning 8
Figure 3-3 Site Access Arrangements 9
Figure 3-4 Existing Public Transport Service 11

Figure 3-5 Existing Pedestrian/Cycling Facilities in the Area Surrounding the Site 12
Figure 4-1 Peak Trip Distribution 14
Figure 4-2 Peak Trip Distribution 16
Figure 4-3 Estimated Background Traffic Volumes 2019 18
Figure 4-4 Estimated Background Traffic Volumes 2029 19
Figure 4-5 Estimated Total Traffic Volumes in 2019 with Development 20
Figure 4-6 Estimated Total Traffic Volumes in 2029 with Development 21
Figure 5-1 Site Access and Existing Intersections 23
Figure 5-2 Lee Point Road / Buffalo Creek Road Intersection Layout 24
Figure 5-3 Lee Point Road / Lee Point Village Resort Intersection Layout 26
Figure 5-4 Lee Point Road / Access Road 1 Intersection Layout 27
Figure 5-5 Lee Point Road / Access Road 2 Intersection Layout 29
Figure 5-6 Lee Point Road / Access Road 3 Intersection Layout 30
Figure 5-7 Lee Point Road / Access Road 2 Intersection Layout 38
Figure 5-8 Lee Point Road / Access Road 3 Intersection Layout 40
Figure 5-9 Lee Point Road / Access Road 4 Intersection Layout 42

1 Introduction and Summary

1.1 Purpose of Report and Study Objectives

Cardno has been commissioned by Defence Housing Australia to prepare a *Transport Impact Assessment* (TIA) for the Muirhead site located at Lot 9370 Lee Point Road, Lee Point, City of Darwin.

The Site will primarily consist of residential development along with a primary school and an active recreational reserve (refer to **Figure 2-1** for the land use summary). The development plan is enclosed in **Appendix A**.

This report has been prepared in accordance with the Austroads *Guide to Traffic Management Part 12: Traffic Impacts of Development*.

The purpose of this report is to determine the overall impact of the development on the surrounding road network along with the performance of nearby intersections and the overall amenity of the area.

1.2 Summary

1.2.1 Site Location and Study Area

The study area and existing intersections within the study area are shown in **Figure 1-1**.

Figure 1-1 Site Location and Existing Intersections

Source: Nearmap

1.2.2 Development Description

The proposed development area for the Site is shown in **Figure 1-2** and will comprise of residential dwellings, rural residential lots, a primary school and an active recreational reserve (refer to **Figure 2-1** for the land use summary). For the purpose of this report, it is anticipated that the development will open in 2019.

Figure 1-2 Development Plan

Source: Defence Housing Australia (DHA)

1.2.3 Types of Studies Undertaken

As the primary access location for the Site is proposed via Lee Point Road, a TIA has been undertaken to determine the effect of the development on the nearby existing intersections (Lee Point Road/Lee Point Village Resort and Lee Point Road/Buffalo Creek Road) and if necessary, whether any improvement to the intersection is required.

1.2.4 Principle Findings

This Transport Impact Assessment has found that all intersections along Lee Point Road will perform satisfactorily for the year 2019 and 2029 in their currently proposed form and no improvement to the intersections are necessary to accommodate the expected increase in traffic.

1.2.5 Conclusions

The development is expected to have minimal impact on the surrounding road network and the overall amenity of the area, therefore no upgrades are necessary to Lee Point Road, as well as the surrounding road network.

1.2.6 Recommendations

No roadway improvements have been proposed for Lee Point Road and the surrounding road network (other than what has been proposed in the Site plans) as it is expected that the Site will have minimal impact on the surrounding area.

2 Proposed Development

2.1 Off-site Development

To the west of the proposed Muirhead development, is the proposed 2CRU development. The 2CRU development site is described as Lot 4873 and is located to the west of Lee Point Road to the north of the Darwin hospital precinct in the Northern Territory. The development has a total site area of approximately 44ha and is proposed to be developed into 340 residential single dwellings lots, 40 duplex lots, 92 town house units, and a variety of tourism, mixed use and general urban developments. The 2CRU development plan is shown in **Figure 2-1**.

Figure 2-1 2CRU North Development Plan

Source: Defence Housing Australian (DHA)

2.2 Description of On-Site Development

2.2.1 Land Use and Intensity

The Muirhead developments are proposed to accommodate residential dwellings, along with rural residential lots, a primary school and an active recreational reserve. The proposed site plan is shown in **Figure 2-3** and a summary of the land uses is shown in **Table 2-1**.

Table 2-1 Land Use Summary – Muirhead Subdivision

Land Use	Traffic Generation Category	Provision
Single Dwelling Residential	Residential	187 dwellings
Multiple Dwelling Residential (duplex)	Small units and flats	20 dwellings
Medium Density Residential	Large units and town houses	27 dwellings
Rural Residential	Rural Residential	33 dwellings
Primary School	Primary School	300 students
Active Recreational Reserve	Tennis courts Gym	4 courts 500m^2 GFA

2.2.2 Location

The location of the proposed Muirhead subdivision (the Site) is shown in **Figure 2-2**.

Figure 2-2 Site Location

Source: Nearmap

2.2.3 Site Plan

A site plan for the proposed subdivision is shown in **Figure 2-3.** High resolution plans of the Site have been provided in **Appendix A.**

Figure 2-3 Site Plan for Muirhead Site.

Source: Defence Housing Australia

2.2.4 Zoning

The subdivision is zoned 'Future Development' under the Northern Territory Planning Scheme.

2.2.5 Phasing and Timing

The preliminary staging plan for both the 2CRU and Muirhead developments is shown in **Figure 2-4**. The Muirhead development is intended to commence after the completion of the 2CRU development.

The overall timing for construction is intended commence in the 2019 dry season and nominally one stage per year to be released. The staging and timing are subject to change due to the environmental approvals process and commercial assessment.

Figure 2-4 Preliminary Staging Plan – Muirhead Subdivision

Source: Defence Housing Australia

3 Existing Area Conditions

3.1 Study Area

3.1.1 Area of Influence

The study area along with surrounding roads and intersections within this area are shown in **Figure 3-1.**

Figure 3-1 Lee Point Road, Lee Point – Area of Influence and Existing Intersections

Source: Nearmap

3.1.2 Area of Significant Transport Impact

The area of significant transportation impact is shown in **Figure 3-1** as this includes the intersections serving the study area.

3.2 Study Area Land Use

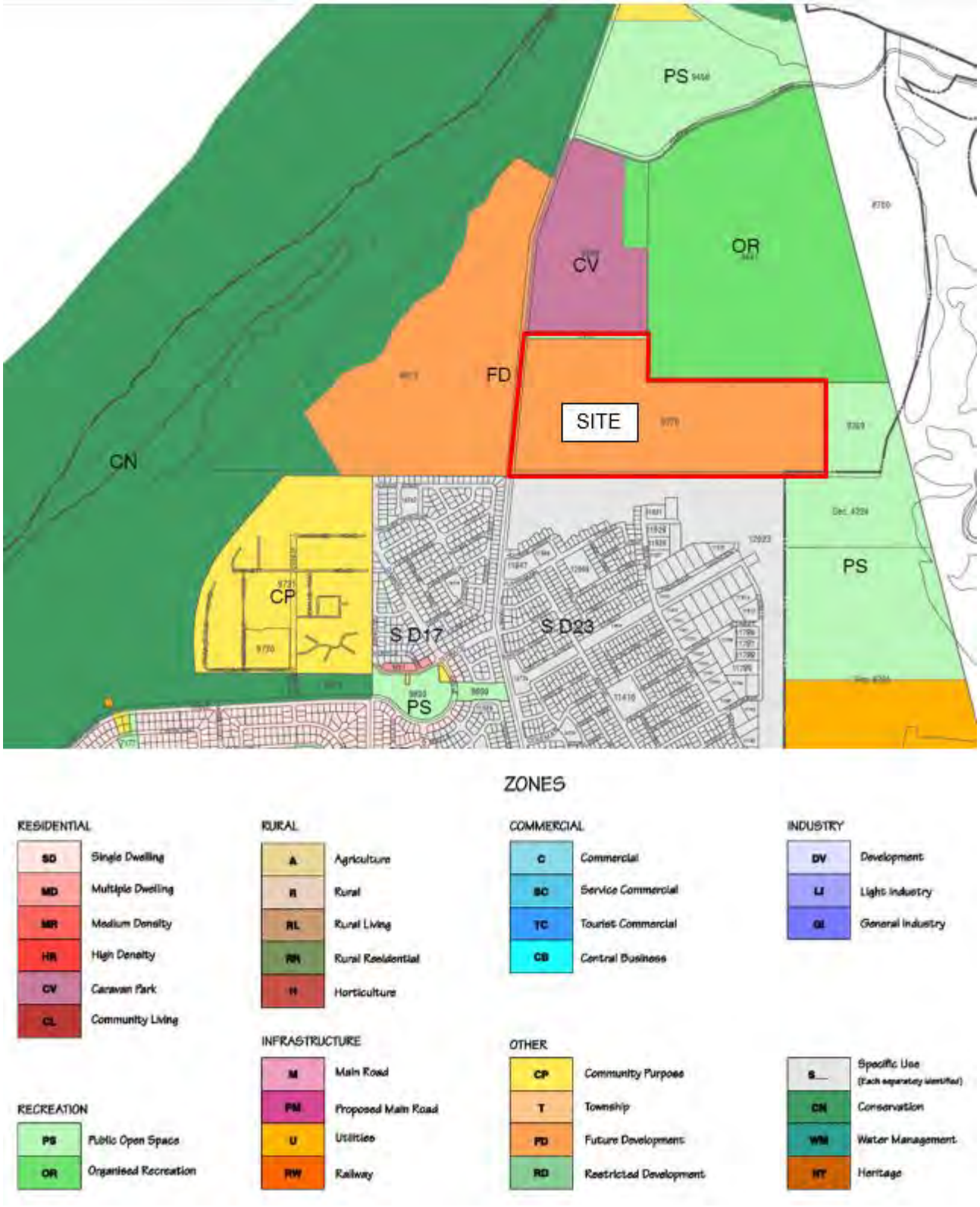
3.2.1 Existing Land Uses

Land use surrounding the Site includes a caravan park and organised recreation to the north, future development to the west, public open space to the east and residential to the south.

3.2.2 Existing Zoning

As shown in **Figure 3-2**, the land within the Site is zoned as 'Future Development' under the Northern Territory Planning Scheme.

Figure 3-2 Land Zoning



Source: Northern Territory Planning Scheme

3.2.3 Anticipated Future Development

It is anticipated that the area will consist of residential dwellings, rural residential lots, a primary school and an active recreational reserve (refer to **Figure 2-1** for the land use summary).

3.3 Site Accessibility

3.3.1 Area Roadway System

3.3.1.1 Existing

There are currently no accesses to the Site.

3.3.1.2 Future

The proposed vehicular access for the development is shown in **Figure 3-3**. A total of three access roads have been proposed:

- **Access 2** – Located on Lee Point Road, full movement roundabout access (providing access to the 2CRU and Muirhead developments)
- **Access 3** – Located on Lee Point Road, full movement roundabout access (providing access to the 2CRU and Muirhead developments)
- **Access 4** – Located on Lee Point Road, full movement give way priority controlled access (providing access the Muirhead development only)

Access 1 is only used by the 2CRU development and is located north of Access 2 along Lee Point Road.

Figure 3-3 Site Access Arrangements

Source: Nearmap

3.3.2 Traffic Volumes and Conditions

A traffic survey for the access to Lee Point Village Resort was conducted in March 2015. The traffic surveys indicated that the AM and PM peak hours for the Lee Point Village Resort access road occurred from 7:30am – 8:30am and 5:45pm – 6:45pm, respectively. Traffic volumes at the Lee Point Road/Buffalo Creek Road intersection were estimated using the volumes collected for the Lee Point Village Resort access. **Table 3-1** provides a summary of the existing traffic volumes.

Table 3-1 Existing Traffic Volumes (two-way)

Road Name	Date	Average Two-way Traffic Volumes	
		Vehicles per AM Peak Hour	**Vehicles Per PM Peak Hour**
Lee Point Village Resort	March 2015	16	15
Buffalo Creek Road	March 2015	28	58
Lee Point Road (At Lee Point Village Resort)	March 2015	35	94
Lee Point Road (At Buffalo Creek Road)	March 2015	18	48

3.3.3 Transit Service

The Northern Territory's public transport services are managed by the Department of Transport (DoT) and operated by a range of contractors. There are currently no public transport services along the section of Lee Point Road fronted by the Muirhead development

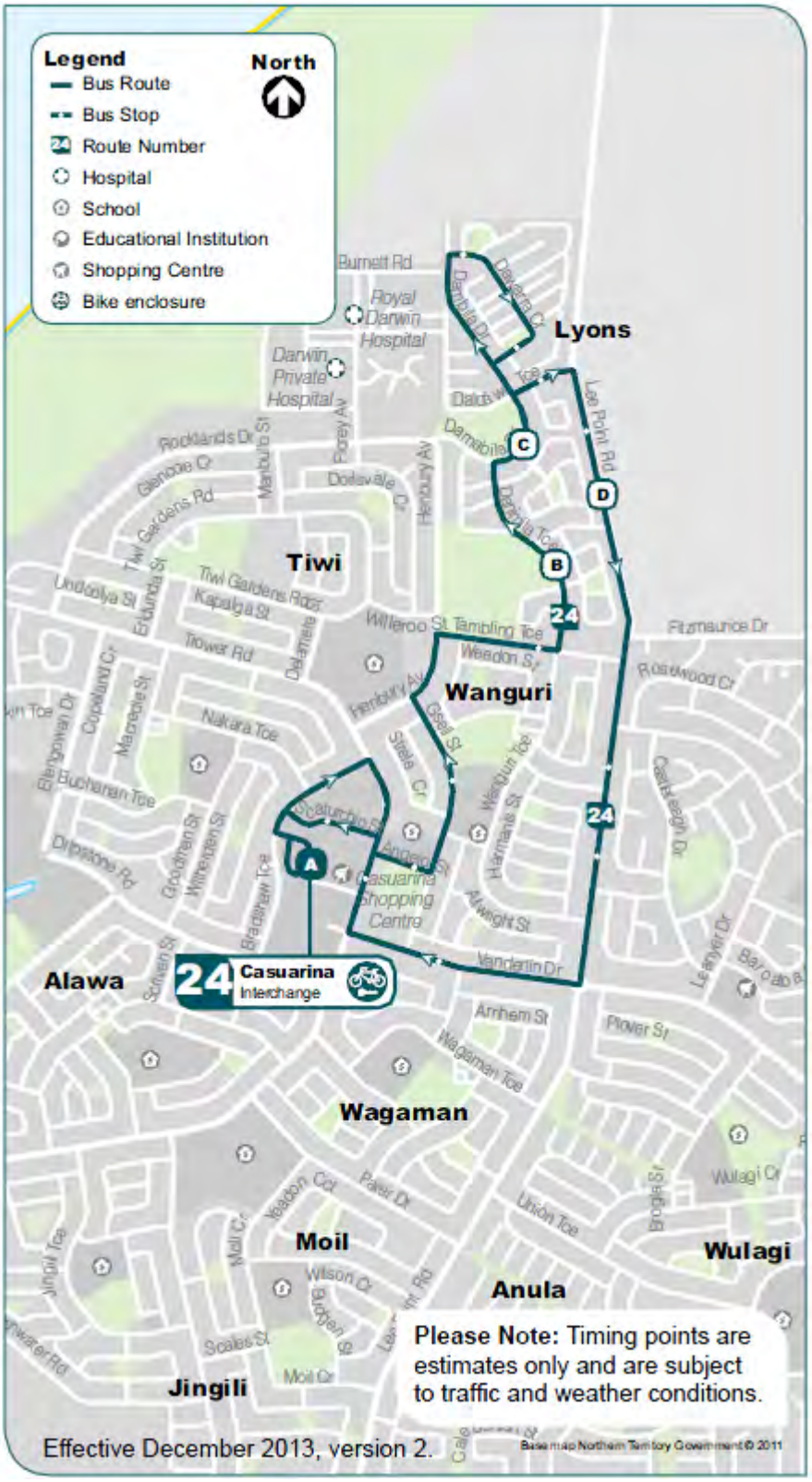
However, bus services do operate along Lee Point Road to the south of the site. Bus route 24 loops from Casuarina to Lyons and travels south along Lee Point Road from Daladawa Terrace to Vanderlin Drive. The closest bus stop from the development for this route is on Lee Point Road, approximately 1km south of the Site. The route has been illustrated in **Figure 3-4** and the frequency of service are as follows:

> Weekdays: Every 30 – 60 minutes

> Weekends and Public Holidays: Every 35 – 70 minutes

Though public transport services do not operate near the Site, future development within the area may create opportunities for new services or extensions of existing services towards the area of the Site.

Figure 3-4 Existing Public Transport Service



Source: Department of Transport NT

3.3.4 Pedestrians and Bicyclists

According to the map provided by Department of Transport, shown in **Figure 3-5**, there are 2.5m shared paths along the eastern side of Damabila Drive and Lee Point Road. Both shared paths end just before the southern border of the Site.

As the area surrounding the Site is undeveloped there is currently a lack of pedestrian and cycling paths, though future development will create new opportunities for path construction.

Figure 3-5 Existing Pedestrian/Cycling Facilities in the Area Surrounding the Site

Source: Department of Transport NT

3.3.5 Existing Relevant Transportation System Management Programs

There are no known existing relevant transportation system management programs that impact on the nominated study area.

4 Projected Traffic

4.1 Site Traffic (Each Horizon Year)

4.1.1 Trip Generation

The trip generation rates for the Site were sourced from the RTA Guide to Traffic Generating Developments (October 2002) and are summarised in **Table 4-1**. The assumed trip directional distribution for the peak-hour trip rates have been summarised in **Table 4-2**. **Table 4-3** summarises the total estimated traffic generated by the development and the distribution.

Table 4-1 Trip Generation Rates (From RTA Guide to Traffic Generating Developments)

Land Use	Weekday Peak Hour (AM and PM)	Daily
Residential	0.85 per dwelling	9 per dwelling
Smaller Units and Flats	0.45	4.5
Larger Units and Town Houses	0.6	6
Rural	0.85 per dwelling	9 per dwelling
Gym	9 per 100m^2 GFA	45 per 100m^2 GFA
Tennis Courts	4 per court	5 per court
Primary School	0.45 per student (AM) 0.15 per student (PM)	2 per student

Table 4-2 Trip Directional Distribution

Land Use	AM Peak		PM Peak	
	In	Out	In	Out
Residential	30%	70%	60%	40%
Smaller Units and Flats	30%	70%	60%	40%
Larger Units and Town Houses	30%	70%	60%	40%
Rural	30%	70%	60%	40%
Gym	50%	50%	50%	50%
Tennis Courts	50%	50%	50%	50%
Primary School	50%	50%	50%	50%

Table 4-3 Trip Generation and Distribution Estimation

Land Use	AM Peak		PM Peak	
	In	Out	In	Out
Residential	48	111	95	64
Smaller Units and Flats	3	6	5	4
Larger Units and Town Houses	5	11	10	6
Rural	8	20	17	11
Gym	23	23	23	23
Tennis Courts	8	8	8	8
Primary School	68	68	23	23
Total	**162**	**247**	**180**	**138**

4.1.2 Trip Distribution

The distribution of traffic to/from the Site has been determined based on the location of the Site in relation to the location of nearby employment/commercial areas and attractions. As the Site is located on the northern fringe of Darwin, it is assumed that the majority of traffic generated from the Site will likely travel south towards the Darwin Town Centre. A small percentage of traffic is expected to travel north to the Casuarina Coastal Reserve and Buffalo Creek boat ramp. It is therefore assumed that the residents would access the Site as follows:

> 5% of trips travel north along Lee Point Road

> 95% of trips travel south along Lee Point Road

The trip distribution for the peak periods are presented in **Figure 4-1**. It is assumed that the distribution is the same for both AM and PM peaks.

Figure 4-1 Peak Trip Distribution

Source: Defence Housing Australia (DHA)

The trips generated by the site onto Lee Point Road will be assigned based on the proximity of land uses to each access and summarised below:

> 45% using Access 2;

> 35% using Access 3;

> 20% using Access 4.

4.1.3 Modal Split

An allowance for typical modal split is incorporated in the *ITE* trip generation rates.

4.1.4 Trip Assignment

It is assumed that all traffic going in and out of the Site will be via Lee Point Road, as it is the primary access point of the Site.

4.2 Through Traffic (Each Horizon Year)

4.2.1 Method Projection

Due to the limited development opportunities to the north of the proposed development, a conservative growth rate has been determined to reflect this scenario. This rate has been applied to the traffic counts provided for 2015 to reflect the estimated traffic volumes for 2019. In addition, the 2CRU development traffic has also been added on top to establish the background 2019 (Muirhead opening year) volumes.

4.2.2 Non-Site Traffic for Anticipated Development in Study Area

The 2CRU development will be added on top of the existing traffic count to establish the background traffic as it is assumed, for the purposed of this assessment, that the 2CRU development will be completed before the commencement of the Muirhead development.

4.2.2.1 Method of Projections

The trip generation rates for the 2CRU development were sourced from the RTA Guide to Traffic Generating Developments (October 2002).

4.2.2.2 Trip Generation

The trip generation for the 2CRU development is summarise in **Table 4-4**.

Table 4-4 Trip Generation and Distribution Estimation

Land Use	AM Peak		PM Peak	
	In	Out	In	Out
Residential	87	202	173	116
Serviced Apartments	20	47	41	27
Hotel Units	18	42	36	24
Smaller Units and Flats	21	48	41	27
Larger Units and Town Houses	25	59	50	34
Commercial	27	5	5	27
Retail	56	56	56	56
Restaurant	20	20	20	20
Total	**274**	**479**	**422**	**331**

Source: 2CRU Subdivision TIA

4.2.2.3 Trip Distribution

The trip distribution for the peak periods are presented in **Figure 4-2**. It is assumed that the distribution is the same for both AM and PM peaks.

Figure 4-2 Peak Trip Distribution

Source: Defence Housing Australia (DHA)

The trips generated by the 2CRU development onto Lee Point Road will be assigned as follows:

> 20% using Access 1;

> 45% using Access 2;

> 35% using Access 3.

4.2.2.4 Modal Split

An allowance for typical modal split is incorporated in the *ITE* trip generation rates.

4.2.2.5 Trip Assignment

It is assumed that all traffic going in and out of the Site will be via Lee Point Road, as it is the primary access point of the Site.

4.2.3 Through Traffic

TMR's Guideline for Assessment of Road Impacts of Development (GARID) recommends that intersection and accesses are designed to accommodate up to 10 years of traffic growth after opening. The opening year for this intersection is assumed to be 2019 and the design year has been selected as 2029.

The background 2029 traffic volumes consists of the existing traffic volumes (with a linear growth rate of 3% p.a.) in addition to the traffic generated from the 2CRU development.

4.2.4 Estimated Volumes

4.2.4.1 Background Conditions

Estimated traffic for the background conditions scenario is shown in **Figure 4-3** and Error! Reference source not found..

Figure 4-3 Estimated Background Traffic Volumes 2019

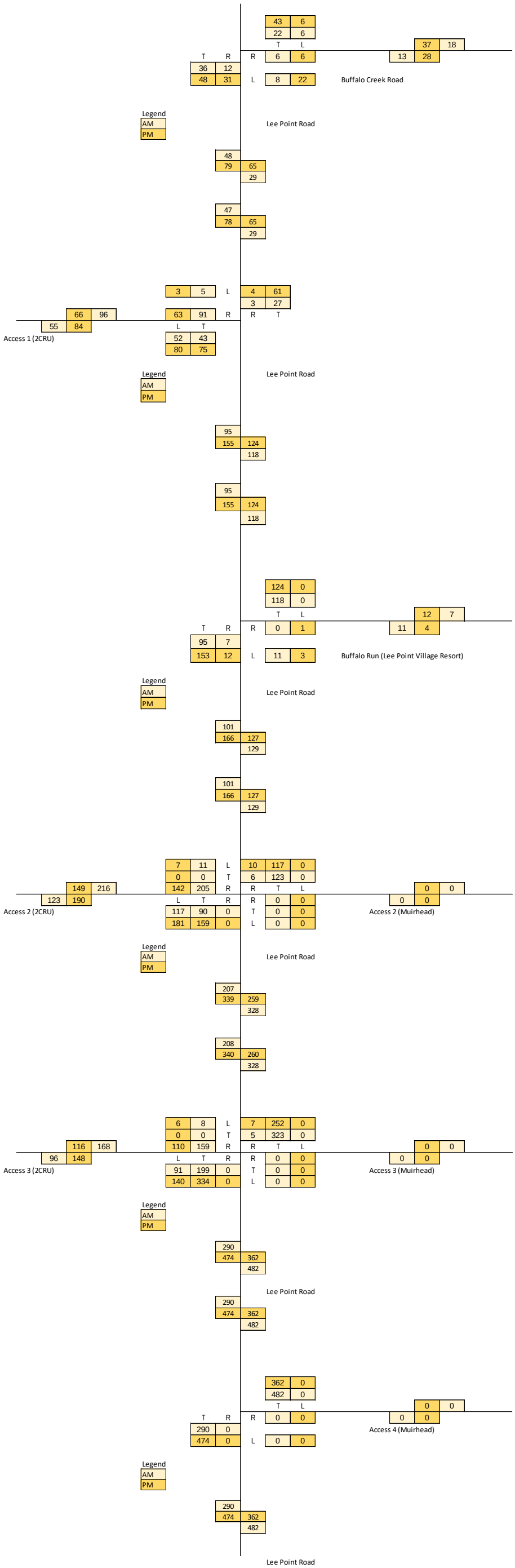
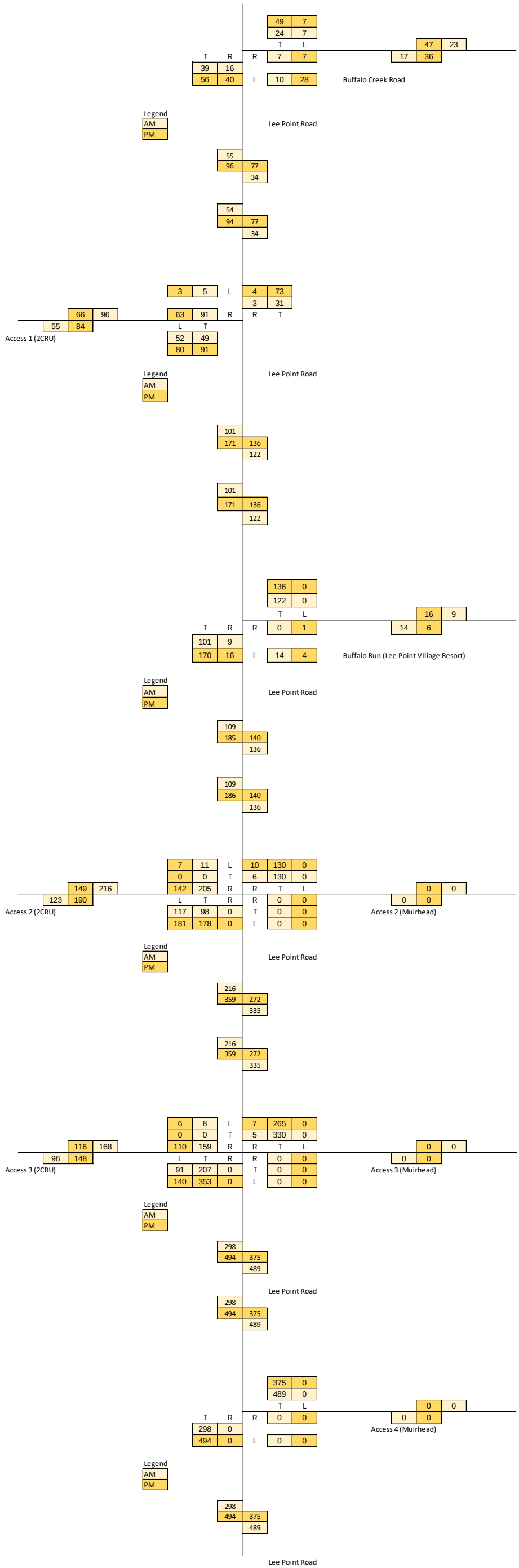


Figure 4-4 Estimated Background Traffic Volumes 2029



4.2.4.2 Total Traffic (with development)

Estimated traffic for the background conditions scenario is shown in **Figure 4-5** and **Figure 4-6.**

Figure 4-5 Estimated Total Traffic Volumes in 2019 with Development

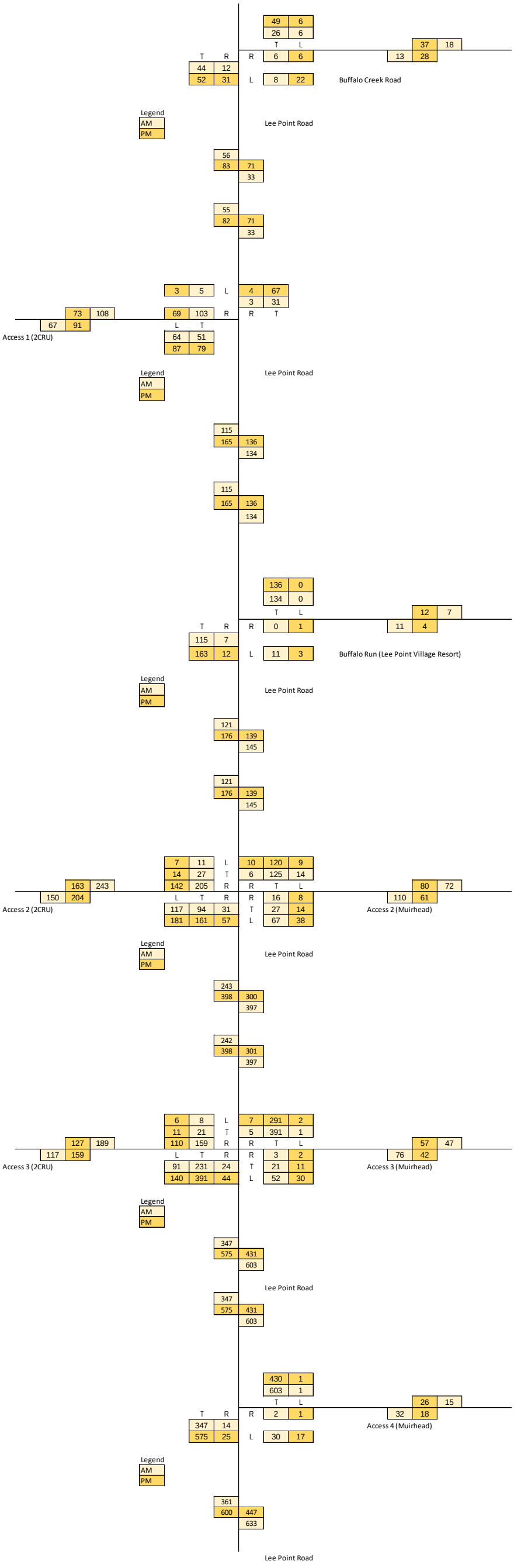
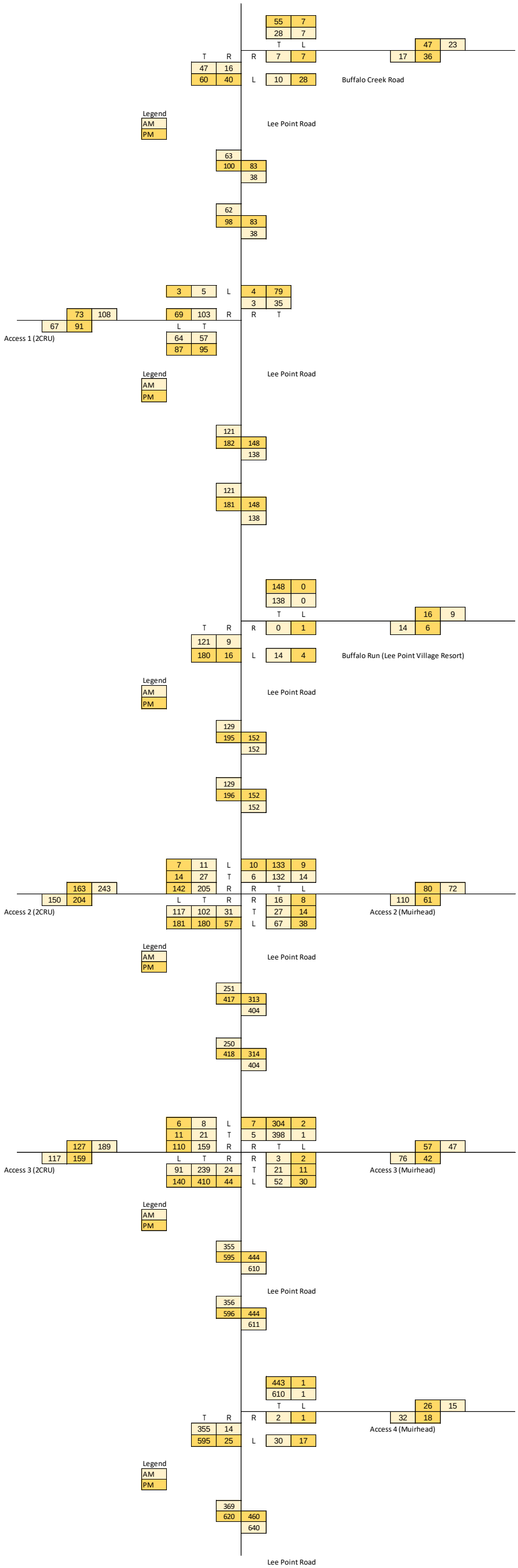


Figure 4-6 Estimated Total Traffic Volumes in 2029 with Development



5 Transportation Analysis

5.1 Summary of Assumptions

A summary of the assumptions used for this analysis are as follows:

Land use:

> The active recreational reserve consists of a gym and 4 tennis courts

> The primary school accommodates up to 300 students

Trip generation:

> No reduction rates have been applied for residential land uses (for internal or multi-purpose trips) to provide a robust assessment.

Trip distribution:

> The distribution of school trips will be separated into 3 zones; the Muirhead zone, the 2CRU zone and the external zone. External zone trips will account for 10% of peak hour trips. The Muirhead and 2CRU developments trip distributions are based on the proportion of residential dwellings within the combined areas. The resulting trip distribution based on this assumption is 63% for the 2CRU development and 27% for the Muirhead development during the peak hours.

> The distribution of the active recreational reserve will be separated into 3 zones; the Muirhead zone, the 2CRU zone and the external zone. External zone trips will account for 20% of peak hour trips. The Muirhead and 2CRU developments trip distributions are based on the proportion of residential dwellings within the combined areas. The resulting trip distribution based on this assumption is 56% for the 2CRU development and 24% for the Muirhead development during the peak hours.)

> The primary school and active recreation reserve trips within the Muirhead zone is assumed to be self-contained within the area and does not add additional trips to the network. (i.e. 27% of school trips and 24% of active recreational reserve trips are self-contained within the Muirhead area.)

> It is assumed that residents would access the site as follows:

- 5% of trips travel north along Lee Point Road
- 95% of trips travel south along Lee Point Road

> The trips generated by the site onto Lee Point Road will be assigned based on the proximity of land uses to each access and summarised below:

- 45% using Access 2;
- 35% using Access 3;
- 20% using Access 4.

Transportation analysis:

> A conservative figure of 5% has been assumed for heavy vehicles

> The background 2019 traffic volumes consists of the existing traffic volumes (with a linear growth rate of 3% p.a.) in addition to the traffic generated from the 2CRU development.

> The background 2029 traffic volumes consists of the existing traffic volumes (with a linear growth rate of 3% p.a.) in addition to the traffic generated from the 2CRU development.

5.2 Site Access and Existing Intersections

As shown in **Figure 5-1**, the only access into the Site is at the three access points along Lee Point Road. All traffic is expected to exit the Site via these access roads then onto Lee Point Road where it distributes to the north or south.

Figure 5-1 Site Access and Existing Intersections

The assessment scenarios are as follows:

> 2019 and 2029 Base Scenarios, Without Development for the following intersections

- Lee Point Road / Buffalo Creek Road Intersection
- Lee Point Road / Lee Point Village Intersection
- Lee Point Road / Access Point 1
- Lee Point Road / Access Point 2
- Lee Point Road / Access Point 3

Access Point 4 does not exist in the scenarios without development.

> 2019 and 2029 Base Scenarios, With Development for the following intersections

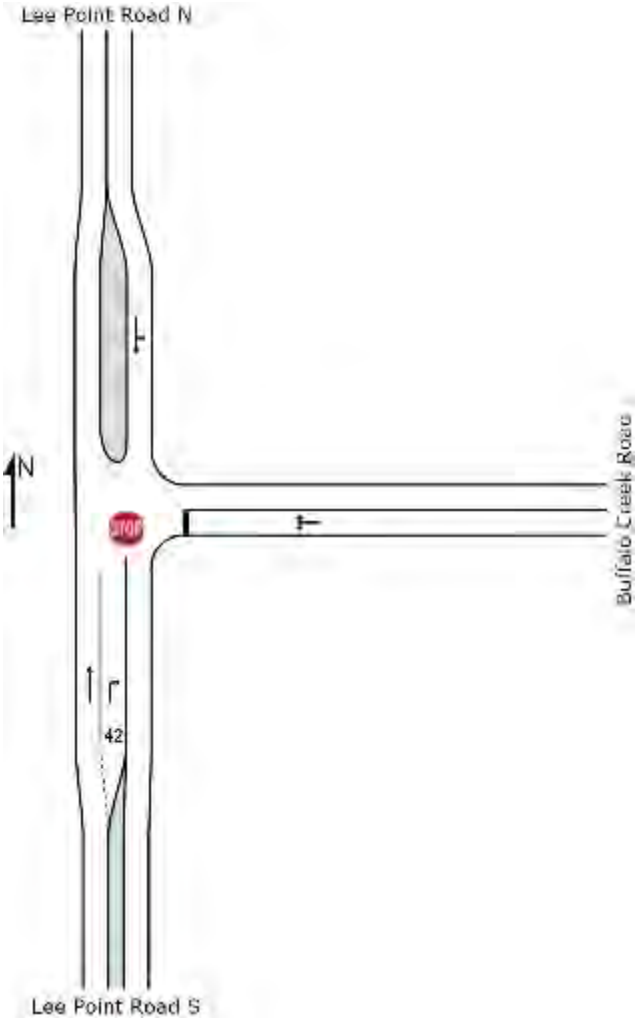
- Lee Point Road / Buffalo Creek Road Intersection
- Lee Point Road / Lee Point Village Intersection
- Lee Point Road / Access Point 1
- Lee Point Road / Access Point 2
- Lee Point Road / Access Point 3
- Lee Point Road / Access Point 4

5.3 Capacity and Level of Service (2019 Base Scenario, Without Development)

5.3.1 Lee Point Road / Buffalo Creek Road Intersection

As shown in **Figure 5-1**, the Lee Point Road / Buffalo Creek Road Intersection is located to the north of the Site. This intersection is a priority controlled intersection with Lee Point Road having priority. The intersection layout of Lee Point Road and Buffalo Creek Road used for all of the analysis scenarios is shown in **Figure 5-2**.

Figure 5-2 Lee Point Road / Buffalo Creek Road Intersection Layout



The results of the SIDRA for the existing condition in the year 2019 without development is shown in **Table 5-1** and **Table 5-2**. The results shows that the intersection will perform satisfactorily in the AM and PM peak background condition in the year 2019.

Table 5-1 Lee Point Road / Buffalo Creek Road Intersection AM Performance – 2019 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
2	T1	36	5.0	0.019	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	12	5.0	0.007	5.6	LOS A	0.0	0.2	0.10	0.56	52.6
Approach		48	5.0	0.019	1.4	NA	0.0	0.2	0.02	0.14	58.0
East: Buffalo Creek Road											
4	L2	8	5.0	0.012	8.3	LOS A	0.0	0.3	0.09	0.94	51.7
6	R2	6	5.0	0.012	8.1	LOS A	0.0	0.3	0.09	0.94	51.2
Approach		14	5.0	0.012	8.2	LOS A	0.0	0.3	0.09	0.94	51.5
North: Lee Point Road N											
7	L2	6	5.0	0.015	5.6	LOS A	0.0	0.0	0.00	0.13	57.0
8	T1	22	5.0	0.015	0.0	LOS A	0.0	0.0	0.00	0.13	58.8
Approach		28	5.0	0.015	1.2	NA	0.0	0.0	0.00	0.13	58.4
All Vehicles		90	5.0	0.019	2.4	NA	0.0	0.3	0.03	0.26	57.0

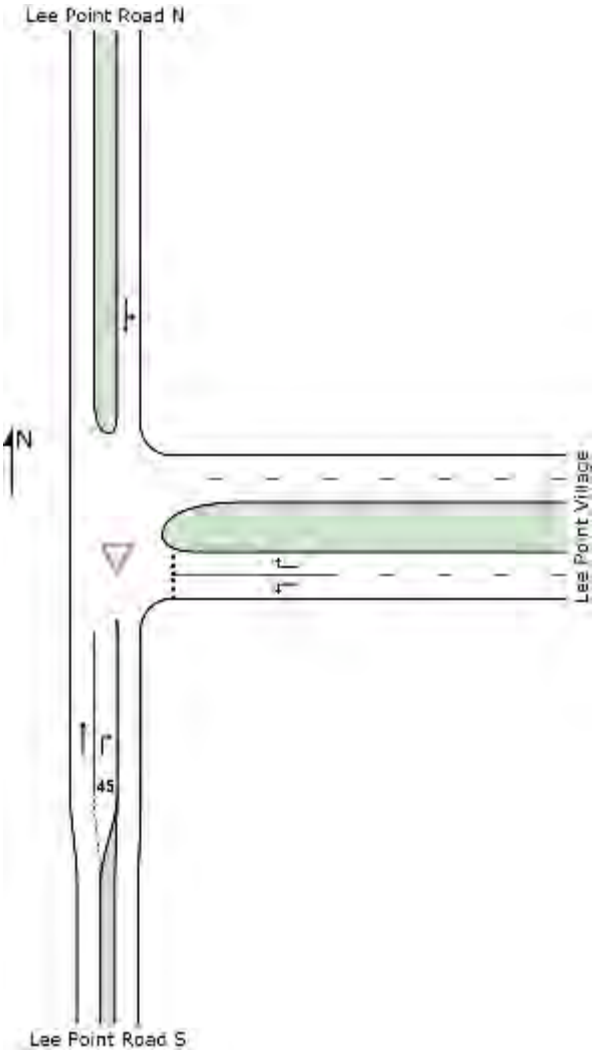
Table 5-2 Lee Point Road / Buffalo Creek Road Intersection PM Performance – 2019 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
2	T1	48	5.0	0.025	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	31	5.0	0.018	5.6	LOS A	0.1	0.6	0.13	0.56	52.5
Approach		79	5.0	0.025	2.2	NA	0.1	0.6	0.05	0.22	56.8
East: Buffalo Creek Road											
4	L2	22	5.0	0.023	8.4	LOS A	0.1	0.7	0.13	0.92	51.6
6	R2	6	5.0	0.023	8.5	LOS A	0.1	0.7	0.13	0.92	51.1
Approach		28	5.0	0.023	8.4	LOS A	0.1	0.7	0.13	0.92	51.5
North: Lee Point Road N											
7	L2	6	5.0	0.026	5.6	LOS A	0.0	0.0	0.00	0.07	57.5
8	T1	43	5.0	0.026	0.0	LOS A	0.0	0.0	0.00	0.07	59.3
Approach		49	5.0	0.026	0.7	NA	0.0	0.0	0.00	0.07	59.1
All Vehicles		156	5.0	0.026	2.8	NA	0.1	0.7	0.05	0.30	56.5

5.3.2 Lee Point Road / Lee Point Village Resort

As shown in **Figure 5-1**, the Lee Point Road / Lee Point Village Resort Intersection is located to the north of the Site. This intersection is a priority controlled intersection with Lee Point Road having priority. The intersection layout of Lee Point Road and Lee Point Village Resort used for all of the analysis scenarios is shown in **Figure 5-3**.

Figure 5-3 Lee Point Road / Lee Point Village Resort Intersection Layout



The results of the SIDRA for the existing condition in the year 2019 without development is shown in **Table 5-3** and **Table 5-4**. The results shows that the intersection will perform satisfactorily in the AM and PM peak background condition in the year 2019.

Table 5-3 Lee Point Road / Lee Point Village Resort Intersection AM Performance – 2019 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
2	T1	95	5.0	0.050	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	7	5.0	0.004	5.9	LOS A	0.0	0.1	0.22	0.53	47.9
Approach		102	5.0	0.050	0.4	NA	0.0	0.1	0.02	0.04	59.4
East: Lee Point Village											
4	L2	11	5.0	0.008	5.9	LOS A	0.0	0.2	0.21	0.53	48.9
6	R2	1	5.0	0.001	6.7	LOS A	0.0	0.0	0.34	0.53	48.1
Approach		12	5.0	0.008	6.0	LOS A	0.0	0.2	0.22	0.53	48.8
North: Lee Point Road N											
7	L2	1	5.0	0.063	5.6	LOS A	0.0	0.0	0.00	0.01	31.8
8	T1	118	5.0	0.063	0.0	LOS A	0.0	0.0	0.00	0.01	59.9
Approach		119	5.0	0.063	0.1	NA	0.0	0.0	0.00	0.01	59.7
All Vehicles		233	5.0	0.063	0.5	NA	0.0	0.2	0.02	0.05	59.1

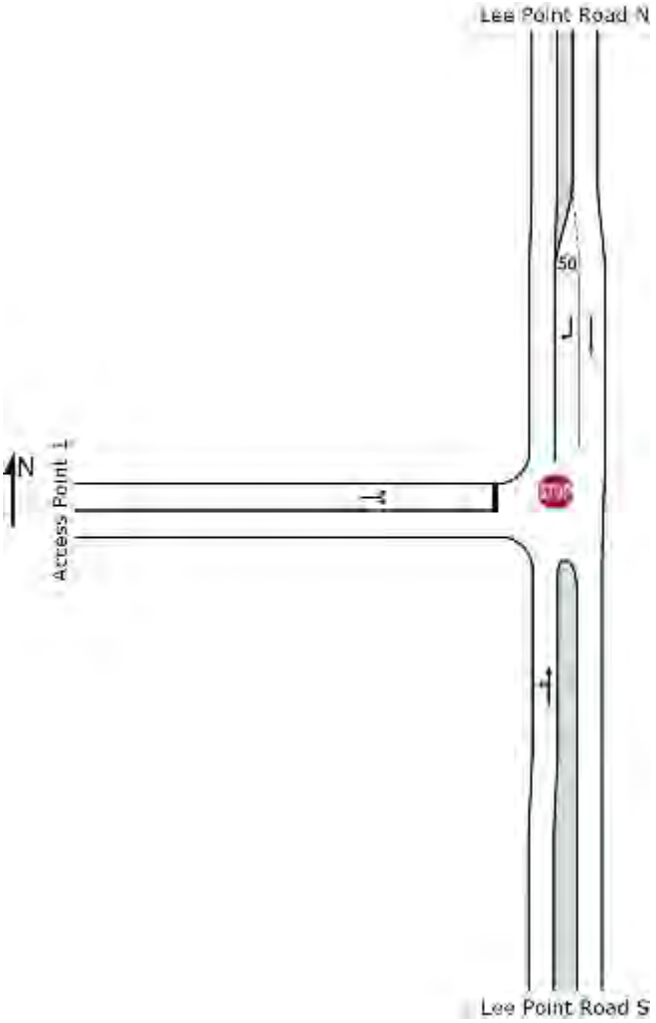
Table 5-4 Lee Point Road / Lee Point Village Resort Intersection PM Performance – 2019 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
2	T1	153	5.0	0.081	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	12	5.0	0.008	5.9	LOS A	0.0	0.2	0.23	0.53	47.8
Approach		165	5.0	0.081	0.4	NA	0.0	0.2	0.02	0.04	59.3
East: Lee Point Village											
4	L2	3	5.0	0.002	5.9	LOS A	0.0	0.1	0.21	0.52	48.9
6	R2	1	5.0	0.001	7.1	LOS A	0.0	0.0	0.39	0.54	47.8
Approach		4	5.0	0.002	6.2	LOS A	0.0	0.1	0.26	0.53	48.6
North: Lee Point Road N											
7	L2	1	5.0	0.066	5.6	LOS A	0.0	0.0	0.00	0.00	31.8
8	T1	124	5.0	0.066	0.0	LOS A	0.0	0.0	0.00	0.00	59.9
Approach		125	5.0	0.066	0.1	NA	0.0	0.0	0.00	0.00	59.7
All Vehicles		294	5.0	0.081	0.4	NA	0.0	0.2	0.01	0.03	59.4

5.3.3 Lee Point Road / Access Road 1 Intersection

As shown in **Figure 5-1**, the Lee Point Road / Access Road 1 intersection is located to the north of the Site. This intersection is a priority controlled intersection with Lee Point Road having priority. The intersection layout of Lee Point Road and Access Road 1 used for all of the analysis scenarios is shown in **Figure 5-4**.

Figure 5-4 Lee Point Road / Access Road 1 Intersection Layout



The results of the SIDRA for the existing condition in the year 2019 without development is shown in **Table 5-5** and **Table 5-6**. The results shows that the intersection will perform satisfactorily in the AM and PM peak background condition in the year 2019.

Table 5-5 Lee Point Road / Access Road 1 Intersection AM Performance – 2019 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
1	L2	52	5.0	0.052	5.6	LOS A	0.0	0.0	0.00	0.32	55.4
2	T1	43	5.0	0.052	0.0	LOS A	0.0	0.0	0.00	0.32	57.1
Approach		95	5.0	0.052	3.1	NA	0.0	0.0	0.00	0.32	56.2
North: Lee Point Road N											
8	T1	27	5.0	0.014	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
9	R2	3	5.0	0.002	5.8	LOS A	0.0	0.1	0.20	0.54	52.4
Approach		30	5.0	0.014	0.6	NA	0.0	0.1	0.02	0.05	59.1
West: Access Point 1											
10	L2	5	5.0	0.100	8.4	LOS A	0.4	3.0	0.23	0.89	51.7
12	R2	91	5.0	0.100	8.4	LOS A	0.4	3.0	0.23	0.89	51.2
Approach		96	5.0	0.100	8.4	LOS A	0.4	3.0	0.23	0.89	51.3
All Vehicles		221	5.0	0.100	5.0	NA	0.4	3.0	0.10	0.53	54.3

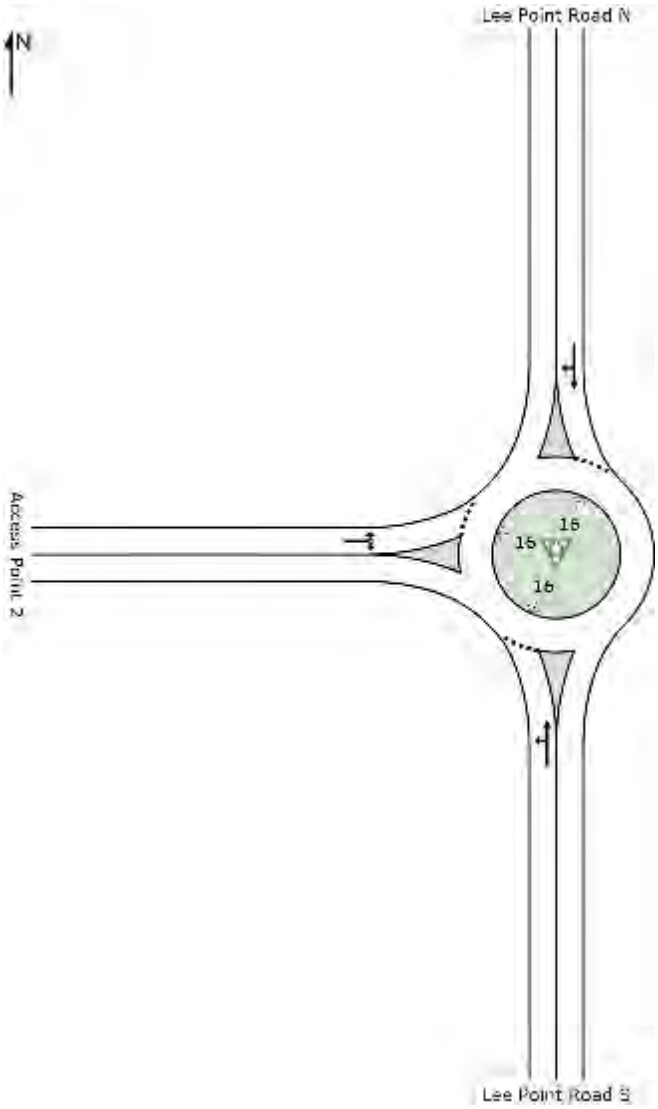
Table 5-6 Lee Point Road / Access Road 1 Intersection PM Performance – 2019 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
1	L2	80	5.0	0.084	5.6	LOS A	0.0	0.0	0.00	0.30	55.6
2	T1	75	5.0	0.084	0.0	LOS A	0.0	0.0	0.00	0.30	57.3
Approach		155	5.0	0.084	2.9	NA	0.0	0.0	0.00	0.30	56.4
North: Lee Point Road N											
8	T1	61	5.0	0.032	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
9	R2	4	5.0	0.003	6.0	LOS A	0.0	0.1	0.26	0.54	52.2
Approach		65	5.0	0.032	0.4	NA	0.0	0.1	0.02	0.03	59.4
West: Access Point 1											
10	L2	3	5.0	0.077	8.5	LOS A	0.3	2.2	0.32	0.88	51.4
12	R2	63	5.0	0.077	9.0	LOS A	0.3	2.2	0.32	0.88	50.9
Approach		66	5.0	0.077	9.0	LOS A	0.3	2.2	0.32	0.88	51.0
All Vehicles		286	5.0	0.084	3.7	NA	0.3	2.2	0.08	0.38	55.7

5.3.4 Lee Point Road / Access Road 2 Intersection

As shown in **Figure 5-1**, the Lee Point Road / Access Road 2 intersection is located to the west of the Site. This intersection is proposed to be a 4 leg approach roundabout. As there is no traffic along the eastern leg of the roundabout, it has been removed for the purposed of this assessment. The intersection layout of Lee Point Road and Access Road 2 used for all of the analysis scenarios is shown in **Figure 5-5**.

Figure 5-5 Lee Point Road / Access Road 2 Intersection Layout



The results of the SIDRA for the existing condition in the year 2019 without development is shown in **Table 5-7** and **Table 5-8**. The results shows that the intersection will perform satisfactorily in the AM and PM peak background condition in the year 2019.

Table 5-7 Lee Point Road / Access Road 2 Intersection AM Performance – 2019 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	117	5.0	0.131	4.1	LOS A	0.7	5.5	0.05	0.46	54.7
2	T1	90	5.0	0.131	4.4	LOS A	0.7	5.5	0.05	0.46	55.9
Approach		207	5.0	0.131	4.2	LOS A	0.7	5.5	0.05	0.46	55.2
North: Lee Point Road N											
8	T1	123	5.0	0.119	5.5	LOS A	0.6	4.5	0.39	0.51	54.2
9	R2	6	5.0	0.119	9.6	LOS A	0.6	4.5	0.39	0.51	53.9
Approach		129	5.0	0.119	5.7	LOS A	0.6	4.5	0.39	0.51	54.2
West: Access Point 2											
10	L2	11	5.0	0.172	4.6	LOS A	0.9	6.5	0.25	0.61	51.2
12	R2	205	5.0	0.172	9.0	LOS A	0.9	6.5	0.25	0.61	52.0
Approach		216	5.0	0.172	8.7	LOS A	0.9	6.5	0.25	0.61	52.0
All Vehicles		552	5.0	0.172	6.3	LOS A	0.9	6.5	0.21	0.53	53.6

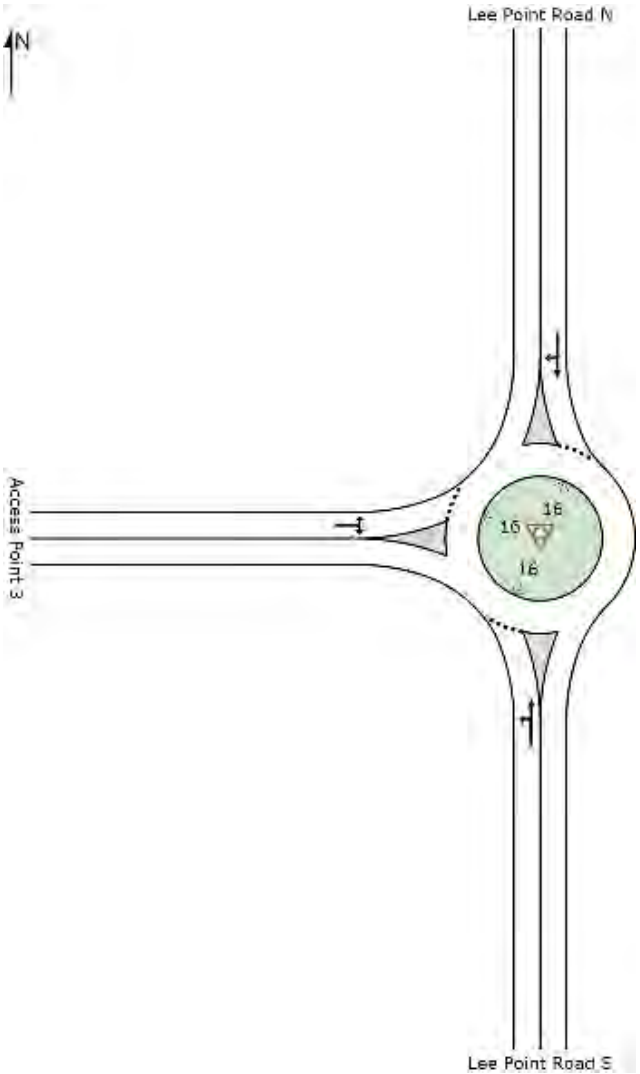
Table 5-8 Lee Point Road / Access Road 2 Intersection PM Performance – 2019 Without Development

Movement Performance - Vehicles											
Mov ID	OD Mov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
1	L2	181	5.0	0.217	4.2	LOS A	1.3	9.6	0.08	0.46	54.6
2	T1	159	5.0	0.217	4.4	LOS A	1.3	9.6	0.08	0.46	55.8
Approach		340	5.0	0.217	4.3	LOS A	1.3	9.6	0.08	0.46	55.2
North: Lee Point Road N											
8	T1	117	5.0	0.112	5.1	LOS A	0.6	4.3	0.33	0.49	54.4
9	R2	10	5.0	0.112	9.2	LOS A	0.6	4.3	0.33	0.49	54.1
Approach		127	5.0	0.112	5.4	LOS A	0.6	4.3	0.33	0.49	54.3
West: Access Point 2											
10	L2	7	5.0	0.131	5.0	LOS A	0.7	4.8	0.34	0.63	50.9
12	R2	142	5.0	0.131	9.4	LOS A	0.7	4.8	0.34	0.63	51.8
Approach		149	5.0	0.131	9.2	LOS A	0.7	4.8	0.34	0.63	51.7
All Vehicles		616	5.0	0.217	5.7	LOS A	1.3	9.6	0.19	0.51	54.1

5.3.5 Lee Point Road / Access Road 3 Intersection

As shown in **Figure 5-1**, the Lee Point Road / Access Road 3 intersection is located to the west of the Site. This intersection is proposed to be a 4 leg approach roundabout. As there is no traffic along the eastern leg of the roundabout, it has been removed for the purposed of this assessment. The intersection layout of Lee Point Road and Access Road 3 used for all of the analysis scenarios is shown in **Figure 5-6**.

Figure 5-6 Lee Point Road / Access Road 3 Intersection Layout



The results of the SIDRA for the existing condition in the year 2019 without development is shown in **Table 5-9** and **Table 5-10.** The results shows that the intersection will perform satisfactorily in the AM and PM peak background condition in the year 2019.

Table 5-9 Lee Point Road / Access Road 3 Intersection AM Performance – 2019 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
1	L2	91	5.0	0.180	4.1	LOS A	1.1	7.9	0.05	0.45	54.7
2	T1	199	5.0	0.180	4.4	LOS A	1.1	7.9	0.05	0.45	55.9
Approach		290	5.0	0.180	4.3	LOS A	1.1	7.9	0.05	0.45	55.5
North: Lee Point Road N											
8	T1	323	5.0	0.283	5.3	LOS A	1.8	12.8	0.41	0.51	54.2
9	R2	5	5.0	0.283	9.5	LOS A	1.8	12.8	0.41	0.51	53.9
Approach		328	5.0	0.283	5.4	LOS A	1.8	12.8	0.41	0.51	54.2
West: Access Point 3											
10	L2	8	5.0	0.152	5.3	LOS A	0.8	5.6	0.38	0.65	50.8
12	R2	159	5.0	0.152	9.6	LOS A	0.8	5.6	0.38	0.65	51.6
Approach		167	5.0	0.152	9.4	LOS A	0.8	5.6	0.38	0.65	51.6
All Vehicles		785	5.0	0.283	5.8	LOS A	1.8	12.8	0.27	0.51	54.1

Table 5-10 Lee Point Road / Access Road 3 Intersection PM Performance – 2019 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
1	L2	140	5.0	0.293	4.2	LOS A	1.9	14.2	0.07	0.44	54.6
2	T1	334	5.0	0.293	4.4	LOS A	1.9	14.2	0.07	0.44	55.8
Approach		474	5.0	0.293	4.3	LOS A	1.9	14.2	0.07	0.44	55.4
North: Lee Point Road N											
8	T1	252	5.0	0.213	5.0	LOS A	1.3	9.3	0.32	0.47	54.5
9	R2	7	5.0	0.213	9.1	LOS A	1.3	9.3	0.32	0.47	54.3
Approach		259	5.0	0.213	5.1	LOS A	1.3	9.3	0.32	0.47	54.5
West: Access Point 3											
10	L2	6	5.0	0.118	6.0	LOS A	0.6	4.3	0.47	0.68	50.6
12	R2	110	5.0	0.118	10.3	LOS B	0.6	4.3	0.47	0.68	51.4
Approach		116	5.0	0.118	10.1	LOS B	0.6	4.3	0.47	0.68	51.3
All Vehicles		849	5.0	0.293	5.3	LOS A	1.9	14.2	0.20	0.48	54.6

5.4 Capacity and Level of Service (2029 Base Scenario, Without Development)

5.4.1 Lee Point Road / Buffalo Creek Road Intersection

The results of the SIDRA for the existing condition in the year 2029 without development is shown in **Table 5-11** and **Table 5-12.** The results shows that the intersection will perform satisfactorily in the AM and PM peak background condition in the year 2029.

Table 5-11 Lee Point Road / Buffalo Creek Road Intersection AM Performance – 2029 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
2	T1	39	5.0	0.021	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	16	5.0	0.009	5.6	LOS A	0.0	0.3	0.10	0.56	52.6
Approach		55	5.0	0.021	1.6	NA	0.0	0.3	0.03	0.16	57.6
East: Buffalo Creek Road											
4	L2	10	5.0	0.015	8.3	LOS A	0.1	0.4	0.10	0.94	51.7
6	R2	7	5.0	0.015	8.2	LOS A	0.1	0.4	0.10	0.94	51.2
Approach		17	5.0	0.015	8.2	LOS A	0.1	0.4	0.10	0.94	51.4
North: Lee Point Road N											
7	L2	7	5.0	0.017	5.6	LOS A	0.0	0.0	0.00	0.13	57.0
8	T1	24	5.0	0.017	0.0	LOS A	0.0	0.0	0.00	0.13	58.8
Approach		31	5.0	0.017	1.3	NA	0.0	0.0	0.00	0.13	58.4
All Vehicles		103	5.0	0.021	2.6	NA	0.1	0.4	0.03	0.28	56.7

Table 5-12 Lee Point Road / Buffalo Creek Road Intersection PM Performance – 2029 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
2	T1	56	5.0	0.030	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	40	5.0	0.024	5.7	LOS A	0.1	0.8	0.15	0.56	52.5
Approach		96	5.0	0.030	2.4	NA	0.1	0.8	0.06	0.23	56.6
East: Buffalo Creek Road											
4	L2	28	5.0	0.029	8.4	LOS A	0.1	0.8	0.14	0.92	51.6
6	R2	7	5.0	0.029	8.6	LOS A	0.1	0.8	0.14	0.92	51.1
Approach		35	5.0	0.029	8.5	LOS A	0.1	0.8	0.14	0.92	51.5
North: Lee Point Road N											
7	L2	7	5.0	0.030	5.6	LOS A	0.0	0.0	0.00	0.07	57.5
8	T1	49	5.0	0.030	0.0	LOS A	0.0	0.0	0.00	0.07	59.3
Approach		56	5.0	0.030	0.7	NA	0.0	0.0	0.00	0.07	59.1
All Vehicles		187	5.0	0.030	3.0	NA	0.1	0.8	0.06	0.31	56.3

5.4.2 Lee Point Road / Lee Point Village Resort

The results of the SIDRA for the existing condition in the year 2029 without development is shown in **Table 5-13** and **Table 5-14**. The results shows that the intersection will perform satisfactorily in the AM and PM peak background condition in the year 2029.

Table 5-13 Lee Point Road / Lee Point Village Resort Intersection AM Performance – 2029 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
2	T1	101	5.0	0.053	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	9	5.0	0.006	5.9	LOS A	0.0	0.2	0.23	0.53	47.8
Approach		110	5.0	0.053	0.5	NA	0.0	0.2	0.02	0.04	59.2
East: Lee Point Village											
4	L2	14	5.0	0.010	5.9	LOS A	0.0	0.3	0.21	0.53	48.9
6	R2	1	5.0	0.001	6.8	LOS A	0.0	0.0	0.35	0.53	48.1
Approach		15	5.0	0.010	6.0	LOS A	0.0	0.3	0.22	0.53	48.8
North: Lee Point Road N											
7	L2	1	5.0	0.065	5.6	LOS A	0.0	0.0	0.00	0.00	31.8
8	T1	122	5.0	0.065	0.0	LOS A	0.0	0.0	0.00	0.00	59.9
Approach		123	5.0	0.065	0.1	NA	0.0	0.0	0.00	0.00	59.7
All Vehicles		248	5.0	0.065	0.6	NA	0.0	0.3	0.02	0.05	59.0

Table 5-14 Lee Point Road / Lee Point Village Resort Intersection PM Performance – 2029 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
2	T1	170	5.0	0.090	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	16	5.0	0.010	6.0	LOS A	0.0	0.3	0.24	0.54	47.8
Approach		186	5.0	0.090	0.5	NA	0.0	0.3	0.02	0.05	59.2
East: Lee Point Village											
4	L2	4	5.0	0.003	5.9	LOS A	0.0	0.1	0.23	0.52	48.8
6	R2	1	5.0	0.001	7.4	LOS A	0.0	0.0	0.41	0.55	47.5
Approach		5	5.0	0.003	6.2	LOS A	0.0	0.1	0.26	0.53	48.6
North: Lee Point Road N											
7	L2	1	5.0	0.073	5.6	LOS A	0.0	0.0	0.00	0.00	31.8
8	T1	136	5.0	0.073	0.0	LOS A	0.0	0.0	0.00	0.00	59.9
Approach		137	5.0	0.073	0.0	NA	0.0	0.0	0.00	0.00	59.7
All Vehicles		328	5.0	0.090	0.4	NA	0.0	0.3	0.02	0.04	59.3

5.4.3 Lee Point Road / Access Road 1 Intersection

The results of the SIDRA for the existing condition in the year 2029 without development is shown in **Table 5-15** and **Table 5-16**. The results shows that the intersection will perform satisfactorily in the AM and PM peak background condition in the year 2029.

Table 5-15 Lee Point Road / Access Road 1 Intersection AM Performance – 2029 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
1	L2	52	5.0	0.055	5.6	LOS A	0.0	0.0	0.00	0.30	55.6
2	T1	49	5.0	0.055	0.0	LOS A	0.0	0.0	0.00	0.30	57.3
Approach		101	5.0	0.055	2.9	NA	0.0	0.0	0.00	0.30	56.4
North: Lee Point Road N											
8	T1	31	5.0	0.016	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
9	R2	3	5.0	0.002	5.8	LOS A	0.0	0.1	0.20	0.54	52.4
Approach		34	5.0	0.016	0.5	NA	0.0	0.1	0.02	0.05	59.2
West: Access Point 1											
10	L2	5	5.0	0.102	8.4	LOS A	0.4	3.0	0.25	0.89	51.7
12	R2	91	5.0	0.102	8.5	LOS A	0.4	3.0	0.25	0.89	51.2
Approach		96	5.0	0.102	8.5	LOS A	0.4	3.0	0.25	0.89	51.2
All Vehicles		231	5.0	0.102	4.9	NA	0.4	3.0	0.10	0.51	54.5

Table 5-16 Lee Point Road / Access Road 1 Intersection PM Performance – 2029 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
1	L2	80	5.0	0.093	5.6	LOS A	0.0	0.0	0.00	0.28	55.8
2	T1	91	5.0	0.093	0.0	LOS A	0.0	0.0	0.00	0.28	57.5
Approach		171	5.0	0.093	2.6	NA	0.0	0.0	0.00	0.28	56.7
North: Lee Point Road N											
8	T1	73	5.0	0.039	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
9	R2	4	5.0	0.003	6.0	LOS A	0.0	0.1	0.28	0.54	52.2
Approach		77	5.0	0.039	0.3	NA	0.0	0.1	0.01	0.03	59.5
West: Access Point 1											
10	L2	3	5.0	0.080	8.6	LOS A	0.3	2.3	0.35	0.88	51.3
12	R2	63	5.0	0.080	9.2	LOS A	0.3	2.3	0.35	0.88	50.8
Approach		66	5.0	0.080	9.2	LOS A	0.3	2.3	0.35	0.88	50.8
All Vehicles		314	5.0	0.093	3.4	NA	0.3	2.3	0.08	0.34	56.0

5.4.4 Lee Point Road / Access Road 2 Intersection

The results of the SIDRA for the existing condition in the year 2029 without development is shown in **Table 5-17** and **Table 5-18**. The results shows that the intersection will perform satisfactorily in the AM and PM peak background condition in the year 2029.

Table 5-17 Lee Point Road / Access Road 2 Intersection AM Performance – 2029 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	117	5.0	0.136	4.1	LOS A	0.8	5.7	0.05	0.46	54.7
2	T1	98	5.0	0.136	4.4	LOS A	0.8	5.7	0.05	0.46	55.9
Approach		215	5.0	0.136	4.2	LOS A	0.8	5.7	0.05	0.46	55.2
North: Lee Point Road N											
8	T1	130	5.0	0.126	5.5	LOS A	0.7	4.8	0.40	0.52	54.2
9	R2	6	5.0	0.126	9.6	LOS A	0.7	4.8	0.40	0.52	53.9
Approach		136	5.0	0.126	5.7	LOS A	0.7	4.8	0.40	0.52	54.1
West: Access Point 2											
10	L2	11	5.0	0.174	4.7	LOS A	0.9	6.6	0.27	0.62	51.1
12	R2	205	5.0	0.174	9.0	LOS A	0.9	6.6	0.27	0.62	52.0
Approach		216	5.0	0.174	8.8	LOS A	0.9	6.6	0.27	0.62	51.9
All Vehicles		567	5.0	0.174	6.3	LOS A	0.9	6.6	0.22	0.53	53.7

Table 5-18 Lee Point Road / Access Road 2 Intersection PM Performance – 2029 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	181	5.0	0.228	4.2	LOS A	1.4	10.3	0.08	0.45	54.6
2	T1	178	5.0	0.228	4.4	LOS A	1.4	10.3	0.08	0.45	55.8
Approach		359	5.0	0.228	4.3	LOS A	1.4	10.3	0.08	0.45	55.2
North: Lee Point Road N											
8	T1	130	5.0	0.123	5.1	LOS A	0.7	4.8	0.34	0.49	54.3
9	R2	10	5.0	0.123	9.3	LOS A	0.7	4.8	0.34	0.49	54.1
Approach		140	5.0	0.123	5.4	LOS A	0.7	4.8	0.34	0.49	54.3
West: Access Point 2											
10	L2	7	5.0	0.134	5.1	LOS A	0.7	4.9	0.36	0.64	50.9
12	R2	142	5.0	0.134	9.5	LOS A	0.7	4.9	0.36	0.64	51.7
Approach		149	5.0	0.134	9.3	LOS A	0.7	4.9	0.36	0.64	51.7
All Vehicles		648	5.0	0.228	5.7	LOS A	1.4	10.3	0.20	0.50	54.1

5.4.5 Lee Point Road / Access Road 3 Intersection

The results of the SIDRA for the existing condition in the year 2029 without development is shown in **Table 5-19** and **Table 5-20**. The results shows that the intersection will perform satisfactorily in the AM and PM peak background condition in the year 2029.

Table 5-19 Lee Point Road / Access Road 3 Intersection AM Performance – 2029 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	91	5.0	0.185	4.1	LOS A	1.1	8.2	0.05	0.45	54.7
2	T1	207	5.0	0.185	4.4	LOS A	1.1	8.2	0.05	0.45	55.9
Approach		298	5.0	0.185	4.3	LOS A	1.1	8.2	0.05	0.45	55.5
North: Lee Point Road N											
8	T1	330	5.0	0.289	5.3	LOS A	1.8	13.2	0.41	0.51	54.2
9	R2	5	5.0	0.289	9.5	LOS A	1.8	13.2	0.41	0.51	53.9
Approach		335	5.0	0.289	5.4	LOS A	1.8	13.2	0.41	0.51	54.2
West: Access Point 2											
10	L2	8	5.0	0.153	5.3	LOS A	0.8	5.7	0.39	0.65	50.8
12	R2	159	5.0	0.153	9.7	LOS A	0.8	5.7	0.39	0.65	51.6
Approach		167	5.0	0.153	9.4	LOS A	0.8	5.7	0.39	0.65	51.6
All Vehicles		800	5.0	0.289	5.8	LOS A	1.8	13.2	0.27	0.51	54.1

Table 5-20 Lee Point Road / Access Road 3 Intersection PM Performance – 2029 Without Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	140	5.0	0.304	4.2	LOS A	2.1	15.0	0.07	0.44	54.6
2	T1	353	5.0	0.304	4.4	LOS A	2.1	15.0	0.07	0.44	55.8
Approach		493	5.0	0.304	4.3	LOS A	2.1	15.0	0.07	0.44	55.5
North: Lee Point Road N											
8	T1	265	5.0	0.223	5.0	LOS A	1.4	9.9	0.33	0.47	54.5
9	R2	7	5.0	0.223	9.1	LOS A	1.4	9.9	0.33	0.47	54.2
Approach		272	5.0	0.223	5.1	LOS A	1.4	9.9	0.33	0.47	54.5
West: Access Point 2											
10	L2	6	5.0	0.119	6.1	LOS A	0.6	4.4	0.49	0.69	50.5
12	R2	110	5.0	0.119	10.5	LOS B	0.6	4.4	0.49	0.69	51.3
Approach		116	5.0	0.119	10.2	LOS B	0.6	4.4	0.49	0.69	51.3
All Vehicles		881	5.0	0.304	5.3	LOS A	2.1	15.0	0.20	0.48	54.6

5.5 Capacity and Level of Service (2019 Base Scenario, With Development)

5.5.1 Lee Point Road / Buffalo Creek Road Intersection

The results of the SIDRA for the existing condition in the year 2019 with development is shown in **Table 5-21** and **Table 5-22.** The results shows that the intersection will perform satisfactorily in the AM and PM peak period in the year 2019.

Table 5-21 Lee Point Road / Buffalo Creek Road Intersection AM Performance – 2019 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
2	T1	44	5.0	0.023	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	12	5.0	0.007	5.6	LOS A	0.0	0.2	0.10	0.56	52.6
Approach		56	5.0	0.023	1.2	NA	0.0	0.2	0.02	0.12	58.2
East: Buffalo Creek Road											
4	L2	8	5.0	0.012	8.3	LOS A	0.0	0.3	0.10	0.93	51.7
6	R2	6	5.0	0.012	8.2	LOS A	0.0	0.3	0.10	0.93	51.2
Approach		14	5.0	0.012	8.3	LOS A	0.0	0.3	0.10	0.93	51.4
North: Lee Point Road N											
7	L2	6	5.0	0.017	5.6	LOS A	0.0	0.0	0.00	0.11	57.2
8	T1	26	5.0	0.017	0.0	LOS A	0.0	0.0	0.00	0.11	59.0
Approach		32	5.0	0.017	1.1	NA	0.0	0.0	0.00	0.11	58.6
All Vehicles		102	5.0	0.023	2.1	NA	0.0	0.3	0.03	0.23	57.3

Table 5-22 Lee Point Road / Buffalo Creek Road Intersection PM Performance – 2019 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
2	T1	52	5.0	0.028	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	31	5.0	0.019	5.7	LOS A	0.1	0.6	0.14	0.56	52.5
Approach		83	5.0	0.028	2.1	NA	0.1	0.6	0.05	0.21	57.0
East: Buffalo Creek Road											
4	L2	22	5.0	0.023	8.4	LOS A	0.1	0.7	0.14	0.91	51.6
6	R2	6	5.0	0.023	8.5	LOS A	0.1	0.7	0.14	0.91	51.1
Approach		28	5.0	0.023	8.4	LOS A	0.1	0.7	0.14	0.91	51.5
North: Lee Point Road N											
7	L2	6	5.0	0.029	5.6	LOS A	0.0	0.0	0.00	0.06	57.5
8	T1	49	5.0	0.029	0.0	LOS A	0.0	0.0	0.00	0.06	59.4
Approach		55	5.0	0.029	0.6	NA	0.0	0.0	0.00	0.06	59.2
All Vehicles		166	5.0	0.029	2.7	NA	0.1	0.7	0.05	0.28	56.7

5.5.2 Lee Point Road / Lee Point Village Resort

The results of the SIDRA for the existing condition in the year 2019 with development is shown in **Table 5-23** and **Table 5-24**. The results shows that the intersection will perform satisfactorily in the AM and PM peak period in the year 2019.

Table 5-23 Lee Point Road / Lee Point Village Resort Intersection AM Performance – 2019 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
2	T1	115	5.0	0.061	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	7	5.0	0.005	6.0	LOS A	0.0	0.1	0.24	0.53	47.8
Approach		122	5.0	0.061	0.3	NA	0.0	0.1	0.01	0.03	59.5
East: Lee Point Village											
4	L2	11	5.0	0.008	5.9	LOS A	0.0	0.2	0.23	0.53	48.8
6	R2	1	5.0	0.001	6.9	LOS A	0.0	0.0	0.37	0.54	48.0
Approach		12	5.0	0.008	6.0	LOS A	0.0	0.2	0.24	0.53	48.8
North: Lee Point Road N											
7	L2	1	5.0	0.072	5.6	LOS A	0.0	0.0	0.00	0.00	31.8
8	T1	134	5.0	0.072	0.0	LOS A	0.0	0.0	0.00	0.00	59.9
Approach		135	5.0	0.072	0.0	NA	0.0	0.0	0.00	0.00	59.7
All Vehicles		269	5.0	0.072	0.5	NA	0.0	0.2	0.02	0.04	59.2

Table 5-24 Lee Point Road / Lee Point Village Resort Intersection PM Performance – 2019 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
2	T1	163	5.0	0.086	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	12	5.0	0.008	6.0	LOS A	0.0	0.2	0.24	0.53	47.8
Approach		175	5.0	0.086	0.4	NA	0.0	0.2	0.02	0.04	59.3
East: Lee Point Village											
4	L2	3	5.0	0.002	5.9	LOS A	0.0	0.1	0.23	0.52	48.8
6	R2	1	5.0	0.001	7.3	LOS A	0.0	0.0	0.41	0.55	47.6
Approach		4	5.0	0.002	6.3	LOS A	0.0	0.1	0.27	0.53	48.5
North: Lee Point Road N											
7	L2	1	5.0	0.073	5.6	LOS A	0.0	0.0	0.00	0.00	31.8
8	T1	136	5.0	0.073	0.0	LOS A	0.0	0.0	0.00	0.00	59.9
Approach		137	5.0	0.073	0.0	NA	0.0	0.0	0.00	0.00	59.7
All Vehicles		316	5.0	0.086	0.3	NA	0.0	0.2	0.01	0.03	59.4

5.5.3 Lee Point Road / Access Road 1 Intersection

The results of the SIDRA for the existing condition in the year 2019 with development is shown in **Table 5-25** and **Table 5-26.** The results shows that the intersection will perform satisfactorily in the AM and PM peak period in the year 2019.

Table 5-25 Lee Point Road / Access Road 1 Intersection AM Performance – 2019 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	64	5.0	0.063	5.6	LOS A	0.0	0.0	0.00	0.33	55.4
2	T1	51	5.0	0.063	0.0	LOS A	0.0	0.0	0.00	0.33	57.1
Approach		115	5.0	0.063	3.1	NA	0.0	0.0	0.00	0.33	56.1
North: Lee Point Road N											
8	T1	31	5.0	0.016	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
9	R2	3	5.0	0.002	5.8	LOS A	0.0	0.1	0.22	0.53	52.3
Approach		34	5.0	0.016	0.5	NA	0.0	0.1	0.02	0.05	59.2
West: Access Point 1 (2CRU)											
10	L2	5	5.0	0.116	8.4	LOS A	0.5	3.5	0.26	0.89	51.6
12	R2	103	5.0	0.116	8.5	LOS A	0.5	3.5	0.26	0.89	51.2
Approach		108	5.0	0.116	8.5	LOS A	0.5	3.5	0.26	0.89	51.2
All Vehicles		257	5.0	0.116	5.1	NA	0.5	3.5	0.11	0.53	54.3

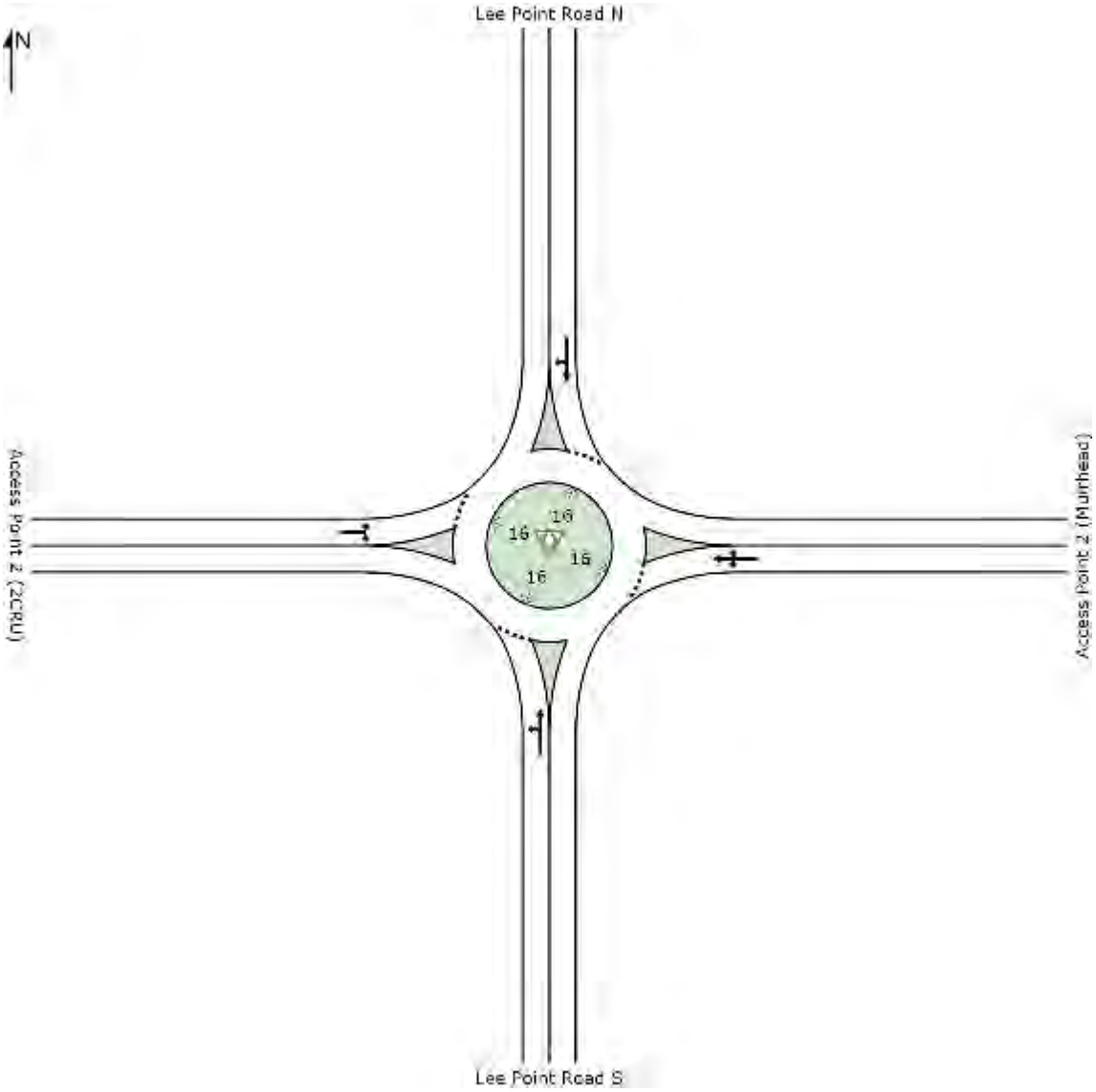
Table 5-26 Lee Point Road / Access Road 1 Intersection PM Performance – 2019 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	87	5.0	0.090	5.6	LOS A	0.0	0.0	0.00	0.31	55.5
2	T1	79	5.0	0.090	0.0	LOS A	0.0	0.0	0.00	0.31	57.2
Approach		166	5.0	0.090	2.9	NA	0.0	0.0	0.00	0.31	56.3
North: Lee Point Road N											
8	T1	67	5.0	0.035	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
9	R2	4	5.0	0.003	6.0	LOS A	0.0	0.1	0.27	0.54	52.2
Approach		71	5.0	0.035	0.3	NA	0.0	0.1	0.02	0.03	59.5
West: Access Point 1 (2CRU)											
10	L2	3	5.0	0.085	8.5	LOS A	0.3	2.5	0.34	0.88	51.3
12	R2	69	5.0	0.085	9.1	LOS A	0.3	2.5	0.34	0.88	50.9
Approach		72	5.0	0.085	9.1	LOS A	0.3	2.5	0.34	0.88	50.9
All Vehicles		309	5.0	0.090	3.8	NA	0.3	2.5	0.08	0.38	55.6

5.5.4 Lee Point Road / Access Road 2 Intersection

As shown in **Figure 5-1**, the Lee Point Road / Access Road 2 intersection is located to the west of the Site. This intersection is proposed to be a 4 leg approach roundabout. The intersection layout of Lee Point Road and Access Road 2 used for all of the analysis scenarios is shown in **Figure 5-7**.

Figure 5-7 Lee Point Road / Access Road 2 Intersection Layout



The results of the SIDRA for the existing condition in the year 2019 with development is shown in **Table 5-27** and **Table 5-28.** The results shows that the intersection will perform satisfactorily in the AM and PM peak period in the year 2019.

Table 5-27 Lee Point Road / Access Road 2 Intersection AM Performance – 2019 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	117	5.0	0.178	4.4	LOS A	1.0	7.6	0.20	0.49	53.7
2	T1	94	5.0	0.178	4.6	LOS A	1.0	7.6	0.20	0.49	54.9
3	R2	31	0.0	0.178	8.7	LOS A	1.0	7.6	0.20	0.49	54.9
Approach		242	4.4	0.178	5.0	LOS A	1.0	7.6	0.20	0.49	54.3
East: Access Point 2 (Muirhead)											
4	L2	67	5.0	0.113	6.0	LOS A	0.6	4.3	0.49	0.61	52.8
5	T1	27	5.0	0.113	6.2	LOS A	0.6	4.3	0.49	0.61	53.9
6	R2	16	5.0	0.113	10.3	LOS B	0.6	4.3	0.49	0.61	53.7
Approach		110	5.0	0.113	6.7	LOS A	0.6	4.3	0.49	0.61	53.2
North: Lee Point Road N											
7	L2	14	0.0	0.141	5.5	LOS A	0.8	5.5	0.45	0.55	53.0
8	T1	125	5.0	0.141	5.8	LOS A	0.8	5.5	0.45	0.55	54.0
9	R2	6	5.0	0.141	10.0	LOS A	0.8	5.5	0.45	0.55	53.7
Approach		145	4.5	0.141	6.0	LOS A	0.8	5.5	0.45	0.55	53.9
West: Access Point 2 (2CRU)											
10	L2	11	5.0	0.206	4.9	LOS A	1.1	8.3	0.34	0.62	51.3
11	T1	27	0.0	0.206	5.1	LOS A	1.1	8.3	0.34	0.62	52.4
12	R2	205	5.0	0.206	9.3	LOS A	1.1	8.3	0.34	0.62	52.1
Approach		243	4.4	0.206	8.6	LOS A	1.1	8.3	0.34	0.62	52.1
All Vehicles		740	4.5	0.206	6.6	LOS A	1.1	8.3	0.34	0.56	53.3

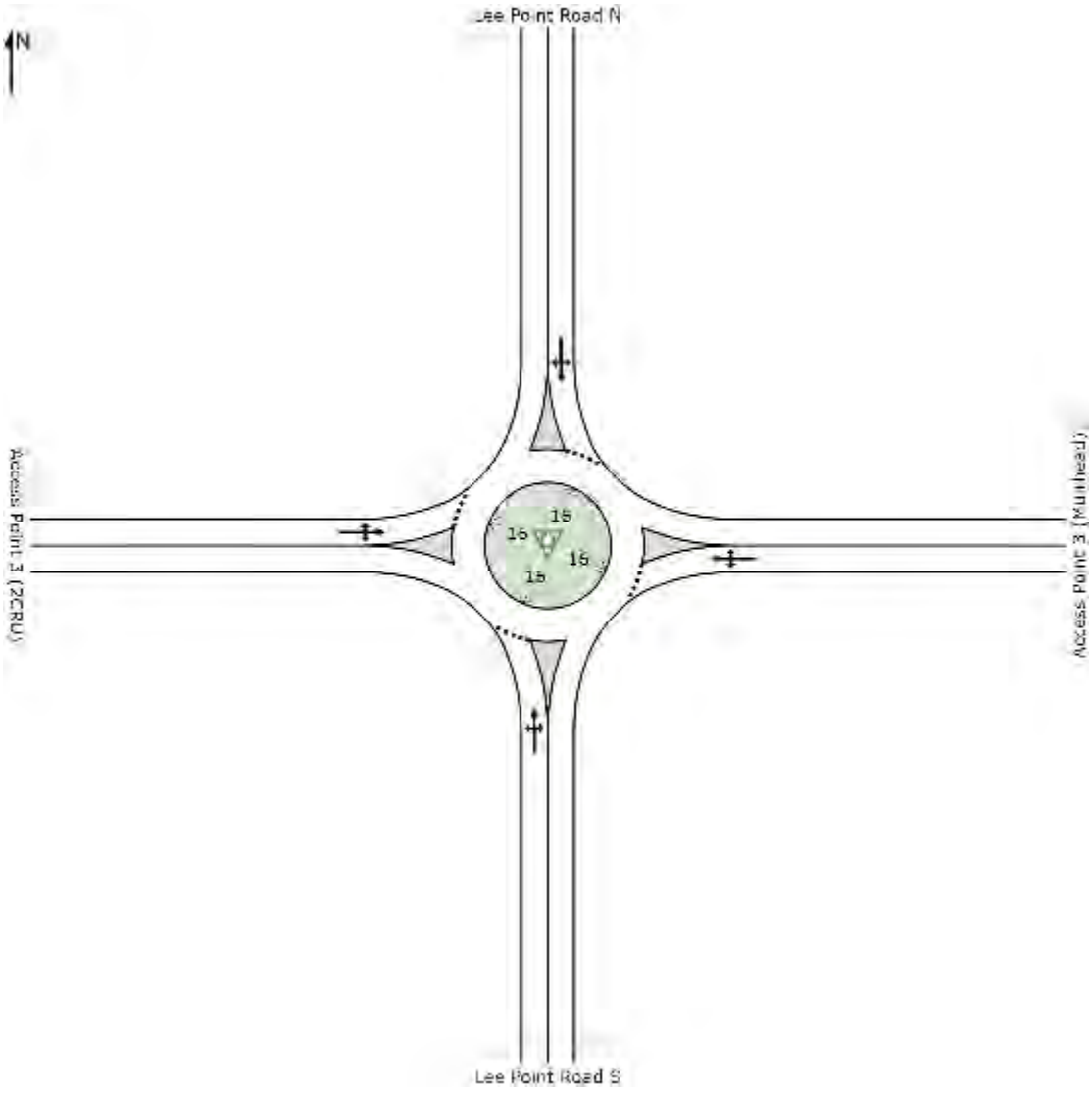
Table 5-28 Lee Point Road / Access Road 2 Intersection PM Performance – 2019 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	181	5.0	0.273	4.3	LOS A	1.7	12.5	0.16	0.48	53.8
2	T1	161	5.0	0.273	4.5	LOS A	1.7	12.5	0.16	0.48	55.0
3	R2	57	0.0	0.273	8.6	LOS A	1.7	12.5	0.16	0.48	55.0
Approach		399	4.3	0.273	5.0	LOS A	1.7	12.5	0.16	0.48	54.5
East: Access Point 2 (Muirhead)											
4	L2	38	5.0	0.059	5.5	LOS A	0.3	2.1	0.43	0.57	53.1
5	T1	14	5.0	0.059	5.7	LOS A	0.3	2.1	0.43	0.57	54.2
6	R2	8	5.0	0.059	9.9	LOS A	0.3	2.1	0.43	0.57	54.0
Approach		60	5.0	0.059	6.2	LOS A	0.3	2.1	0.43	0.57	53.4
North: Lee Point Road N											
7	L2	9	0.0	0.129	5.2	LOS A	0.7	5.0	0.41	0.53	53.1
8	T1	120	5.0	0.129	5.5	LOS A	0.7	5.0	0.41	0.53	54.1
9	R2	10	5.0	0.129	9.6	LOS A	0.7	5.0	0.41	0.53	53.8
Approach		139	4.7	0.129	5.8	LOS A	0.7	5.0	0.41	0.53	54.0
West: Access Point 2 (2CRU)											
10	L2	7	5.0	0.152	5.4	LOS A	0.8	5.8	0.41	0.65	51.0
11	T1	14	0.0	0.152	5.5	LOS A	0.8	5.8	0.41	0.65	52.1
12	R2	142	5.0	0.152	9.8	LOS A	0.8	5.8	0.41	0.65	51.8
Approach		163	4.6	0.152	9.2	LOS A	0.8	5.8	0.41	0.65	51.8
All Vehicles		761	4.5	0.273	6.1	LOS A	1.7	12.5	0.28	0.53	53.7

5.5.5 Lee Point Road / Access Road 3 Intersection

As shown in **Figure 5-1**, the Lee Point Road / Access Road 3 intersection is located to the west of the Site. This intersection is proposed to be a 4 leg approach roundabout. The intersection layout of Lee Point Road and Access Road 3 used for all of the analysis scenarios is shown in **Figure 5-8**.

Figure 5-8 Lee Point Road / Access Road 3 Intersection Layout



The results of the SIDRA for the existing condition in the year 2019 with development is shown in **Table 5-29** and **Table 5-30.** The results shows that the intersection will perform satisfactorily in the AM and PM peak period in the year 2019.

Table 5-29 Lee Point Road / Access Road 3 Intersection AM Performance – 2019 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	91	5.0	0.238	4.3	LOS A	1.6	11.3	0.16	0.45	54.0
2	T1	231	5.0	0.238	4.5	LOS A	1.6	11.3	0.16	0.45	55.2
3	R2	24	5.0	0.238	8.6	LOS A	1.6	11.3	0.16	0.45	54.9
Approach		346	5.0	0.238	4.7	LOS A	1.6	11.3	0.16	0.45	54.9
East: Access Point 3 (Muirhead)											
4	L2	52	5.0	0.096	7.4	LOS A	0.5	3.9	0.63	0.68	52.2
5	T1	21	5.0	0.096	7.6	LOS A	0.5	3.9	0.63	0.68	53.3
6	R2	3	5.0	0.096	11.8	LOS B	0.5	3.9	0.63	0.68	53.0
Approach		76	5.0	0.096	7.6	LOS A	0.5	3.9	0.63	0.68	52.5
North: Lee Point Road N											
7	L2	1	5.0	0.359	5.5	LOS A	2.4	17.3	0.49	0.56	52.7
8	T1	391	5.0	0.359	5.7	LOS A	2.4	17.3	0.49	0.56	53.8
9	R2	5	5.0	0.359	9.9	LOS A	2.4	17.3	0.49	0.56	53.6
Approach		397	5.0	0.359	5.8	LOS A	2.4	17.3	0.49	0.56	53.8
West: Access Point 3 (2CRU)											
10	L2	8	5.0	0.181	5.6	LOS A	1.0	7.0	0.45	0.66	50.9
11	T1	21	5.0	0.181	5.9	LOS A	1.0	7.0	0.45	0.66	52.0
12	R2	159	5.0	0.181	10.0	LOS A	1.0	7.0	0.45	0.66	51.7
Approach		188	5.0	0.181	9.3	LOS A	1.0	7.0	0.45	0.66	51.7
All Vehicles		1007	5.0	0.359	6.2	LOS A	2.4	17.3	0.38	0.55	53.7

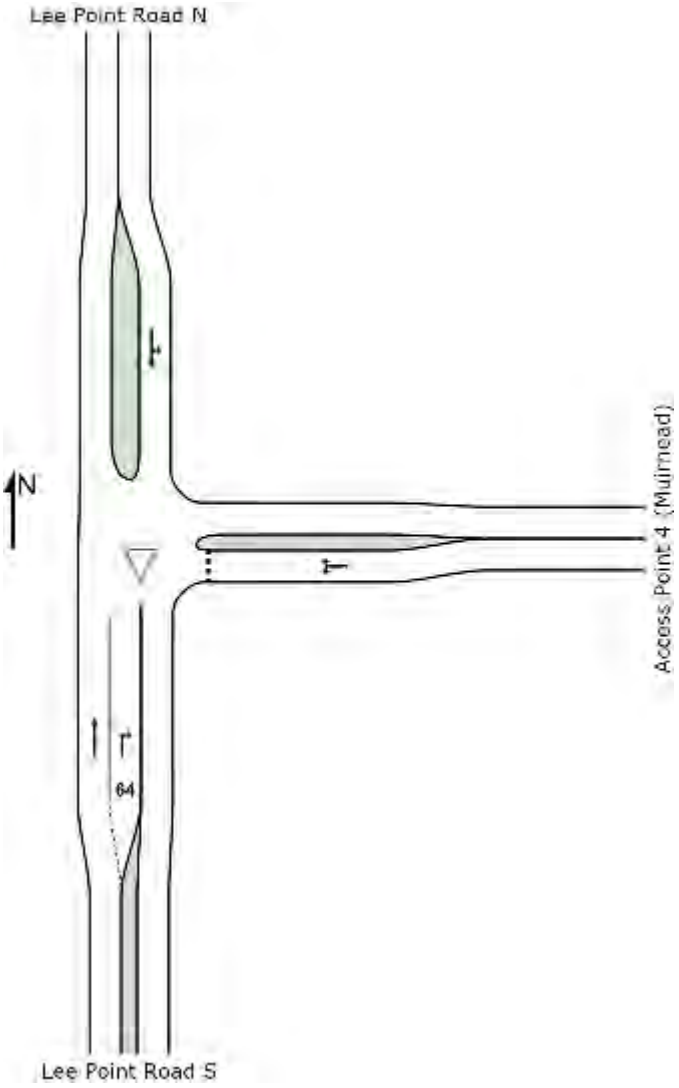
Table 5-30 Lee Point Road / Access Road 3 Intersection PM Performance – 2019 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	140	5.0	0.373	4.2	LOS A	2.7	19.9	0.14	0.45	54.1
2	T1	391	5.0	0.373	4.5	LOS A	2.7	19.9	0.14	0.45	55.3
3	R2	44	5.0	0.373	8.6	LOS A	2.7	19.9	0.14	0.45	55.0
Approach		575	5.0	0.373	4.7	LOS A	2.7	19.9	0.14	0.45	54.9
East: Access Point 3 (Muirhead)											
4	L2	30	5.0	0.047	6.3	LOS A	0.2	1.8	0.52	0.60	52.9
5	T1	11	5.0	0.047	6.5	LOS A	0.2	1.8	0.52	0.60	54.0
6	R2	2	5.0	0.047	10.6	LOS B	0.2	1.8	0.52	0.60	53.8
Approach		43	5.0	0.047	6.5	LOS A	0.2	1.8	0.52	0.60	53.2
North: Lee Point Road N											
7	L2	2	5.0	0.263	5.1	LOS A	1.6	11.7	0.41	0.51	53.0
8	T1	291	5.0	0.263	5.4	LOS A	1.6	11.7	0.41	0.51	54.2
9	R2	7	5.0	0.263	9.5	LOS A	1.6	11.7	0.41	0.51	53.9
Approach		300	5.0	0.263	5.5	LOS A	1.6	11.7	0.41	0.51	54.1
West: Access Point 3 (2CRU)											
10	L2	6	5.0	0.140	6.7	LOS A	0.7	5.4	0.55	0.72	50.3
11	T1	11	5.0	0.140	6.9	LOS A	0.7	5.4	0.55	0.72	51.3
12	R2	110	5.0	0.140	11.0	LOS B	0.7	5.4	0.55	0.72	51.1
Approach		127	5.0	0.140	10.5	LOS B	0.7	5.4	0.55	0.72	51.1
All Vehicles		1045	5.0	0.373	5.7	LOS A	2.7	19.9	0.28	0.51	54.1

5.5.6 Lee Point Road / Access Road 4 Intersection

As shown in **Figure 5-1**, the Lee Point Road / Access Road 4 intersection is located to the east of the Site. This intersection is proposed to be a give way priority intersection. The intersection layout of Lee Point Road and Access Road 4 used for all of the analysis scenarios is shown in **Figure 5-9**.

Figure 5-9 Lee Point Road / Access Road 4 Intersection Layout



The results of the SIDRA for the existing condition in the year 2019 with development is shown in **Table 5-31** and **Table 5-32**. The results shows that the intersection will perform satisfactorily in the AM and PM peak period in the year 2019.

Table 5-31 Lee Point Road / Access Road 4 Intersection AM Performance – 2019 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
2	T1	347	5.0	0.177	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	14	5.0	0.016	8.3	LOS A	0.1	0.5	0.55	0.67	51.1
Approach		361	5.0	0.177	0.3	NA	0.1	0.5	0.02	0.03	59.6
East: Access Point 4 (Muirhead)											
4	L2	30	5.0	0.044	8.4	LOS A	0.2	1.1	0.55	0.73	50.9
6	R2	2	5.0	0.044	17.3	LOS C	0.2	1.1	0.55	0.73	50.6
Approach		32	5.0	0.044	9.0	LOS A	0.2	1.1	0.55	0.73	50.9
North: Lee Point Road N											
7	L2	1	5.0	0.309	5.6	LOS A	0.0	0.0	0.00	0.00	58.0
8	T1	603	5.0	0.309	0.0	LOS A	0.0	0.0	0.00	0.00	59.9
Approach		604	5.0	0.309	0.0	NA	0.0	0.0	0.00	0.00	59.9
All Vehicles		997	5.0	0.309	0.4	NA	0.2	1.1	0.03	0.03	59.4

Table 5-32 Lee Point Road / Access Road 4 Intersection PM Performance – 2019 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
2	T1	575	5.0	0.294	0.0	LOS A	0.0	0.0	0.00	0.00	59.9
3	R2	25	5.0	0.022	7.2	LOS A	0.1	0.7	0.47	0.62	51.8
Approach		600	5.0	0.294	0.3	NA	0.1	0.7	0.02	0.03	59.5
East: Access Point 4 (Muirhead)											
4	L2	17	5.0	0.020	7.2	LOS A	0.1	0.5	0.47	0.63	51.7
6	R2	1	5.0	0.020	18.5	LOS C	0.1	0.5	0.47	0.63	51.4
Approach		18	5.0	0.020	7.9	LOS A	0.1	0.5	0.47	0.63	51.7
North: Lee Point Road N											
7	L2	1	5.0	0.220	5.6	LOS A	0.0	0.0	0.00	0.00	58.1
8	T1	430	5.0	0.220	0.0	LOS A	0.0	0.0	0.00	0.00	59.9
Approach		431	5.0	0.220	0.0	NA	0.0	0.0	0.00	0.00	59.9
All Vehicles		1049	5.0	0.294	0.3	NA	0.1	0.7	0.02	0.03	59.5

5.6 Capacity and Level of Service (2029 Base Scenario, With Development)

5.6.1 Lee Point Road / Buffalo Creek Road Intersection

The results of the SIDRA for the existing condition in the year 2029 with development is shown in **Table 5-33** and **0.** The results shows that the intersection will perform satisfactorily in the AM and PM peak period in the year 2029.

Table 5-33 Lee Point Road / Buffalo Creek Road Intersection AM Performance – 2029 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
2	T1	47	5.0	0.025	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	16	5.0	0.009	5.6	LOS A	0.0	0.3	0.11	0.56	52.6
Approach		63	5.0	0.025	1.4	NA	0.0	0.3	0.03	0.14	57.9
East: Buffalo Creek Road											
4	L2	10	5.0	0.015	8.3	LOS A	0.1	0.4	0.11	0.93	51.6
6	R2	7	5.0	0.015	8.2	LOS A	0.1	0.4	0.11	0.93	51.1
Approach		17	5.0	0.015	8.3	LOS A	0.1	0.4	0.11	0.93	51.4
North: Lee Point Road N											
7	L2	7	5.0	0.019	5.6	LOS A	0.0	0.0	0.00	0.12	57.1
8	T1	28	5.0	0.019	0.0	LOS A	0.0	0.0	0.00	0.12	58.9
Approach		35	5.0	0.019	1.1	NA	0.0	0.0	0.00	0.12	58.5
All Vehicles		115	5.0	0.025	2.3	NA	0.1	0.4	0.03	0.25	57.0

Table 5-34 Lee Point Road / Buffalo Creek Road Intersection PM Performance – 2029 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
2	T1	60	5.0	0.032	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	40	5.0	0.024	5.7	LOS A	0.1	0.8	0.16	0.56	52.5
Approach		100	5.0	0.032	2.3	NA	0.1	0.8	0.06	0.22	56.7
East: Buffalo Creek Road											
4	L2	28	5.0	0.029	8.4	LOS A	0.1	0.8	0.15	0.91	51.6
6	R2	7	5.0	0.029	8.7	LOS A	0.1	0.8	0.15	0.91	51.1
Approach		35	5.0	0.029	8.5	LOS A	0.1	0.8	0.15	0.91	51.5
North: Lee Point Road N											
7	L2	7	5.0	0.033	5.6	LOS A	0.0	0.0	0.00	0.07	57.5
8	T1	55	5.0	0.033	0.0	LOS A	0.0	0.0	0.00	0.07	59.4
Approach		62	5.0	0.033	0.6	NA	0.0	0.0	0.00	0.07	59.2
All Vehicles		197	5.0	0.033	2.9	NA	0.1	0.8	0.06	0.30	56.4

5.6.2 Lee Point Road / Lee Point Village Resort

The results of the SIDRA for the existing condition in the year 2029 with development is shown in **Table 5-35** and **Table 5-36.** The results shows that the intersection will perform satisfactorily in the AM and PM peak period in the year 2029.

Table 5-35 Lee Point Road / Lee Point Village Resort Intersection AM Performance – 2029 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
2	T1	121	5.0	0.064	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	9	5.0	0.006	6.0	LOS A	0.0	0.2	0.25	0.53	47.8
Approach		130	5.0	0.064	0.4	NA	0.0	0.2	0.02	0.04	59.3
East: Lee Point Village											
4	L2	14	5.0	0.010	6.0	LOS A	0.0	0.3	0.23	0.53	48.8
6	R2	1	5.0	0.001	7.0	LOS A	0.0	0.0	0.38	0.54	47.9
Approach		15	5.0	0.010	6.0	LOS A	0.0	0.3	0.24	0.53	48.8
North: Lee Point Road N											
7	L2	1	5.0	0.074	5.6	LOS A	0.0	0.0	0.00	0.00	31.8
8	T1	138	5.0	0.074	0.0	LOS A	0.0	0.0	0.00	0.00	59.9
Approach		139	5.0	0.074	0.0	NA	0.0	0.0	0.00	0.00	59.7
All Vehicles		284	5.0	0.074	0.5	NA	0.0	0.3	0.02	0.05	59.1

Table 5-36 Lee Point Road / Lee Point Village Resort Intersection PM Performance – 2029 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
2	T1	180	5.0	0.095	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	16	5.0	0.010	6.0	LOS A	0.0	0.3	0.26	0.54	47.7
Approach		196	5.0	0.095	0.5	NA	0.0	0.3	0.02	0.04	59.2
East: Lee Point Village											
4	L2	4	5.0	0.003	6.0	LOS A	0.0	0.1	0.24	0.52	48.8
6	R2	1	5.0	0.001	7.5	LOS A	0.0	0.0	0.43	0.55	47.4
Approach		5	5.0	0.003	6.3	LOS A	0.0	0.1	0.28	0.53	48.5
North: Lee Point Road N											
7	L2	1	5.0	0.079	5.6	LOS A	0.0	0.0	0.00	0.00	31.8
8	T1	148	5.0	0.079	0.0	LOS A	0.0	0.0	0.00	0.00	59.9
Approach		149	5.0	0.079	0.0	NA	0.0	0.0	0.00	0.00	59.7
All Vehicles		350	5.0	0.095	0.4	NA	0.0	0.3	0.02	0.03	59.3

5.6.3 Lee Point Road / Access Road 1 Intersection

The results of the SIDRA for the existing condition in the year 2029 with development is shown in **Table 5-37** and **Table 5-38.** The results shows that the intersection will perform satisfactorily in the AM and PM peak period in the year 2029.

Table 5-37 Lee Point Road / Access Road 1 Intersection AM Performance – 2029 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
1	L2	64	5.0	0.066	5.6	LOS A	0.0	0.0	0.00	0.31	55.5
2	T1	57	5.0	0.066	0.0	LOS A	0.0	0.0	0.00	0.31	57.2
Approach		121	5.0	0.066	3.0	NA	0.0	0.0	0.00	0.31	56.3
North: Lee Point Road N											
8	T1	35	5.0	0.019	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
9	R2	3	5.0	0.002	5.9	LOS A	0.0	0.1	0.23	0.53	52.3
Approach		38	5.0	0.019	0.5	NA	0.0	0.1	0.02	0.04	59.3
West: Access Point 1 (2CRU)											
10	L2	5	5.0	0.117	8.5	LOS A	0.5	3.5	0.27	0.89	51.6
12	R2	103	5.0	0.117	8.6	LOS A	0.5	3.5	0.27	0.89	51.1
Approach		108	5.0	0.117	8.6	LOS A	0.5	3.5	0.27	0.89	51.1
All Vehicles		267	5.0	0.117	4.9	NA	0.5	3.5	0.11	0.51	54.5

Table 5-38 Lee Point Road / Access Road 1 Intersection PM Performance – 2029 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	Distance m	Prop. Queued	Effective Stop Rate per veh	Average Speed km/h
South: Lee Point Road S											
1	L2	87	5.0	0.099	5.6	LOS A	0.0	0.0	0.00	0.28	55.7
2	T1	95	5.0	0.099	0.0	LOS A	0.0	0.0	0.00	0.28	57.5
Approach		182	5.0	0.099	2.7	NA	0.0	0.0	0.00	0.28	56.6
North: Lee Point Road N											
8	T1	79	5.0	0.042	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
9	R2	4	5.0	0.003	6.1	LOS A	0.0	0.1	0.29	0.54	52.2
Approach		83	5.0	0.042	0.3	NA	0.0	0.1	0.01	0.03	59.6
West: Access Point 1 (2CRU)											
10	L2	3	5.0	0.089	8.6	LOS A	0.3	2.5	0.36	0.89	51.2
12	R2	69	5.0	0.089	9.4	LOS A	0.3	2.5	0.36	0.89	50.7
Approach		72	5.0	0.089	9.3	LOS A	0.3	2.5	0.36	0.89	50.7
All Vehicles		337	5.0	0.099	3.5	NA	0.3	2.5	0.08	0.35	55.9

5.6.4 Lee Point Road / Access Road 2 Intersection

The results of the SIDRA for the existing condition in the year 2029 with development is shown in **Table 5-39** and **Table 5-40.** The results shows that the intersection will perform satisfactorily in the AM and PM peak period in the year 2029.

Table 5-39 Lee Point Road / Access Road 2 Intersection AM Performance – 2029 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	117	5.0	0.184	4.4	LOS A	1.1	7.9	0.20	0.48	53.7
2	T1	102	5.0	0.184	4.6	LOS A	1.1	7.9	0.20	0.48	54.9
3	R2	31	0.0	0.184	8.7	LOS A	1.1	7.9	0.20	0.48	54.9
Approach		250	4.4	0.184	5.0	LOS A	1.1	7.9	0.20	0.48	54.4
East: Access Point 2 (Muirhead)											
4	L2	67	5.0	0.114	6.0	LOS A	0.6	4.3	0.49	0.62	52.8
5	T1	27	5.0	0.114	6.3	LOS A	0.6	4.3	0.49	0.62	53.9
6	R2	16	5.0	0.114	10.4	LOS B	0.6	4.3	0.49	0.62	53.7
Approach		110	5.0	0.114	6.7	LOS A	0.6	4.3	0.49	0.62	53.2
North: Lee Point Road N											
7	L2	14	0.0	0.148	5.5	LOS A	0.8	5.8	0.45	0.55	53.0
8	T1	132	5.0	0.148	5.8	LOS A	0.8	5.8	0.45	0.55	54.0
9	R2	6	5.0	0.148	10.0	LOS A	0.8	5.8	0.45	0.55	53.7
Approach		152	4.5	0.148	6.0	LOS A	0.8	5.8	0.45	0.55	53.9
West: Access Point 2 (2CRU)											
10	L2	11	5.0	0.208	5.0	LOS A	1.2	8.4	0.35	0.62	51.2
11	T1	27	0.0	0.208	5.1	LOS A	1.2	8.4	0.35	0.62	52.4
12	R2	205	5.0	0.208	9.3	LOS A	1.2	8.4	0.35	0.62	52.0
Approach		243	4.4	0.208	8.7	LOS A	1.2	8.4	0.35	0.62	52.1
All Vehicles		755	4.5	0.208	6.6	LOS A	1.2	8.4	0.34	0.56	53.3

Table 5-40 Lee Point Road / Access Road 2 Intersection PM Performance – 2029 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	181	5.0	0.285	4.3	LOS A	1.8	13.3	0.16	0.48	53.8
2	T1	180	5.0	0.285	4.5	LOS A	1.8	13.3	0.16	0.48	55.0
3	R2	57	0.0	0.285	8.6	LOS A	1.8	13.3	0.16	0.48	55.0
Approach		418	4.3	0.285	5.0	LOS A	1.8	13.3	0.16	0.48	54.5
East: Access Point 2 (Muirhead)											
4	L2	38	5.0	0.059	5.6	LOS A	0.3	2.1	0.44	0.57	53.0
5	T1	14	5.0	0.059	5.8	LOS A	0.3	2.1	0.44	0.57	54.2
6	R2	8	5.0	0.059	9.9	LOS A	0.3	2.1	0.44	0.57	53.9
Approach		60	5.0	0.059	6.2	LOS A	0.3	2.1	0.44	0.57	53.4
North: Lee Point Road N											
7	L2	9	0.0	0.142	5.2	LOS A	0.8	5.5	0.41	0.53	53.1
8	T1	133	5.0	0.142	5.5	LOS A	0.8	5.5	0.41	0.53	54.1
9	R2	10	5.0	0.142	9.7	LOS A	0.8	5.5	0.41	0.53	53.8
Approach		152	4.7	0.142	5.8	LOS A	0.8	5.5	0.41	0.53	54.0
West: Access Point 2 (2CRU)											
10	L2	7	5.0	0.155	5.5	LOS A	0.8	5.9	0.43	0.66	50.9
11	T1	14	0.0	0.155	5.6	LOS A	0.8	5.9	0.43	0.66	52.1
12	R2	142	5.0	0.155	9.9	LOS A	0.8	5.9	0.43	0.66	51.7
Approach		163	4.6	0.155	9.3	LOS A	0.8	5.9	0.43	0.66	51.7
All Vehicles		793	4.5	0.285	6.1	LOS A	1.8	13.3	0.29	0.53	53.7

5.6.5 Lee Point Road / Access Road 3 Intersection

The results of the SIDRA for the existing condition in the year 2029 with development is shown in **Table 5-41** and **Table 5-42**. The results shows that the intersection will perform satisfactorily in the AM and PM peak period in the year 2029.

Table 5-41 Lee Point Road / Access Road 3 Intersection AM Performance – 2029 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	91	5.0	0.242	4.3	LOS A	1.6	11.6	0.16	0.45	54.0
2	T1	238	5.0	0.242	4.5	LOS A	1.6	11.6	0.16	0.45	55.2
3	R2	24	5.0	0.242	8.6	LOS A	1.6	11.6	0.16	0.45	54.9
Approach		353	5.0	0.242	4.7	LOS A	1.6	11.6	0.16	0.45	54.9
East: Access Point 3 (Muirhead)											
4	L2	52	5.0	0.096	7.5	LOS A	0.5	3.9	0.63	0.68	52.1
5	T1	21	5.0	0.096	7.7	LOS A	0.5	3.9	0.63	0.68	53.3
6	R2	3	5.0	0.096	11.8	LOS B	0.5	3.9	0.63	0.68	53.0
Approach		76	5.0	0.096	7.7	LOS A	0.5	3.9	0.63	0.68	52.5
North: Lee Point Road N											
7	L2	1	5.0	0.365	5.5	LOS A	2.4	17.8	0.49	0.56	52.7
8	T1	398	5.0	0.365	5.8	LOS A	2.4	17.8	0.49	0.56	53.8
9	R2	5	5.0	0.365	9.9	LOS A	2.4	17.8	0.49	0.56	53.6
Approach		404	5.0	0.365	5.8	LOS A	2.4	17.8	0.49	0.56	53.8
West: Access Point 3 (2CRU)											
10	L2	8	5.0	0.182	5.7	LOS A	1.0	7.1	0.46	0.67	50.9
11	T1	21	5.0	0.182	5.9	LOS A	1.0	7.1	0.46	0.67	52.0
12	R2	159	5.0	0.182	10.0	LOS B	1.0	7.1	0.46	0.67	51.7
Approach		188	5.0	0.182	9.4	LOS A	1.0	7.1	0.46	0.67	51.7
All Vehicles		1021	5.0	0.365	6.2	LOS A	2.4	17.8	0.38	0.55	53.7

Table 5-42 Lee Point Road / Access Road 3 Intersection PM Performance – 2029 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
1	L2	140	5.0	0.385	4.2	LOS A	2.9	20.9	0.14	0.45	54.1
2	T1	410	5.0	0.385	4.5	LOS A	2.9	20.9	0.14	0.45	55.3
3	R2	44	5.0	0.385	8.6	LOS A	2.9	20.9	0.14	0.45	55.0
Approach		594	5.0	0.385	4.7	LOS A	2.9	20.9	0.14	0.45	54.9
East: Access Point 3 (Muirhead)											
4	L2	30	5.0	0.048	6.4	LOS A	0.2	1.8	0.53	0.60	52.8
5	T1	11	5.0	0.048	6.6	LOS A	0.2	1.8	0.53	0.60	54.0
6	R2	2	5.0	0.048	10.7	LOS B	0.2	1.8	0.53	0.60	53.7
Approach		43	5.0	0.048	6.6	LOS A	0.2	1.8	0.53	0.60	53.2
North: Lee Point Road N											
7	L2	2	5.0	0.274	5.2	LOS A	1.7	12.3	0.41	0.51	53.0
8	T1	304	5.0	0.274	5.4	LOS A	1.7	12.3	0.41	0.51	54.1
9	R2	7	5.0	0.274	9.5	LOS A	1.7	12.3	0.41	0.51	53.9
Approach		313	5.0	0.274	5.5	LOS A	1.7	12.3	0.41	0.51	54.1
West: Access Point 3 (2CRU)											
10	L2	6	5.0	0.143	6.8	LOS A	0.8	5.5	0.56	0.72	50.2
11	T1	11	5.0	0.143	7.0	LOS A	0.8	5.5	0.56	0.72	51.3
12	R2	110	5.0	0.143	11.2	LOS B	0.8	5.5	0.56	0.72	51.0
Approach		127	5.0	0.143	10.6	LOS B	0.8	5.5	0.56	0.72	51.0
All Vehicles		1077	5.0	0.385	5.7	LOS A	2.9	20.9	0.29	0.51	54.1

5.6.6 Lee Point Road / Access Road 4 Intersection

The results of the SIDRA for the existing condition in the year 2029 with development is shown in **Table 5-43** and **Table 5-44.** The results shows that the intersection will perform satisfactorily in the AM and PM peak period in the year 2029.

Table 5-43 Lee Point Road / Access Road 4 Intersection AM Performance – 2029 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
2	T1	355	5.0	0.181	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
3	R2	14	5.0	0.016	8.3	LOS A	0.1	0.5	0.55	0.68	45.9
Approach		369	5.0	0.181	0.3	NA	0.1	0.5	0.02	0.03	59.5
East: Access Point 4 (Muirhead)											
4	L2	30	5.0	0.044	8.4	LOS A	0.2	1.1	0.55	0.73	46.3
6	R2	2	5.0	0.044	17.7	LOS C	0.2	1.1	0.55	0.73	45.9
Approach		32	5.0	0.044	9.0	LOS A	0.2	1.1	0.55	0.73	46.3
North: Lee Point Road N											
7	L2	1	5.0	0.312	5.6	LOS A	0.0	0.0	0.00	0.00	31.6
8	T1	610	5.0	0.312	0.0	LOS A	0.0	0.0	0.00	0.00	59.9
Approach		611	5.0	0.312	0.0	NA	0.0	0.0	0.00	0.00	59.9
All Vehicles		1012	5.0	0.312	0.4	NA	0.2	1.1	0.03	0.03	59.4

Table 5-44 Lee Point Road / Access Road 4 Intersection PM Performance – 2029 With Development

Movement Performance - Vehicles											
Mov ID	ODMov	Demand Flows Total	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South: Lee Point Road S											
2	T1	595	5.0	0.304	0.0	LOS A	0.0	0.0	0.00	0.00	59.9
3	R2	25	5.0	0.023	7.3	LOS A	0.1	0.7	0.48	0.63	46.8
Approach		620	5.0	0.304	0.3	NA	0.1	0.7	0.02	0.03	59.5
East: Access Point 4 (Muirhead)											
4	L2	17	5.0	0.021	7.3	LOS A	0.1	0.6	0.48	0.64	47.3
6	R2	1	5.0	0.021	19.5	LOS C	0.1	0.6	0.48	0.64	46.9
Approach		18	5.0	0.021	7.9	LOS A	0.1	0.6	0.48	0.64	47.3
North: Lee Point Road N											
7	L2	1	5.0	0.227	5.6	LOS A	0.0	0.0	0.00	0.00	31.6
8	T1	443	5.0	0.227	0.0	LOS A	0.0	0.0	0.00	0.00	59.9
Approach		444	5.0	0.227	0.0	NA	0.0	0.0	0.00	0.00	59.9
All Vehicles		1082	5.0	0.304	0.3	NA	0.1	0.7	0.02	0.03	59.5

5.7 Transportation Safety

5.7.1 Operating Speeds

The posted speed limit for Lee Point Road is 70km/h. As it currently operates, there is some degree of hooning which occurs at the northern section of Lee Point Road. Its location along the outskirts of Darwin and away from built up areas may attribute to hooning along Lee Point Road. However, as development into the northern areas increase, hooning would likely decrease as the road is modified and upgraded to accommodate developments and complaints against this behaviour increases.

Operating speeds at the frontage and other nearby roads of the primary school should be 40km/h during school peak hours as per Northern Territory Government requirements.

5.7.2 Guidance and Delineation

The Site plans show that Lee Point Road is likely to be upgraded to improve amenity and accessibility for residents and visitors to and from the Site. Improvements include:

> Access to the site via three new intersections described as follows:

- Access 2, roundabout intersection (providing access to the 2CRU and Muirhead development)
- Access 3, roundabout intersection (providing access to the 2CRU and Muirhead development)
- Access 4, give way priority intersection (providing access to Muirhead development only)

> Cycling lanes along both sides of the road. This includes roundabouts designed to accommodate cyclist movement.

> A median strip to accommodate right turn movements at intersections.

In addition to these measures, the following should be implemented to improve guidance and delineation:

> Advance warning signs to indicate upcoming intersections

> Appropriate linemarking to delineate road lanes and stop/give way lines

> Wayfinding signage such as street name signs

> Regulatory signage such as stop, give way and parking restriction signs

> Appropriate school zone signage such as signs indicating speed limits and school zone times.

5.8 Traffic Signals

This is not applicable as there are no signalised intersection in the vicinity of the Site.

5.9 Site Circulation and Parking

The proposed road circulation network is shown on the Site plan in **Appendix A**. Note that these plans are not final and the road network layout may change in future iterations.

Parking is expected to be provided within individual lots. In regards to the primary school and active recreational reserve, the parking provision should satisfy the local statutory requirements.

6 Improvement Analysis

6.1 Improvements to Accommodate Existing Traffic

The SIDRA analysis indicate that all intersections performed satisfactorily with LoS of A for all legs, therefore no improvements are necessary to accommodate existing traffic.

6.2 Improvements to Accommodate Background Traffic

The SIDRA analysis indicate that all intersections performed satisfactorily with LoS of A for all legs, therefore no improvements are necessary to accommodate background traffic.

6.3 Additional Improvements to Total Traffic (with Development)

The SIDRA analysis indicate that all intersections performed satisfactorily with LoS of A for all legs, therefore no improvements are necessary to accommodate total traffic.

6.4 Alternative Improvements

No additional alternative improvements have been evaluated.

6.5 Status of Improvements Already Funded, Programmed, or Planned

To the best of Cardno's knowledge, there are no improvements that have been funded or programmed.

6.6 Evaluation

No potential mitigation measures have been evaluated as the current intersection form is adequate to accommodate all traffic scenarios analysed in this report.

7 Findings

7.1 Site Accessibility

SIDRA analysis has shown that the main accesses into the Site, i.e. Access 2, Access 3 and Access 4 will perform satisfactorily with the background and development traffic in the year 2029.

7.2 Transportation Impacts

As the Site generates relatively low traffic volumes, it is expected that the Site will have negligible impact on the surrounding road network.

7.3 Needs for Any Improvements

No improvements are recommended at this stage as the Lee Point Road/Lee Point Village Resort and Lee Point Road/Buffalo Creek Road intersections are expected to perform satisfactorily in its current form. The development will have minimal impact on the surrounding road network.

7.4 Compliance with Applicable Local Codes

No applicable local standards have been relevant to this assessment, however any future modifications to the proposed site plans may require the need for additional assessment to meet the required standards.

8 Recommendation

8.1 Site Access / Circulation Plan

No recommendations or mitigation measures are proposed for the Site.

8.2 Roadway Improvements

8.2.1 On-Site

No recommendations for roadway improvement are proposed for the Site.

8.2.2 Off-Site

No recommendations for roadway improvement are proposed for the Site.

8.3 Transit, Pedestrians and Bicycles

No improvements to transit, pedestrian or bicycle infrastructure or services are recommended.

8.4 Transportation System Management / Transportation Demand Management Actions

8.4.1 Off-Site

Not applicable due to the nature and location of the Site.

8.4.2 On-Site Operational

Not applicable due to the nature and location of the Site.

8.4.3 On-Site

Not applicable due to the nature and location of the Site.

2CRU Development, Lee Point

APPENDIX A

SITE PLAN

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LEGEND

- SUBJECT SITE
- PROPOSED STAGING BOUNDARY
- COMMUNITY USE
- OPEN SPACE
- ENCUMBERED OPEN SPACE
- PROPOSED COASTAL RESERVE
- PROPOSED CONSERVATION RESERVE
- PARKING (WITHIN BASEMENT)
- PARKING (WITHIN CARCOURT)

DWELLING YIELD SUMMARY TABLE

LOT YIELD	TOTAL AREA (Ha)	NO. LOTS	AVERAGE LOT SIZE (m2)
Standard Residential Lots	35.30	704	494
Rural Lots	14.19	32	4305

STANDARD LOT TYPES	TOTAL AREA (m2)	NO. LOTS	% (TOTAL STANDARD RES. LOTS)
240 - 360 m 2 (Medium Density)	30,000	100	14%
360 - 450 m 2 (Small Lot)	63,990	158	22%
450 - 550 m 2 (Medium Lot)	85,000	170	24%
550 - 650 m 2 (Large Lot)	114,600	191	27%
650 - 750 m 2 (Duplex)	59,500	85	12%
TOTAL STANDARD LOTS	353,090	704	100%

SPECIAL SITES - APARTMENTS	SITE AREA (m2)	DWELLINGS	TYPE
TOURISM PRECINCT - ACCOMMODATION	2.70	300	
TP1 - Height Limit 12 Storeys	1.12	180	Hotel/ serviced apartments
TP2 - Height Limit 12 Storeys	0.51	80	Hotel/ serviced apartments
TP3 - Height Limit 8 Storeys	0.42	40	Hotel/ serviced apartments
TP4 - No Residential Included	0.65	0	
MIXED USE - HEIGHT LIMIT 4 STOREYS	1.00	60	Private apartments
GENERAL URBAN - HEIGHT LIMIT 3 STOREYS	3.00	160	Private apartments
TOTAL APARTMENTS		520	

BEAGLE GULF
CASUARINA COASTAL RESERVE
2CRU BOUNDARY 82.03HA
PARK A 0.75Ha
RB 03 0.26 Ha
HERITAGE RESERVE 0.18Ha
STAGE 5
RB 02 0.62 Ha
TOURISM ACTIVITY AREA
LINEAR RESERVE A 0.29 Ha
LEE POINT VILLAGE RESORT CARAVAN PARK LOT 9289
GREEN CORRIDOR
CREEK
TP 4
TP 1
PARK B 0.52 Ha
TP 2
TP 3
SANDY
PROPOSED COASTAL RESERVE
PROPOSED PRIMARY SCHOOL + COMMUNITY HUB
PROPOSED COMMUNITY CENTRE 0.2Ha
PARK C 0.59 Ha
PARK F 1.43 Ha
LINEAR RESERVE B 0.16 Ha
STAGE 2A
PARK E 0.52 Ha
STAGE 1A
PARK D 0.31 Ha
ROYAL DARWIN GOLF COURSE
ROYAL DARWIN HOSPITAL
LINEAR RESERVE C 0.10Ha
PARK G 0.92 Ha
RB 06/ GREEN CORRIDOR 0.51Ha
PROPOSED COASTAL RESERVE 21.13 Ha
PARK H 0.51 Ha
STAGE 3
STAGE 4
RB 01 3.74 Ha
PARK K 0.34Ha
PARK I 0.3 Ha
PARK J 0.11 Ha
2CRU BOUNDARY [82.03HA]
ROYAL DARWIN GOLF COURSE
CASUARINA SQUARE SHOPPING CENTRE
BREEZES HOTEL
ROYAL DARWIN HOSPITAL
LEE POINT ROAD
PROPOSED PRIMARY SCHOOL + COMMUNITY HUB 3.5Ha
ACTIVE RECREATIONAL RESERVE 2 Ha
PARK L 0.19 Ha
RB 07/ GREEN CORRIDOR 1.04 Ha
STAGE 1B
RB 08 0.56 Ha
PARK M 0.59 Ha
GREEN CORRIDOR
MUIRHEAD NORTH
MUIRHEAD NORTH 49.32HA
RB 09/ GREEN CORRIDOR 0.28 Ha
STAGE 2B
RURAL LOTS 14.19 Ha
DRAINAGE RESERVE [RB 04 +RB 05] 6.15Ha
RB 10/ GREEN CORRIDOR 0.26 Ha
CONSERVATION AREA 1.57 Ha
RB 11/ GREEN CORRIDOR 0.13 Ha

Lee Point | Master Plan
Lee Point Road, Lee Point
City of Darwin, Northern Territory

REF NO	DRAW NO	REV
DHA LEE	RD 3102	C

NOTES:
MP reference:
RD3003F Lee Point_Illustrative Master Plan_170215

Land budget reference:
RD4501E DHA LEE_ Preliminary_Land Budget_170215

REV	DESCRIPTION	DDMMYY	DRAWN	APPR'D
C	per SB 16.02.15 - RD3003F	170215	KT	EP
B	per SB 02.02.15 - RD3003E	110215	KT	EP
A	per SB 081214	101214	KT	EP

SCALE 1:2,500 SIZE A0
50 100 150 200 250 300m

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APPENDIX M

Black-footed Tree-rat report

EcOz Environmental Consultants

Black-footed Tree-rat Survey Report

Lee Point Master-planned Urban Development EIS

www.ecoz.com.au

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Table of Contents

1 Introduction 1
1.1 Purpose 1
1.2 Scope 1
1.3 Status and distribution 2
1.4 Ecology 2
2 Methodology 3
2.1 Habitat assessment 3
2.2 Camera surveillance survey 4
3 Results 7
3.1 Habitat quality categorisation 7
3.2 Camera surveillance survey 10
4 Likely presence and distribution 11
4.1 Previous studies 11
4.2 Likelihood of presence 12
4.3 Area of occupancy 13
5 References 14

Tables

Table 1. Comparing implemented survey program against recommended guidelines 5
Table 2. Categorisation of Black-footed Tree-rat habitat quality 7
Table 3. Black-footed Tree-rat habitat quality assessment 8
Table 4. Summary of previous Black-footed Tree-rat studies in the Lee Point area. 11

Figures

Figure 1. Map of the location of the proposed development 1
Figure 2. Map of the location of Black-footed Tree-rat camera and habitat assessment survey sites 6
Figure 3. Map showing the results of the habitat quality assessment 9

Appendices

Appendix A Camera trap images of Black-footed Tree-Rats

Appendix B Photos taken at sites surveyed for habitat quality

1 Introduction

1.1 Purpose

Defence Housing Australia is proposing to establish a master-planned residential in the northern suburbs of Darwin. There are two parcels of land involved – one to the east of Lee Point Road known as 'Muirhead North' and the other to the west known as '2CRU' (see Figure 1).

Both sites have already undergone previous surveys and assessments to identify key ecological values. These indicated that there was potentially-suitable habitat for the Black-footed Tree-rat (*Mesembriomys gouldii gouldii*) within the proposed development area, and historic records in the surrounding area. The Black-footed Tree-rat is listed as threatened under both NT and Commonwealth legislation. Therefore, a targeted survey was required to determine the presence of the species within the proposed development area and, if present, to map suitable onsite habitat.

1.2 Scope

This report is an assessment of the Black-footed Tree-rat with regard to the proposed development of 2CRU and Muirhead North) and includes:

- Species information (status, description and distribution)
- Camera surveillance survey methodology and results
- Habitat suitability assessment methodology and results
- Assessment of the local population within a regional context.

Figure 1. Map of the location of the proposed development

1.3 Status and distribution

The Kimberley and mainland Northern Territory sub-species of Black-footed Tree-rat (*Mesembriomys gouldii gouldii*) is listed as Vulnerable under the *Territory Parks and Wildlife Act* (*TPWC Act*) and, in June 2015, became listed as Endangered under the *Environment Protection and Biodiversity Conservation Act* (*EPBC Act*).

The sub-species occurs in the Top End of the Northern Territory and the Kimberley in the Western Australia (Hill 2012). Early distribution records from Eastern Arnhem Land and the Gulf of Carpentaria suggest that the species distribution had contracted in the Northern Territory (Friend & Calaby 1995) The elevated listing has been due to a sharp decline in abundance and further decline from its former range (Woinarski et al. 2010). Declines have been reported for the Kakadu area (Woinarski et al. 2001 and Woinarski et al. 2010), and more broadly across the Top End of the Northern Territory (Ziembicki et al. 2013). The driver for this decline is unknown, but is thought to be related to changes in fire regime. In contrast to other parts of its range, the Black-footed Tree-rat may be relatively abundant in the Darwin rural area (Price et al. 2005). In an analysis of small mammals in the Darwin region from 2001 to 2014, Stokeld and Gillespie (2015) found that capture rates of Black-footed Tree-rat have been relatively consistent around Darwin, in comparison to most other species which had declined.

1.4 Ecology

The Black-footed Tree-rat is a large (500 to 900 g), nocturnal, murid rodent, that is restricted to open forests and woodlands near coastal areas in the Kimberley and the Northern Territory (Friend & Calaby 1995 and Rankmore 2003). The sub-species has a robust body with grizzly grey fur, large black feet and ears. The most distinctive feature is a long hairy tail – 30 to 40 cm – that has a brush of white hairs at the end. Knowledge of Black-footed Tree-rat ecology comes from studies in the Kimberley and mainland Northern Territory (specifically Friend & Taylor 1985, Friend 1987 and Rankmore 2006).

Black-footed Tree-rats forage on the ground and in trees, with an average home range in un-fragmented open forests of 67.3 ± 10.4 hectares and in fragmented habitat of 27.1 ± 8.4 ha (Rankmore 2006). The sub-species is predominantly frugivorous – preferring both fleshy and hard fruits and seeds – with pandanus fruit a particular favourite (Friend and Calaby 1995). The diet also includes some invertebrates, flowers and grass (Morton 1992, Rankmore 2006 and Rankmore & Friend 2008).

Being nocturnal, Black-footed Tree-rats prefer to nest in tree hollows during the day, but have also been recorded nesting in Pandanus where hollows are limited (Pittman 2003). The sub-species prefers open forests and woodlands dominated by *Eucalyptus miniata* and *E. tetrodonta,* with a developed shrubby understorey (Friend & Taylor 1985 and Friend 1987). A well-formed understory with large diameter trees is typical of a low frequency or intensity of fires; and frequent, intense fires may also be detrimental by reducing the abundance of hollow-bearing large trees (Price et al. 2005).

Originally considered to be a solitary species (Friend 1987), evidence now suggests Black-footed Tree-rats are more gregarious. During a radio-tracking study of the species by the author, the majority of radio collars removed were damaged through chewing, which could not be attributed to the collared individual. Moreover, recent camera trapping studies have frequently captured images of multiple individuals at a bait station (Brydie Hill, Flora and Fauna Branch of the NT Department of Land and Resource Management, pers. comm.).

2 Methodology

2.1 Habitat assessment

There is ground-truthed vegetation mapping for both sites. Using that mapping – and field observations of the location and extent of Gamba Grass infestations – 2CRU and Muirhead North were divided into broad categories of Black-footed Tree-rat habitat suitability. Within these, fifteen sites were selected to undertake on-ground habitat quality assessment. Sites were selected to provide replication across the broadly-defined habitat quality categories and to provide a spread across the two sites (see Figure 3). It was evident from aerial imagery and previous site visits that much of 2CRU comprised recently burnt and/or low diversity vegetation, and therefore the some of the habitat assessments at 2CRU were less detailed.

Three key habitat criteria were selected to measure the quality of habitat available for Black-footed Tree-rats:

- Presence and availability of denning/nesting sites – measured by the number of large trees, number of hollows observed and presence of pandanus.
- Presence of plant species known to be food resources for Black-footed Tree-rats.
- Density and composition of ground cover and grassy weed cover (high densities restrict the mobility of Black-footed Tree-rats).

Denning resources

Black-footed Tree-rats prefer denning in hollow-bearing, large diameter trees – particularly rough-barked species like *Eucalyptus tetrodonta* (Griffiths et al. 2002 and Rankmore 2006).

A single Bitterlich sweep using a multiplier of 0.25 was undertaken at each of the 15 sites to provide an indication of the size of trees present. For each individual tree scored, DBH was visually estimated as falling within one of four class sizes (>5 cm, 5 to 20 cm, 20 to 50 cm, and >50 cm). All tree species registering a hit were scored separately. Observed tree hollows were also recorded.

Black-footed Tree-rats have also been recorded denning in *Pandanus spiralis* (Griffiths et al. 2002, Pittman 2003 and Rankmore 2006); therefore, the presence of Pandanus at each site was also recorded.

Food resources

Abundance and availability of food resources are considered to be important factors influencing natural populations. In addition to the list of species recorded through the Bitterlich sweep, the dominant vegetation species were recorded. The list of species recorded at each site was analysed for the presence of known food resources of Black-footed Tree-rats.

Access and mobility

The Black-footed Tree-rat that prefers vegetation that is relatively long-unburnt (Friend and Taylor 1985). While these areas tend to support higher densities of fruiting, understorey plants (Williams et al. 1999b); often have larger trees (and thus more hollows) (Woinarski 2004); and often provide an open or patchy grassy understorey. As Black-footed Tree-rats spend a considerable amount of time foraging on the ground, a more open groundcover provides them with ease of movement during foraging.

At each site, ground cover was categorised and scored at 1 m intervals along a 100 m transect to determine a percentage cover estimate of both grassy weeds and ground vegetation cover.

2.2 Camera surveillance survey

Because of the species' recent listing, there are no formalised EPBC survey methods for Black-footed Tree-rat. The *Survey Guidelines for Australia's Threatened Mammals* (DSEWPaC 2011) present an overview of survey techniques to detect medium-sized ground-dwelling (a category that broadly includes the Black-footed Tree-rat). Therefore, advice on minimum sampling requirements was sought from the Northern Territory Department of Land and Resource Management (DLRM). At present, DLRM is analysing existing data to determine a suitable survey methodology for the species. This methodology is based on the use of camera traps and requires 1 site per 20 ha of vegetation/habitat types that are likely to support the species, with 1 camera installed per site for 4 weeks. It appears that the Black-footed Tree-rat has a high detectability on camera traps.

Having evaluated the recommended standard camera surveillance survey methods (*Guidelines for detecting mammals listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999*) and interim recommendations of the Northern Territory Government, EcOz designed the survey to ensure it complied with minimum requirements. Surveys were undertaken by Dr Brooke Rankmore (EcOz) whose PhD was on this species.

Camera surveillance site selection was made prior to the habitat assessment described in Section 2.1 being undertaken, but was on the author's experience of preferred Black-footed Tree-rat habitat. As it turned out, the results of the habitat assessment were that 2CRU and Muirhead North contain 13 ha and 17.5 ha, respectively, of higher quality habitat (i.e. habitat 'likely' to support the species).

As the survey site is located on the edge of town, there is a high level of people utilising the area for recreational activities and as an itinerant camping site. To reduce interference and theft of camera traps the number of cameras was increased to reduce the length of survey required. Cameras and bait stations were checked daily.

Camera installation was based on Gillespie et al. (2015), with reference to Meek and Fleming (2014). It involved attaching the camera to a tree and directing it at a bait canister containing rolled oats, peanut butter and honey at a distance of between 1.5 to 2.5 m. The field of view was cleared of small plants and debris that may result in 'false triggers'. The cameras used were KeepGuard KG690 digital cameras which are equipped with motion detection and infra-red flash (applicable for dark environments and at night). Cameras were set to record continually (day and night), to the highest sensitivity setting and to take three photographs (with 1 second interval) per trigger, with a 10 second interval between triggers. After the 4 nights in the field, all camera trap images were reviewed to determine if Black-footed Tree-rats had been detected.

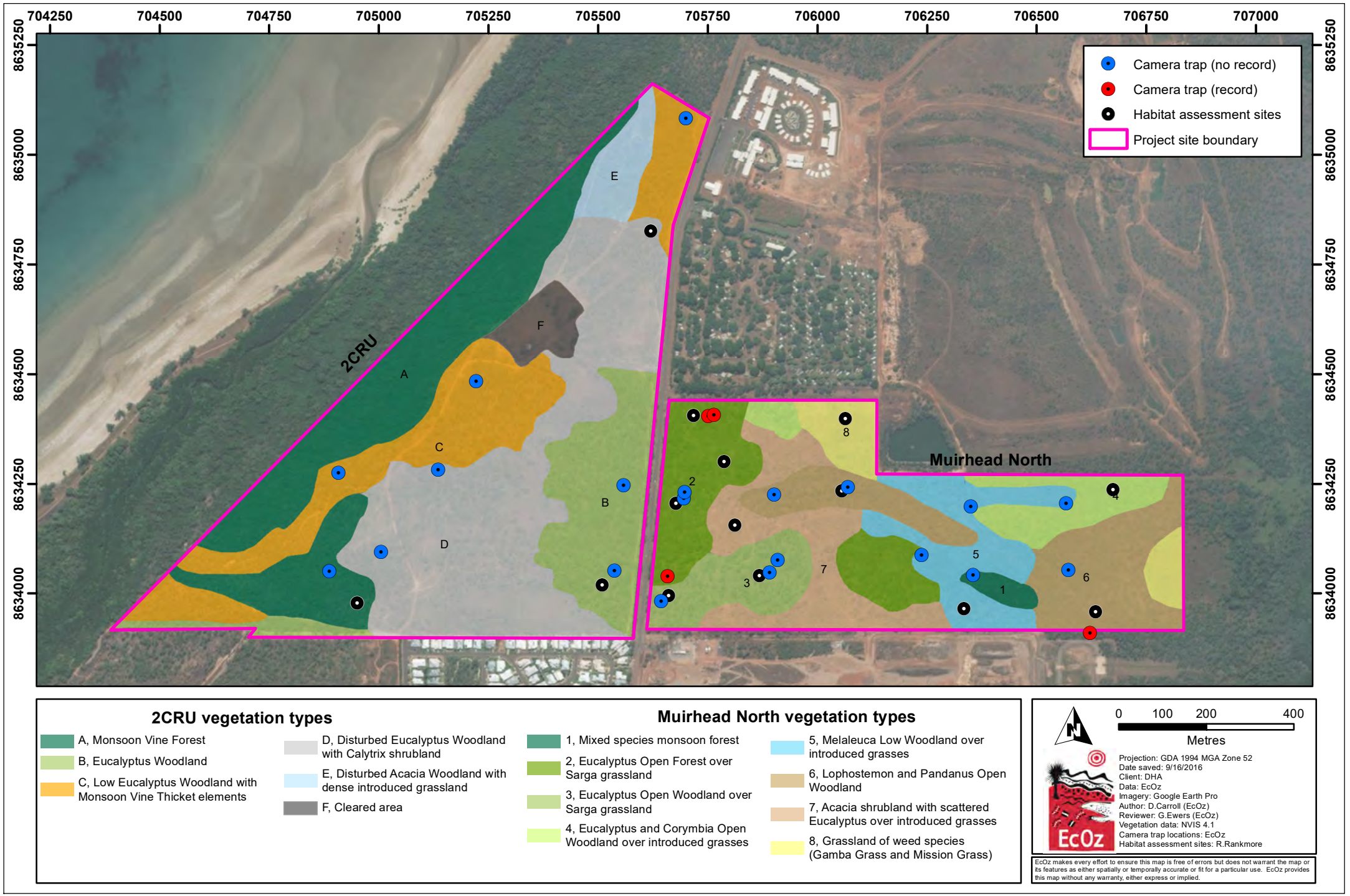
Cameras were predominantly located in areas that were considered likely habitat for Black-footed Tree-rats (abundance of mid-storey fruiting trees, and/or large hollows in *Eucalyptus tetrodonta* and *E. miniata*) and were also located to give a spread across the project area. At four sites – located in the highest quality habitat – two cameras were set up per site to maximise detectability.

Twenty-four cameras – 8 in 2CRU and 16 in Muirhead North – were installed across 20 sites (see

Figure 2). Cameras were set to capture footage over a 4 day/night period. This totals 32 camera trap days for 2CRU and 64 camera trap days for Muirhead North. This is in line with the abovementioned DLRM interim requirement of 1 camera installed for 4 weeks (i.e. 28 camera trap days) per 20 ha of likely habitat, which can be adjusted for the purposes of this assessment to 4 camera trap days per 3 hectares of likely habitat. The camera trapping regime undertaken for 2CRU and Muirhead North exceeds the minimum NT Government interim survey requirements for Black-footed Tree-rat. At Muirhead North survey effort was 80 camera trap days across 28 hectares of likely habitat, adjusted to approximately 8 camera days per 3 hectares of likely habitat. At 2CRU, four cameras were located in likely habitat covering in area of approximately 12 hectares, resulting in 16 camera trap days or 4 camera trap days per 3 hectares of good quality habitat. The remaining four cameras at 2CRU were located in areas of poorer quality habitat to ensure there was adequate coverage across the site.

Table 1. Comparing implemented survey program against recommended guidelines

	Survey guidelines	2CRU	Muirhead North
Target	28 camera trap days per 20 hectares of good quality habitat.	28 camera trap days per 20 hectares of good quality habitat.	28 camera trap days per 20 hectares of good quality habitat.
Targeted (adjusted to four day survey program)	4 camera trap days per 3 hectares of good quality habitat	4 camera trap days per 3 hectares of good quality habitat	4 camera trap days per 3 hectares of good quality habitat
Achieved	N/A	80 camera trap days across 28 hectares of good quality habitat.	16 camera trap days across 12 hectares of good quality habitat.
Achieved (adjusted to target)	N/A	8 camera trap days per 3 hectares of good quality habitat.	4 camera trap days per 3 hectares of good quality habitat.
Meets or exceeds survey guidelines		Yes. Exceeds the minimum survey effort stipulated in the recommended survey guidelines by double.	Yes. Meets the minimum survey effort stipulated in the recommended survey guidelines.



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ16063 - Muirhead 2CRU EIS\01 Project Files\Figure 2. Vegetation map and survey sites.mxd

Figure 2. Map of the location of Black-footed Tree-rat camera and habitat assessment survey sites

3 Results

3.1 Habitat quality categorisation

Habitat quality for Black-footed Tree-rats was assessed across the sites, looking at the availability of denning resources, food resources and groundcover (which influences the sub-species' mobility) (see Table 3). A selection of habitat photographs from the project area is provided in Appendix 2. Each site was ranked out of a total score of three, with the highest quality habitat onsite receiving a score of three and the poorest quality habitat a score of zero. To receive a habitat quality score of three the site had to have many large trees with hollows present and/or the presence of pandanus, known food plants present at the site, and lower levels of ground cover and limited invasion by grassy weeds. Having ranked the sites, a map of the quality of habitat across 2CRU and Muirhead North was produced (see Figure 3).

Areas of higher quality habitat are those that rank 5 and above. For 2CRU and Muirhead North, there is 13 ha and 17.5 ha, respectively, of higher quality habitat.

While ranking the sites provides information on the distribution and quality of habitat available within the 2CRU and Muirhead North locations it does not inform how the habitat compares in a broader context. Using expert knowledge of Black-footed Tree-rat habitat requirements, the author developed habitat quality categories using a scale of one to ten (with ten the highest quality) (see Table 2). The habitat at 2CRU and Muirhead North was then compared against the broader habitat quality categories, with the highest quality on-site habitat receiving a category score of seven.

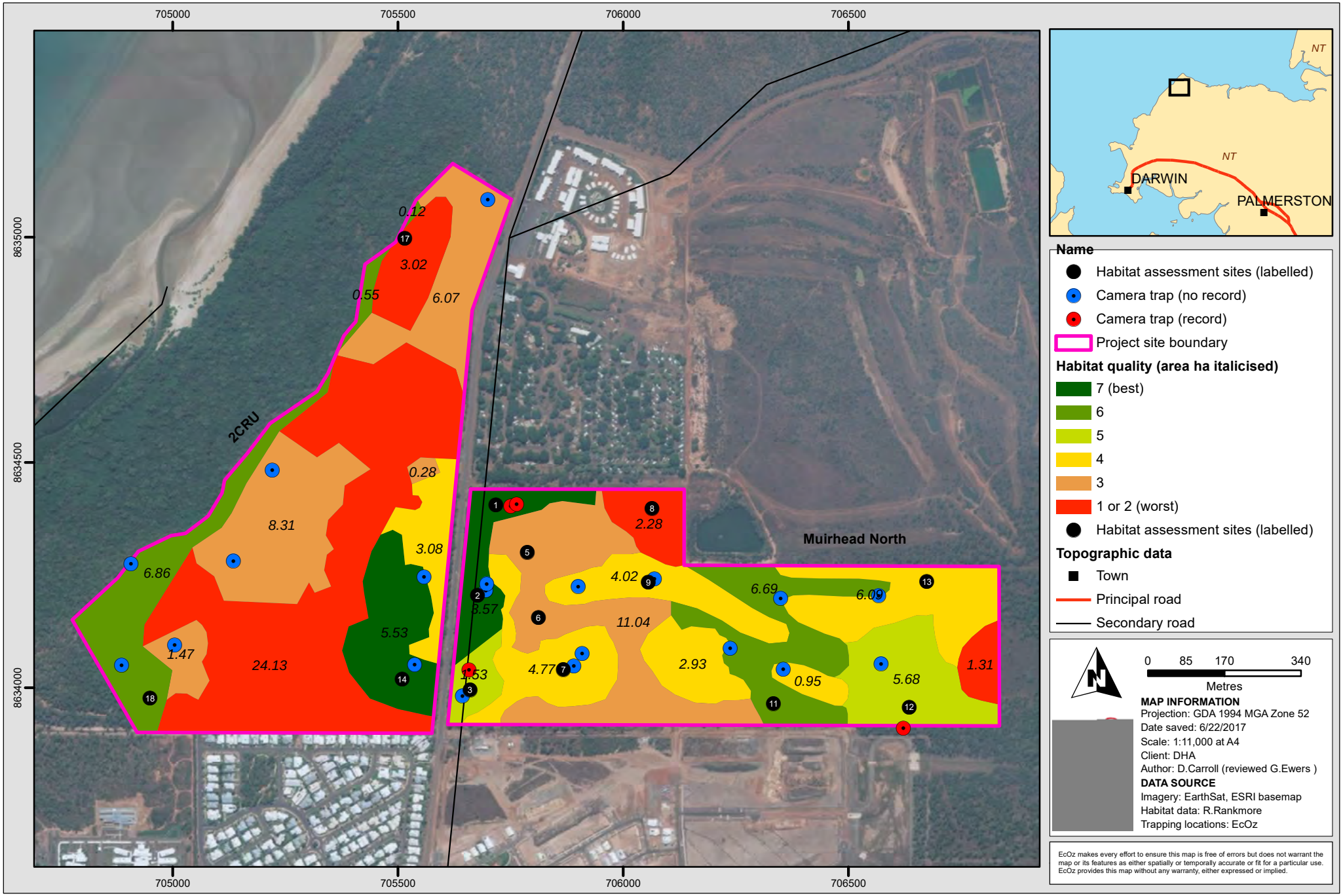
Table 2. Categorisation of Black-footed Tree-rat habitat quality

Category	Description
10	Long unburnt with a HIGH number of large DBH trees, abundant hollows, well developed and diverse mid-storey of fruiting species, sparse mixed grass understorey.
9	Long unburnt with a HIGH number of large DBH trees, hollows present, well developed and diverse mid-storey of fruiting species, patchy mixed grass understorey.
8	Infrequently burnt with large DBH trees, hollows present, well developed and mid-storey of fruiting species, patchy grass understorey.
7	Approx. 3-5 year burn cycles with large DBH trees, hollows present, mid-storey with fruiting species present, patchy grass understorey.
6	Approx. 2-4 year burn cycles with SOME large DBH trees and hollows or pandanus present, mid-storey with fruiting species present, patchy grass understorey.
5	Frequently burnt with SOME large DBH trees and hollows or pandanus present, mid-storey with SOME fruiting species present, sorghum dominated grass understorey.
4	Frequently burnt with FEW large DBH trees and hollows or pandanus present, little to no mid-storey, sorghum dominated grass understorey.
3	Frequently burnt with FEW large DBH trees and hollows or pandanus present, little to no mid-storey, sorghum dominated grass understorey with grassy weeds present.
2	Frequently burnt with NO large DBH trees, NO mid-storey, grassy weed dominated understorey.
1	Open grassland

Table 3. Black-footed Tree-rat habitat quality assessment

Site†	Denning habitat			Food	Mobility		Rank	Quality score**	Description
	# trees >50 cm DBH	# hollows	Pandanus	Food plants	Ground cover*	Grassy weeds*			
M01	13	3	No	Yes	44	9	**3.00**	7	Many large trees, hollows, food, high mobility, low Gamba Grass
M02	3	3	Yes	Yes	71	1	**2.75**	7	Some large trees, hollows, food, high mobility, low Gamba Grass
M14	3	3	Yes	Yes	61	21	**2.75**	7	Some large trees, hollows, food, high mobility, low Gamba Grass
M18	2	2	Yes	Yes	burnt	burnt	**2.50**	6	Few large trees, hollows, food, mobility, low evidence of Gamba Grass
M11	2	2	Yes	Yes	74	51	**2.25**	6	Few large trees, hollows, food, moderate mobility, moderate Gamba Grass
M12	0	0	Yes	Yes	57	31	**2.00**	5	No large trees but pandanus, no hollows, food, mobility, moderate Gamba Grass
M03	1	0	No	Yes	63	5	**2.00**	5	Few large trees, no hollows, food, mobility, low Gamba Grass
M09	0	0	Yes	Yes	88	49	**1.75**	4	No large trees but pandanus, no hollows, food, reduced mobility, moderately high Gamba Grass
M07	0	0	Yes	Yes	91	59	**1.50**	4	No large trees but pandanus, no hollows, food, low mobility, moderately high Gamba Grass
M13	0	0	No	Yes	69	36	**1.25**	4	No roosting sites, food, moderate mobility, moderate Gamba Grass
M05	2	1	No	No	90	61	**1.00**	3	Few large trees, limited hollows, no food, low mobility, high Gamba Grass cover
M06	0	0	No	No	91	8	**0.50**	3	A large tree, no pandanus, no hollows, no food, low mobility, moderate Gamba Grass
M08	1	0	No	No	100	100	**0.25**	2	No large trees, no pandanus, no hollows, no food, limited mobility, total Gamba Grass cover
M17	0	0	No	No	100	100	**0.00**	1	No large trees, no pandanus, no hollows, no food, limited mobility, total Gamba Grass cover

*† There was no assessment undertaken at sites M04, M10, M15 or M16; * Points along the 100 m transect; ** See Table 2*



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ16063 - Muirhead 2CRU EIS\01 Project Files\Figure 3. Habitat quality assessment.mxd

Figure 3. Map showing the results of the habitat quality assessment

3.2 Camera surveillance survey

Black-footed Tree-rats were detected at three sites on four cameras (Figure 2). A selection of photographs from the surveillance survey is provided in Appendix 1. Other species detected on the camera were Common Brush-tailed Possum (northern) (*Trichosurus vulpecula arnhemensis*), Northern Brown Bandicoot *Isoodon macrourus*, Agile Wallaby (*Macropus agilis*), Dog (*Canis familiaris*) and Orange-footed Scrub-fowl (*Megapodius reinwardt*).

Both the 2CRU and Muirhead North have experienced past disturbance and have varying levels of grassy weed invasion, particularly Gamba Grass (*Andropogon gayanus*). Black-footed Tree-rats was detected on five cameras within two small areas of high quality habitat, where Gamba Grass was uncommon. During surveys, there were no additional signs of Black-footed Tree-rats at any of the sites (e.g. chewed pandanus fruit).

4 Likely presence and distribution

4.1 Previous studies

A review of previous studies undertaken in the Lee Point area has been completed to validate the findings of the targeted survey, and to inform the presence of Black-footed Tree-rat in adjoining areas.

Table 4 below summarises the Black-footed Tree-rat surveys reviewed with further discussion in the sections that follow.

Table 4. Summary of previous Black-footed Tree-rat studies in the Lee Point area.

Study	Date	Location	Method	Findings
Griffiths et al. (2002)	May – August 2000	2CRU site and adjoining Lyons site (prior to residential development)	Radio-tracking of three captured Black-footed Tree-rat for approximately four months.	Black-footed Tree-rat showed high affinity to den trees. Two radio-tracked animals were recorded almost exclusively in the Casuarina Coastal Reserve. Third animal remained in woodland north of hospital. Only 6/92 recordings of Black-footed Tree-rat were within area of 2CRU proposed to be developed.
Rankmore et al. (2001)	19-23 March 2001	2CRU site and adjoining Lyons site (prior to residential development)	25 Elliot traps and 1 Tomahawk Cage Trap across seven quadrats for five days/nights.	Species recorded in two quadrats along northern boundary of current Lyons site. Species not recorded in quadrats located in 2CRU site.
Stokeld and Gillespie (2015)	January – March 2014	In woodland in the Casuarina Coastal Reserve directly south of Sandy Creek (approx. 1 kilometre south-west of the 2CRU southern boundary) In woodland north of Buffalo Creek Road (approx. 1 kilometre north of the Muirhead North site)	25 Elliot traps and 4 cage traps at each site for four nights/days. Five camera traps at each site for four weeks.	Black-footed Tree-rat recorded using camera traps at Buffalo Creek site at frequency of 3 captures every 100 days. Species not captured at same site using live trapping. Black-footed Tree-rat not recorded at Sandy Creek site using either method.
Charles Darwin University (ongoing)	October 2016	In woodland adjoining the Charles Darwin University (approx. 2.6 km south-west of the 2CRU southern boundary)	8 cage and 16 Elliot traps for 3 days, 5 camera traps for 5 days.	Black-footed Tree-rat recorded using both live trapping and camera-trapping.
EcOz Environmental Services (2008)	8-11 December 2008	In Muirhead North and adjoining Breezes site (prior to development)	25 Elliot traps and 4 cage traps at each site.	No Black-footed Tree-rat recorded.

Black-footed Tree-rat was recorded within the 2CRU site by Griffiths et al. (2002) as part of a radio-tracking study investigating the day-time tree-use and activity area of the species. However, their study – which was completed in 2000 – found that the three individuals monitored preferred nesting sites adjoining 2CRU site (namely the current Lyons site, north of Royal Darwin Hospital and the Casuarina Coastal Reserve) than within 2CRU itself. Furthermore, two of the three individuals showed a high fidelity to the same nesting trees. Of the 92 observations made for the three Black-footed Tree-rat monitored, only six were in the 2CRU site proposed to be developed, all of which were at different locations suggesting the use of tree nests was opportunistic.

Another Black-footed Tree-rat study covering a similar study area was conducted approximately twelve months later by Rankmore et al. (2001). This study used live-trapping techniques over a five day/night period in March 2001, with five quadrats located in the current Lyons development site (pre development) and two quadrats located in the 2CRU site in close proximity to the records of Griffiths et al. (2002). One of the quadrats was located in the area near Lee Point Road that has the highest quality Black-footed Tree-rat habitat on 2CRU (see Figure 3). Black-footed Tree-rat was recorded repeatedly by Rankmore et al. (2002) at two quadrats in the north of the Lyons site along the boundary with 2CRU. One of the sites has subsequently been cleared and the other site is now surrounded by houses. No Black-footed Tree-rats were recorded in the 2CRU quadrats.

Separate to the camera trapping study undertaken as part of this study, there have been no other Black-footed Tree-rat surveys within the 2CRU site. The small mammal study by Stokeld and Gillespie (2015) included a study site approximately one kilometre south-west of 2CRU in the woodland forming part of the Casuarina Coastal Reserve. A combination of live trapping and cage-trapping methods were employed, but no Black-footed Tree-rats were recorded. Charles Darwin University conduct periodic monitoring of a woodland site approximately 2.6 kilometres south-west of 2CRU, and recorded Black-footed Tree-rat in October 2016.

Mammal trapping was undertaken at the Muirhead North site and adjoining Breezes site (prior to development) by EcOz Environmental Services (2008). The study employed the same live trapping methods used by Rankmore et al. (2001) and Stokeld and Gillespie (2015) over four day/nights. No Black-footed Tree-rats were recorded at Muirhead North or the Breezes site. Black-footed Tree-rat was recorded approximately 1 kilometre north of the Muirhead North in woodland near the Buffalo Creek ramp by Stokeld and Gillespie (2015). The species was detected at a frequency of 3/100 camera days, but was not recorded using live-trapping methods.

4.2 Likelihood of presence

Based on the results of the camera trap surveys completed across 2CRU and Muirhead North, and a review of previous studies, the species is considered to be present at Muirhead North and unlikely to be present at 2CRU. There is a low-medium potential for the species to be found in the areas of the 2CRU site to be retained as part of the conservation reserve.

Habitat within the 2CRU site is mostly unsuitable for Black-footed Tree-rat. Approximately 43 hectares of the 59 hectares of 2CRU to be removed was assessed as having a habitat-quality score of ≤ 3/10. These areas do not contain any large trees suitable for nesting, and the ground-layer is dominated by grassy weeds, namely Gamba Grass. Only a 5.5 hectare path along the boundary with Lee Point Road was found to have multiple large trees with hollows (habitat quality score = 7/10), while the remaining 10.5 hectares had infrequent large trees and a patchy understorey dominated by grass (habitat quality score = 4-6/10).

As shown by Griffiths et al. (2002), Black-footed Tree-rat shows a high fidelity to nesting trees. It is therefore unlikely that the species would move across from the Muirhead North site to utilise nesting trees in the 5.5 hectare path of good quality habitat in 2CRU. Regular traffic along Lee Point Road is also likely to be a deterrent for the species crossing from one site to the other. Furthermore, the live trapping study by Rankmore et al. (2001) included a quadrat located within the 5.5 hectare patch at 2CRU and the species was not recorded. While camera-trapping has been shown to have higher rates of detection than live trapping (i.e. Stokeld and Gillespie 2015), Rankmore et al. (2001) was still able to detect Black-footed Tree-rat frequently in quadrats in the adjoining Lyons site.

While development in the Lee Point area over the past fifteen years – including housing development and improved visitor facilities along the Casuarina Coastal Reserve – would have contributed to the decline of Black-footed Tree-rat in the region due to habitat loss and fragmentation, it is unlikely that the species would have depended upon 2CRU since the site was established as a Defence base. Over this time the site has been cleared and burnt, and the ground-layer significantly disturbed. While there has been regrowth of overstorey species, the majority of trees do not contain hollows and the ground-layer is dominated by exotic grasses and devoid of Black-footed Tree-rat's preferred edible fruiting plants. The findings of Griffith's et al. (2002) support this claim, with radio-tracking showing the species' movements are concentrated around the periphery of 2CRU in the Casuarina Coastal Reserve, Royal Darwin Hospital and the site which is now the Lyons development.

Finally, the results of the camera-trapping in 2CRU which were undertaken in accordance with the required survey guidelines support the conclusion that Black-footed Tree-rat is unlikely to occur within the areas of 2CRU to be developed.

4.3 Area of occupancy

Black-footed Tree-rat was recorded on five separate camera traps at Muirhead North located within areas where the habitat quality score was ≥ 5/10. Approximately 13 hectares of Muirhead North has a habitat quality score of ≥ 5/10 and this is where the species is likely to occur. It is likely that the species would be found in areas of poorer quality habitat in Muirhead North, but only when dispersing between areas of better quality habitat, and it is unlikely the species would be dependent upon such areas for food or nesting. The species may also move between Muirhead North and good quality eucalypt woodland located to the east of the site. There is also contiguous habitat for Black-footed Tree-rap between Muirhead North, behind the Lee Point Village Resort, and near Buffalo Creek Boat Ramp where the species was detected by Stokeld and Gillespie (2015).

5 References

Friend, G.R. and Taylor, J.A. (1985). Habitat preferences of small mammals in tropical open-forest of the Northern Territory. *Australian Journal of Ecology*. **10**: 173-185.

Friend G, (1987), Population ecology of Mesembriomys gouldii, Australian Mammalogy, 23:181-183.
Gibbons, P. and Lindenmayer, B.D. (2002). *Tree Hollows and Wildlife Conservation in Australia.* CSIRO Publishing, Australia.

Gillespie G, Gentles T, Hill B, Low Choy J, Mahney T, Stevens A and Stokeld D, (2015), *A guide for the use of remote cameras for wildlife surveillance in Northern Australia*, Prepared by the Flora and Fauna Division of the Dept. Land Resource Management, Northern Territory Government.

Griffiths A, Koenig J, Carrol F and Price O, (2002), Activity area and day-time tree use of the Black-footed Tree-Rat Mesembriomys gouldii, *Australian Mammalogy*, 23:181-183.

Meek P and Flemming P (eds.), (2014), Camera Trapping: Wildlife Management and Research, CSIRO Publishing.

Pittman, G.W. (2003). *Occurence and use of tree hollows by mammals in fragmented and continuous savanna woodlands in Northern Australia.* Honours thesis, Faculty of Education, Health and Science, Northern Territory University, Darwin.

Price, O. Rankmore, B.R., Milne, D., Brock, C., Tynan, C., Kean, L., Roager, L., (2005). Regional patterns of mammal abundance and their relationship to landscape variables in eucalypt woodlands near Darwin, northern Australia *Wildlife Research* 32, 435-446.

Rankmore, B.R. (2006). *Impacts of habitat fragmentation on the vertebrate fauna of the tropical savannas of northern Australia; with special reference to medium-sized mammals*. PhD Thesis. School of Environmental Research, Charles Darwin University, Darwin, Northern Territory.

Rankmore B and Friend G, (2008), Black-footed Tree-rat Mesembriomys gouldii, *The Mammals of Australia*, S Van Dyck & R Strahan (eds.), 3rd Edition, Reed New Holland, Sydney, NSW, Australia.

Stokeld D and Gillespie G, (2015), *Assessment of Small Mammal Fauna of the Darwin Area*, prepared by the Flora and Fauna Division (Department of Land Resource Management) and NERP Northern Australia Hub.

Williams, R.J., Cook, G.D., Gill, A.M. and Moore, P.H.R. (1999). Fire regime, fire intensity and tree survival in a tropical savanna in northern Australia. *Australian Journal of Ecology*. **24**: 50-59.

Woinarski, J.C.Z., Milne, D.J.,and Wanganeen, G. (2001). Changes in mammal populations in relatively intact landscapes of Kakadu National Park, Northern Territory, Australia. Austral Ecology 26, 360-370.

Woinarski, J.C.Z. (2004). The forest fauna of the Northern Territory: knowledge, conservation and management. In *Conservation of Australia's Forest Fauna,* ed. D. Lunney, Zoological Society of NSW, Mossman.

Woinarski, J.C.Z., Armostrong, M., Brennan, K., Fisher, A., Griffiths, A.D., Hill, B., Milne, D.J., Palmer, C., Ward, S., Watson, M., Winderlich, S., and Young, S. (2010). Monitoring indicates rapid and sever decline of native mammals in Kakadu National Park, northern Australia. *Wildlife Research* 37, 116-126.

Ziembicki, M. R. Woinarski, J.C.Z., and Mackey, B. (2013). Evaluating the status of species using indigenous knowledge: novel evidence for major native mammal declines in northern Australia. *Biological Conservation* 157, 78-92.

Appendix A Camera trap images of Black-footed Tree-Rats

KeepGuard ECOZ 11
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12-07-2016 01:09:56

Appendix B Photos taken at sites surveyed for habitat quality

Habitat at Site M1

Habitat at Site M2

Habitat at Site M3

Habitat at Site M5

Habitat at Site M8

Habitat at Site M12

Habitat at Site M13

Habitat at Site M14

Habitat at Site M17

Habitat at Site M18

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APPENDIX N

Migratory Shorebird report

Report on potential impacts from disturbance to migratory shorebirds in Darwin:

Defence Housing Australia – Lee Point Master-planned Urban Development

January 2017

Report to EcOz Environmental Consultants

Amanda Lilleyman
Consultant Ornithologist

Report on potential impacts from disturbance to migratory shorebirds in Darwin: Defence Housing Australia – Lee Point Master-planned Urban Development

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EXECUTIVE SUMMARY

The Defence Housing Australia (DHA) Lee Point Master-planned Urban Development has the potential to impact migratory shorebirds through increased human access to the important roosting and feeding site Sandy Creek, on the northern beaches of Darwin, Northern Territory. There is the possibility that impacts of increased anthropogenic disturbance (due to a significant increase in the number of beach users) from this housing development will be significant and potentially harm the population of migratory shorebirds. This site is classified as nationally important and supports populations of migratory shorebirds listed under the *Environment Protection and Biodiversity Conservation Act 1999*. It also supports internationally important numbers of the Critically Endangered Great Knot.

This report provides information on the importance of habitat used by migratory shorebirds in Darwin and the numbers of birds and species present in the region. Ways to mitigate potential impacts are suggested, along with management recommendations. These recommendations include a monthly monitoring program conducted in the austral summer months when birds are present; community engagement activities; information about migratory shorebirds on community notice boards; and educational signs along boardwalks and at each beach entry access path.

While the proposed housing development will not lead to a direct loss of habitat for shorebirds, the proponent should consider that this development activity will have other negative effects on the shorebird population, and these combined with past and future habitat loss in the greater Darwin region will work synergistically to deplete the quality of habitat for shorebirds. Given the rapid decline in populations of migratory shorebirds that visit Australia, it is essential that all important non-breeding sites are protected to conserve shorebirds. If these significant impacts remain unchecked, there is grave concern that the impacts of increased visitation to beaches from the DHA housing development will only exacerbate the decline of species.

CONTENTS

EXECUTIVE SUMMARY 1

1. Introduction 3

1.1. Migratory shorebird ecology 3

1.2. Threats to migratory shorebirds 4

1.3. Global and national protection of migratory shorebirds 5

1.4. Criteria for listing internationally and nationally important habitat for migratory shorebirds 5

1.5. Migratory shorebirds and listed Threatened species 6

2. Migratory shorebirds in the Darwin region 10

2.1. Habitat choice and site availability 10

2.2. Importance of the northern beaches of Darwin for migratory shorebirds 13

2.3. Disturbance to shorebirds in Darwin 18

3. Migratory shorebird management 19

3.1 Impact mitigation – disturbance 19

3.2 Impact mitigation – community education 22

4. Monitoring program 23

4.1. Methodology 26

4.2. Triggers and responses to trigger exceedances 29

5. Recommendations and conclusions 31

References 33

Appendices 35

1. Introduction

1.1. Migratory shorebird ecology

Most shorebirds in Australia are long-distance migrants that breed in the northern hemisphere and visit Australian shores in their thousands in the austral summer. Their annual migration is determined by the phenology of food availability, reproduction and individual survival. Australia is part of the East Asian-Australasian Flyway (EAAF) for migratory shorebirds (**Figure 1**). On arrival in Australia, shorebirds spend the duration of the austral summer seeking out high-quality food resources on the intertidal zone of coastlines. Tidal cycles dictate foraging and roosting times for most coastal shorebirds that feed on benthic macroinvertebrates on exposed mudflats during low tide. At high tide, when the foraging grounds are submerged, shorebirds retreat to roosts on sandy beaches, mangroves, rocky reefs and ponds, where they typically rest. Roost sites are usually selected for their proximity to feeding grounds to allow for a short commute time, good visibility of potential predators, for thermoneutrality (shallow water to help cool birds down in tropical environments), tide height, and disturbance levels (Rogers *et al.* 2006; Rosa *et al.* 2006; Zharikov and Milton 2009).

Figure 1. The East Asian-Australasian Flyway for migratory shorebirds. Image credit: http://www.roebuckbay.org.au/our-bay/migratory-shorebirds/

Migratory shorebirds use a network of sites in a region for roosting and feeding. Several feeding sites are used to ensure that there is always one available site that the birds can forage at but shorebirds also need available roosting sites above the high tide mark. However, optimising the use of several sites in a region requires that birds monitor conditions at these sites sufficiently to be able to make economic foraging decisions. Conditions are not always ideal and disturbances to shorebirds force birds away from optimal habitat. If shorebirds are disturbed at a site and forced to depart they will travel to a nearby site, but if the refuge site is not available then birds would have to find sub-par habitat, thus increasing energy costs. Foraging theories suggest that shorebirds can learn where good foraging patches are; therefore birds will feed and roost at the best site/s available to them (Charnov 1976). The time spent travelling between feeding sites affects the average rate of capture of prey and thus affects the duration of foraging at a site before the rate of return drops below the average for the environment. If the birds forage at sites close to their roost the costs of commuting are reduced and the deficit can be recouped over a shorter foraging period. Thus, according to the theory, foraging sites close to roost sites should be preferred over sites that are further away if foraging success rates are the same.

1.2. Threats to migratory shorebirds

Migratory shorebirds are a highly threatened group of birds. In the East Asian-Australasian Flyway these birds are rapidly declining due to the loss of intertidal habitat through reclamation development projects in the Yellow Sea region (MacKinnon *et al.* 2012; Moores *et al.* 2016; Murray *et al.* 2014). They also face other threats such as hunting, impacts from climate change and sea-level rise, pollution, and disturbance (Harding *et al.* 2007). In Australia, the key threats to migratory shorebirds are coastal development that destroys habitat, and disturbance that disrupts their normal activities (Harding *et al.* 2007). The proposed development will not impact migratory shorebirds through a loss of habitat, thus the focus in this report will be on the potential impacts to shorebirds from disturbance. Disturbance to shorebirds normally occurs where humans and wildlife co-occur – on beaches shorebirds face anthropogenic disturbances in the form of pedestrian walkers, dogs, fishermen, kite-surfers, boats, low-flying aircraft and skydivers. Natural disturbances are usually by birds of prey flying over flocks of birds.

Disturbance is a recognised threat to shorebirds worldwide (Kirby *et al.* 1993; Rogers *et al.* 2006; Rosa *et al.* 2006). As disturbance can cause shorebirds to depart sites, there is a need for a network of sites that are connected and maintained as suitable habitat for shorebirds. Disturbance to shorebirds can have negative effects and mitigation measures should be considered in the management and conservation of these birds (Lilleyman *et al.* 2016). While disturbances to shorebirds may be short in duration compared to long-distance migration flights, the cumulative effect of daily disturbances has the potential to reduce energy reserves to levels below the threshold that can be replenished daily (Rehfisch *et al.* 1996). Chronic disturbance to shorebirds could be unsustainable and may lead to birds abandoning staging sites that have high rates of disturbance (Lilleyman *et al.* 2016) (refer to **Section 2.3** for more detail).

1.3. Global and national protection of migratory shorebirds

Australia has agreed to protect and conserve migratory shorebirds under several international conservation agreements; the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention), Japan-Australia Migratory Bird Agreement (JAMBA), China-Australia Migratory Bird Agreement (CAMBA) and Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA). These agreements recognise the need to protect shorebirds by cooperating across jurisdictions. Australia has obligations to protect migratory shorebird habitat and maintain sustainable populations when birds are in Australia (Department of the Environment Water Heritage and the Arts 2009). As a consequence of being a signatory to these conventions, migratory shorebirds are classified as **Matters of National Environmental Significance** and are protected under the highest level of national conservation legislation, the Environmental Protection and Biodiversity Conservation Act 1999 (**Table 1**). The EPBC Act "*provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places*" (Department of the Environment 2013). The EPBC Act is the key mechanism for meeting Australia's responsibilities under these agreements. In addition to the EPBC Act, all states and territories have legislation that protects biodiversity and native species (Department of the Environment Water Heritage and the Arts 2009).

Planning for development in Darwin Harbour should be consistent with international agreements and commonwealth legislation.

1.4. Criteria for listing internationally and nationally important habitat for migratory shorebirds

Criteria exist for assessing significant impacts on populations of migratory shorebirds. Proposals that potentially impact migratory shorebirds that are listed under the EPBC Act 1999 need to be assessed according to criteria listed in Commonwealth of Australia (2015a): Internationally important habitat for migratory shorebirds is recognised if the habitat supports at least:

- 1 per cent of the individuals in a population of one species or subspecies of waterbird, or
- A total abundance of at least 20000 waterbirds.

Nationally important habitat for migratory shorebirds is recognised if the habitat supports at least:

- 0.1 per cent of the flyway population of a single species
- 2000 migratory shorebirds, or
- 15 shorebird species.

1.5. Migratory shorebirds and listed Threatened species

Every year, 37 species of migratory shorebird visit Australia, those species are listed in **Table 1**. The EPBC Act listed threatened species considered in this report and their conservation statuses are described in **Table 2**.

Table 1. Conservation status and listing for 37 species of migratory shorebirds in the East Asian-Australasian Flyway. Taxonomy and species order follows Christidis and Boles (2008). *LC = Least Concern; NT = Near Threatened; VU = Vulnerable; EN = Endangered; CR = Critically Endangered. TPWC = Territory Parks and Wildlife Conservation Act.*

Shorebird	Scientific name	EPBC Act	EPBC Mig sp list	TPWC Act	In Darwin Harbour
Pacific Golden Plover	*Pluvialis fulva*	-	protected	-	yes
Grey Plover	*Pluvialis squatarola*	-	protected	-	yes
Little Ringed Plover	*Charadrius dubius*	-	protected	-	yes
Double-banded Plover	*Charadrius bicinctus*	-	protected	-	-
Lesser Sand Plover	*Charadrius mongolus*	EN	protected	VU	yes
Greater Sand Plover	*Charadrius leschenaulltii*	VU	protected	VU	yes
Oriental Plover	*Charadrius veredus*	-	protected	-	yes
Latham's Snipe	*Gallinago hardwickii*	-	protected	-	-
Pin-tailed Snipe	*Gallinago stenura*	-	protected	-	-
Swinhoe's Snipe	*Gallinago megala*	-	protected	-	-
Black-tailed Godwit	*Limosa limosa*	-	protected	-	yes
Bar-tailed Godwit (Northern Siberian)	*Limosa lapponica menzbieri*	CR	protected	VU	yes
Bar-tailed Godwit (Western Alaskan)	*Limosa lapponica baueri*	VU	protected	VU	probable
Little Curlew	*Numenius minutus*	-	protected	-	yes
Whimbrel	*Numenius phaeopus*	-	protected	-	yes
Eastern Curlew	*Numenius madagascariensis*	CR	protected	VU	yes
Terek Sandpiper	*Xenus cinereus*	-	protected	-	yes
Common Sandpiper	*Actitus hypoleucos*	-	protected	-	yes
Grey-tailed Tattler	*Tringa brevipes*	-	protected	-	yes
Wandering Tattler	*Heteroscelus incanus*	-	protected	-	-
Common Greenshank	*Tringa nebularia*	-	protected	-	yes
Marsh Sandpiper	*Tringa stagnatilis*	-	protected	-	yes
Common Redshank	*Tringa totanus*	-	protected	-	-
Wood Sandpiper	*Tringa glareola*	-	protected	-	yes
Ruddy Turnstone	*Arenaria interpres*	-	protected	-	yes

Shorebird	Scientific name	EPBC Act	EPBC Mig sp list	TPWC Act	In Darwin Harbour
Asian Dowitcher	*Limnodromus semipalmatus*	-	protected	VU	yes
Great Knot	*Calidris tenuirostris*	CR	protected	VU	yes
Red Knot	*Calidris canutus*	EN	protected	VU	yes
Sanderling	*Calidris alba*	-	protected	-	yes
Red-necked Stint	*Calidris ruficollis*	-	protected	-	yes
Long-toed Stint	*Calidris subminuta*	-	protected	-	-
Pectoral Sandpiper	*Calidris melanotos*	-	protected	-	-
Sharp-tailed Sandpiper	*Calidris acuminata*	-	protected	-	yes
Curlew Sandpiper	*Calidris ferruginea*	CR	protected	VU	yes
Broad-billed Sandpiper	*Calidris falcinellus*	-	protected	-	-
Ruff	*Philomachus pugnax*	-	protected	-	-
Red-necked Phalarope	*Phalaropus lobatus*	-	protected	-	-
Oriental Pratincole	*Glareola maldivarum*	-	protected	-	-

Table 2. EPBC Act listed threatened species of migratory shorebird, their conservation status, habitat and distribution.

Threatened Species	EPBC Status	TPWC Status	Habitat & Distribution
Charadrius leschenaultii **Greater Sand Plover**	VU	VU	**Habitat:** Inhabits coasts and estuaries with intertidal sand and mudflats as well as nearby beaches, rocky shores, salt lakes, brackish swamps and shallow freshwater wetlands (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide. **Distribution:** Widespread around the Australian coast, less common in the south and inland. In the NT, It has been recorded from most of the coastline (Chatto 2003).
Charadrius mongolus **Lesser Sand Plover**	EN	VU	**Habitat:** Coastal littoral and estuarine, especially large intertidal sandflats or mudflats in sheltered bays, harbours and estuaries, and occasionally sandy ocean beaches, coral reefs, wave-cut rock platforms and rocky outcrops (Marchant and Higgins 1993). Sometimes occurs in short saltmarsh or among mangroves. Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide. **Distribution:** Widespread around the northern Australian coast, less common in the south and inland.
Limosa lapponica **Bar-tailed Godwit**	CR (*menzbieri*) VU (*baueri*)	VU	**Habitat:** Inhabits coasts and estuaries, especially intertidal sandflats and mudflats, and coastal lagoons. Also occurs in saltlakes and brackish wetlands near coasts, sandy ocean beaches, rock platforms, and coral reef-flats (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide. **Distribution:** Widespread around the Australian coast. In the NT they have been reported all along the coastline and were one of the more frequently recorded and abundant species in shorebird surveys by Chatto (2003).
Numenius madagascariensis **Eastern Curlew**	CR	VU	**Habitat:** Inhabits coasts and estuaries, as well as mangroves. Also occurs in saltlakes and brackish wetlands near coasts. Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide (Higgins and Davies 1996). **Distribution:** Widespread in small numbers around the Australian coast. Chatto (2003) considered the more important areas in the NT for the species to be along the coast either side of Darwin, the Millingimbi to Buckingham Bay area, the Roper and Limmen Bight River mouths, and the Port McArthur area.
Limnodromus semipalmatus **Asian Dowitcher**	-	VU	**Habitat:** Occurs in sheltered coastal environments, such as bays, coastal lagoons, estuaries and tidal creeks, also in exposed mudflats or sandflats or at near-coastal swamps, lakes or beaches (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide. **Distribution:** Rare around the northern Australian coast, seldom in the south. In the Northern Territory they have been reported in small numbers in the Darwin region, central coastal Arnhem Land, Blue Mud Bay and the Port McArthur region. They probably occur at a number of other locations on the NT coast, but never in large numbers (Chatto 2003).
Calidris tenuirostris **Great Knot**	CR	VU	**Habitat:** Inhabits sheltered coasts and estuaries with intertidal mudflats and sand-flats, especially in mangrove areas (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide. **Distribution:** Mostly widespread around the northern Australian coast, less common in the south, with few inland records, centred around Alice Springs (Garnett *et al.* 2011).
Calidris canutus **Red Knot**	EN	VU	**Habitat:** Inhabits coasts and estuaries with tidal mudflats (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide. **Distribution:** Widespread around the northern Australian coast, less common in the south, with few inland records (Garnett *et al.* 2011).
Calidris ferruginea **Curlew Sandpiper**	CR	VU	**Habitat:** Inhabits coasts and estuaries, especially intertidal mudflats, as well as beaches, rocky shores and around lakes, dams and floodwaters (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide. **Distribution:** Mostly widespread around the northern Australian coast, less common in the south, with few inland records at Alice Springs and Newhaven Station (Chatto 2003).

2. Migratory shorebirds in the Darwin region

2.1. Habitat choice and site availability

The Darwin region supports a high diversity of migratory shorebirds. There have been 25 species of migratory shorebird recorded across a range of monitored sites within the Darwin Harbour region (**refer to Table 1 and Figure 2**). Shorebirds begin arriving in Darwin in August with peaks in September, October and November and then start departing for their northward migration in February and March. A number of sites in Darwin are monitored throughout the year; these are listed in **Table 3**. These sites have been monitored by a local volunteer (Gavin O'Brien) to contribute to the national Shorebirds 2020 program (http://birdlife.org.au/projects/shorebirds-2020) and more recently and intensively for a PhD program through Charles Darwin University (A. Lilleyman et al, unpublished). These sites were selected for monitoring because they are the most important sites for shorebirds in the Darwin region. The monitoring sites all differ in the type and size of suitable habitat for shorebirds, thus supporting differing species assemblages and providing either roosting or feeding habitat (or both). Roost sites are usually selected for their proximity to feeding grounds to allow for a short commute time, good visibility of potential predators, for thermoneutrality (shallow water to help cool birds down in tropical environments), tide height, and disturbance levels (Rogers et al. 2006; Rosa et al. 2006; Zharikov and Milton 2009).

The following tables (**Table 3-4**) have been compiled using data gathered as part of the PhD project (by the author) on migratory shorebirds in Darwin Harbour. The data were collected from 2013 – 2016 and the study sites were more intensively studied than previous survey work done for the Shorebirds 2020 program. This dataset, despite being shorter in duration, was selected instead of long-term monitoring data, because it will better represent the current state of Sandy Creek as a site of importance for migratory shorebirds.

As part of the PhD on migratory shorebirds in Darwin Harbour, Amanda Lilleyman surveyed for shorebirds across all of the roosting and feeding sites listed in **Table 3**. Roost surveys were conducted during spring high tides (every fortnight) during tides of >6.5 m during day light hours. All shorebirds and waterbirds were identified and counted. All disturbances to shorebirds and disturbance stimuli at the monitoring sites were recorded. Foraging surveys were conducted during falling low tides from 5.5 m. All shorebirds were identified and counted. These methods meet EPBC Act survey requirements for detecting migratory shorebirds as outlined in the EPBC Act Policy Statement 3.21

Note: The two subspecies of Bar-tailed Godwit are known to occur in the Darwin region but were not distinguished apart during the 2013-2016 surveys. Additional expert opinion has been sought and subspecies menzbieri is more common in the area but baueri is probable. As such, all references to counts of Bar-tailed Godwit are at the species level, but for the purpose of conserving this species, all actions should be taken to conserve individuals at both subspecies levels (i.e.: ***critically endangered and vulnerable****).*

Table 3. Monitoring site descriptions, EPBC Act listed threatened migratory shorebird species recorded at the sites.

Site	Description	Max. number of birds (date)	Max. number of species (date)	EPBC Act listed Threatened species recorded at this site
Lee Point-Buffalo Creek	One of the most important sites for migratory shorebirds in the Darwin region. Situated within the Casuarina Coastal Reserve (CCR) and managed by the Parks and Wildlife Commission Northern Territory. Important for feeding and roosting. Extensive sandy beach connected to sandflats where thousands of shorebirds feed at low tide. Shorebirds can roost anywhere along the stretch of beach but are generally found closer to the Buffalo Creek end. Shorebirds that roost and feed at Lee Point have been recorded moving between this site and saltpans in the Shoal Bay region to the East. It is likely that shorebirds also use the extensive beach between Tree Point and Gunn Point, but surveys at Tree Point/Gunn Point reveal high human disturbance and space constraints from high spring tides. These factors and low shorebird numbers make it unlikely that this site is of equal importance to the Lee Point and northern beaches sites.	7423 (January 2016)	16 (September 2015 and February 2016)	Lesser Sand Plover Greater Sand Plover Bar-tailed Godwit Eastern Curlew Great Knot Red Knot Curlew Sandpiper
Sandy Creek	Supports a similar assemblage of shorebirds as Lee Point but since previous monitoring in 2011, 2012, Sandy Creek has been used as a refuge site if birds are disturbed at Lee Point or Nightcliff Rocks. The available space to roost at Sandy Creek is constrained by high spring tides and birds are forced to leave the site if the tide is too high. Shorebirds roost along the western side of the creek, in front of the mangroves and Casuarina trees. Shorebirds also feed at low tide at Sandy Creek. This site is situated within the Casuarina Coastal Reserve (CCR) and managed by the Parks and Wildlife Commission Northern Territory.	4903 (October 2015)	14 (September 2014)	Lesser Sand Plover Greater Sand Plover Bar-tailed Godwit Eastern Curlew Great Knot Red Knot
Nightcliff Rocks	Small rocky outcrop out from the urban 'Sunset Park' in the suburb of Nightcliff. Shorebirds often roost on the rocks furthest from land and human activity. This site has high human traffic and disturbances to shorebirds are common. Recently the City of Darwin constructed a seawall and fence atop the land edge. It is predicted that this fence will act as a barrier to humans and will discourage access to the rocky platform. High spring tides can cover this entire platform making it unsuitable for roosting shorebirds.	3084 (December 2013)	15 (December 2013 and November 2015)	Lesser Sand Plover Greater Sand Plover Bar-tailed Godwit Eastern Curlew Great Knot Red Knot
East Point	Similar to Nightcliff Rocks with rocky platforms bordering the land. Similarly to Nightcliff Rocks, high spring tides can cover this entire platform making it unsuitable for roosting shorebirds. East Point is mostly used as a roost site but some species have been recorded foraging amongst the rocks.	2611 (February 2015)	14 (October-November 2015 and February-March 2015)	Lesser Sand Plover Greater Sand Plover Bar-tailed Godwit Eastern Curlew Great Knot Red Knot

Spot on Marine	Large saltpan surrounded by mangroves that experiences tidal flow on tides above 7 metres. This site is used for roosting only but can become unsuitable for roosting during particularly high spring tides.	1651 (March 2015)	10 (March 2014)	Greater Sand Plover Bar-tailed Godwit Eastern Curlew Great Knot Red Knot
Ludmilla Bay	Extensive sandflat system where shorebirds and waterbirds feed during low tide. This site is not considered suitable for roosting due to the tide covering most of the sandflat. This site is not available at all tide heights, but is often used by foraging shorebirds during the austral summer. Shorebirds that forage at Ludmilla Bay at low tide will often roost at East Point or Nightcliff Rocks at high tide. This site is commonly used for recreational activities during low tides. This site is currently not well protected and is at risk of being developed for commercial purposes.	2150 (March 2015)	9 (January 2015)	Lesser Sand Plover Greater Sand Plover Bar-tailed Godwit Eastern Curlew Great Knot Red Knot
East Arm Wharf	East Arm Wharf (Darwin Port) is a man-made site with several dredge-spoil ponds within the fenced boundary. Darwin Port is within Darwin Harbour and the site is used for importing and exporting goods from the wharf berths. The dredge ponds are shallow, muddy ponds with clear visibility of surroundings and access to the harbour mudflats for feeding at low tide. The dredge ponds are used for roosting at high tide and some shorebirds feed in the freshwater ponds during all tide heights. This roost site is available to shorebirds at all tide heights and is particularly important as a refuge site from harsh monsoonal weather conditions in January and February of the wet season. East Arm Wharf is a privately owned site; it is owned by Darwin Port and is managed so that access is restricted to the public. Shorebirds that roost at East Arm Wharf feed nearby on the mudflats of Darwin Harbour.	1036 (November 2015)	17 (September 2014)	Lesser Sand Plover Greater Sand Plover Bar-tailed Godwit Eastern Curlew Great Knot Red Knot Curlew Sandpiper

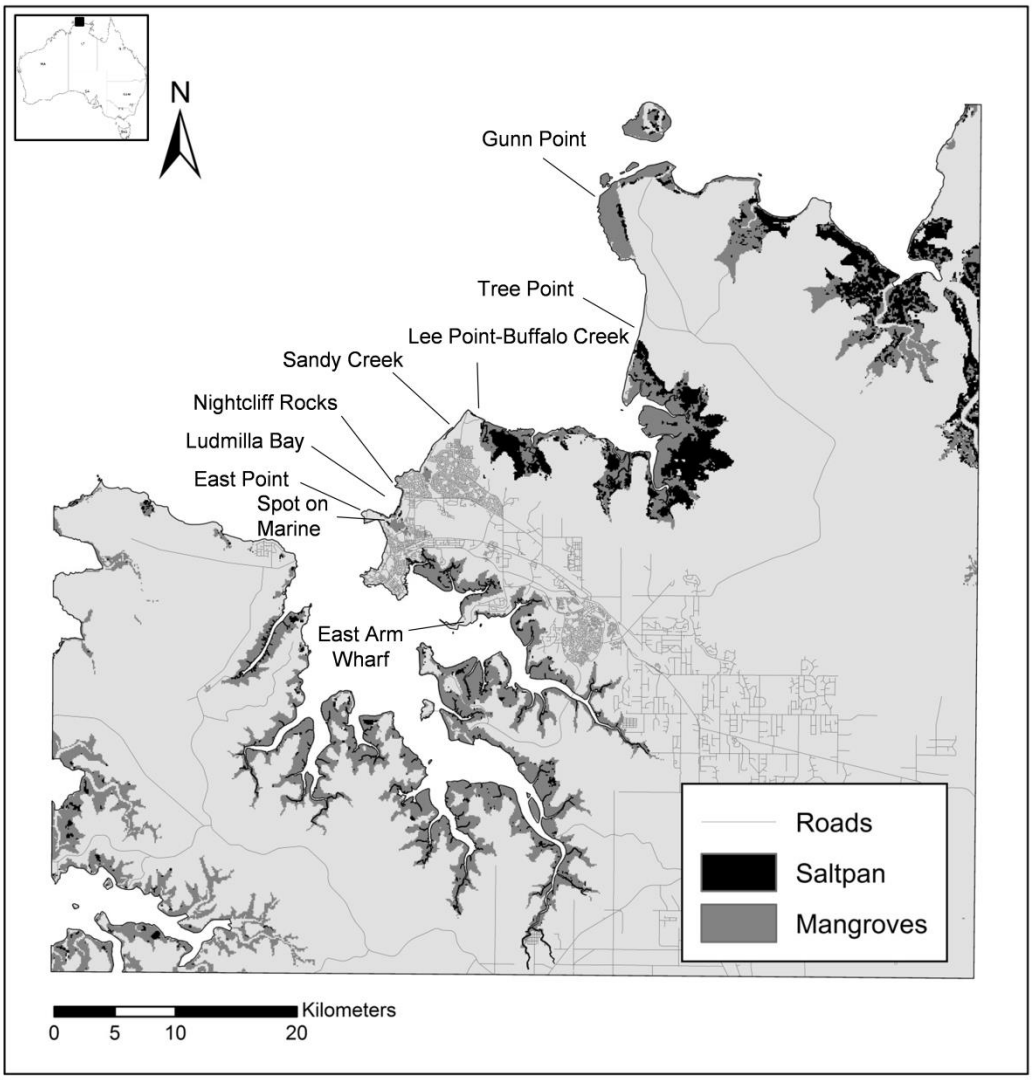

Figure 2. Map displaying the monitored shorebird roosting and feeding sites in the Darwin Harbour region.

2.2. Importance of the northern beaches of Darwin for migratory shorebirds

Sandy Creek and Lee Point-Buffalo Creek both meet EPBC Act criteria (**Section 1.4 of this report**) to be listed as nationally and internationally important habitat (Commonwealth of Australia 2015a). **Table 4** lists the importance of these sites and the corresponding shorebird values. **Table 5** lists all migratory shorebird species present at Sandy Creek, the maximum count, number of times recorded at the site, and thresholds for internationally and nationally important numbers for species.

Buffalo Creek is the preferred feeding site for shorebirds on the northern beaches of Darwin, and because of this most birds roost close by at Lee Point or Sandy Creek (see **Figure 2 and 3** for roosting and feeding sites at Lee Point-Buffalo Creek and Sandy Creek). <u>These sites are all within 3 km to the proposed DHA housing development.</u>

Figure 3. Roosting and feeding areas for migratory shorebirds at Sandy Creek and Lee Point-Buffalo Creek. Image credit: EcOz environmental consultants.

Table 4. Importance of Sandy Creek and Lee Point-Buffalo Creek for migratory shorebirds.

Site	Meets EPBC national threshold?	No. surveys performed (2013-2016)	Largest congregation (species and year)	Most abundant species
Sandy Creek	**Yes.** Sandy Creek meets two of the criteria for listing as nationally important habitat. Supports nationally and internationally important numbers of Critically Endangered Great Knot. Supports nationally important populations of Greater Sand Plover, Great Knot, Red Knot, and Sanderling.	55	Sandy Creek, being a smaller roost site and not being able to support as many individuals as Lee Point-Buffalo Creek, had its largest congregation of shorebirds in October 2015, with 4903 individuals of 13 species and also supported 4110 individuals of 10 species in March 2015. During the 2013 to 2016 surveys at Sandy Creek, there was one occasion where 14 species of shorebird were recorded in September 2014, but three occasions where 13 species were recorded.	The most abundant species at Sandy Creek were Great Knot, Greater Sand Plover, Red Knot, Sanderling, and Red-necked Stint (in descending order). Despite these high abundances, the species most frequently recorded at the site were Eastern Curlew, Grey Plover, Greater Sand Plover, Sanderling, and Whimbrel and Bar-tailed Godwit to a lesser extent.
Lee Point-Buffalo Creek	**Yes.** Lee Point-Buffalo Creek meets all criteria for listing as nationally important habitat for migratory shorebirds. Supports nationally and internationally important numbers of Critically Endangered Great Knot. Supports nationally important populations of Greater Sand Plover, Terek Sandpiper, Grey-tailed Tattler, Great Knot, Red Knot, and Sanderling.	162	7423 with 15 species of shorebird present in January 2016; February 2016 had 6399 individuals of 16 species; and November 2015 had 6269 individuals of 15 species	The most abundant species at Lee Point-Buffalo Creek were Great Knot, Greater Sand Plover, Red Knot, Terek Sandpiper, Red-necked Stint, Sanderling, and Common Sandpiper (in descending order). At Lee Point, Greater Sand Plovers were most commonly recorded, and then Great Knot, Eastern Curlew, Grey Plover, Sanderling, Red-necked Stint, and to a lesser extent, Whimbrel and Grey-tailed Tattler.

Table 5. Migratory shorebird species recorded at Sandy Creek, maximum count, numbers of times recorded at the site, and thresholds for internationally and nationally important numbers for species.
Note: species that were not recorded at Sandy Creek during the 2013-2016 survey period are not included in the table. Shaded grey = EPBC Act listed threatened species.

Shorebird	Maximum count	No. times counted	% present in counts	1 % threshold	0.1 % threshold
Pacific Golden Plover	12	3	5	1250	125
Grey Plover	14	39	71	790	79
Lesser Sand Plover	31	7	13	1470	147
Greater Sand Plover	980	37	67	1660	166
Oriental Plover	1	1	2	2320	232
Black-tailed Godwit	14	3	5	1470	147
Bar-tailed Godwit	13	34	62	3000	300
Whimbrel	8	34	62	640	64
Eastern Curlew	8	44	80	310	31
Terek Sandpiper	4	8	15	460	46
Common Sandpiper	3	15	27	2520	252
Grey-tailed Tattler	9	12	22	610	61
Common Greenshank	6	20	36	660	66
Marsh Sandpiper	5	1	2	940	94
Ruddy Turnstone	17	6	11	300	30
Great Knot	4640	28	51	3250	325
Red Knot	390	15	27	1010	101
Sanderling	139	36	65	340	34
Red-necked Stint	114	21	38	4660	466
Sharp-tailed Sandpiper	3	2	4	850	85

High tide roost surveys have been performed at Sandy Creek and Lee Point by Amanda Lilleyman and Gavin O'Brien (experienced shorebird volunteer researcher) simultaneously to determine movement and activity between these sites. Records suggest that shorebirds move between these two sites at high tide if there is a disturbance at a site and the birds are seeking refuge elsewhere, or if the tide becomes too high at Sandy Creek and the birds have no space to roost, they usually fly to Lee Point. As part of the PhD study (A. Lilleyman et al, unpublished) on shorebirds in Darwin, an extensive catching and banding exercise has allowed individual birds to be tracked and resighted across the monitored sites from 2014 to 2016. There was high site fidelity of tagged shorebirds returning to sites in Darwin after the 2015 breeding season (between seasons), and high site fidelity within the austral summer season with records of individual birds feeding at low tide at Buffalo Creek and Sandy Creek and then roosting at high tide at Lee Point and at the Sandy Creek roost (within season).

While shorebirds usually select Buffalo Creek tidal flats at low tide for feeding, the extensive tidal flats along Sandy Creek beach are important feeding grounds at certain times of the year, possibly due

to unreliable food resources at other sites. High numbers of shorebirds (>500) have been recorded feeding at Sandy Creek in March 2015 (**Figure 4-5**). This was 10 days before most shorebirds departed Darwin for their northward migration, suggesting that this was an important feeding site in the 2015 austral summer season.

Figure 4. Migratory shorebirds feeding at Sandy Creek intertidal sandflats in March 2015, 10 days before departing for their northward migration. Photo credit: Amanda Lilleyman, 2015.

Figure 5. Migratory shorebirds feeding at Sandy Creek intertidal sandflats in March 2015, 10 days before departing for their northward migration. Photo credit: Amanda Lilleyman, 2015.

2.3. Disturbance to shorebirds in Darwin

When shorebirds are disturbed at high-tide roosts they use energy that would otherwise be reserved for foraging and maintaining fat reserves. Alarm flights incur a higher rate of energy usage than resting, as birds take off rapidly, must ascend and descend, and undertake flapping flight – all of which have high energy costs (Nudds and Bryant 2000). The Casuarina Coastal Reserve, where Sandy Creek and Lee Point-Buffalo Creek sit, has an annual visitation rate of over one million users (Parks and Wildlife Commission 2016). This level of human recreation use unavoidably places an increased pressure on shorebirds that use this coastline. The effects of disturbance on shorebirds at a Lee Point-Buffalo Creek were measured and the rates of anthropogenic and natural disturbance were quantified in a research project by Amanda Lilleyman in 2011 and 2012. These results were recently published and have been used to inform management of shorebirds within the Casuarina Coastal Reserve by the NT Parks and Wildlife Commission.

Anthropogenic disturbance is additional to the background level of natural disturbance, and negatively affects shorebirds by forcing them to use energy reserves that would otherwise accumulate for the long-distance migration flight (Lilleyman et al. 2016). Migratory shorebirds were recorded flying away from humans when disturbed, and these alarm flights were longer in the period when shorebirds had recently arrived in Darwin from their southward migration (Lilleyman et al. 2016). It was suggested that the level of anthropogenic disturbance might indirectly decrease the survival likelihood of shorebirds by inducing high costs of predator avoidance behaviours at the high-tide roost. This is problematic as shorebirds that are disturbed may seek refuge elsewhere, such as Sandy Creek, but this site is also experiencing higher rates of disturbance. Lilleyman et al. (2016) stated that "*the compounded effects of an increase in disturbances and increased time spent in alarm flight negatively affect migratory shorebirds at an important roost site near Darwin*" and that these disturbances on the non-breeding grounds could "*place additional and unsustainable pressures on populations that are already experiencing major declines*".

3. Migratory shorebird management

Increased anthropogenic disturbance to shorebirds is the main potential impact from this development proposal. Increased disturbance to shorebirds at this site has the potential to harm the population.

3.1 Impact mitigation – disturbance

The Commonwealth Government's Wildlife Conservation Plan for Migratory Shorebirds states that "*Disturbance which renders an area unusable is equivalent to habitat loss and can exacerbate population declines. Disturbance is greatest where increasing human populations and development pressures may have an impact on important habitats*" (Commonwealth of Australia 2015b). Anthropogenic disturbance is considered a high risk to shorebirds that requires mitigation action and an adaptive management plan, and the precautionary principle should be applied (Commonwealth of Australia 2015b; Department of the Environment Water Heritage and the Arts 2009). The Background paper to the EPBC Act policy statement 3.21 suggests that "*it is important to consider the combined effects of disturbance with other threats when assessing the likely impact*" (Department of the Environment Water Heritage and the Arts 2009). The Proponent should consider this when planning mitigation to the potential impacts to shorebirds from disturbance.

Shorebirds are prone to the effects of anthropogenic disturbances as most coastal shorebirds roost and feed along beaches where humans co-occur. By increasing and improving the access to the Sandy Creek beach it is likely that pedestrian traffic will increase disturbances to shorebirds that also use this beach. Shorebirds roost on beaches because they have nowhere else to go while the tide is high. If humans or dogs approach the birds then it is most likely that the birds will take flight in response to the disturbance. The distance at which birds take flight from disturbance stimuli is referred to as the flight-initiation distance (FID) and these FIDs have been quantified for shorebirds in Australia and the world (for a full review see Weston *et al.* 2012), and more recently in Darwin (Lilleyman *et al*. 2016). In Darwin, FID measurements for Great Knots and Greater Sand Plovers were estimated, and from this the safe buffer distance that humans should keep from birds is a minimum of 100 m (Lilleyman *et al.* 2016). Flight-initiation distances were not recorded for other larger species in this study but it is predicted that the current buffer zones will not be sufficient to protect larger shorebirds such as Far Eastern Curlew (Lilleyman *et al.* 2016). Other studies suggest a greater buffer distance is required for larger shorebirds (Glover *et al.* 2011).

The current Casuarina Coastal Reserve Plan of Management states that there is a 100 m buffer zone either side of Sandy Creek where dogs should be leashed but there are no signs within the area to this effect, thus visitors to the reserve are not aware of zoning regulations and continue to cause disturbances to shorebirds (Parks and Wildlife Commission Northern Territory 2016). This buffer distance does not adequately protect all shorebirds using the Sandy Creek roost as some species, such as Far Eastern Curlew roost between Sandy Creek and the Casuarina Surf Life Saving Club. Further to this, four-wheel drive vehicles are often recorded illegally driving along the beach to gain access to

popular fishing locations at Sandy Creek. This illegal act disturbs shorebirds on the beach and is destructive to the beach ecosystem. As a first step in managing disturbances and prohibited vehicle access, the Parks and Wildlife Commission NT could improve the security of fences and gates that lead to unauthorised vehicle entry to the beach.

Most shorebirds that roost at Sandy Creek use the sandbanks on the western side of the creek and the shore along Casuarina beach; however some birds have been recorded roosting on the eastern side of the creek. Because shorebirds prefer to roost on the western side, it is recommended that any new access paths from the proposed housing development site through the CCR be positioned on the north-eastern side of Sandy Creek. Information signs would enhance the visitor experience through education about the natural environment, historical and cultural values, and would also help to protect biodiversity. Educational signs about shorebirds and the need to minimise disturbance are an effective management tool, and has been shown to decrease disturbance rates to shorebirds (Burger 2004). Access tracks to the beach should have educational signs at the beginning, throughout and at the endpoint of the track (on the beach) to inform visitors of the environmental and biological values of the CCR. See **Figure 6** for examples of educational signs.

Additionally, barrier fencing positioned on the western side of Sandy Creek at 100 m from the mouth of the creek would protect shorebirds by alerting humans to the presence of birds on the beach. The barrier fencing (water and salt resistant/protected) should be perpendicular to the tide line and extend from the dune to approximately 10 – 20 metres across the sand (see example in **Figure 7**). The Proponent will need to consider the costs associated with maintaining the barrier fence – including corrosion from saltwater, vandalism and natural weathering of materials. In the instance that any of these issues arise, then the Proponent should replace the fence or parts of the fence. Protecting the shorebirds through serious management measures outweighs the possibility of the barrier fencing not lasting a long time in harsh tropical conditions.

Figure 6. Examples of educational signs about migratory shorebirds. Signs are from Moreton Bay in Queensland. Image credit: jappliedecologyblog.wordpress.com and www.visitmoretonbayregion.com.au

Figure 7. Example of a wire rope fence that could be constructed on the beach to protect migratory shorebirds from anthropogenic disturbance. Image credit:

https://redoubtreporter.wordpress.com/2010/02/17/fence-for-dunes-hits-barriers-%E2%80%94-efforts-to-protect-kasilof-beach-more-complex-than-anticipated/

3.2 Impact mitigation – community education

A community awareness program on shorebirds and their use of Sandy Creek as a roost will help protect the birds and the habitat they depend on. Implementing a community awareness and engagement program is an essential part of managing threatened species in an urbanised environment. As anthropogenic disturbance is considered a high risk to shorebirds with negative impacts on individuals, ensuring that the Sandy Creek roost is protected is crucial to managing the population.

As well as a number of educational signs along access tracks and on the beach, community awareness can be achieved by delivering information pamphlets to local residents of the housing development, and by providing information sessions to raise awareness about dog zoning and safe buffer distances from shorebirds. Local organisations, with the support of Parks and Wildlife Commission NT have previously held successful community engagement events at Lee Point and Sandy Creek to raise the profile of these remarkable, yet highly threatened birds. These events included: sessions where people could learn about the birds then view them through binoculars and spotting telescopes; BBQs with dogs invited to show support for dog walking as a recreational activity, but with an emphasis on using *correct* dog zoning areas; and inviting community members to be involved with regular survey monitoring with the aim that they then become advocates for shorebirds (**Figure 8** shows a dog attending the 'Darwin Doggie Dinner' – educational event held at Lee Point in 2011.

Figure 8. A dog attending the 'Darwin Doggie Dinner' at Lee Point in 2011; held by volunteers and the Northern Territory Field Naturalists' Club Inc. Image credit: Peter Kyne.

4. Monitoring program

The fieldwork component of the PhD on migratory shorebirds in Darwin has finished and all current shorebird monitoring is performed by one volunteer in the region. There is no guarantee that this level of monitoring will continue into the future, thus it is critical that a new and more robust monitoring program be developed.

A well designed community awareness program needs to be coupled with regular monitoring of shorebird numbers and disturbance rates to determine the efficacy of the program. A monitoring program should be developed to detect any significant changes in shorebird usage of Sandy Creek. It is recommended that this program detects significant changes in the population that are attributable to the impacts of the development and not external or regional factors. Therefore it is recommended that the program intensively surveys two sites (Sandy Creek and Lee Point) that are expected to be exposed to higher rates of anthropogenic disturbance as a result of the DHA housing development. It is also recommended that an additional three sites are surveyed (Nightcliff Rocks, East Point and Spot on Marine) so that the wider Darwin region shorebird population is adequately surveyed. It is important that any variation in species and abundances are detected over the migration months. Therefore all months during the austral summer season when shorebirds are expected to occur in

Darwin should be included in the monitoring program, as northern Australia is a known staging site for shorebirds during northward and southward migration (Commonwealth of Australia 2015a). The population of shorebirds in Darwin varies over the summer months and it is important to monitor those months – which include the southern migration period, the core non-breeding period and the northern migration period.

Monitoring data from this period should be compared against Shorebirds 2020 data and the data presented here in this report to detect any local changes to shorebirds at the monitoring sites.

It is expected that uptake of houses in the DHA development area will be staggered and the increased use of the CCR, Sandy Creek and Lee Point beaches will take some time; therefore the duration of the monitoring program should reflect the uptake of houses within the development and it should start once all houses have been taken up. The monitoring program should then remain in place for five years. A monitoring period of five years will be sufficient to detect local changes to the shorebird population that are due to the DHA housing development.

The survey methodology outlined in section **4.1 Methodology** exceeds EPBC Act survey requirements for detecting migratory shorebirds as outlined in the EPBC Act Policy Statement 3.21 (see **Table 6** for survey guidelines) (Commonwealth of Australia 2015a; Department of the Environment Water Heritage and the Arts 2009). The outcomes of the monitoring program should be reviewed and evaluated using the steps outlined in **Figure 9**. Resources for the monitoring program are listed in the **Appendices**.

The aim of the monitoring program is to quantify the magnitude of impact of disturbances to migratory shorebirds associated with the proposed development (Commonwealth of Australia 2015a). A significant impact on the regional population of migratory shorebirds would be: 1) a decrease in the size of the population (outlined in **section 4.2**) that visits the northern beaches of Darwin each year that cannot be reasonably attributed to other factors or broader population trends and; 2) an increase in the number of disturbances (>10 per survey session) that these shorebirds are exposed to at the monitoring sites.

Table 6. Survey Guidelines for migratory shorebirds set out in the EPBC Act Policy Statement 3.21 (Commonwealth of Australia 2015a).

Coverage	Timing	Effort	Minimum data requirements
- All of the habitat thought to be used by the same population of shorebirds. - The entire area of contiguous habitat where shorebirds may occur.	- The months when the majority of migratory shorebirds are present in the area. - Numbers of shorebirds may vary during these months, particularly in the north of the country, due to presence of additional shorebirds during inbound and outbound migration at the beginning and end of the non-breeding season. Local knowledge should be sought to determine optimum survey times. - The northern hemisphere breeding season (mid-April to mid-August) to obtain data on non-breeding; non-migrating populations of immature migratory shorebirds.	- Four surveys for roosting shorebirds during the period when the majority of shorebirds are present in the area - Replicate surveys over this period are important to measure population variability. Some areas will meet the importance criteria only during the migration periods when many birds are temporarily stopping over. In most cases, one survey in December, two surveys in January, and one survey in February will be adequate.	- *Shorebird statistics relating to roosting areas:* total abundance (total number of birds present across all species); species richness (number of species observed); species abundance (number of birds of each species present). - *Shorebird behaviour*: activity (roosting, foraging); foraging location (spatial data of the area used by shorebirds for feeding to enable mapping of foraging habitat). - *Survey conditions*: date, time of day; tide height; weather conditions (temperature, precipitation, wind speed & direction). - Number of observers and experience level. - Method used to conduct the survey. - *The following habitat characteristics may also be useful*: dominant landform type; hydrology; dominant terrestrial and aquatic vegetation types; intertidal substrate characteristics; invasive species; current disturbance regime; presence of suitable nocturnal roosting areas.
	Surveys for roosting shorebirds should be conducted as close to the time of high tide as practicable and at a maximum of no more than two hours either side of high tide (unless local knowledge indicates a more suitable time).	One survey during the northern hemisphere breeding season to capture data on birds that remain in Australia during the breeding season.	

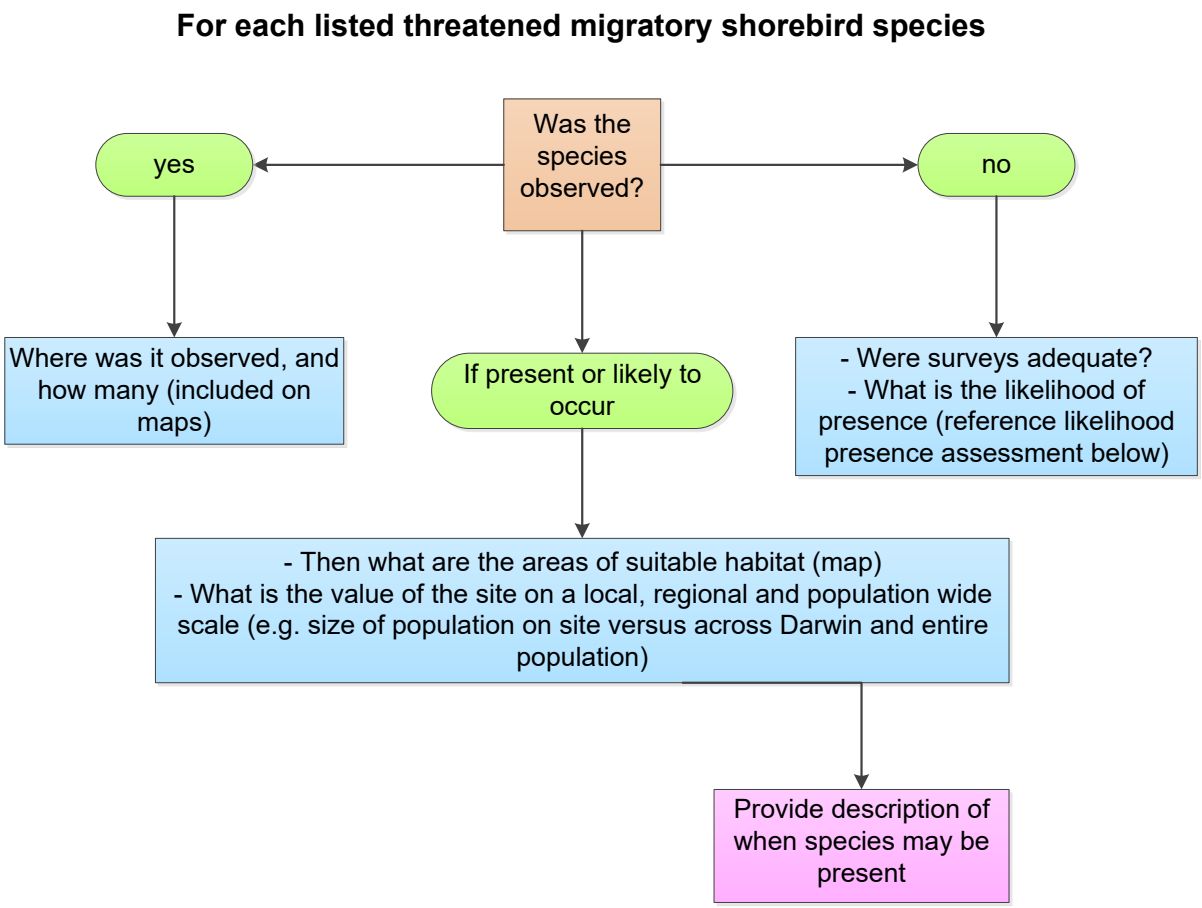

Figure 9. Flow chart for evaluating monitoring survey program for migratory shorebirds.

4.1. Methodology

The shorebird monitoring program should consist of one survey per month from September through to April each austral summer season at the following sites: Sandy Creek and Lee Point [performed simultaneously; e.g.: two personnel], East Point, Nightcliff Rocks, and Spot on Marine (**Table 7-8; see Appendices for suggested resources**). Migratory shorebirds begin arriving in Darwin from August and depart as late as May the following year. An additional survey in July each year should be performed at all monitoring sites to capture information on shorebirds that remain at the survey sites during the northern hemisphere breeding season. The surveys should be performed at high tides of >6.5 m during the spring tide cycle, and during daylight hours. Surveys should be conducted two hours either side of the peak of the high tide. The semi-diurnal tides mean that two high tides occur per day, usually with one in the morning (sunrise) and one in the evening (sunset). Surveys should be conducted for a minimum duration of two hours. All shorebirds and all other waterbirds should be identified and counted. Shorebird activity should be recorded (foraging, roosting). The start and end time of the survey should be recorded. Any changes to the environment should be recorded. Surveys can be performed by one person (the observer) per site. The observer should be competent in shorebird identification and counting techniques. The observer should perform the survey from a

distance of 100 m or more so as not to cause a disturbance. The observer should use binoculars and a zoom spotting scope of 20-60 x magnification. Survey areas for Lee Point and Sandy Creek are outlined in **Figure 10** and the other three sites are shown in **Figure 2**.

All disturbances and potential disturbances to shorebirds and other birds should be recorded. If the disturbance stimulus is close enough to the flock of birds it should be recorded as a disturbance and the response (flight, walking away, no response) of the birds should be recorded. If the disturbance stimulus is not close enough to cause a disturbance then it should be recorded as a potential disturbance (i.e.: this is the no response category and is simply a measure of the number of people using the beach and additionally helps in creating appropriate buffer zones through recording the distance of the stimulus to the birds). The time of the disturbance should be recorded along with the details (e.g.: human [walking, running, cycling etc.], human with dog [leashed or unleashed], vehicle on the beach, kite surfer, aircraft, bird of prey) and the number of each disturbance stimuli. The observer should also record where the disturbance stimulus entered the beach from (if possible) and the exit point (which access path).

Table 7. Survey timing, guidelines and effort for the migratory shorebird monitoring program.

Month	Guidelines	Effort
September October November December January February March April	Perform shorebird surveys simultaneously at Sandy Creek and Lee Point. Perform surveys at Nightcliff Rocks, East Point and Spot on Marine during the same spring tide cycle as Lee Point an Sandy Creek. Count all shorebirds (species and abundance) and all other birds in the survey area. Record all disturbances and potential disturbances to shorebirds and other birds. Record any physical changes to the environment.	1 high tide survey at 5 sites for 2 hours, each month = 10 hours per month = 80 survey hours per austral summer season
July	As above	1 high tide survey at 5 sites for 2 hours for the month of July. = 10 hours
Total survey hours per season		**90**

Figure 10. Roosting and feeding areas for migratory shorebirds at Sandy Creek and Lee Point-Buffalo Creek. Image credit: EcOz environmental consultants.

4.2. Triggers and responses to trigger exceedances

Monthly survey monitoring data should be reviewed to detect any significant changes in the shorebird subpopulation for both Sandy Creek and Lee Point (following the steps outlined in **Figure 11**). The Proponent should review monitoring data for the five monitoring sites and calculate the combined population of shorebirds for the northern beaches region. If shorebirds are detected at all sites but not at Sandy Creek then this will cause a trigger to check the total abundance data. If the total abundance of shorebirds for Lee Point or Sandy Creek is >4000 individuals (from October to November) then that trigger is terminated. If it is <4000 individuals across all five sites then this will cause a trigger and the Proponent should investigate if the population changes are attributable to a site specific event at Sandy Creek or other environmental changes in the Darwin region.

If the monitoring guidelines are not followed and surveys are performed on tides lower than 6.5 m then there is the chance that shorebirds will not be sighted during the surveys. It is important that these guidelines are followed to fully represent the shorebird population in the Darwin region.

If any triggers are exceeded then the Proponent will need to investigate if conditions at the local sites are attributable to the changes in the shorebird population. After examination of the abundance data, the Proponent should examine the disturbance data to determine the rate of anthropogenic disturbance compared to the background rate of natural disturbance by birds of prey, and compare this against baseline disturbance data reported in Lilleyman *et al.* (2016). For example, if the number of disturbances exceeds 10 alarm flights per survey session, then the Proponent should seek an increase the number of patrols by Parks and Wildlife rangers and City of Darwin council rangers to ensure that visitors to the beach roost sites are abiding by dog zoning regulations and are not disturbing shorebirds in spite of educational signs and barrier fencing.

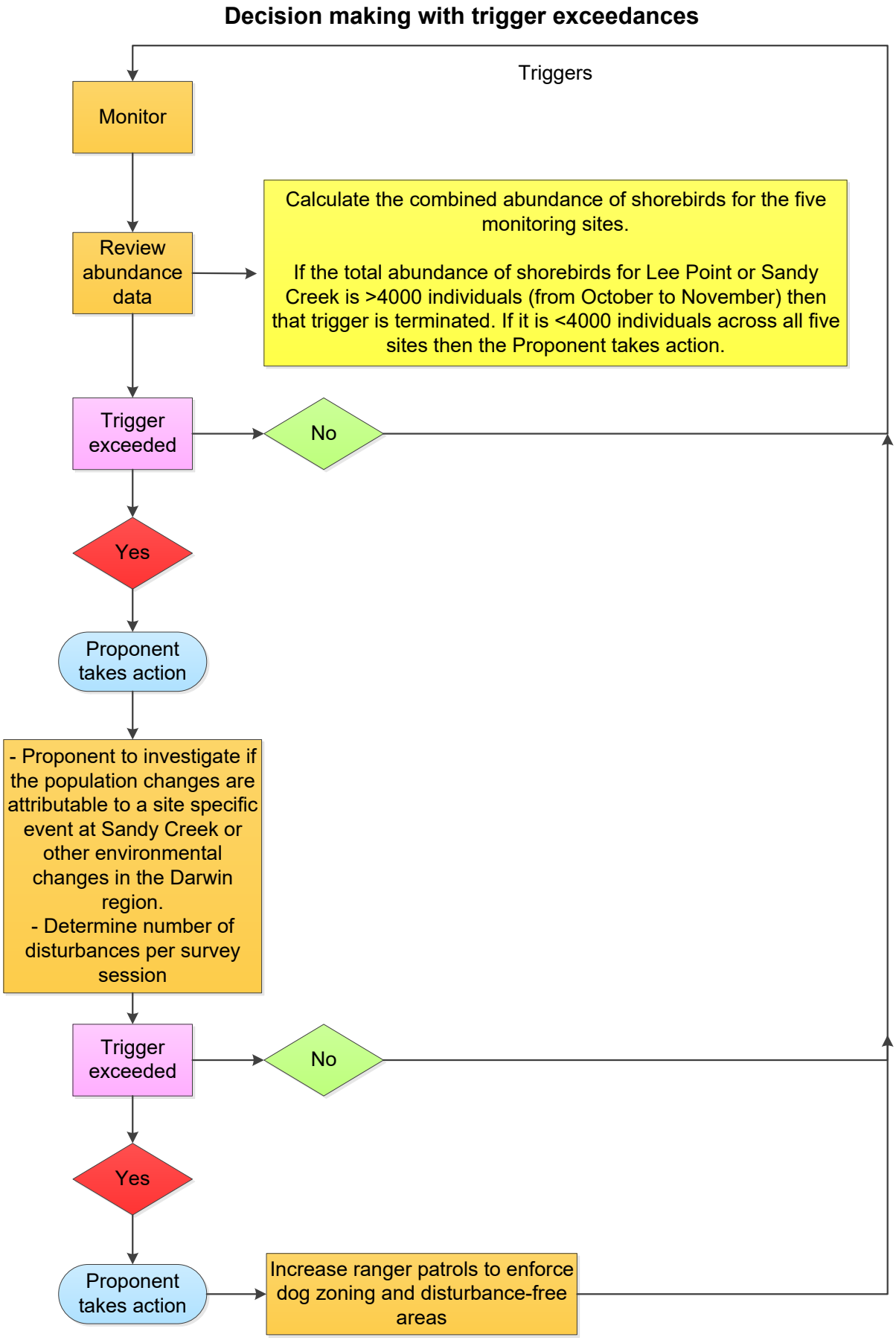

Figure 11. Flow chart to detect significant changes in the migratory shorebird population at Sandy Creek.

5. Recommendations and conclusions

Sandy Creek is considered a site of national importance for migratory shorebirds that visit Australia for the summer season. The site has at times supported internationally important numbers of migratory shorebirds and also acts as an important feeding ground for shorebirds before departing for their northward migration.

Anthropogenic disturbance is the key threatening process to migratory shorebirds in this development context, and this has serious consequences for the shorebird population that visits Darwin every year. As stated in Lilleyman et al. (2016) "*There is concern that with expansion of the Darwin urban centre in northern Australia, disturbances will increase to unsustainable levels for migratory shorebirds and ultimately divert migratory shorebirds from this important non-breeding site*". While the development does not directly impact shorebirds through habitat loss or destruction, it is important for the Proponent to consider cumulative effects of increased anthropogenic disturbances with increasing coastal development in the Darwin region. By following the proposed recommendations, the Proponent will be working towards maintaining and enhancing the environmental and biological values of Sandy Creek to support nationally and internationally important populations of migratory shorebirds.

The potential impacts to migratory shorebirds have been reviewed and considered in this report and it is concluded that there is a very high likelihood that the number of visitors to Sandy Creek and associated beaches will increase, thus increasing the rate of anthropogenic disturbance to shorebirds.. This has consequences, including abandonment of the roost site by shorebirds, increased energy expenditure on alarm flights from disturbances and reduced ability to maintain fat stores for migration and breeding. Therefore the following recommendations are given:

- Access tracks should be positioned to the north-eastern side of Sandy Creek so that **visitation does not increase and impact upon migratory shorebirds** that roost on the western side of Sandy Creek.
- Maintain current **dog zoning regulations** and place educational signs along Sandy Creek beach.
- **Construct barrier fencing** (water and salt resistant/protected) perpendicular to the tide line at the 100 m buffer zone either side of Sandy Creek that will act as a reminder to beach visitors that they are about to enter important shorebird habitat.
- Proponent to liaise with Parks and Wildlife Commission NT and City of Darwin council rangers to develop a **regular schedule to monitor visitation and dog zoning regulation** at the Sandy Creek roost site.
- Proponent to liaise with Parks and Wildlife Commission NT to collaborate on **community engagement programs and events** so that there is one strong key message about shorebird conservation.

- Install **educational signage** at each access path entry and exit point.
- Invite **residents of the DHA** housing development to **join shorebird monitoring surveys and local committees/working groups** that aim to protect the environment (e.g: Casuarina Coastal Reserve Advisory Committee, Landcare group).
- **Follow migratory shorebird monitoring program** and adapt management techniques according to trigger thresholds (**Figure 11**).

References

Burger, J., Jeitner, C., Clark, K., and Nile, L. J. (2004) The effect of human activities on migrant shorebirds: successful adaptive management. *Environmental Conservation* **31**(04), 283-288.

Charnov, E.L. (1976) Optimal foraging, the marginal value theorem. *Theoretical population biology* **9**(2), 129-136.

Chatto, R. (2003) The distribution and status of shorebirds around the coast and coastal wetlands of the Northern Territory, Technical Report 73 (Ed. Parks and Wildlife Commission of the Northern Territory). (Northern Territory Government: Darwin)

Christidis, L., and Boles, W.E. (2008) 'Systematics and Taxonomy of Australian Birds ' (CSIRO Publishing)

Commonwealth of Australia (2015a) EPBC Act Policy Statement 3.21—Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species. (Ed. Department of the Environment). Commonwealth of Australia: Canberra

Commonwealth of Australia (2015b) Wildlife Conservation Plan for Migratory Shorebirds. (Ed. Department of the Environment). Commonwealth of Australia: Canberra

Department of the Environment (2013) Environment Protection and Biodiversity Conservation Act. (Ed. Department of the Environment). Commonwealth of Australia: Canberra

Department of the Environment Water Heritage and the Arts (2009) Significant impact guidelines for 36 migratory shorebird species. Background paper to EPBC Act policy statement 3.21 (Ed. Department of the Environment Water Heritage and the Arts). Australian Government

Garnett, S.T., Szabo, J.K., and Dutson, G. (2011) 'Action plan for Australian birds 2010.'

Glover, H.K., Weston, M.A., Maguire, G.S., Miller, K.K., and Christie, B.A. (2011) Towards ecologically meaningful and socially acceptable buffers: Response distances of shorebirds in Victoria, Australia, to human disturbance. *Landscape and Urban Planning* **103**(3-4), 326-334.

Harding, S.A., Wilson, J.R., and Geering, A. (2007) Threats to shorebirds and conservation actions. In 'Shorebirds of Australia.' (Ed. A Geering, Agnew, L., and Harding, S.) pp. 197-212. (CSIRO Publishing)

Higgins, P.J., and Davies, S.J.J.F. (1996) 'Handbook of Australian, New Zealand and Antarctic Birds: Snipe to Pigeons.' (Oxford University Press: Melbourne)

Kirby, J.S., Clee, C., and Seager, V. (1993) Impact and extent of recreational disturbance to wader roosts on the Dee estuary: some preliminary results. *Wader Study Group Bulletin* **68**, 53-58.

Lilleyman, A., Franklin, D.C., Szabo, J.K., and Lawes, M.J. (2016) Behavioural responses of migratory shorebirds to disturbance at a high-tide roost. *Emu* **116**(2), 111-118.

MacKinnon, J., Verkuil, Y.I., and Murray, N. (2012) IUCN situation analysis on East and Southeast Asian intertidal habitats, with particular reference to the Yellow Sea (including the Bohai Sea). Occasional Paper of the IUCN Species Survival Commission No. 47., Gland, Switzerland and Cambridge, UK.

Marchant, S., and Higgins, P.J. (1993) 'Handbook of Australian, New Zealand and Antarctic Birds: Raptors to Lapwings.' (Oxford University Press: Melbourne)

Moores, N., Rogers, D.I., Rogers, K., and Hansbro, P.M. (2016) Reclamation of tidal flats and shorebird declines in Saemangeum and elsewhere in the Republic of Korea. *Emu* **116**(2), 136-146.

Murray, N.J., Clemens, R.S., Phinn, S.R., Possingham, H.P., and Fuller, R.A. (2014) Tracking the rapid loss of tidal wetlands in the Yellow Sea. *Frontiers in Ecology and the Environment* **12**(5), 267-272.

Nudds, R.L., and Bryant, D.M. (2000) The energetic cost of short flights in birds. *Journal of experimental biology* **203**(10), 1561.

Parks and Wildlife Commission Northern Territory (2016) Casuarina Coastal Reserve Management Plan 2016. (Ed. Parks and Wildlife Commission Northern Territory). Parks and Wildlife Commission Northern Territory,: Darwin

Rehfisch, M.M., Clark, N.A., Langston, R.H.W., and Greenwood, J.J.D. (1996) A guide to the provision of refuges for waders: An analysis of 30 years of ringing data from the Wash, England. *Journal of Applied Ecology* **33**(4), 673-687.

Rogers, D.I., Battley, P.F., Piersma, T., van Gils, J.A., and Rogers, K.G. (2006) High-tide habitat choice: insights from modelling roost selection by shorebirds around a tropical bay. *Animal Behaviour* **72**(3), 563-575.

Rosa, S., Encarnacao, A.L., Granadeiro, J.P., and Palmeirim, J.M. (2006) High water roost selection by waders: maximizing feeding opportunities or avoiding predation? *Ibis* **148**(1), 88-97.

Weston, M.A., McLeod, E.M., Blumstein, D.T., and Guay, P.-J. (2012) A review of flight-initiation distances and their application to managing disturbance to Australian birds. *Emu* **112**(4), 269-286.

Zharikov, Y., and Milton, D.A. (2009) Valuing coastal habitats: predicting high-tide roosts of non-breeding migratory shorebirds from landscape composition. *Emu* **109**(2), 107-120.

Appendices

Resources for migratory shorebird monitoring program:

Shorebird identification sheets: http://birdlife.org.au/documents/SB-IDsheetsALL.pdf

Shorebirds 2020 field datasheet: http://birdlife.org.au/documents/SB-countform.pdf

Table 8. Suggested field datasheet (with example data) to record disturbances to migratory shorebirds observed during the monitoring program.

Date: 28/11/2015	Site: Sandy Creek	Researcher: Amanda Lilleyman	Tide height (m): 7.2	Tide time: 18:42	Notes: All shorebirds roosting in front on mangroves near the mouth of Sandy Creek.		
Time of disturbance	Duration of disturbance stimulus (mins)	Disturbance type (human, dog, bird of prey etc.)	Shorebird response (flight, walk, no response)	Shorebird species affected	Shorebird species numbers affected (total flock)	Did the affected birds leave the site after the disturbance? (Y/N)	Entry and exit point of disturbance stimulus
17:30	2	Human walking with 2 dogs (leashed)	Flight	Great Knot, Greater Sand Plover, Eastern Curlew and Bar-tailed Godwit	2436	N	Casuarina beach (walking along beach)

APPENDIX O

Water Quality Monitoring Plan

Final Report

Lee Point Master-planned Urban Development – Water Quality Monitoring Plan

Prepared for

Defence Housing Australia

April 2018

Ecology and Heritage Partners Pty Ltd

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Draft 3	Address comments from DoEE	JT	11/10/2017
Draft 4	Address additional comments from DoEE regarding Buffalo Creek	TW	30/10/2017
Final	Address comments from public exhibition period and include preliminary water quality testing results	TW	10/04/2018

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CONTENTS

1 INTRODUCTION 5
1.1 Background 5
1.2 Purpose 5
1.3 Objectives 6
1.4 Scope of Work 6
1.5 Study Area 6
1.5.1 Sandy Creek Estuary 6
1.5.2 Buffalo Creek Estuary 7
2 RELEVANT LEGISLATION AND POLICY, GUIDELINES 8
3 EXISTING ENVIRONMENT 9
3.1 Climate 9
3.2 Hydrology 9
3.3 Flora and Fauna 10
3.4 Uses and Environmental Values 11
4 POTENTIAL IMPACTS 13
5 MONITORING PROGRAM 15
5.1 Monitoring Sites and Parameters 15
5.2 Quality assurance and quality control 17
5.2.1 Instrument calibration 17
5.2.2 Sampling technique 17
5.2.3 Storage and Transport 17
6 WATER QUALITY MANAGEMENT 19
6.1 Water Quality Trigger Values 19
6.2 Reporting 20
6.3 Contingency 21
6.3.1 Adverse weather 21
6.3.2 Human error / accidental spills 21
6.3.3 Ineffective stormwater treatment 21
7 REFERENCES 23

FIGURES 25

1 INTRODUCTION

1.1 Background

This Water Quality Monitoring Plan (WQMP) has been prepared by Ecology and Heritage Partners Pty Ltd to support the Environmental Impact Statement (EIS) for the Lee Point Master-planned Urban Development (herein referred to as 'the Project'), including the 2CRU site and Muirhead site, located on Lee Point Road, Lee Point, Darwin, Northern Territory (Figure 1).

The primary purpose of the Defence Housing Australia (DHA) development is to provide residential housing with smaller sections dedicated for commercial purposes and potential tourism/hotel development. This report details the water quality monitoring requirements for the pre-construction (baseline), construction and occupation of the project site.

1.2 Purpose

Assessing estuary ecosystem health requires a framework for setting the objectives, selecting appropriate indicators, monitoring and reporting to measure components of the ecosystem that contribute to its overall health. The purpose of this WQMP is to determine baseline water quality conditions and natural variability in both the Sandy Creek and Buffalo Creek tidal estuaries. It also provides the framework once baseline values are obtained to conduct subsequent monitoring that will enable the detection of change in water quality and condition of these systems during the construction and occupation of the Project. The monitoring plan is designed to assist DHA in their determination on the cause of any change beyond natural variability (e.g., construction; erosion; stormwater runoff/discharge; spills) as a result of the project and what mitigation measures are required.

As no baseline data currently exists for Sandy Creek, it is advised that if any works take place prior to the implementation of this monitoring plan, that the DHA refer to the default guideline trigger values provided in Tables 3.3.4-3.3.5 for Tropical Australia in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000) (herein referred to as 'the guidelines'). The guidelines recommend trigger values, which represent bioavailable concentrations or unacceptable levels of contamination, that if exceeded, trigger the incorporation of additional information or further investigation to determine whether or not a real risk to the ecosystem exists and, where possible, to adjust the trigger values into regional, local or site-specific guidelines (ANZECC, 2000). In the case of Buffalo creek, baseline data can be extrapolated from previous monitoring conducted by both the NT Government and Power and Water Corporation (PWC), as per the data described within the various Darwin Harbour, Shoal Bay and Buffalo creek report cards (2009-2016).

The ability to delineate influences on these systems from pre-, during- and post-construction activities versus other natural and human influences presents a challenge. The WQMP takes into account that no data has been collected for Sandy creek to date and Buffalo creek is influenced by multiple cumulative industry discharges. Seasonal constraints (i.e. Wet and Dry season) are reflected in how the monitoring data will be collected and used to determine baseline variability for these systems. It is important to recognise that the Sandy Creek catchment currently forms part of a slightly-moderately disturbed system, and the Buffalo Creek catchment forms part of a highly disturbed system with multiple urban and industrial (waste) point sources.

1.3 Objectives

The objectives of the monitoring plan, as per Section 5.3.1 of the Terms of Reference (ToR) for the EIS, include:

- To ensure that surface water resources and quality are protected both now and in the future, such that ecological health and land uses, and the health, welfare and amenity of people are maintained.
- Available water supplies will be sufficient to fulfil the Project needs over the predicted life of the Project, both construction and occupation, without causing environmental or social impacts.
- Ensure minimal sedimentation and turbidity increases as a result of Project activities.

1.4 Scope of Work

As per section 5.3 of the ToR, this water quality monitoring plan will form part of the overall Construction Environment Management Plan (CEMP), to:

- Identify surface water values (environmental, baseline and trigger values) within Sandy Creek estuary and Buffalo Creek estuary.
- Identify potential surface water impacts.
- Identify clear thresholds and management (contingency) measures in response to potential impacts.
- Implement the surface water monitoring plan to achieve environmental objectives and protect environmental values.
- Provide relevant water quality data and information collected to assess the effectiveness of the Erosion and Sediment Control Plan (ESCP) and Stormwater Management Plans (SMPs).

The monitoring plan will also outline contingency measures that will be implemented over the stages of the Project in the event that a significant change in the environmental values is detected.

1.5 Study Area

1.5.1 Sandy Creek Estuary

Sandy Creek estuary is located approximately 13 kilometres north north-east of Darwin city and forms part of the Darwin Harbour Watershed and Finniss River Catchment. The creek originates in the suburb of Lyons and flows past the Royal Darwin Hospital before entering the Casuarina Coastal Reserve where its channel flows parallel to the western boundary of the 2CRU site through to Darwin Harbour.

Sandy Creek's catchment area has been substantially altered by previous urban developments; however, as the water quality has not been monitored the impact of urban development is not known. As only a small portion of the Sandy Creek catchment is within the area proposed for the current development and all stormwater discharge will be managed through a detention basin shown on the master plan in the south-west corner of the 2CRU site, the developments contribution to cumulative impacts is expected to be relatively minor.

1.5.2 Buffalo Creek Estuary

Buffalo Creek is located approximately 14 km north north-east of Darwin's CBD and forms part of the Darwin Harbour Watershed (Figure 2). This tidal influenced creek flows into Shoal Bay, listed by the Northern Territory (NT) Government as a *Site of International Significance* (NRETAS, 2007) for a number of reasons including:

- Extensive tidal flats providing important feeding and roosting area for migratory shorebirds
- Small inland freshwater wetlands frequented by up to 5,000 waterbirds
- Patches of rainforest around the margin of the tidal flats
- Threatened species including three plants, ten vertebrates and one invertebrate.

Buffalo Creek is a highly disturbed tributary, as a result of a number of past and present land uses including the Leanyer-Sanderson Sewerage Treatment Plant (LSSTP) that continues to discharge secondary treated sewage directly into Buffalo Creek since 1971, untreated urban stormwater, landfills, recreational activities (including a caravan park, a water park and recreational boating), a historic quarry mine, and historical use as a military training range (Drewry, 2010).

The areas proposed for development occur across both Buffalo Creek and Sandy Creek catchments and drainage lines (Figure 2). Surface water from the western portion of the 2CRU site currently drains west to Sandy Creek via overland flows, gullies and minor drainage lines, with the main point of discharge occurring in the southwestern corner of the site to a drainage line that flows through Casuarina Coastal Reserve and into Sandy Creek. Surface water from the eastern portion of the Muirhead site currently drains east to Buffalo Creek via overland flows, gullies and minor drainage lines, with the main point of discharge occurring in the south-eastern corner of the site to a drainage line that flows through Buffalo creek management area Reserve and into Sandy Creek. Both the Sandy Creek and Buffalo Creek catchments currently receive stormwater discharge from existing urban/residential areas and Buffalo Creek also receives discharge of treated sewage effluent from the Leanyer Sanderson Wastewater Treatment Ponds approximately 5 km upstream of the mouth.

2 RELEVANT LEGISLATION AND POLICY, GUIDELINES

The principal legislative basis for water quality management in the Northern Territory is the *Water Act 1992.* The legislation includes a process for:

- Identifying and declaring beneficial uses or environmental values. These include environment, cultural and human use values; and
- Establishing corresponding water quality objectives or water quality standards to protect identified beneficial uses.

Water Quality Objectives (WQOs) can be declared under Part 7, Section 73 of the Act. This declaration allows natural resource managers and regulators to use WQOs as benchmarks for regulation to protect beneficial uses and for their use as performance measures for monitoring and reporting.

Other relevant strategies, guidelines and policies include the:

- National Water Quality Management Strategy (NWQMS) 1992;
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ, 2000);
- National Water Initiative (2005)
- *Environmental Assessment Act* 2013
- *Territory Parks and Wildlife Conservation Act 2014* (TPWC Act)

3 EXISTING ENVIRONMENT

The main coastal landforms in the Casuarina Coastal Reserve include intertidal sandflats, offshore reefs, dune, beach ridges, estuarine fringes and waterways including Sandy, Rapid and Buffalo Creeks (Parks and Wildlife, 2016). Sandy Creek is tidally influenced and is dominated primarily by mangroves and salt tolerant vegetation. The intertidal sandflats provide habitat for marine invertebrates, migratory waders and turtles. This area also receives the highest level of visitor use in the Reserve.

Buffalo Creek begins as a freshwater system gradually mixing into an estuarine tidal system consisting of a long, narrow channel gently meandering near its confluence with Shoal Bay, containing a large intertidal sand bar (Haese, et al., 2009). In its upper reaches, it splits into two tributaries, fed by stormwater drains and dominated by salt flats and fringing closed grassland / sedgeland communities. Towards the mid to lower reaches, the creek is fringed by mangroves in its intertidal zone, consisting mostly of *Rhizophora stylosa*, *Bruguiera exaristata* and *Camptostemon schultzii* closed to open forest.

The following sections describe the existing environment, potential impacts and proposed water quality monitoring and management of Sandy Creek and Buffalo Creek tidal estuary.

3.1 Climate

Darwin has a tropical monsoonal climate with distinct wet and dry seasons. Climate data has been extracted from the Bureau of Meteorology (BOM) Darwin Airport station (Site number: 014015). The dry season is typical of a semi-desert climate, which runs from April/May to October, experiencing an annual maximum temperature of 39°C with an annual mean of 32°C, which varies very little year-round and is generally recorded over 30°C most days of the year (BOM, 2017). Darwin experiences a mean annual rainfall of 1722 mm, with the highest recorded rainfall occurring over the Wet season between November and April with humidity highest in the morning at between 72-83%. The Wet season is also known as cyclone season for its cooling tropical rainstorms.

3.2 Hydrology

There is little known information regarding the hydrology of the catchment area of Sandy Creek. It is a short narrow channel situated within a mangrove-dominated coastal reserve, with a few drainage lines and no connected tributaries (Plate 1 and 2). It lies within an area with a mesotidal or low-macrotidal range (>4 m tidal range). There is no available data on the freshwater inputs and water quality data for the system.

NT Government report cards that describe the condition of Buffalo creek from 2009-2016, state an overall water quality rating of 'E', (i.e. V*ery poor water quality. No water quality indicators meet desired levels)*), where <30% of the indicators were compliant with water quality objectives. It is considered that Buffalo Creek has poor ecosystem health due to long residence times of sewage discharge, a larger nutrient load, low denitrification efficiency, and poor tidal flushing (Haese, et al., 2009). According to the Northern Territory Government Department of Natural Resource, Environment, The Arts and Sport (NRETAS), the deteriorating water quality is a direct result of the LSSTP discharge directly into Buffalo Creek (NRETAS, 2010). There are,

however, other sources of pollution including the direct discharge of untreated urban runoff directly into the creek in the upper reaches resulting in cumulative impacts.

Plate 1. Sandy Creek estuary directly below 2CRU (Ecology and Heritage Partners Pty Ltd 31/05/2016).

Plate 2. Sandy Creek estuary at Casuarina Beach (Ecology and Heritage Partners Pty Ltd 31/05/2016).

Plate 3. Buffalo Creek estuary near the LSSTP (DENR 2010).

3.3 Flora and Fauna

Sandy Creek flows into Casuarina Beach that forms part of Shoal Bay, which is listed by the NT Government as a Site of International Significance (NRETAS, 2007) for a number of reasons. Six sites in Shoal Bay are listed on the Register of the National Estate for their natural values including Casuarina Beach-Lee Point-Buffalo Creek Area (Australian Heritage Council).

There are approximately 273 native plant species, 266 native vertebrate species, and 213 species of birds recorded in the Reserve (Parks and Wildlife, 2016). This includes two threatened flora species and at least 10 threatened fauna species (DLRM, 2014; Parks and Wildlife, 2016). The Reserve supports a wide variety of coastal habitats that are typical of the area, with Lee Point, Sandy Creek and Buffalo Creek all recognised as nationally and internationally important sites for migratory and resident shorebirds (Chatto R. 2003, Parks and Wildlife, 2016). These sites are used for feeding and roosting by shorebirds, making this an important shorebird area over the dry season and especially over the wet season. The migratory shorebirds that use the Reserve

are protected under several bilateral agreements including the Convention of Migratory Species of Wild Animals (Bonn Convention), Japan-Australia Migratory Bird Agreement (JAMBA), China-Australia Migratory Bird Agreement (CAMBA) and Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA), as it forms part of the East Asian-Australasian Flyway. Flatback *Chelodina depressa,* Olive Ridley *Lepidochelys olivacea* and Green turtles *Chelodina mydas* are known to use Casuarina Beach and the waters of the Reserve. These marine turtles are listed on the Bonn Convention for the Protection of Migratory Species of Wild Animals and Marine and Migratory under the EPBC Act.

Buffalo Creek provides important aquatic habitat, known to contain two species of national and regional significance, namely the Dwarf Sawfish (*Pristis clavata*) and the Green Sawfish (*P .zijsron*), listed as Vulnerable under the EPBC Act; and Vulnerable by the NRETAS (Larson, et al., 2011; Aurecon 2013). Buffalo Creek is also a known bird watching location, as one of the most important sites for migratory shorebirds in the Darwin region. It is both an important feeding and roosting location with extensive sandy beach connected to sandflats where thousands of shorebirds feed at low tide. Overall, Buffalo Creek has important Aquatic Ecosystem value as it drains into Shoal Bay, which is listed by the NT Government as being of *International Significance.*

3.4 Uses and Environmental Values

Environmental Values (EV) are those qualities of a waterway that make it suitable to support particularly aquatic ecosystems and human uses, also known as beneficial uses. These are divided into a variety of categories reflecting the types of human use (e.g recreational activities, boating, swimming etc.) while aquatic ecosystem EVs are divided into condition classes reflecting the degree of modification from natural conditions. These values can be categorised as high conservation/ecological value systems 'HCV or HEV' (e.g. national parks, conservation reserves), slightly-moderately disturbed systems 'SMD' (e.g. minor changes but are not considered so degraded as to be highly disturbed) and highly disturbed system 'HD' (e.g. degraded systems with lower levels of naturalness) (NWQMS, 1998).

Darwin Harbour, between Charles Point and Lee Point, is managed to maintain aquatic ecosystem protection, recreational water quality and aesthetics beneficial uses, as declared under section 73(1) of the Water Act. The management of water resources in the Reserve is consistent with the declared beneficial uses and the environmental values for Darwin Harbour and are therefore applicable to Sandy Creek (Table 1). The environmental values specific to the area of Sandy Creek would come under the slightly-moderately disturbed systems.

Table 1 Sandy Creek – applied environmental values

Environmental values of water	Examples of use	Potential application to Sandy Creek (Yes or No)	Comments
Aquatic ecosystems	Maintenance of aquatic ecosystems; Fish breeding and spawning; Biodiversity conservation; Aquaculture; Eco-tourism	Yes	Sandy creek estuary mouth provide important habitat for migratory birds of international significance
Primary industry	Irrigated agriculture; Aquaculture; Human consumption of aquatic foods; Stock drinking water	No	N/A

Recreation and aesthetics (primary and secondary)	Swimming; Recreational fishing; Boating; Visual amenity	Yes	Fishing and Boating occurs. Used as a recreation area for bird watching also.
Industrial water	Washing; Cooling; Processing	No	N/A
Cultural and spiritual	Sacred sites; spiritual use; presence of certain plant and animal communities; traditional use	No	N/A

Shoal Bay, between Lee Point and Gunn Point, is managed to maintain aquatic ecosystem protection, recreational water quality and aesthetics beneficial uses, as declared under section 73(1) of the Water Act. The management of water resources in the Reserve is consistent with the declared beneficial uses and the environmental values for Shoal Bay and Darwin Harbour and are therefore applicable to Buffalo Creek (Table 2). The environmental values specific to the area of Buffalo Creek would come under the highly disturbed systems.

Table 2 Buffalo creek – applied environmental values

Environmental values of water	Examples of use	Potential application to Buffalo Creek (Yes or No)	Comments
Aquatic ecosystems	Maintenance of aquatic ecosystems; Fish breeding and spawning; Biodiversity conservation; Aquaculture; Eco-tourism	Yes	Buffalo Creek provides an important aquatic habitat for two fish species of national and regional significance (*Pristis clavata* and *P. Zijsron*). Buffalo Creek discharges into Shoal Bay, which is listed as being of International Significance as well as provide important habitat for migratory birds listed of international significance
Primary industry	Irrigated agriculture; Aquaculture; Human consumption of aquatic foods; Stock drinking water	No	N/A
Recreation and aesthetics (primary and secondary)	Swimming; Recreational fishing; Boating; Visual amenity	Yes	Fishing does occur in the lower reaches. Buffalo creek is a recreation area, and is a known bird watching location.
Industrial water	Washing; Cooling; Processing	No	N/A
Cultural and spiritual	Sacred sites; spiritual use; presence of certain plant and animal communities; traditional use	Yes	There is a recorded sacred site, under the *Northern Territory Sacred Sites Act* at Buffalo Creek. A World WWII observation post is situated at Buffalo Creek and is listed on the Register of the National Estate.

4 POTENTIAL IMPACTS

The Project has the potential to alter local hydrology and water quality that may impact on the Casuarina Coastal Reserve and both Buffalo and Sandy Creek estuary ecosystems abutting the Reserve. Potential impacts may include but are not limited to the short-term direct effects from increased freshwater inputs to the estuaries (e.g. increased runoff of poor water quality, altered flow), followed by spatial and/or temporal changes in water quality (e.g. reduced light penetration, decrease in water temperature, alteration of mixing zones). This can result in impacts for flora and fauna both within the estuaries themselves and along the beach of the Casuarina foreshore and coastal reserve, containing protected migratory shorebird habitat.

Increased urbanisation and construction activities such as land clearing, earthworks, dewatering and establishment of a stormwater drainage system, detention basin and discharge system has the potential to increase sediment and nutrient loads entering both creeks and the reserve via runoff and discharge. Construction works could also increase the potential for environmental incidents such as hydrocarbon and chemical spills associated with the refuelling of plant and equipment or leakage from fuel storages which can temporarily impact on the quality of receiving surface waters and sensitive receptors. The Engineering Services report prepared by SMEC (2015) indicates that the design philosophy for drainage shall ensure that downstream discharges are limited to existing flows.

The main areas of erosion risk have been determined as occurring in the south-west corner of the 2CRU site in association with an existing overland flow path and along the existing low escarpment where steep slopes are present. If erosion of soils were to occur this could cause siltation and reduction of water quality in Sandy Creek with subsequent effects upon the connected shorebird habitat. To date, there is no known water quality information for Sandy Creek.

The key contaminants of concern from construction activities and urbanisation include:

- Hydrocarbons and other chemicals,
- Heavy metals,
- Nutrients; and
- Sediments.

Urban development can impact on catchment hydrology and the deterioration of local water quality. Construction activities can result in increased erosion and sedimentation issues and potential for spills, whilst post-development can result in a multitude of pollutants from stormwater runoff being introduced to aquatic ecosystems, including:

- Toxicants (heavy metals, hydrocarbons, ammonia);
- Nutrients (phosphorus, nitrogen, carbon);
- Oxygen depleting substances (organic material, sulphides);
- Physical contaminants (suspended solids);
- Trace organic compounds (insecticides, herbicides, personal care products);

- Gross pollutants (plastics products, cigarette butts, vegetation etc.); and,
- Altered hydrology (e.g. water levels, frequency).

With respect to stormwater drainage, the Project has designed a pit and pipe stormwater system that will extend along the road network, and will carry stormwater to a detention basin in the south-west corner of 2CRU (Figure 3). The detention basin will collect all post-development stormwater flow prior to discharge to an existing drainage line through to Sandy Creek and Buffalo Creek estuary. During construction, erosion and sediment control measures will be implemented to collect and direct runoff as per the ESCP.

Several drains from the neighbouring suburbs, the hospital precinct and Charles Darwin University currently feed into the coastal reserve and into Sandy Creek. Whilst Buffalo Creek receives stormwater from drainage directly upstream from two main tributaries as well as secondary effluent from the LSSTP. These pollution point sources have the potential to create erosion, sedimentation or pollution issues upstream of the Projects discharge location. It is noted that water quality issues that may occur upstream can have flow on effects for downstream aquatic health and beneficial values as stated above.

Potential cumulative impacts may include:

- Deteriorated water quality from additional stormwater discharge and runoff contaminant contributions (e.g. increased sedimentation (suspended solids), high nutrient loads, bacteria, metals, hydrocarbons etc.);
- Altered hydrology (e.g. increased flow inputs);
- Altered ecosystem processes and services;
- Deterioration of habitat, shorebird feeding and roosting sites and food web dynamics;
- Landform structural failure/erosion from increased flows at inappropriate times of year (i.e. dry season) or lack of vegetation and protection;
- Spread of pest species (flora and fauna); and
- Increased mosquitoes/biting midge and breeding opportunities.

5 MONITORING PROGRAM

Water quality exhibits distinct differences between the wet and dry seasons in waterways and estuaries in the northern tropics of Australia. High rainfall in the wet season produces large freshwater inflows with associated nutrients, sediments and pathogens dispersed via high volumes of runoff resulting in poor water clarity and deteriorated water quality.

This monitoring plan has been developed to obtain data for physico-chemical and some biological parameters for monitoring the water quality within both the Sandy Creek and Buffalo Creek estuary, as well as directly at the three discharge locations.

As per Section 5.3.4 of the EIS ToR Guidelines, the Stormwater Management Plan and ESCP outline details of monitoring programs that would be implemented throughout the construction and post-construction phase. This is to determine the effectiveness of the mitigation measures including the Stormwater Management Plan and ESCP.

5.1 Monitoring Sites and Parameters

Water quality monitoring sites have been identified and defined based upon the two discharge locations situated in the north-west and south-west corner of the 2CRU site, and single discharge location situated in the south-east corner of the Muirhead site. Monitoring sites include a point source monitoring location at the discharge locations as well as both upstream and downstream monitoring locations in the affected creeks (Table 3) (Figure 3). A second monitoring point is included for the discharge location in the north-west of 2CRU as stormwater does not discharge into a permanent water bodies (Table 3) (Figure 3).

At each monitoring location, measurements will be collected *in situ* using a multi-parameter water quality meter and any other related instruments (e.g. turbidity meter, secchi disk) within the upper and lower water column within 1 hr of the slack of both flood and ebb tides. All physico-chemical parameters as stated within this plan will be recorded on a data sheet.

Baseline monitoring and sampling will be undertaken on a monthly basis at Sandy Creek for up to a period of 6 months prior to construction during the wet season and twice during the dry season (during neap spring tides). This will assist in determining current water quality values to use for tentative baseline data. If there is not sufficient baseline data collected prior to the commencement of construction, the project will revert to the default guideline trigger values provided in Tables 3.3.4-3.3.5 for Tropical Australia for reporting exceedances.

During construction, monitoring will continue at the same frequency (six times in wet season, twice in dry season). After occupation, monitoring will continue until there is at least twelve months of monitoring data with no exceedances recorded.

The monitoring field program will be undertaken before or after, but not during the slack of the tide (1 hr either side of high or low tide). Monitoring will be undertaken for both flood and ebb tidal flows during both the wet and dry seasons (if water is present). Prior to field deployment, staff will record recent rainfall (within 24 hrs), tide type (flood or ebb), time of day and weather conditions. It is important to take into account tidal

influence, time of day, stratification/mixing zones during monitoring as these can influence the data collected and compared over time.

In situ monitoring parameters will include:

- Water level (m) of upper and lower column depth
- Flow measurements
- Total depth (m)
- Temperature (°C)
- pH
- Conductivity (EC) and Salinity
- Dissolved oxygen (DO) (% Saturation) and (mg/L)
- Chlorophyll a
- Turbidity (NTU)
- Light penetration using Secchi disk

Sampling parameters for the Laboratory program include:

- The In situ measurements
- Total Suspended Solids (TSS)
- Total nutrients (TN and TP), ammonia, nitrite and nitrate
- Biochemical oxygen demand (BOD)
- Bacteria – microbiological indicators
- Total and Filtered dissolved metals

Grab samples will be taken from the middle of the water column and sent off to a NATA certified laboratory. Water quality monitoring can be used as an indicator of the environmental values likely to be supported by a system and in turn can indicate how much change is acceptable to maintain those values. This will also assist in defining Water Quality Objectives (WQOs) and site-specific guideline trigger values, where required (i.e. Sandy Creek). All data recorded on site and received from the laboratory will be maintained in a Project Database.

Table 3. Location of monitoring sites.

Site – Site Code	UTM Coordinates		
2CRU	**Zone**	**Easting**	**Northing**
Sandy Creek 1 – SC1	52L	704542.03 m	-8634075.95 m
Sandy Creek 2 – SC2	52L	704241.99 m	-8633128.98 m
Sandy Creek 3 – SC3	52L	704229.94 m	-8633909.08 m

Site – Site Code	UTM Coordinates		
Sandy Creek 4 – SC4	52L	704942.00 m	-8634734.00 m
Sandy North 1 – SN1	52L	705612.91 m	-8635152.05 m
Sandy North 2- SN2	52L	705486.73 m	-8635339.29 m
Muirhead North	**Zone**	**Easting**	**Northing**
Buffalo Creek 1 – BC1	52L	706646.96 m	-8633836.09 m
Buffalo Creek 3 – BC3	52L	707414.04 m	-8633779.00 m
Buffalo Creek 4 – BC4	52L	707657.01 m	-8634292.99 m

5.2 Quality assurance and quality control

Quality assurance and quality control (QA/QC) measures are a set of operating and sampling procedures carried out by the monitoring team that help to ensure that calibration, sampling techniques, storage, transport and analysis of samples are consistent. This is to ensure there is minimal variation in results due to incorrect procedures or contamination (e.g. handling error). The QA/QC results will be uploaded and stored in the Projects database and compared to the results from a reference site for each monitoring date.

5.2.1 Instrument calibration

Instrument calibration and records of calibration will be maintained prior to each monitoring session. Staff must follow the instructions of the instrument manufacturer to calibrate instruments. The likely range of values being measured are to be noted and calibrate accordingly. The instrument will perform better if it is calibrated for the data ranges expected in the field, which will be obtained during the pre-construction monitoring period.

5.2.2 Sampling technique

The NATA certified laboratory engaged for the Project, will provide specific instructions to follow when sampling as well as a Chain of Custody (CoC). Duplicate, field and trip blank samples will be taken at a nominated sampling site allowing results to be compared and any inconsistencies identified.

5.2.3 Storage and Transport

Collection and storage of samples will be discussed with the laboratory to ensure adequate volumes are collected, storage is appropriate and adequate field and laboratory QA/QC procedures are in place.

5.3 Preliminary Results

Water quality monitoring commenced in February 2018. In situ parameters have been sampled on a weekly basis, while water quality parameters to be tested in the laboratory have been tested monthly. A summary of the results is provided in the Appendices.

6 WATER QUALITY MANAGEMENT

The mitigation and management measures to be implemented during construction will be included within the ESCP and CEMP and align with best practice measures. All water affected by sediment or stormwater originating from site will be treated via the detention system designed in the Stormwater Management Plans and released in conjunction with existing flows. Water quality management triggers can be specified using a three tier hierarchy management response when an exceedance from the ANZECC guideline trigger values (or tentative baseline values) is detected, including:

- Level 1: Identify, investigate and continue to monitor;
- Level 2: No change in condition, prepare to stop works and continue to monitor or investigate further; and.
- Level 3: Condition deteriorating and impacting sites of significance, act and manage accordingly.

The monitoring plan includes a reporting framework to ensure timely notification of water quality results and any identified exceedances and non-compliances of the monitoring plan. Reports will be provided to both the DHA and the relevant authorities until the relaxation of management measures as a response to recovery of the water quality.

In accordance with ToR, DHA has made a strong commitment to implementing the WQMP until the water quality returns within range of the ANZECC guideline trigger values (or the tentative baseline values, if appropriate). This can be summarised as part of an annual report including an assessment of all monitoring data collected as part of the WQMP and all exceedances and management actions implemented over the duration of the monitoring period.

In addition, the Area Plan within the Master Plan shows an area of 21.8 ha that will be zoned Conservation (CN) as part of the planning application. This area of land will be transferred to the Northern Territory Government to become part of the Casuarina Coastal Reserve. It is intended that excluding this land from development will assist in avoiding impacts to the sensitive Monsoon Vine-thicket vegetation and provide a buffer to potential storm surge inundation and biting insect breeding areas.

6.1 Water Quality Trigger Values

Water quality trigger values for all indicators will be determined by taking into account the level of protection (high, moderate or low as a result from its level of disturbance). For physical and chemical stressors and toxicants in water, the approach to deriving trigger values follows the following order:

- Use of biological effects data;
- Then local reference data (mainly physical and chemical stressors); and
- Finally (least preferred) the tables of default values provided in the ANZECC Guidelines.

When using local reference data (baseline) for physical and chemical stressors, ANZECC guidelines recommend using 3 years of data or 3-5 reference sites, from which you would determine upper (80th percentile) and lower limits (20th percentile) for upstream and downstream sites to derive a range of values. This would incorporate spatial and temporal variations (e.g. wet/dry seasons), to create site-specific guideline trigger values that

incorporates natural variability of the area. For Sandy creek estuary however there is approximately 6 months remaining prior to construction commencing on site. Sandy creek is also already potentially influenced by runoff from urban and industrial areas that may potentially discharge into the upper reaches of the creek (e.g. Royal Darwin Hospital and existing urban/commercial developments).

As such, the collection of baseline data is unlikely to be attainable in accordance with ANZECC guidelines; nonetheless, pre-construction monitoring will occur and commence in late 2017/early 2018. All data collected will be used to define the WQOs for Sandy Creek, as the derived data would be more accurate of local conditions than deferring to the ANZECC guidelines. For monitoring periods when baseline data could not be obtained, data will be compared against the ANZECC Guidelines for tropical Australia for slightly to moderately disturbed ecosystems (Table 4).

Buffalo creek has been regularly monitored and reported on by the NT Government and the Power and Water Corporation. In addition, pre-construction monitoring of Buffalo Creek will commence in late 2017/early 2018. Given the proposed staging plan envisages construction in Muirhead North would not commence until April 2019 (see Table 3 in the EIS/PER), it is possible that a full twelve months of monitoring data could be collected before any run-off from the site reaches Buffalo Creek.

In the event that pre-construction monitoring cannot be completed over a full year period, than WQOs and trigger values for Buffalo Creeks will be extrapolated from NT Government and Power and Water Corporation data. Monitoring at the discharge location before entering Buffalo Creek will be compared against the ANZECC values for tropical Australia for slightly to moderately disturbed ecosystems (Table 4).

As the second discharge location in 2CRU does not discharge into a creek or water body, pre-construction monitoring will not be undertaken. Rather, the trigger values from ANZECC guidelines for tropical Australia for slightly to moderately disturbed ecosystems will be adopted (Table 3).

Prior to the commencement of construction, DHA will notify the NT EPA and DoEE in writing of the WQOs and trigger values which will be used to compare the post-construction monitoring data for Sandy Creek and Buffalo Creek.

Table 4 ANZECC values for tropical Australia for slightly to moderately disturbed ecosystems

Type	Chl a	TP	FRP	TN	NO_x	NH_4^+	DO %Sat Lower	DO %Sat Upper	pH Lower	pH Upper	Turb NTU
Estuaries	2	20	5	250	30	15	80	120	7.0	8.5	1-20

6.2 Reporting

Water quality data collected including both field and laboratory results will be presented in a table and graph format and interpreted against the baseline values and/or ANZECC Guideline trigger values as part of an annual report. This report will contain other information as collected in the field, including weather and tidal information, limits of reporting (LOR) and measures of uncertainty, any calculations and any results that exceed the trigger values as well as a comparison against a summary of the previous month's results.

The annual report will be made available to the NT EPA and DoEE.

All monitoring reports will be been prepared with reference to the NT EPA's *Guideline for the Reporting on Environmental Monitoring* (NT EPA 2016) and the ANZECC *Australian Guidelines for Water Quality Monitoring and Reporting* (ANZECC & ARMCANZ 2000b).

In the event of any exceedance, a report will be prepared and submitted to NT EPA and DoEE within one week of DHA becoming aware of the exceedance.

6.3 Contingency

Contingency measures have been developed in case of the following events which have potential to adversely affect water quality:

- Adverse weather (i.e. cyclone or severe storm causing overflow, abnormal erosion and sedimentation issues)
- Human error / accidental spills
- In effective stormwater treatment.

6.3.1 Adverse weather

Even with properly installed erosion and sedimentation control measures, overflow and higher than normal runoff events could occur as a result of unexpected extreme weather events (i.e cyclone, severe storm). This could result in collapse of silt fencing, overflow or bypass of barriers and detention basins, slope failures, and other problems which could lead to higher than expected sedimentation flowing into the creeks. If sedimentation occurs, immediate action will be taken to temporarily contain the sediment as quickly as practical. When site conditions allow, permanent protection measures will be installed on affected and potentially vulnerable surfaces. If the erosion and sedimentation resulted from a construction-related activity, the activity will cease immediately until management have rectified the situation and water quality recovers to guideline values.

6.3.2 Human error / accidental spills

During construction, an accidental spill of fluids may occur, of which the impact of the spill will depend upon the magnitude and extent, and the environmental and socio-economic conditions in which it takes place. Upon accidental release of any hydrocarbon-based construction fluid, DHA in conjunction with the site contractor will immediately determine the magnitude and extent of the spill and immediately take measures to contain it. Release of sediment will also be treated as a potential spill depending on the magnitude and extent. Spills will be immediately reported to the head contractor.

Spill containment equipment will be readily available, especially near watercourses such as Sandy creek and Buffalo creek. Personnel will be trained in the use of spill containment equipment.

6.3.3 Ineffective stormwater treatment

Stormwater Management Plans have been developed for the project, and have been designed to comply with relevant Guidelines for treatment of stormwater. Testing of the Stormwater Management Plans show they would adequately remove sufficient quantities of Total Suspended Solids, Total Nitrogen, Total Phosphorous

and Gross Pollutants. In the event that exceedances of water quality are detected, ineffective stormwater treatment will be considered (provided all other reasonable factors have been ruled out).

As part of the monitoring and reporting program (see Section 6.2), any detected exceedances will include a review of the effectiveness of stormwater treatment. In consultation with a hydrologist, the following changes to the stormwater treatment may be required:

- Bioretention/Detention Basin size.
- Replace Ecosol Net Guards.
- Construct additional WSUD treatments such as bioswales and rain gardens.

7 REFERENCES

ANZECC & ARMCANZ (2000a). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. National Water Quality Management Strategy Paper No. 4, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra ACT.

ANZECC & ARMCANZ (2000b). *Australian Guidelines for Water Quality Monitoring and Reporting.* National Water Quality Management Strategy Paper No. 7, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra ACT

Aurecon 2013. Buffalo Creek Water Quality Improvement Plan, Project: Muirhead Residential Development. Reference: 38110. Prepared for the Defence Housing Australia, Revision 0. 25 January 2013

Australian Heritage Database. Darwin Foreshores, Darwin NT, Australia – Register of the National Estate. Place ID 16107.

Bureau of Meteorology (2017). Climate statistics for Australian locations; Darwin Airport. Viewed 26 May 2017 online:http://www.bom.gov.au.

Chatto R. (2003). The distribution and status of shorebirds around the coast and coastal wetlands of the Northern Territory. Technical Report 73. Parks and Wildlife Commission of the Northern Territory, Northern Territory Government, Darwin.

DLRM (2013) Darwin Harbour Region Report Card 2013 [Report]. - Palmerston, NT, Australia: Department of Land Resource Management., 2013. Online: https://denr.nt.gov.au/__data/assets/pdf_file/0010/254755/Darwin-Harbour-Report-Card-A4-March-2014_13.3.14_online.pdf.

DLRM (2014) Darwin Harbour Region Report Card 2014 [Report]. - Palmerston, NT, Australia: Department of Land Resource Management., 2014. Online: https://denr.nt.gov.au/__data/assets/pdf_file/0006/397509/Darwin-Harbour-Report-Card-A4-Feb-19.pdf

DLRM (2015) Darwin Harbour Region Report Card 2015 [Report]. - Palmerston, NT, Australia: Department of Land Resource Management., 2015. Online: https://denr.nt.gov.au/__data/assets/pdf_file/0020/262127/darwin-harbour-region-report-card-2015.pdf

DENR (2016) Darwin Harbour Region Report Card 2016 [Report]. - Palmerston, NT, Australia: Department of Environment and Natural Resources., 2015. Online: https://denr.nt.gov.au/__data/assets/pdf_file/0010/397108/Darwin-Harbour-Report-Card-2016_V2_lowres.pdf

Haese R R., and Smith J. (2009). The role of sediments in nutrient cycling in the tidal creeks of Darwin Harbour [Journal] // Geoscience Australia, AusGeo News. - 2009. - 95.

Harrison L., McGuire L., Ward S., Fisher A., Pavey C., Fegan M. and Lynch B. (2009). An inventory of sites of international and national significance for biodiversity values in the Northern Territory. Department of Natural Resources, Environment, The Arts and Sport, Northern Territory Government.

Fortune, J (2015). Supplement to the 2014 Darwin Harbour Region Report Card. Report No. 01/2015D. Aquatic Health Unit, Department of Land Resource Management. Palmerston, NT. Website: www.nt.gov.au/lrm/water/aquatic/index.html (Online: https://denr.nt.gov.au/__data/assets/pdf_file/0007/397510/RC-supp-2014.pdf)

Fortune, J and Patterson, R (2016). Darwin Harbour Region 2015 Report Card Water Quality Supplement. Report No. 4/2016D. Aquatic Health Unit, Department of Land Resource Management. Palmerston, NT. Website: http://www.lrm.nt.gov.au/water/darwin-harbour/reportcards (Online: https://denr.nt.gov.au/__data/assets/pdf_file/0003/262128/darwin-harbour-water-quality-supplement.pdf)

Fortune, J. (2016). Darwin Harbour Region 2016 Report Card Water Quality Supplement. Report No. 22/2016D. Aquatic Health Unit, Department of Environment and Natural Resources. Palmerston, NT. Website: http://www.denr.nt.gov.au/water/darwin-harbour/reportcards (Online: https://denr.nt.gov.au/__data/assets/pdf_file/0011/397109/WQ-Supp-2016_V0.pdf)

Mauraud, N. (2013): Darwin Harbour Water Quality: Supplement to the 2013 Darwin Harbour Region Report Card. Report No 12/2013D. Aquatic Health Unit, Department of Land Resource Management, Northern Territory Government.

NRETAS (2009) Shoal Bay and Buffalo Creek Report Card 2009 [Report]. - Palmerston, NT, Australia: Department of Natural Resources, Environment, The Arts and Sport., 2009. Online: https://denr.nt.gov.au/__data/assets/pdf_file/0007/254725/shoalbay_buffalocreek.pdf

NRETAS (2010) Shoal Bay and Buffalo Creek Report Card 2010 [Report]. - Palmerston, NT, Australia: Department of Natural Resources, Environment, The Arts and Sport, 2010. Online: https://denr.nt.gov.au/__data/assets/pdf_file/0009/254736/reportcard_shoal_bay_buff_ck.pdf

NRETAS (2011) Shoal Bay and Buffalo Creek Report Card 2011 [Report]. - Palmerston, NT, Australia: Department of Natural Resources, Environment, The Arts and Sport., 2011. Online: https://denr.nt.gov.au/__data/assets/pdf_file/0003/254748/Shoal-Bay-and-Buffalo-Creek.pdf

NRETAS (2012) Shoal Bay and Howard Creek Report Card 2012 [Report]. - Palmerston, NT, Australia: Department of Natural Resources, Environment, The Arts and Sport., 2012. Online: https://denr.nt.gov.au/__data/assets/pdf_file/0011/254765/2012-11-shoal-bay-report-card.pdf

NRETAS (2007) Sites of Conservation Significance in the NT [Online] // Natural Resources, Environment, The Arts and Sport. - 2007. – Accessed Online: July 2017.

NRETAS (2010) Water Quality Objectives for the Darwin Harbout Region - Background Document [Report]. - Darwin : Northern Territory Government, 2010.

NT EPA (2016). Northern Territory Environment Protection Authority *Guideline for the Reporting on Environmental Monitoring.* May 2016. Version 1.0

Parks and Wildlife (2016) Casuarina Coastal Reserve Management Plan, April 2016. Parks and Wildlife Commission of the Northern Territory

Skinner, L., Townsend, S., and Fortune, J. (2009). The impact of urban land-use on total pollutant loads entering Darwin Harbour. Department of Natural Resources and Environment.

FIGURES

Legend

- Project area
- Localities
- Local Government Areas

Figure 1

Location of project area

Environmental Impact Statement water quality monitoring plan, Lee Point, Northern Territory

N

0 900 1,800

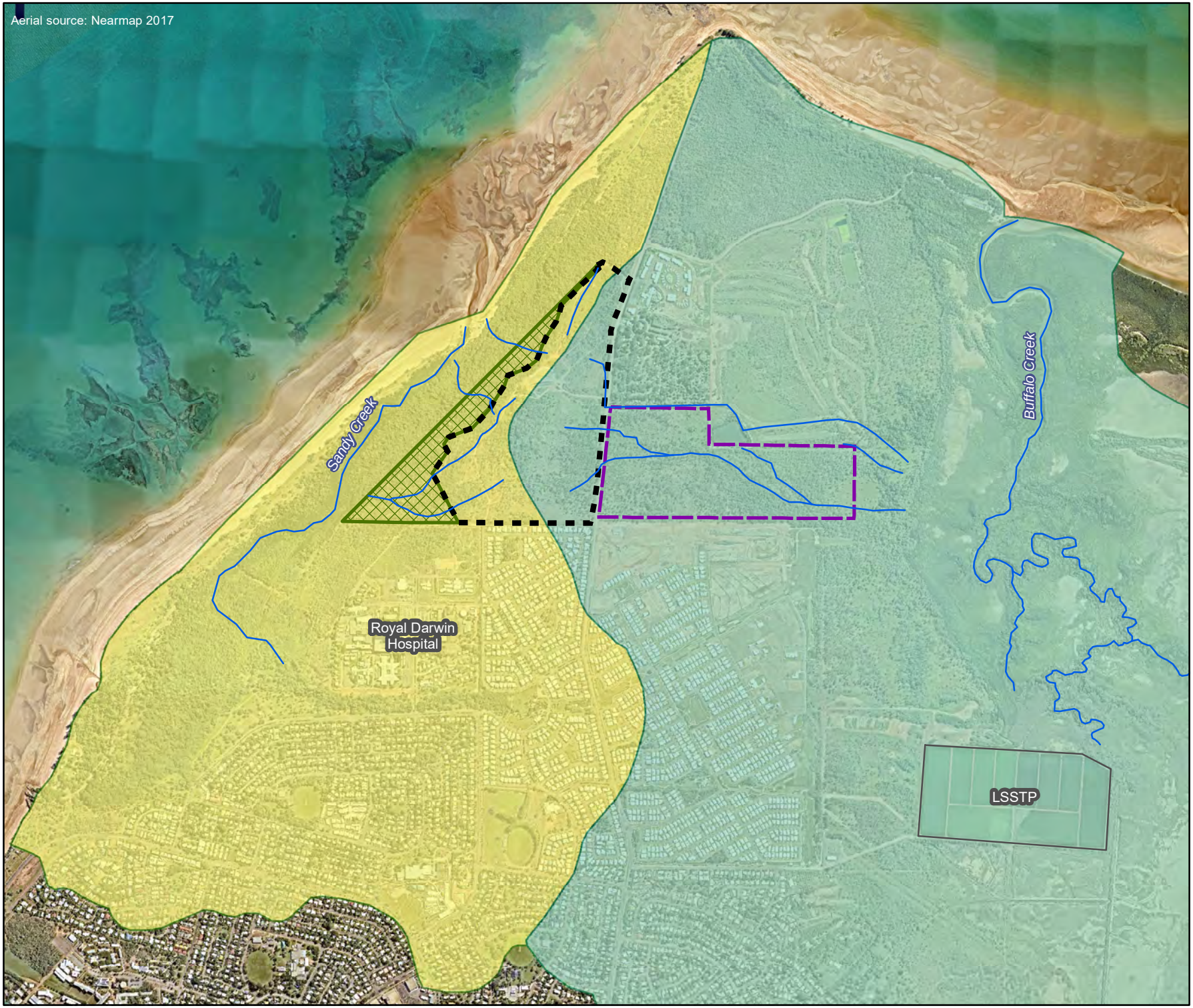
Metres

Map Scale: 1:50,000

Coordinate System: MGA Zone 52 (GDA94)

ecology & heritage partners

Base data sourced from data.gov.au. Used under Creative Commons licences 3.0 and 4.0. Date 25/05/2017.
Project area derived from client provided information.
Ecology and Heritage Partners makes effort to ensure maps are free of errors. However, it does not warrant the map and features are spatially or temporally accurrate or fit for a particular use.



Legend

- Area Zoned Conservation

Proposed development areas

- 2CRU
- Muirhead North

Catchments

- Buffalo Creek
- Sandy Creek
- Waterways / assumed drainage lines

Figure 2

Site location and surface water sensitive receptors

Environmental Impact Statement water quality monitoring plan, Lee Point, Northern Territory

0 400 800
Metres

Map Scale: 1:24,000
Coordinate System: MGA Zone 52 (GDA94)

ecology & heritage partners

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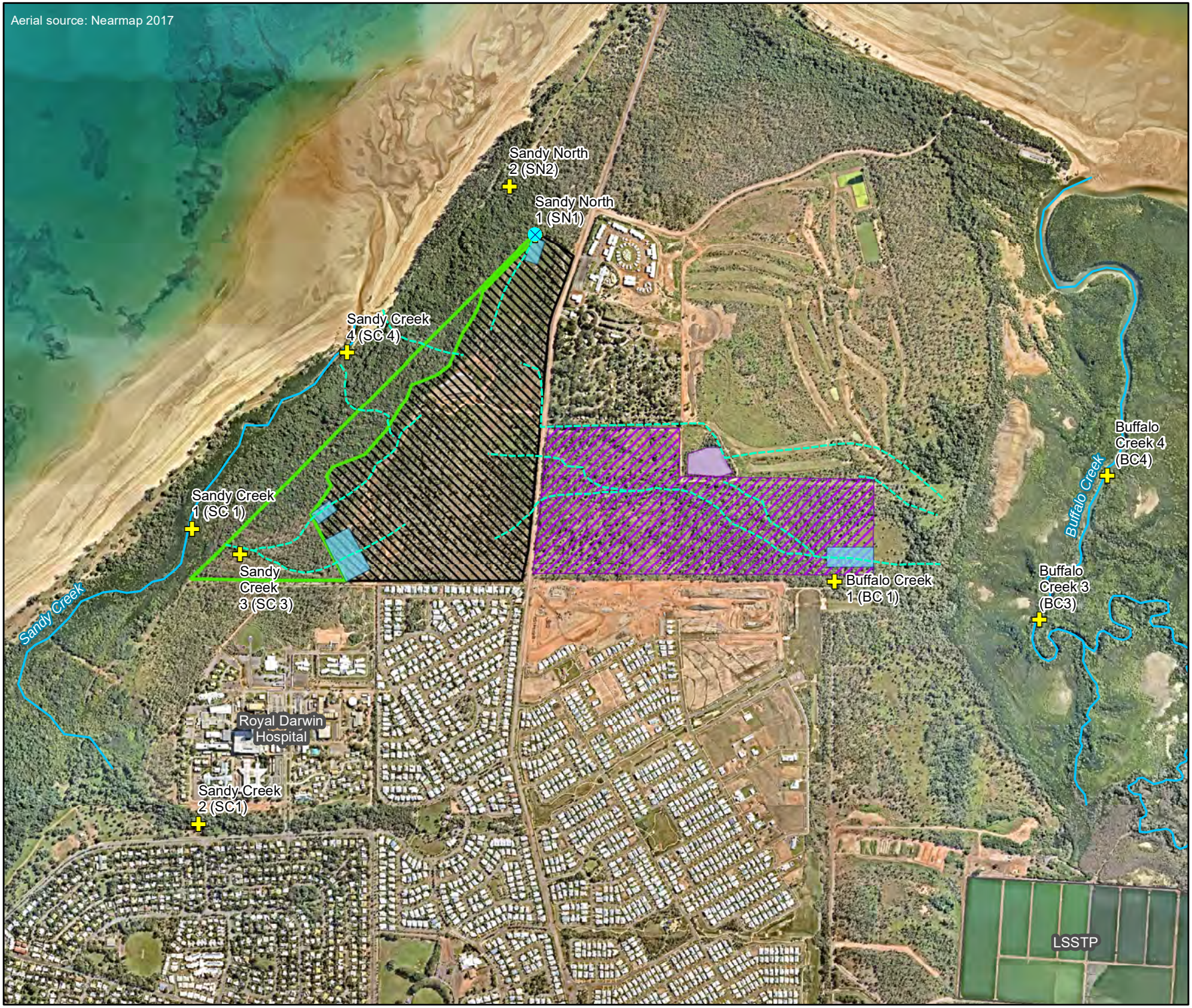

Legend

- Monitoring point
- Area Zoned Conservation
- Detention basin
- Dam
- Waterway
- Assumed drainage lines

Proposed development areas

- 2CRU
- Muirhead North

Figure 3

Surface monitoring locations

Environmental Impact Statement water quality monitoring plan, Lee Point, Northern Territory

0 250 500
Metres

Map Scale: 1:18,000
Coordinate System: MGA Zone 52 (GDA94)

ecology & heritage partners

Base data sourced from data.gov.au. Used under Creative Commons licences 3.0 and 4.0. Date 25/05/2017.
Project area derived from client provided information.
Ecology and Heritage Partners makes effort to ensure maps are free of errors. However, it does not warrant the map and features are spatially or temporally accurate or fit for a particular use.

APPENDICES

Table 5. Preliminary water quality monitoring results (February 2018)

Site	Date	Temp (°C)	EC (ms/cm)	DO (%)	DO (mg/L)	pH (pH units)	Turbidity (NTU)	Salinity (PSS)	Total Suspended Solids (mg/L)	Total Nitrogen (mg/L)	Total Phosphorous (mg/L)
SC1	8/02/2018	30.12	140	78.7	5.88	6.35	4.26	0.07	<5	0.42	0.015
	15/02/2018	29.6	181	56.0	4.42	7.36	8.81	0.09	<5	0.38	0.011
	22/02/2018	31.6	214	68.2	4.66	6.75	12.10	0.1	<5	0.50	0.017
SC2	8/02/2018	28.18	4320	80.0	8.12	7.21	20.60	2.32	14	0.25	0.078
	15/02/2018	27.86	1302	49.1	3.69	7.56	17.30	0.67	14	0.22	0.04
	22/02/2018	31.5	3270	52.1	3.76	7.27	28.30	1.71	27	0.38	0.04
SC3	8/02/2018	28.42	50	78.1	0.03	6.23	23.30	0.03	<5	<0.01	0.017
	15/02/2018	28.41	26	63.3	5.01	7.36	41.90	0.02	6	0.03	0.012
	22/02/2018	32.92	151	68.2	4.92	7.53	16.50	2.02	<5	0.15	0.011
SC4	8/02/2018	28.76	14580	73.6	5.61	7.44	15.30	8.17	<5	0.30	0.035
	15/02/2018	27.8	6160	58.3	4.6	6.7	14.30	3.35	10	0.26	0.023
	22/02/2018	30.43	6870	66.8	5.09	7.57	16.10	2.02	12	0.28	0.012
SN2	8/02/2018	32.52	7600	90.3	6.87	7.66	3.72	4.22	<5	0.47	0.078
	15/02/2018	28.79	3240	58.0	4.81	7.24	7.63	1.7	5	0.26	0.04
	22/02/2018	29.12	4430	59.7	4.57	7.18	2.02	2.36	<5	0.28	0.04
BC1	8/02/2018	32.96	80	96.6	6.81	7.11	26.60	0.04	<5	0.20	0.014
	15/02/2018	32.01	77	76.5	5.67	7.18	61.80	0.04	8	0.09	0.021
	22/02/2018	30.32	68	96.4	7.44	6.75	10.70	0.04	<5	0.37	0.015

Site	Date	Temp (°C)	EC (ms/cm)	DO (%)	DO (mg/L)	pH (pH units)	Turbidity (NTU)	Salinity (PSS)	Total Suspended Solids (mg/L)	Total Nitrogen (mg/L)	Total Phosphorous (mg/L)
BC3	8/02/2018	30.11	3300	32.1	2.4	7.05	23.20	1.74	10	1.46	0.344
	15/02/2018	27.22	1570	58.0	4.46	6.90	67.80	0.79	48	1.00	0.220
	22/02/2018	29.21	16300	42.2	3.11	7.44	26.60	9.77	19	2.07	0.133
BC4	8/02/2018	30.73	12830	33.4	2.35	7.24	23.60	6.24	16	1.72	0.328
	15/02/2018	27.43	1690	58.1	4.46	6.85	62.00	0.85	41	0.97	0.199
	22/02/2018	29.35	21100	52.2	3.79	7.57	14.30	9.77	15	2.61	0.139

APPENDIX P

Supplement to the EIS

Introduction

In accordance with the NT EPA and DoEE guidelines, a draft EIS was displayed on public exhibition between 18 November and 1 February 2018. During this period, government organisations, non-government organisations and members of the public had an opportunity to provide comment on the draft EIS. Responses were received from the following Northern Territory Government advisory bodies including:

- Department of Environment and Natural Resources;
- Parks and Wildlife Commission;
- Department of Health;
- Department of Trade, Business and Innovation;
- Department of Attorney General;
- Department of Tourism (Heritage Branch);
- Aboriginal Areas Protection Authority;
- Department of Tourism and Culture;
- Police Fire and Emergency Services; and,
- Power and Water Corporation.

Comments were also received from non-Government organisations, corporations and members of the public including:

- Justin Tutty;
- Larrakia Development Corporation;
- Anna Gazzard;
- Grusha Leeman;
- Nick Fewster;
- Environment Centre NT;
- Nicole Bergs;
- Tom Poulsom;
- Andris Bergs;
- Darwin Off-roach Cyclists Committee;
- NextGen Garamanak;
- Eric Garcia;
- Kylie Welch;
- Rebecca Spain;
- Deb Hall;

- Clara Penton; and,
- Kevin Costello.

Comments from these organisations and individuals have been summarised in the tables below with a response to how each comment has been addressed in the EIS. Responses have been provided as either:

- Clarification: information already exists in EIS to address comment. Sections within the EIS is provided of where relevant information exists. As a result, there are no changes to the EIS; or,
- Change: information has been added to the EIS to address comment. Sections within the EIS is provided where relevant information has been added.

Where comments received from different organisations and/or individuals relate to a similar issue, the comment has only been addressed once. Similar comments are cross-referenced to the section of the supplement where the change has been made.

Comments

Table 81. Justin Tutty

Comment #	Comment	Response
1.1	Concerned about loss of flora and fauna habitat	**Clarification.** The EIS acknowledges that there will be an impact on flora and fauna. Section 7 of the EIS describes the flora and fauna values within the project site in detail, as well as the potential impacts and measures to retain and minimise impacts to these values.
1.2	Unconvinced about need for new housing	**Clarification.** The Lee Point project has been developed in consultation with the NT Government and City of Darwin and community stakeholders with the objective of meeting all economic and social needs for the ongoing development of the City of Darwin as well as sustaining the financial milestones for a DHA community development. The DHA 10 year Capital Plan identifies an ongoing need for 30 per cent of land developed to be required for ongoing Defence Housing provisioning. The balance of the community lots will be required at a rate of approximately 100 per annum for ongoing household creation numbers. The suburb of Muirhead commenced development in 2011 and is in the final stage of construction and sale in 2018 with a total yield of 1184 lots, 30 per cent of which are allocated to Defence Housing. This equates to a demand of 200 lots per annum. The Lee Point project is identified by the Department of Infrastructure, Planning and Logistics 10 Year Infrastructure Plan as an integral part of the future growth and development of Darwin.
1.3	Proposed development is too large/tall and dense and in close proximity to conservation reserve where it might have negative environmental impacts on the reserve	**Clarification.** The potential impacts to the conservation reserve have been considered in detail in Section 7.
1.4	Offset arrangement is "poorly defined"	**Change.** Refer to Comments 17.7, 17.8 and 17.9.
1.5	Adverse water quality impacts on nearby creeks. Buffalo creek and Sandy creek	**Clarification and Change.** The project is fully sewered and drainage outflows are restricted to the current overland flows already existing on site. Baseline testing of nearby creeks and water courses is underway. The existing Stormwater Management Plans and Water Quality Monitoring Plan will ensure impacts to Buffalo and Sandy Creeks are minimised, with potential for an improvement in water quality at Sandy Creek. Water quality data collected

Comment #	Comment	Response
		during the public exhibition period has been included (refer to Appendices of Water Quality Monitoring Plan).
1.6	Sea level rise is not factored into design and management	**Clarification.** The project is well above sea level and there are no Q100 impacts or coastal surge impacts on the site. See Figure 12.
1.7	Inadequate attention to Larrakia cultural heritage	**Change.** Refer to Comments 2.1 – 2.7.
1.8	Report fails to acknowledge the impact on local traffic	**Clarification.** Traffic impacts from the project are considered in Section 6.2.3, Appendix K and Appendix L. The Traffic Impact Assessment reports have been prepared in accordance with Austroads *Guide to Traffic Management Part 12: Traffic Impacts of Development.*
1.9	Concerned domestic animals/pets will have an adverse impact on native fauna	**Clarification.** The management of domestic pets in residential developments is a matter for the City of Darwin and the NT Government to manage and legislation where required. See Section 7.3.2.13 regarding threat from domestic cats.

Table 82. Larrakia Development Corporation

Comment #	Comment	Response
2.1	Project should provide alternative areas of land on Larrakia Country for the appropriate offsets	**Change.** DHA are currently working with rangers from the Larrakia National Aboriginal Corporation to locate a suitable off-site offset on Larrakia land. A potential site at Cox's Peninsula has been identified. Further information on this offset proposal is provided in Section 7.5.2.
2.2	Initial Ecology and Heritage Partners report fails to reference the Larrakia people by name or any prospective cultural, tourism, heritage, or economic development opportunities.	**Change.** See first paragraph of Section 2.2, Section 8.4.5.1 and Section 7.2.4.5 for references to Larrakia people. See Table 46 and Section 7.3.2.11 for how Larrakia Development Corporation will be involved in heritage monitoring during works and preparation of interpretive signage. Section 8.5.3.3 has been updated to describe how the LDC and LNAC will be engaged during the project. Section 8.5.3.5 has been updated to describe benefits for existing tourism businesses run by traditional owners.
2.3	Lack of consultation with Larrakia Development Corporation (LDC) and the Larrakia Nation Aboriginal Corporation (LNAC) where Larrakia people can contribute to the project.	**Change.** Representatives from LDC and LNAC were consulted following public exhibition period. This included discussions on how these organisations can contribute to the project. LDC provided detailed explanation of range of services it can provide throughout life-cycle of project. LDC and LNAC will be directly engaged on project (refer to Comment 2.2.). Dates of consultation are provided in Section 8.4.6.
2.4	Consultation with LDC, the LNAC or the Kenbi Ranger Group to discuss environmental offsets for the Black Footed Tree Rat.	**Change.** Refer to Comment 2.1
2.5	DHA to consider elevating the LDC to a first point of preference for any number of Sub or lead contracting opportunities relating to the Commonwealth Indigenous Procurement Policy	**Change.** Refer to Comments 2.2 and 2.3. The LDC will be directly engaged for specific activities, and have been informed of opportunities to partner with primary contractor.
2.6	DHA and Northern Territory Government to consider prioritising discussions with the LDC for the development of any proposed affordable housing models for the proposed development models. This could include LDC leading discussions with the Yilli Rreung Housing Aboriginal Corporation and Ironbark Corporation	**Clarification.** The need for affordable housing in the Lee Point area and wider Darwin region for Larrakia people was discussed. While it is acknowledged that housing affordability is a significant issue for Larrakia people, it is beyond the reach of this project to address the problem.
2.7	Lack of Larrakia influence in the proposed tourism/hospitality components of the proposed development. This must advance the standing of Larrakia as traditional owners of the development area and its surrounds	**Change.** Refer to Comment 2.3.

Table 83. Anna Gazzard

Comment #	Comment	Response
3.1	Insufficient community consultation, community meeting poorly advertised	**Clarification.** Stakeholder consultation with the Government and local community has been undertaken, refer to Section 8.4.6 for details.
3.2	Proposed development will have negative visual and related aesthetic impact on the area.	**Clarification.** As discussed in Chapter 2 and Section 8.4 the project is based on single level dwellings for the residential component with one dwelling per lot prerequisite with a maximum height of 2 storeys as per the NT planning scheme and project design parameters. In accordance with the approved rezone in 2015, there is a General Use and Multi Use sector which are 3 storeys and 4 storeys height limit respectively. The Tourism Precinct sites are to revert to the NT Govt. for short term tourist hotel type accommodation with designated heights in accordance with the approved rezone.
3.3	No economic case for project construction	**Clarification.** The project is a designated growth area under the Darwin Vibrant Future plan and forms part of the 10 year infrastructure plan for the future of Darwin. The economic demand for the project are addressed in Section 8.5.
3.4	Land clearing for this development would remove critical fauna habitat (particularly in Lot 4873)	**Clarification.** Impacts to fauna including threatened species have been considered in detail in Sections 7.2.4, 7.3 and 0.
3.5	Rejection of the statement that "in the Draft EIS that the Casuarina Coastal Reserve would provide a sufficient corridor for the movement of wildlife."	**Change.** The role of Casuarina Coastal Reserve as a wildlife corridor is outlined in the reserve's management plan. The Casuarina Coastal Reserve Management plan is now referenced in Table 48
3.6	Development will only further fragment the remnant vegetation	**Clarification.** Fragmentation impacts have been addressed in risk assessment (Table 47).
3.7	Development needs to consider sea level rise	**Clarification.** Refer to Comment 1.6.
3.8	Increased people traffic in the area will have negative consequences especially in the Casuarina Coastal Reserve and beach adjacent to the proposed development	**Clarification.** The potential impacts of increased human visitation along the Casuarina Beach is acknowledge with mitigation measures to address these impacts. See 'human disturbance' impact under risk assessment, as well as sections 7.3.2.7, 7.3.2.8 and 7.3.2.9.

Table 84. Grusha Leeman

Comment #	Comment	Response
4.1	Darwin Harbour Report Card 2016 was missing from report.	**Change.** The 2016 report card was not published until after the public exhibition period commenced. Figure 14 has been updated with 2016 report card.
4.2	Sea level rise will negativity effect the proposed development	**Clarification.** Refer to Comment 1.6.
4.3	Need for baseline monitoring of Sandy Creek	**Change.** Water quality monitoring for Buffalo Creek and Sandy Creek commenced during the public exhibition period. Results from the monitoring included in WQMP (Appendix O).
4.4	Aboriginal heritage needs more attention. No mention of traditional owners of Larrakia in the EIS the 50 metre wide transect was inadequate	**Change.** Refer to comments 2.1 to 2.8.
4.5	Removal of trees negatively effects local environment and fauna habitat	**Clarification.** Removal of fauna habitat has been considered in detail in Section 7.3.
4.6	Lack of weed management is an issue, levels on site are too high especially Gamba grass	**Clarification.** The presence of Gamba grass and other weeds has been acknowledged. DHA have been undertaking a weed management program on site as mentioned in Table 57.
4.7	Roads in the area need to be widened including Lee Point Road. This included the addition of pedestrian crossings	**Clarification.** Road design is in accordance with Austroad road design principles and is subject to review and approval by the City of Darwin and NT Department of Transport (as is incorporation of pedestrian crossings).
4.8	Limit domestic animals access to Casuarina Costal Reserve and new suburbs	**Clarification.** Refer to Comment 1.9.
4.9	Extend rear of the Lee Point Village Reserve to already cleared land	**Clarification.** The project area is in accordance with the approved rezone of 2015.
4.10	Poor housing design. Issues with heat and airflow in Lyons and Muirhead, no insect screens.	**Clarification.** All housing is constructed under strict design guideline parameters and thoroughly policed. All housing is cyclone rated and all Defence dwellings are constructed to additional Defence compliance standards including air conditioning in addition to fans, louvres, and breezeways. Defence houses require security screens with insect mesh to all dwellings

Table 85. Nick Fewster

Comment #	Comment	Response
5.1	Fauna Habitat removal. Development clears land of the EPBC listed Black Footed Tree Rat and places pressures on EPBC listed migratory bird species.	**Clarification.** Potential impacts to Black-footed Tree-rat and Migratory shorebirds have been addressed in Section 7.4.1.
5.2	No baseline data on the Floodplain Monitor, waterway health or management strategies waterways to indicate changes to that system from the development.	**Clarification and Change.** Water health addressed through Stormwater Management Plans (Appendix E and Appendix F) and Water Quality Monitoring Plan (Appendix O). Refer to Comment 4.3 regarding baseline monitoring of Sandy Creek and Buffalo Creek. Floodplain monitor was not recorded during the various field surveys. Targeted surveys were not completed for this species. The likelihood assessment in Table 44 considers the species 'may' occur in the project site. If so, it is likely to be found in environs close to Sandy Creek and Buffalo Creek that will not be impacted by the project. Further the species is likely to disperse from the site at its own accord if construction activities do impact on species' habitat. Likelihood of occurrence description in Table 44Table 47 has been updated accordingly.
5.3	Other stages of Defence Housing adjacent have completely cleared the remnant forest site and planted new trees.	**Clarification.** Greening Australia undertook an environmental stocktake and harvested seeds from native species and harvested seeds from native species and propagated trees for replanting throughout the Muirhead 'Breezes' project.
5.4	Unclear if development will retain mature trees within the street scapes	**Clarification.** Due to ongoing disturbance from fire, as well as historic military uses, most trees are immature. Cycads will be salvaged and incorporated into landscaping.

Table 86. Power and Water Corporation

Comment #	Comment	Response
6.1	There is currently no water or sewer infrastructure in this area. PWC has no current program to provide reticulated water or sewerage to this, or any other development in the adjacent areas.	**Clarification.** The subject parcels are not currently services however reticulated water and sewerage services are available in the area and the proposed developments can be services with headwork upgrades.
6.2	Any Development above 28.0m AHD ground level is not an acceptable option without major headwork upgrades.	**Change.** It is agreed that headwork upgrades are required to service development above 28.0 m AHD. The proponent is working with PWC on this issue and both parties agree that there are options to address this. See changes to Section 6.2.1.
6.3	The proposed development (2CRU) may exceed the total 1675 EP load allocation for the ultimate 2CRU development & 1623 EP allocation for ultimate Muirhead North development	**Clarification and Change.** Updated EP load calculations based on the current development layouts have been presented to PWC. The projected EP loadings for 2CRU and Muirhead North are 2,053 and 851 respectively. The total EP's are less than the combined EP allocation for both sites. The EP loading discharging to the Lyons SPS from the 2CRU west catchment is 567. This exceeds the DCP EP allowance by 3%. It is acknowledged that the proponent will be required to undertake minor upgrades to the Lyons SPS. The EP loading discharging to the Muirhead SPS from the 2CRU east catchment and Muirhead North is 2,337, which is less than the DCP EP allowance of 2,747. See changes to Section 6.2.2.
6.4	There is no Master Plan Report or Headwork upgrading proposals for the entire area covering 2CRU & Muirhead North development.	**Clarification.** The proponent is working with PWC to determine headwork requirements for the entire area covering 2CRU and Muirhead North. Both parties agree that suitable solutions are available and will be documented to PWC's satisfaction.
6.5	A sufficient sewerage and water services plan must be provided to PWC from the proponent, consistent with the proposed development plans, to the satisfaction of PWC	**Clarification.** Sewerage and water services plans will be updated in consultation with PWC during the DA stage.
6.6	Consideration of reuse/recycle systems will require formal engagement with Power and Water Services and the regulator, the Department of Health,	**Clarification.** Neither the proponent nor PWC are currently proposing any reuse/recycle systems.
6.7	Water for construction purposes may not be available from all existing PWC mains in this area due to network constraints.	**Clarification.** Possible constraints on water for construction purposes are noted. Any constraints or limitations will be agreed prior to construction.

Comment #	Comment	Response
6.8	Section 2.4 discussed future extensive development proposal without any consideration of overall Developers Master Plan & Headwork upgrading requirements. It also did not address EP load & Maximum Ground Elevation limitation for such development.	**Clarification.** Section 2.4 of the EIS is intended to provide a general description of the proposed development in the context of the Lee Point Area Plan. Infrastructure requirements are addressed in Section 6.
6.9	The overall 2 CRU proposals prepared without consideration of maximum 28.0m Ground level restriction or addressing how the Infrastructures will be developed to support the development in various stages.	**Change.** Refer to comment 6.2.
6.10	The proposed water servicing approach described in Section 6.2.1 of the Draft EIS document is not formally confirmed or accepted by PWC and cannot be used for proper modelling assessment as proposed without further clarification with PWC.	**Clarification.** The proponent is working with PWC to determine the best water servicing approach for short and long term needs. Both parties agree that suitable solutions are available and will be documented to PWC's satisfaction.
6.11	PWC has no fund allocation to construct Marrara Elevated Tank as proposed. However, the proposed 2CRU development would tiger construction of such Elevated Water Tank to meet minimum pressure requirements.	**Clarification.** The proponent is working with PWC on headworks options and triggers and is open to making a fair contribution to the proposed Marrara Elevated Tank and/or addressing short term requirements with a booster pump station and ground level storage.
6.12	Current & ultimate boundary condition with available pressure proposed in the report is not valid and cannot be used to assess internal or external headwork requirements as proposed.	**Clarification.** The boundary conditions stated in the EIS were provided by PWC. The proponent has discussed this with PWC and it is agreed that the modelling can be updated to reflect any change in conditions advised by PWC.
6.13	A detail overall Master plan with water & sewer Network proposal required from developer based on agreed boundary condition & strategy to develop the entire area. DN 200 reticulation pipe is not PWC standard size and cannot be used as proposed.	**Clarification.** The proponent is working with PWC to determine overall water and sewer requirements for the entire area covering 2CRU and Muirhead North. Both parties agree that suitable solutions are available and will be documented to PWC's satisfaction. As determined by hydraulic modelling DN200 is the minimum required pipe size to service some sections of the reticulation network. For construction DN225 pipe will be used in these locations in accordance with PWC standards
6.14	Pressure Booster system is not PWC preferred headwork option and is not acceptable to current PWC Standard as a suitable alternative option to replace Elevated Storage Tank as proposed.	**Clarification.** Please refer to comment 6.11.
6.15	Section 6.2.2 The proposed ultimate 2106 EP load discharge to Muirhead SPS must be the total EP load allocation from both 2CRU & Muirhead North Development. This must be clarified in the Master Plan Report.	**Clarification and Change.** Please refer to comment 6.3.

Comment #	Comment	Response
6.16	Section 6.2.2 There are no plans by Power and Water Corporation to upgrade the existing plant apart from its current investment of $15.4 million in constructing new inlet works.	**Clarification and Change.** It is understood that LSWSP has spare capacity of approximately 22,000 EP's and no upgrade is required to service the proposed development. See changes to Section 6.2.2.

Table 87. Environment Centre NT

Comment #	Comment	Response
7.1	Apartment vacancy rates in Darwin and surrounds have risen substantially, population growth needs to be approached thoughtfully.	**Clarification.** Refer to Comment 1.2.
7.2	Concerned that this sensitive and valued area may be cleared without the current demand to match all of Darwin's planned and in construction housing projects.	**Clarification.** Refer to Comment 1.2.
7.3	Most of the economic stimulus for this project will be temporary during the construction phase of the new suburb. We wonder if there are other projects that would be more suited to this area that would create long term social, ecological and economic outcomes.	**Clarification.** Refer to Comment 1.2.
7.4	Defence Housing Australia, housing design issues. design to reduce stormwater runoff and minimum design principles applicable to tropical housing design, to reduce the reliance on air conditioning	**Clarification.** Refer to Comment 4.10.
7.5	Removal of native remnant vegetation and associated Fauna habitat reduction. Black-footed tree-rat habitat	**Clarification.** Impacts to native fauna and Black-footed Tree-rat are considered in detail in Section 7.
7.6	Loss of biodiversity and slow growth of re-veg sites in the monsoonal climate of Darwin.	**Clarification.** Refer to Comment 7.5 regarding loss of biodiversity. Slow growth of revegetation is a valid point to raise. However, there are numerous successful revegetation projects in the Darwin area including on DHA sites.
7.7	Baseline water quality monitoring and management of Sandy Creek, when, how funding and release of results to public	**Clarification and Change.** Water Quality Monitoring Plan (Appendix O) has been updated to state that funding will be by DHA and that annual monitoring results will be published on DHA's website and submitted to the NT EPA and DoEE. Water Quality Monitoring Plan (Appendix O) and Stormwater Management Plans (Appendix E and F) outline how water quality will be managed and monitored.
7.8	Water quality issues of Buffalo Creek including stormwater runoff from the study area and release of information surrounding this issue	**Clarification.** Refer to Comment 7.7 regarding Stormwater Management Plans.
7.9	The decision to not impose rainwater tank requirements, nor incentives to reduce paving and roof size is disappointing.	**Clarification.** The project is subject to the approval of City of Darwin and NT Government development standards with regards to paving and rainwater tank requirements. The project is compliant with these standards.

Comment #	Comment	Response
7.10	Implementation of water sensitive urban design features	**Clarification.** Table 11 and Table 47 provide details of how Water Sensitive Urban Design has been incorporated into the project.
7.11	Further detail is required regarding monitoring of the health of the monsoon rainforest to determine whether stormwater flows are appropriate for sustaining the patch. This information should be made publicly available	**Change.** Refer to comment 17.11.
7.12	We urge testing to be done for acid sulphate soils for all stages of the project, despite the elevations of the site	**Clarification.** Acid-sulphate soil testing will be undertaken in Stage 2B only under the direction of a suitably qualified environmental scientist, for reasons explained in Section 53
7.13	We question whether there is a conflict between the 'biting insect management plan' (limiting tree cover to 10%) and habitat for the black-footed tree-rat.	**Clarification.** Thinning in the esplanade area is a Department of Health requirement to address biting insect requirements. DHA have accounted for these losses as part of the impact and offset calculations for Black-footed Tree-rat (see Section 7.5).
7.14	Habitat mapping at 2CRU. When will this deficit of the habitat mapping be addressed and how will the results be made public? What opportunities will there be for public comment on this additional habitat mapping.	**Change.** The detailed habitat mapping for Black-footed Tree-rat in 2CRU is no longer proposed and this statement has been removed from the EIS. More detailed habitat mapping was proposed because the current habitat mapping was considered course and over-estimated the extent of suitable Black-footed Tree-rat habitat on 2CRU by not differentiating between access tracks and woodland.
7.15	Areas of prime habitat (7/10 and 5/10) for the threatened black-footed tree-rat exist on the eastern side of the 2CRU. This habitat should be preserved.	**Clarification.** The project does avoid impacts to areas of BFTR habitat. As described in Section 7.3.2.1, 21.95 and 0.88 hectares of habitat for BFTR will be retained with 2CRU and Muirhead North respectively. No further retention of BFTR habitat could be included without compromising the viability of the project.
7.16	Domestic cat control within the Lee Point suburb and domestic cat predation of native fauna	**Clarification.** Refer to Comment 1.9.
7.17	Lack of survey for Floodplain Monitor and threat form cane toads.	**Change.** Refer to Comment 5.2.
7.18	Health of the seasonal watercourse that flows into the monsoon rainforest present in Muirhead North	**Clarification.** The seasonal watercourse and health of the Monsoon Rainforest present in Muirhead North is fully preserved. See Section 4.3.2.2 and Stormwater Management Plan (Appendix F).
7.19	In reserving the Monsoon rainforest (0.88ha) within a 1.57ha area, will this be a big enough to protect the patch of Monsoon rainforest? Should there be a larger vegetated buffer zone around the rainforest?	**Clarification.** The Monsoon Rainforest will be preserved within a buffer area of 3.87 hectares. The key environmental factor for preserving the Monsoon Rainforest is hydrology, and the stormwater management plan have been designed to preserve flow to the area.

Comment #	Comment	Response
7.20	What assessment criteria will be used to ascertain if this vegetation is retained?	**Clarification and Change.** Monitoring the health and extent of native vegetation is described in Section 7.3.2.10. Refer to Comment 17.11 regarding additional information provided on monitoring of retained vegetation.
7.21	The EIS states that it is expected that 'native vegetation in the rural lots…will be partially retained…'. There is nothing in place to ensure that native vegetation, and habitat will be retained	**Clarification.** This statement is based on similar sized lots in Darwin area. DHA cannot require landowners to retain all native vegetation on rural lots.
7.22	We contend that clear-felling native vegetation does substantially alter the landscape features, even if some of the 2CRU is already heavily degraded.	**Clarification.** The significant impact assessment for landscape features was done in accordance with EPBC Act guidelines (See Table 52). In accordance with these guidelines, the project was not considered to have a significant impact on landscape features.
7.23	Suitable fencing would allow for the movement of native animals and prevent larger animals like dogs from accessing the area being conserved	**Clarification.** Fencing is in accordance with City of Darwin and NT Government design guidelines.
7.24	Lack of public exposure of the Casuarina Coastal Reserve Landcare Group	**Change.** The Casuarina Coastal Reserve Landcare Group will be consulted during preparation of the management plans for the 21.95 hectare conservation reserve. See last paragraph in Section 7.3.2.1.
7.25	Migratory shorebird education and monitoring signage has been in place at Buffalo Creek and Lee Point for some years and proven quite ineffective. Predation of the birds from disturbance by dogs.	**Clarification and Change.** The effectiveness of the existing signage has been considered when determining migratory shorebird signage and awareness. However, the signage and awareness program was a recommendation of an independent migratory shorebird expert (see Appendix N). Last paragraphs in Section 7.3.2.7 and Section 7.3.2.8 have been added describing how the involvement of NT Parks and Wildlife Commission will lead to a better outcome.
7.26	Clearing of vegetation including introduced species could have adverse impact to the Black-footed Tree-rats. Lack of details regarding offsets for the Black-footed Tree-rat.	**Clarification and Change.** Impacts to Black-footed Tree-rat have been discussed in detail in Sections 7.2.4.3 and 7.4.1.2. Refer to Comment 2.1 regarding additional information that has been provided in relation to Black-footed Tree-rat offsets.
7.27	Management of weeds if the integrity of the conservation areas is to be retained.	**Clarification.** An extensive weed management program focussing primarily on Gamba grass is already underway. First paragraph of Section 7.3.2.1 states that weed management works will be carried out in conservation area.
7.28	Housing developments in less sensitive areas should be prioritised first and this area be developed last and only when there is a pressing need for housing.	**Clarification.** The Lee Point masterplan has been developed in full consultation with the CoD, NT Govt., and the greater Darwin community prior to bein rezoned and is now part of the Darwin 10 year growth plan to meet housing growth requirements.

Table 88. Nicole Bergs

Comment #	Comment	Response
8.1	Preservation of reserves (such as those found at Casuarina and Lee Point)	**Clarification.** An additional 21.95 hectares of DHA-own land will be transferred to NT Government and will be managed by Parks and Wildlife Commission as part of Casuarina Coastal Reserve.
8.2	Lack of public awareness of migratory bird habitat	**Clarification.** Section 7.3.2.8 discusses proposal to increase awareness and migratory shorebird habitat.
8.3	Water quality of Buffalo Creek and effort to maintain its current standings as to not change the patterns of the swordfish.	**Clarification.** Water quality impacts to Buffalo Creek will be managed in accordance with Stormwater Management Plan. Water quality will be monitored in accordance with Water Quality Monitoring Plan (Appendix O) to ensure no deterioration in water quality.
8.4	Other native wildlife which reside in this area have also not been mentioned. Will there be a survey conducted in the near future to determine reptile population numbers? How will their population be supported through the certain introduction of household pets including cats and dogs?	**Clarification.** Numerous surveys have been undertaken to establish fauna presence in area. See Section 7.2.4.1 for a summary. No further surveying is proposed. See Section 7.3.2.13 regarding threat from domestic cats.
8.5	How will planning ensure that the water feeding the rainforest in the wet season is the same quality as that which it is currently?	**Clarification.** Water quantity not water quality is the key determining factor in maintaining health of Monsoon Rainforest patch in Muirhead North. Please refer to Section 4.3.2.2 for description of drainage design to maintain hydrology to Monsoon Rainforest.

Table 89. Tom Poulson

Comment #	Comment	Response
9.1	Foul smell of Leanyer-Sanderson water treatment plant. Our concern is that the proposed development will worsen this problem.	**Change.** See changes to Section 5.2.2 and 5.3.2.
9.2	Taken into account the high number of properties currently available for rent in the Northern Suburbs, I see little value in clearing more land to make space for new houses	**Clarification.** Refer to Comment 1.2.
9.3	The creation of this new urban development will bring more domestic animals to the area. My particular concern are the possible increased abundance of cats in areas next to a coastal reserve.	**Clarification.** See Section 7.3.2.13 regarding threat from domestic cats.

Table 90. Andris Bergs

Comment #	Comment	Response
10.1	Project rationale is lacking, unsure if demand for the housing being generated by the project will be used.	**Clarification.** Refer to Comment 1.2.
10.2	This assessment does not explain over what period of time the $350 million would be generated; which of the jobs would be temporary; or the business modelling around the entertainment industry and education.	**Clarification.** Staging Plan is provided in Table 3. The Lee Point project will be completed over a 10-year timeframe with consequent entertainment, retail and education and community facilities evolving with the development's implementation.
10.3	It does not factor in the costs to taxpayers of the development; the opportunity costs of government funds being diverted directly to this project and to mitigating its broader effects on the Darwin community; or those existing jobs which might be lost or relocated through the creation of the new school, shopping centre and tourist / entertainment region.	**Clarification.** DHA will fund the development from its own capital resources and return a dividend to treasury in accordance with its operating charter
10.4	Potential implications for fauna and flora. Floodplain Monitor, Black-Footed Tree -Rat, and to the various migratory bird species which visit CCR. Threats to Darwin Cycad were not considered significant.	**Clarification.** Impacts to biodiversity considered comprehensively in Section 7, including for Floodplain Monitor, Black-footed Tree-rat and Migratory Shorebirds.. Regarding Darwin Cycad, the significance assessment was only completed for nationally significant species. Darwin Cycad is threatened a territory level only and there are no significance assessment guidelines under NT legislation or policy
10.5	There was little regard to the longer-term implications of the development on the water quality of Buffalo Creek	**Clarification.** Water quality monitoring will be undertaken in Buffalo Creek (see Appendix O). There is considered a low risk to water quality in Buffalo Creek due to the existing poor water quality conditions in Buffalo Creek (see Figure 14) proposed Stormwater Management Plans (Appendix F) and ESCP (Appendix D). Any impacts are most likely to be detected during the construction phase of the project (i.e. within 10 years of construction commencing). Any exceedance of stated Water Quality Objectives (WQOs) will trigger a modification to stormwater management.
10.6	Benefits of proposed 'environmental offsets' to the region were not detailed.	**Change.** Refer to Comment 2.1
10.7	Consideration ought to be given to fencing the boundary of the development with CCR to help prevent informal tracks being created by those residents. A suitable barrier may also serve to reduce predation on wildlife in CCR by domestic cats and dogs.	**Change.** Fencing is proposed along top of escarpment. See first paragraph in Section 7.3.2.1. Fencing will be in accordance with City of Darwin and NT Government standards. **See Section 7.3.2.13 regarding threat from domestic cats.**
10.8	Increase in traffic is a concern also related road safety issues connected with the increase in population due to the project development	**Clarification**. Traffic Management Plans have been prepared. Traffic impacts considered in Section 6.2.3 (and Appendix K and L). The project design provides for the majority of traffic to enter and exit the master-planned

Comment #	Comment	Response
		project via roundabouts on Lee Point road. The project provides for significant funding upgrades to Lee Point road in consultation with responsible authorities. There is a proposed bus link from Lyons and Darwin Hospital precinct at the request of the NT Dept. of Transport. NB- Tambling Terrace is a designated arterial road linking Lee Point road to Darwin Hospital
10.9	The likely impacts to the Darwin community beyond the development site do not appear to have been considered in detail and therefore not addressed.	**Clarification.** Social and economic impacts (positive and negative) have been considered in detail in Section 8.

Table 91. Darwin Off-road Cyclists Committee

Comment #	Comment	Response
11.1	Development of the suburb will result in direct social impacts for the community which have not been identified in the EIS and require mitigation.	**Clarification.** Refer to Comment 10.9.
11.2	Mountain Bike Tracks will be unusable if development is approved and constructed.	**Clarification and Change.** A mountain bike is proposed along the western boundary of the project site. Further information is provided at the bottom of 6.2.3.3 regarding the mountain bike track, which the NT Government will be the lead agency. The project does not provide any intention of impacting on existing mountain bike tracks on NT Government land. The access track from the project site to Casuarina Beach will be designed so as not to interfer with mountain bike tracks.

Table 92. NextGen Garamanak

Comment #	Comment	Response
12.1	Lack of consultation with traditional owners in particular with Larrakia members	**Change.** Refer to Comment 2.3.
12.2	Desecration of registered/recorded sacred sites and the ongoing illegally obtained 'consent to destroy an archaeological site'	**Clarification and Change.** As discussed in Section 7.2.4.5, there are no registered sacred sites in the project site. Section 7.3.2.12 has been updated to reflect the work AAPA undertakes with custodians of sacred sites to ensure they are protected. Table 5 of CEMP updated as well.
12.3	Outright objection	**Clarification.** DHA firmly believes the project will be undertaken in accordance with all legitimate community concerns and the public interest will be well served by the development.
12.4	Land stealing	**Clarification.** DHA acquired the site from the Department of Defence under a legally binding contract as the legitimate freehold owner.
12.5	No follow-up to paragraphs “ToR 5.4”	**Clarification.** Section 5.4 of the Terms of Refence has been addressed in the EIS in Sections 7.2.4.5, 7.3.2.12, 7.4.2.3 and 7.4.2.4, and Table 5 of the CEMP.

Table 93. Erica Garcia

Comment #	Comment	Response
13.1	Oversupply of houses in Darwin	**Clarification.** Refer to Comment 1.2
13.2	Negative effects of clearing native bushland	**Clarification.** The impacts to native vegetation clearing are considered in Table 47, with mitigation measures proposed in Section 7.3.2.1. and Table 2 of the CEMP.
13.3	No consistent water quality monitoring of Sandy or Buffalo Creek.	**Clarification.** The Water Quality Monitoring Plan (Appendix O) has been prepared with reference to ANZECC guidelines for Water Quality Objectives (WQO). A specialist consultancy firm will be engaged to undertake the water quality monitoring to establish baseline conditions and whether any changes to the WQO is required. The WQO are likely to be different for Buffal Creek and Sandy Creek however the monitoring method is the same.
13.4	Loss of black footed rat habitat	**Clarification.** Impacts to Black-footed Tree-rat are addressed in Section 7.2.4.3 and 7.4.1.2. Impacts to the species will be offset in accordance with the Commonwealth Offset policy (see Section 7.5).
13.5	Could cats be excluded from the new suburb?	**Clarification. See Section 7.3.2.13 regarding threat from domestic cats.**
13.6	Black footed rat habitat offset plan is lacking detail	**Change.** Refer to Comments 17.7, 17.8 and 17.9.
13.7	No Floodplain Monitor surveys were conducted. There are no measures listed in the report about monitoring or protecting this reptile	**Change.** Refer to Comment 5.2
13.8	Threats to migratory bird habitat.	**Clarification.** Impacts to migratory birds is addressed in Sections 7.2.4.3 and 7.4.1.3, while mitigation and avoidance measures are discussed in Sections 7.3.2.7 and 7.3.2.8 and Table 2 of the CEMP.

Table 94. Kylie Welch

Comment #	Comment	Response
14.1	Odour impacts from Leanyer-Sanderson Wastewater Treatment Ponds are greater than stated in report	**Change.** See changes to Section 5.2.2 and 5.3.2.
14.2	Lack of pedestrian/cycle connections into the adjacent suburbs.	**Clarification.** The pedestrian bikeway corridors are extensive within the project and connect in to Lyons and the location preferred and requested following detailed community consultation (see Section 8.4.6) and by the respective responsible authorities, i.e. City of Darwin and Department of Transport.
14.3	Increased traffic volumes need greater speed control through Lyons past the main parkland areas	**Clarification.** Traffic Impact Assessment reports have been prepared in accordance with Austroads guidelines (Appendix K and Appendix L). The bulk of the Lee Point traffic will access directly on to Lee Point road with only minor volumes to utilise the Lyons connection and speed control will continue to be the responsibility of the City of Darwin, Department of Transport and NT Police force.
14.4	The EIS doesn't make it clear that the construction of a new school would be the responsibility of the NT Government. The short to medium term impact on these schools has not been considered in the assessment of social impacts associated with the development.	**Clarification and Change.** First paragraph of Section 8.4.2 has been updated to make it clear the NT Government will be responsible for building the new school. The timing of when the school will be constructed is the responsibility of the NT Government.
14.5	Biting Insects is a key risk that has not been adequately addressed in the Draft EIS. Explain how each of the Medical Entomology recommendations will be addressed, what role the developer will play and what will be left up to NTG to address.	**Clarification and Change.** The EIS has been prepared to comply with the recommendations of the biting insect management plan (Appendix G). Further information has been provided on how design of project meets biting insect requirements, including third paragraph below Table 12 (discharge rates and location), Table 47 (vegetation management to reduce biting insect risks) and Section 7.3.2.4 (infilling of gully erosion). Biting insects is already discussed in Section 6 of the CEMP.
14.6	Lack of detail relating to funding of drains all the way through to the tidal sections of Sandy Creek and excising these from the Coastal Reserve so that they can be adequately managed.	**Clarification.** Section 4.3.2.2 provides details on the drainage system which will be constructed to ensure run-off rates do not exceed pre-construction levels. DHA will be responsible for construction and management of drains in accordance with City of Darwin and NT Government design standards. Detailed designs will be provided during the Development Assessment stage.

Comment #	Comment	Response
14.7	Stormwater Management Plan that finishes at the site boundary is inadequate to address the complexities of biting insect management in the area.	**Clarification.** The NT Government Entomology Department have been fully consulted and have conditioned the project with design parameters to ensure compliance with biting insect interaction in accordance with Northern Territory Government policy. The drain will discharge within the tidal section of Sandy Creek and Buffalo Creek to prevent pooling of water that may provide for breeding insects.

Table 95. Rebecca Spain

Comment #	Comment	Response
15.1	General concerns with impacts to native flora and fauna.	**Clarification.** Impacts to biodiversity, including proposed avoidance, mitigation and offsetting measures are addressed in detailed in Section 7.

Table 96. Deb Hall

Comment #	Comment	Response
16.1	Can the clearing of more woodland be justified?	**Clarification.** The project has been designed to retain as much native vegetation as possible. Approximately 110 hectares of degraded native vegetation that is common to the region will be cleared. The vegetation is also of a poor quality, particularly in 2CRU. All sensitive vegetation types, i.e. Monsoon Vine-thicket and Monsoon Rainforest, will be retained, conserving approximately 22.5 ha of native vegetation on site.

Table 97. Department of Environment and Natural Resources

Comment #	Comment	Response
17.1	In the Supplement, please outline how surface water runoff from stage 1A and 1B would be managed prior to the construction of the drainage reserve in Stage 2B.	**Change.** To ensure compliance with Stormwater Management Plan, development of drainage system and treatment train will need to be carried out in early stages of project. See Staging section added to bottom of Section 4.3.2.2 for further details.
17.2	In the Supplement, please outline how surface water runoff from stages 2A and 3 would be managed prior to construction of the drainage reserves	**Change.** Refer to Comment 17.1.
17.3	The draft EIS does not discuss other aspects of the hydrology that would change as a result of the Project. In particular, there is likely to be increased runoff quantity due to greater areas of impervious surfaces. The Supplement should discuss the potential impacts of this increased runoff to Sandy Creek, the monsoon vine thicket and Buffalo Creek	**Clarification.** The risk associated with increased run-off is addressed in detail in Section 4.3. Management of stormwater will ensure no increase in run-off compared to pre-construction levels. See Section 4.3.2.2, Appendix E and Appendix F for further details.
17.4	The Supplement should identify any risks and potential impacts to the environment (erosion/scouring, vegetation change, waterlogging and creation of habitat for biting insects, etc.) associated with increasing the quantity of water being discharged from the site, increased discharge time and reduced rate from drainage reserves for Sandy and Buffalo Creeks and sensitive vegetation.	**Clarification.** As stated in Section 4.3.2.2, the stormwater treatment train has been designed to ensure no change in peak flows discharging into Sandy Creek and Buffalo Creek, and detention basins have been designed to retard flow and prevent erosion and scouring.
17.5	The report provides a summary of the results of previous surveys in the local region but does not provide information on the significance of *M. gouldii gouldii* habitat at 2CRU/Muirhead North in a regional context. Provide a regional assessment which identifies suitable/occupied habitat and dispersal corridors for the species.	**Change.** Final paragraph of Black-footed Tree-rat section in Section 7.2.4.3 added to discuss regional context of population of Black-footed Tree-rat.
17.6	The risk assessment proposes the use of boundary mesh fencing to prevent black-footed tree rats from entering the site. It is noted that this measure is unlikely to be effective due to the arboreal nature of the species which is adept at climbing. The outcome in the risk assessment needs to be revised with more appropriate avoidance measures identified in the Supplement.	**Clarification.** This measure was only proposed to avoid the species moving across Lee Point Road. There is no canopy connectivity across Lee Point Road, so animal proof fencing is considered suitable to prevent the species moving from established areas of habitat in Muirhead North into 2CRU during clearing.
17.7	In the Supplement, outline how the offsets proposed in the draft EIS address that policy and demonstrate that it will adequately compensate for the loss of *M. gouldii gouldii* individuals and habitat.	**Clarification and Change.** Section 7.5 provides detail regarding how the offset complies with policy on basis of calculation. Further information is provided on how the payment system to a 3rd party contributes to policy.

Comment #	Comment	Response
17.8	Section 7.5 of the draft EIS proposes the funding of $4500 for each hectare of *M. gouldii gouldii* habitat removed for the development. As the proposed offset is based on the Eastern Leases Project approval, clarify why the proposed offset only applies for habitat for *M. gouldii gouldii* and not all native vegetation cleared for the development. In the Supplement, clarify whether DHA intends to offset the loss of all native vegetation or only habitat for *M. gouldii gouldii*.	**Change**. See third paragraph of Section 7.5.2.
17.9	The draft EIS is unclear with respect to the scope and benefit of land management works that would be funded through this offset. It is recommended that DHA provide costings of the types of works that would be undertaken, an estimate of the cost and likely benefit for *M. gouldii gouldii* in the Supplement.	**Change.** See first paragraph of Section 7.5.2.
17.10	The amount of habitat for *C. armstrongii* impacted by the development has not been quantified in the draft EIS. For the purposes of assessing the Project's impact to the species, provide quantities of the areas (in hectares) mapped as having none, low and moderate densities of *C. armstrongii* (Figure 33 of the draft EIS).	**Change.** See new Table 43.
17.11	Provide further detail on the person(s)/agency that would be responsible for monitoring the rainforest patch, the monitoring methods, trigger values and additional actions if the development is having an impact.	**Clarification and Change.** Monitoring method is described in Section 7.3.2.10 and Section 5 of the CEMP. Trigger values and reporting requirements added to these sections.
17.12	In the Supplement, provide the total amount of monsoon vine thicket within 2CRU (including areas zoned CN) and provide an estimate of the area that would be disturbed as a result of the development (including detention basins and erosion stabilisation works).	**Clarification and Change.** The conservation area is 21.95 ha. The area of Monsoon Vine-thicket to be retained in the conservation area is 20.1 hectares, the rest is Low Eucalypt Woodland. Report altered throughout to provide consistency. Due to existing impacts, the erosion stabilisation works are not considered to reduce area of Monsoon Vine-thicket. Approximately 0.5 ha of Monsoon Vine-thicket will be removed as part of construction of detention basin in south-west of 2CRU.
17.13	In the Supplement, please map and clearly identify the area of monsoon vine thicket that would be protected. Furthermore, provide details on the size of the vegetated buffer between the outer edge of the 'Conservation Area' and the monsoon vine thicket.	**Clarification and Change.** The Conservation Area and Monsoon Vine-thicket are the same, as such there is no buffer between the two. Refer to Comment 17.12 regarding Monsoon Vine-thicket loss.
17.14	In the Supplement clarify the total area of monsoon vine thicket that would be impacted for all components of the development (including erosion control and detention basins).	**Change.** Refer to Comment 17.12

Comment #	Comment	Response
17.15	In the Supplement, provide further detail around who would be responsible for undertaking the annual audit of weeds and managing any found on-site or in adjoining areas of the coastal reserve. The period over which the annual audits needs to be clearly outlined to assess the ongoing risks from weeds.	**Clarification.** Table 2 of the CEMP states that weed monitoring will be conducted by weed contractor and ecologist appointed by head contractor.
17.16	The Supplement should outline the bushfire prevention and management measures that would be implemented at the site. Consideration should be given to the inclusion of asset protection zones, the frequency and timing of controlled burns and the person that would be responsible for undertaking the burns and maintaining asset protection zones.	**Clarification.** Development would reduce risk of bushfire due to replacement of woodland vegetation and grassy weeds with built form and manicured areas. No further bushfire prevention strategies are considered necessary.
17.17	In the Supplement, provide strategies for ensuring that clearing, preparation of the site and construction of buildings do not generate dust to an extent that the monsoon vine thicket would be negatively affected.	**Clarification.** Strategies for addressing impacts of dust are provided in Section 5.2.5 and Table 2 of CEMP.
17.18	The Supplement should provide a management strategy which would be implemented for the life of the action to ensure the floristic diversity and integrity of the monsoon vine thicket 'Conservation Area' is retained.	**Change.** A Conservation and Offset Management Plan will be prepared for the Conservation Area as outlined in Section 7.3.2.1.
17.19	Throughout the draft EIS there are different values for the size of the conservation area and the monsoon vine thicket that would be protected at Muirhead North.	**Change.** Discrepancies have been addressed.
17.20	In the Supplement outline the size of the monsoon vine thicket patch, the area proposed to be contained in the conservation area and the width of vegetated buffers around the monsoon vine thicket patch.	**Change.** Refer to Comment 17.12, 17.13 and 17.14.
17.21	In the Supplement, provide a strategy for ensuring that the thinning of the biting insect buffer would not create or exacerbate erosion issues along the north-western edge of the 2CRU.	**Clarification.** Thinning of native vegetation in biting insect buffer is not considered to be a risk to erosion as understorey vegetation and groundcover will be maintained. Any risk will be addressed through standard measures to be included in the ESCP.
17.22	To demonstrate that there would be adequate erosion and sediment controls in place during each stage of the development, please provide an overarching Erosion and Sediment Control Plans (ESCP) which identifies specific measures that would be used for stabilising soils and managing fine sediments.	**Clarification.** Overarching ESCP framework included in Section 6 of the CEMP.
17.23	The CEMP has not identified a maintenance schedule and/or monitoring during the development to ensure that erosion and sediment controls are effective and being managed appropriately.	**Clarification.** This information will be contained within the ESCP.

Comment #	Comment	Response
17.24	Expand on this further to indicate how works would be undertaken and when monitoring and maintenance of erosion and sediment control measures would occur. Monitoring and maintenance should occur throughout the life of the Project and particularly prior to the Wet season to ensure accumulated sediments are not mobilised.	**Clarification.** Refer to Comment 17.22 and 17.23.
17.25	The development would increase effluent inflows to the LSWTP with subsequent increased discharges into Buffalo Creek. The comments by the Power and Water Corporation confirm that no such upgrades are planned to occur. In the Supplement provide an analysis of the increased quantity of effluent that the development would contribute to the *Leanyer Sanderson Wastewater Treatment Plant* (LSWTP). Furthermore, provide an analysis of the current assimilative capacity of the receiving environment (Buffalo Creek) and provide an assessment of the risks/potential impacts resulting from the increase to treated effluent being discharged from LSWTP	**Change.** See Sections 4.2.5, 4.3.1, 6.2.2 and 6.3.1.1 as well as Appendix T and Appendix U.
17.26	Provide information on other methods for managing effluent including re-use and recycling.	**Clarification.** Following discussions with PWC, neither PWC nor DHA are proposing any re-use or recycle systems.
17.27	Provide details of quantity and quality of runoff from stages 2A and 3, and how contaminants/pollutants in runoff from stages 2A and 3 would be managed prior to the construction of detention basins 2 and 3 constructed during stage 4 of the Project.	**Change.** Refer to Comment 17.1
17.28	In the Supplement, provide an analysis of the likely impacts to water quality in Buffalo Creek prior to the construction of the drainage reserve proposed in Stage 2B. Consideration should be given to the existing water quality and the assimilative capacity of Buffalo Creek to receive additional urban stormwater water from stages 1A and 1B of the development.	**Change.** Refer to Comment 17.1
17.29	In the Supplement provide evidence of consultation with the Parks and Wildlife Commission and the outcomes of negotiations relating to migratory shorebirds at Lee Point beach and the mouth of Sandy Creek. Describe the proposed monitoring as well as the funding, timing and ongoing implementation of mitigation and control measures.	**Change.** See Sections 7.3.2.8 and 8.4.6. Refer to Comment 7.25. Parks and Wildlife Commission will have input into the Conservation and Offset Management Plan for the Conservation Area, and practical measures to minimise impacts to migratory shorebirds. Parks and Wildlife Commission were consulted on 14 March 2018. See correspondence from Parks and Wildlife Commission in Q
17.30	In the Supplement, provide an assessment of the risks of the Project on nesting/hatchling turtles due to sky glow and light pollution. The assessment should include consideration of measures for addressing the risk including the	**Change.** Refer to Comment 20.5.

Comment #	Comment	Response
	use of lighting to minimise risks to marine turtles (i.e.an appropriate wavelength, shielding and low light fixtures).	
17.31	The Proponent should prepare a Dust Monitoring sub-plan as part of the CEMP. The sub-plan would include provisions for monitoring dust prior to clearing and would continue for the life of the Project. Furthermore, the sub-plan would identify trigger thresholds and clearly outline the mitigation and management measures that would be implemented when necessary to manage dust.	**Clarification.** Dust is addressed in Section 10 of the CEMP.
17.32	In the Supplement, provide details of the final land use of the heritage site referred to in Jung (2015) and how the Konfrontasi cruciform (KAS-1) site would be retained *in situ* as a heritage feature.	**Change.** See changes to Section 7.3.2.12. Local military historians will work with landscape architects to preserve military history within areas of public open space.
17.33	In the Supplement, please outline further heritage studies that will inform the development of interpretation material referred to in Table 46 of the draft EIS.	**Clarification.** No further studies are proposed as the location of military sites is well understood.
17.34	Comments from the Aboriginal Areas Protection Authority (AAPA) suggest that there may be previously unrecorded sacred sites located on or adjacent to the Project area. In the Supplement, outline the consultations that have been undertaken with relevant NT Government agencies and Larrakia stakeholders and the outcomes of those consultations.	**Change.** Refer to Comments 2.1-2.7.
17.35	Ensure all actions all within the new draft NT Noise Management Framework guidelines for public comment. The draft guideline is available at: www.ntepa.nt.gov.au/about-ntepa/for-your-comment/comments-open/nt-noise-managementframework-guidelines	**Clarification.** Noise impacts have been assessed in accordance with the guidelines referenced in the Terms of Reference. As the guidelines are draft only and still at public comment stage (and therefore likely to be revised before finalising), it is considered in appropriate to base the EIS on them at this stage.
17.36	In the Supplement, clarify whether DHA intends to undertake construction activities that may disturb the sleep of sensitive receptors. If so, provide an updated noise management sub-plan which identifies the sensitive receptors and the relevant measures that would be implemented to avoid impacts to sleep. The measures should be consistent with the NT EPA's noise guidelines.	**Change.** Section 9.2.3.2 and Table 79, as well as Table 7 of CEMP have been updated to ensure that avoidance measures are in place to prevent sleep disturbance to sensitive receptors.
17.37	The noise targets identified in the Construction Environmental Management Plan are inconsistent with the NT EPA's draft noise management framework guideline. To avoid potential impacts on existing and future residents, it is recommended that DHA consider updating the Noise Management Sub-plan consistent with the NT EPA's draft guideline. That guideline is available at: www.ntepa.nt.gov.au/about-ntepa/for-your-comment/comments-open/nt-noise-managementframework-guidelines	**Clarification.** Refer to Comment 17.35.

Comment #	Comment	Response
17.38	DHA is encouraged to meet with the Operations team at the NT EPA to discuss the known footprint of areas impacted by odour in the northern suburbs of Darwin In addition to the results of the odour assessment (Appendix J of the draft EIS), a summary of the area known to be impacted by odour should be provided in the Supplement.	**Change.** See changes to Section 5.2.2 and 5.3.2.
17.39	In the Supplement, provide the location of the relevant sewage pumping stations (Lyons and Muirhead) and demonstrate that the relevant separation distances are in place around those areas where it relates to this Project. The guidelines are available on the NT EPA website at: https://ntepa.nt.gov.au/__data/assets/pdf_file/0006/453192/guideline_recommended_land_separation_distances_oct.pdf.	**Clarification.** The Lyons and Muirhead sewage pumping stations are existing sewage pumping stations constructed as part of previous residential development to the south. Separation distances to these pump stations from the proposed 2CRU and Muirhead North developments are several hundred metres, well in excess of the recommendations in the NTEPA guidelines.
17.40	In the Supplement please outline what works have been undertaken to identify/remove/remediate contaminants and hazardous materials (asbestos, PCBs, hydrocarbons etc.) from the site. Furthermore, please provide an overview of any site reports, audit statements and plans that have were prepared to ensure that the site is fit for its future intended use.	**Change.** Findings of site auditors report for 2CRU included in Section 4.3.2.1 'impacts to water quality groundwater during construction activities', and Sections 5.2 and 5.2.5 regarding asbestos. Emu-picking grid walks included as a mitigation measure in Section 5.2.5 and CEMP to identify any residual surface asbestos containing materials as recommended by site auditor. Also see Appendix R and S for site reports.

Table 98. Clara Penton

Comment #	Comment	Response
18.1	General concerns with relating to the impact of Black Footed Tree Rats in the area	**Clarification.** Impacts and avoidance measures relating to Black-footed Tree-rat are considered in detail in Section 7.2.4.3, 7.4.1.2 and 7.5.
18.2	Cameras used during Black Footed Tree Rats survey were not deployed for the correct amount of time in relation to (Davies et al. 2017). (4 day/night as opposed to 7day/night recommended) Davies, H, McCarthy, M, Firth, R, Woinarski, J, Gillespie, G, Anderson, A, Geyle, H, Nicholson, E & Murphy, B 2017, 'Top-down control of species distributions: feral cats driving the regional extinction of a threatened rodent in northern Australia', *Diversity and Distributions*, vol. 23, pp. 272-283.	**Clarification.** The study of Davies et al. 2017 was targeted at a different species to Black-footed Tree-rat. The survey design utilised in this EIS was discussed and agreed with NT DENR prior to commencement and complies with relevant guidelines. See Section 7.2.3.2 for further information
18.3	Significant impact on Black Footed Tree Rats within the proposed sites due to habitat loss in particular loss of mature trees and hollows.	**Clarification.** Refer to Comment 18.1.
18.4	Current proposed mitigation to have a fauna spotter-catcher only mitigates the direct threat of death or injury as land is cleared.	**Clarification.** Measures to avoid impacts to fauna include retention of native vegetation and migratory shorebird awareness program.
18.5	There is no proposal to mitigate the loss of hollow-bearing trees from the area which not only will negatively impact BFTR but all other hollow dependant fauna in the area.	**Clarification.** The loss hollow-bearing trees will be offset by protecting suitable habitat offsite that either contains hollow-bearing trees, or will develop into hollow-bearing trees based on the proposed mitigation measures.
18.6	Funding should be allocated for the translocation and/or monitoring of BFTR that currently reside in the area	**Clarification.** Funding is allocated to the proposed offset (onsite and off-site). The DENR do not recommend translocation of Black-footed Tree-rat due to stress induced injury or death.

Table 99. Parks and Wildlife Commission

Comment #	Comment	Response
19.1	Rehabilitation work done to control erosion in the gullies in the southwest of 2CRU must be to the satisfaction of the Commission. Included in the Development Agreement between the Northern Territory of Australia and Defence Housing Australia.	**Change.** ESCP will require approval of Parks and Wildlife Commission and DENR. See Table 52 and Section 7.3.2.4, and Section 6 of the CEMP.
19.2	The proposed Erosion and Sediment Control Plan must be subject to approval from the Land Management Unit, Department of Environment and Natural Resources (DENR).	**Change.** Refer to Comment 19.1.
19.3	Initial litter mitigation measures prior to Stage 4 are not identified. The proposed Erosion and Sediment Control Plan will need to address this.	**Change.** DHA will remove any rubbish and engage a site auditor to determine the presence of contaminants and threat to humans. See Sections 5.2.5 and 7.3.2.1. and CEMP.
19.4	Any existing rubbish and debris from previous defence operations within the proposed Conservation Area must be removed before transfer of responsibility for the land to the Commission.	**Change.** Refer to Comment 19.3.
19.5	The 2CRU area need to be closely examined for further asbestos contamination. Asbestos containing material may have been washed down from the site into the Conservation Area below.	**Clarification and Change.** A site audit report has been completed for 2CRU. Refer to Comment 17.40 regarding additional measures in place to address asbestos risks.
19.6	The EIS does not contain details about the mountain bike track and access to the beach as contained in the initial agreement	**Clarification and Change.** Refer to Comment 11.2 regarding mountain bike track. Section 7.3.2.7 discusses general location of access track. Detailed design of access track will be completed prior to Development Approval. See additional text in Section 7.3.2.7 regarding to how location of access track will utilise existing degraded areas to minimise removal of native vegetation.
19.7	There is a lack of information regarding the infrastructure required to restrict access to the conservation area post construction. In particular the fence between the proposed Conservation Area and the 'Escarpment Park' (top edge of the escarpment).	**Change.** Information on fence provided in Section 7.3.2.7.
19.8	There is a lack of detail regarding the revegetation of native flora in part to provide habitat for the Black-footed Tree-rat and rehabilitation plans of areas that have been damaged by erosion	**Clarification and Change.** Revegetation in erosion gullies discussed in ESCP section of CEMP.
19.9	The proponent will be responsible for ongoing weed management within the Conservation Area until the area is transferred to the NT Government in accordance with the Agreement.	**Change.** Section 7.3.2.1 updated to make it clear DHA will be responsible for management until a hand-over time is agreed with Parks and Wildlife Commission.

Comment #	Comment	Response
19.10	There is a lack of details regarding the proposed barrier fence 100 metres on the western and eastern side of Sandy Creek described in section 7.3.2.7 is within the Casuarina Coastal Reserve (CCR). The same comment applies to the proposed signage described in sections 7.3.2.8 and 7.3.2.9	**Clarification and Change.** Detailed plans regarding the location of barrier fencing will be prepared prior to the Development Authority approval. Parks and Wildlife Commission were consulted on 14 March 2018 regarding this matter. It was agreed that the fence and signage would be implemented under the guidance of Parks and Wildlife Commission who have experience with these matters. See changes to Sections 7.3.2.7 and 7.3.2.8.
19.11	The Commission have not been consulted on the management action 'Improved awareness of values of conservation area as part of broader signage programs for migratory shorebirds and threatened sawfish.' (pg. 159)	**Change.** Refer to Comment 19.10.
19.12	The change of zone of the Conservation Area is a very slight indirect mechanism that adds to protection for threatened species. There is no management change that will benefit the BFTR	**Clarification.** Refer to Comment 20.3.
19.13	The impact of the proposed mountain bike trail and walkway through the Conservation Area is not mentioned.	**Clarification and Change.** Refer to Comment 19.6.
19.14	Details surrounding the funding of the Conservation Area is questioned. The Commission expect that DHA would be financially responsible for the offset beyond this time.	**Clarification.** DHA will be financially responsible for management of Conservation Area until hand-over to Parks and Wildlife Commission, in accordance with the agreement with NT Government.
19.15	Details in the CEMP need to be included regarding the construction of the mountain bike track, access way to the beach and fence line along the escarpment. Also regarding asbestos the CEMP need to contain mitigation measures in wash down areas and the process if asbestos is discovered during construction.	**Clarification and Change.** Asbestos mitigation measures discussed in Section 10 of CEMP but refer to Comments 19.3 and 19.4 for changes to asbestos mitigations. Details regarding the construction of the mountain bike track, access way and escarpment fence will be addressed after detailed design.
19.16	Who will fund the mosquito breeding rectification program in Casuarina Coastal Reserve and the Buffalo Creek Management Area	**Clarification.** DHA will fund the rectification program in the Casuarina Coastal Reserve (i.e. remediation of erosion gullies) and Buffalo Creek Management Area (i.e. infill of existing breeding sites).
19.17	There is a lack of consultation with the commission regarding use of the Conservation Area as an offset area for BFTR, installation of fencing and signage within the Casuarinas Coastal Reserve, educational programs to be conducted by the Commission, potential increase in the number of patrols by the Commission and the mosquito breeding rectification program to be initiated in Casuarina Coastal Reserve and the Buffalo Creek Management Area	**Change.** Refer to Comments 17.29, 19.11 and 19.16.

Table 100. Department of Environment and Natural Resources (consolidated comments)

Comment #	Comment	Response
20.1	Proposed works will fragment BFTR habitat and reduce habitat connectivity. Development will permanently alter one of the last landscape-scale continuous linkages of woodland within the northern suburbs of Darwin. In addition, the staged removal of habitat to allow fauna an opportunity to relocate will be of little benefit if there is not sufficient habitat in which to relocate.	Clarification. Impacts to Black-footed Tree-rat habitat is addressed in detail in Sections 7.2.4.3, 7.4.1.2 and 7.5. Staged removal of habitat is generally considerd best practice. Casuarina Coastal Reserve and woodland along Buffalo Creek provide suitable sink locations for Black-footed Tree-rat. Ecologists will be on site to salvage any species that do not move to these areas at their own accord.
20.2	Details lacking in EIS regarding BFTR impacts this includes no evidence that the habitat near the hospital is of better quality than that of the project site, nor is there sufficient evidence presented to demonstrate that there is adequate habitat in areas adjoining the project site to sustain breeding, or movement of animals from inside the project footprint.	Clarification and Change. The results of Griffith et al. (2002) and Rankmore et al. (2001) support better quality BFTR habitat than in the impacted area of 2CRU based on number of records. See Section 7.2.4.3. Reference to results of Rankmore (2006) added to Table 48 regarding home range of Black-footed Tree-rat.
20.3	Offset mapping of BFTR is based on certain parameters which could also take into account that BFTR is a highly mobile species with relatively large home range and may partly rely on lower quality habitat. The reservation of the monsoon vine thicket area is a mitigation action and should not be considered an offset. Rehabilitating illegal access points to the beach are also not suitable offsets for Black-footed Tree-rats, as they are unlikely to provide direct benefits to the species.	Clarification. The offset mapping does take into consideration the mobile nature of the species. For instance, dirt roads, Gamba grass infested areas are mapped as habitat albeit at a low rating. The reservation of the Monsoon Vine-thicket was undertaken during the rezoning process which was proposed by DHA as part of the develoment of the study area and can be considered as part of the same action under the EPBC Act. Under the EPBC Act, the protection of an offset site prior to clearing is considered more advantageous to the species and can be assigned additional points using the EPBC Act calculator. However, no additional points for early offsetting were included in the offset calculation in the EIS. While we acknowledge the benefit from revegetating tracks is low, this should not be considered a reason not to proceed with the works and there are plenty of successful revegetation projects implemented in the greater Darwin area. .
20.4	Further details is needed in regard to impact reduction strategies for migratory shorebirds. This includes; community awareness and engagement program, implementation and maintenance of the rehabilitation of informal tracks between the project site and the beach, the installation of barrier fencing on the western and eastern side of Sandy Creek and installation of signage, the security offences and gates that lead to unauthorised vehicle entry to beach is included in Appendix N as a mitigation action, but this was not adopted in the EIS. The objectives, design and implementation of the proposed shorebird monitoring.	Clarification. Impact reduction strategies are discussed in Sections 7.3.2.77.3.2.8, and Table 2 of the CEMP and Appendix N. The objectives, design and implementation of the shorebird monitoring is articulated in the CEMP (see performance indicators, monitoring and management actions).

Comment #	Comment	Response
20.5	FLighting impacts to turtles have not been addressed in the EIS	**Change**. Mitigation and CEMP updated to include mitigating light impacts to turtle. Flatback Turtle and Olive Ridley only species recorded on beach. Olive Ridley considered vagrant. Lighting from house, buildings at least 400 m from nesting sites. Main risk is from multistorey buildings in main streets. Refer to Environmental Assessment Guidelines for Protecting Marine Turtles from Light Impacts (WA EPA 2010). See Section 7.3.2.11 and changes to CEMP.
20.6	Ongoing management of the smaller area (1.57 ha) of monsoon rainforest in Muirhead North has not been described. No further mitigation to reduce negative impacts on the rainforest is proposed if a trigger point is reached.	**Clarification and Change.** No management of Monsoon Rainforest in Muirhead North considered necessary provided hydrology is maintained. Refer to Comment 17.11 regarding values that will be used to trigger a management response.
20.7	No weed management plan was included in the draft EIS. Additionally, the draft EIS uses the past/defunct genus and species for the perennial mission grass (Pennisetum polystachion) instead of the current genus and species Cenchrus polystachios.	**Clarification and Change.** Weed management is covered in Table 2 of the CEMP. Mission grass botanical name updated.

Table 101. Department of Health

21.1	Biting insect issues have been left out of the risk assessment and needs to be included. Infrastructure mitigation measures in Sandy Creek, Muirhead discharge drain are to include biting insect management features. The possibility of nearby mosquito breeding in CCR, Lee Point and Buffalo Creek affecting residents needs to be addressed.	**Change.** Refer to Comment 14.5.
21.2	The 2CRU open wind buffer should be at least 50 m wide, to minimise pest problems from a short dispersing jungle mosquito (Verrallina funerea)	**Clarification.** Mentioned that buffer is 50 m in Table 47, and Sections 7.2.4.3 and 7.3.2.1.
21.3	Infrastructure designed to be low maintenance, and that all discharge drains and associated access easements have been excised from conservation zoned land and appropriately zoned to allow easy future maintenance. Furthermore bioretention basins, lakes and other stormwater treatment devices design should allow effective maintenance by the relevant authority and be completely free draining within a few hours or within 3-4 days after the rain event. Lakes would need to be stocked with small native fish and have appropriate edge design to minimise the potential for dense semi-aquatic vegetation growth and subsequent mosquito breeding	**Change.** See last paragraph in Section 4.3.2.2 regarding stormwater treatment train.
21.4	The proposed 2CRU development occurs within 300 m of a helicopter mosquito spray zone in CCR, which may contradict civil aviation regulations.	**Clarification.** It will be up to the NT Government the height of buildings in the commercial zone of 2CRU. Any contraventions of civil aviation regulations will be considered by the Government when they take ownership of their sites.
21.5	There should be no dry season low flows directed into the monsoon patch. This is an attempt to stop the patch becoming a weed infested mosquito breeding swamp. Medical Entomology is not a handover authority for stormwater drainage.	**Clarification.** The stormwater drainage system has been designed to mimic the natural hydrology so there should be no change in breeding habitat conditions within Monsoon Fainforest Patch. Furthermore, the Government requires that the Monsoon Rainforest patch be retained and thus some stormwater will need to be redirected to patch.

Table 102. Department of Trade, Business and Innovation

Comment #	Comment	Response
22.1	No comment.	Not applicable.

Table 103. Department of the Attorney General and Justice

Comment #	Comment	Response
23.1	No comment.	Not applicable.

Table 104. Department of Tourism and Culture (Heritage Branch).

Comment #	Comment	Response
24.1	Draft EIS document contains a number of references to NRET (NT Natural Resources, Environment and the Arts) The department no longer operates under this name, any references to NRET or NRETA in relation to Heritage issues should be amended to now read Department of Tourism and Culture (DTC).	**Change.** Department name updated.

Table 105. Aboriginal Area Protection Authority

Comment #	Comment	Response
25.1	No previous certificate over the area and therefore there could be risk to the development associated with previously unrecorded sacred sites. The proponent will obtain an Authority Certificate from the AAPA prior to commencement of works. AAPA have reviewed the project and it is highly recommend the proponent seek an Authority Certificate.	**Change.** Refer to Comment 12.2.

Table 106. Department of Tourism and Culture.

Comment #	Comment	Response
26.1	Discrepancies between residential population, noted as between 2700 and 3100 persons on page 173 and values (2516) stated in the adopted master plan page 60.	**Clarification.** Correct figure is those stage in EIS.
26.2	Encourage the proposed bus service along Coastal Esplanade to continue up to Lee Point.	**Clarification.** The bus route has been developed based on requests of NT Transport Department, consultation with the public and NT Government regulations.
26.3	The maps do not confirm where the pedestrian and cycle path/s that have been referenced on page 67 are to be located.	**Clarification.** Refer to Comment 14.2.
26.4	Suggested that “safe pedestrian infrastructure” include shaded walkways/paths and water fountains around high use areas such as the proposed Tourist Precinct.	**Clarification.** Refer to Comment 14.2.
26.5	Tourism question why local Larrakia Rangers have not been suggested as the group like to carry out the black footed tree rat surveying.	**Change.** Refer to Comment 2.1.

Table 107. Police Fire and Emergency Service

Comment #	Comment	Response
27.1	No comment	Not applicable.

APPENDIX Q

Correspondence

NORTHERN TERRITORY GOVERNMENT

DEPARTMENT OF
TOURISM AND CULTURE

Parks, Wildlife and Heritage
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Jape Homemaker Village,
356 Bagot Road, Millner, NT 0810

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File Ref: DPW2017/0098~0017
Your Ref:

Dr Thomas Wright
Project Manager
Ecology & Heritage Partners
292 Mt Alexander Rd,
Ascot Vale, VIC 3032

Dear Dr Wright

Re: Lee Point EIS

In December 2017, the Parks, Wildlife and Heritage Division (the Division) of the Department of Tourism and Culture prepared responses to a draft *Environmental Impact Statement: Lee Point Master-planned Urban Development*, prepared for Defence Housing Australia (DHA) by Ecology and Heritage Partners Pty Ltd.

In March 2018, Ecology & Heritage Partners and the Division met to discuss issues raised by the Commonwealth and consequently there was a requirement for an updated EIS submission from the proponent. The updated submission included a revised version of both the EIS (Draft 8 – 10/4/2018) and CEMP.

The amendments made to address the Division's comments during earlier discussions and post the public exhibition period, were further discussed at a subsequent meeting in May 2018. At this meeting it was agreed that the Division is now comfortable with the changes made to the EIS in relation to matters raised by the Division. The comments addressed are listed (19.1-19.17) in Appendix P *Supplement to the EIS*, Table 99 (pp 284-285).

Please accept this letter as confirmation that the Division is satisfied that its comments and matters raised in relation to the EIS have been addressed adequately.

Yours sincerely

MARK ASHLEY
Executive Director Parks, Wildlife and Heritage

10 July 2018

APPENDIX R

Site Auditors Report (AECOM 2016)

AECOM

2CRU Independent Audit Report
Defence Housing Authority
19-Jul-2016

Site Audit Report - 2CRU Lee Point, Darwin, NT

Independent Audit of Remedial Works of Compound Area

Site Audit Report - 2CRU Lee Point, Darwin, NT

Independent Audit of Remedial Works of Compound Area

Client: Defence Housing Authority

ABN: 96 306 045 169

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This site audit report was prepared for Defence Housing Authority and provides the Auditor's review of documentation provided by Site Environmental and Remediation Services Pty Ltd (SERS). Based on information provided the Defence Housing Authority, this audit is considered to be a non-statutory site audit under the Contaminated Land Management (CLM) Act (1997). It is based on a review of the condition of the site at the time of the completion of investigation in the SERS reports. This audit report has been prepared in consideration of the relevant guidelines used for contamination management in Northern Territory and New South Wales at the time that the audit was performed. The Auditor notes that subsurface conditions can vary over short distances and it is possible that small areas of contaminated soil may have not been detected between the sampling points. However, in the opinion of the Auditor, these should not present an unacceptable risk to present or future occupants of the site based on the information provided for review.

Quality Information

Document Site Audit Report - 2CRU Lee Point, Darwin, NT

Ref 60469416

Date 19-Jul-2016

Prepared by Ross McFarland

Reviewed by Alana Court

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
0	14-June-2016	Draft Final Report	Ross McFarland Chief Environmental Scientist	
1	19-Jul-2016	Final Report	Ross McFarland Chief Environmental Scientist	

Table of Contents

Statement of Environmental Audit i
Auditor's Declaration iii
1.0 Introduction 4
1.1 General 4
1.2 Site Identification 4
2.0 The Site Audit Process 5
2.1 Purpose of the Site Audit 5
2.2 Parties Involved 5
2.3 Summary of Audit Activities 5
2.4 Documents Reviewed 5
2.5 Relevant Guidance Documents 6
2.6 General Stages of a Site Audit 7
3.0 Site Information 8
3.1 Site Identification and Description 8
3.2 Surrounding Land Use and Zoning 9
3.3 Environmental Setting 10
3.3.1 Climate 10
3.3.2 Topography and Drainage 10
3.3.3 Geology and Hydrogeology 10
3.3.4 Acid Sulfate Soils 11
3.3.5 Sensitive Local Environments 11
3.4 History of Site 11
3.4.1 Potential Sources of Contamination and Contaminants of Concern 12
4.0 Summary of Investigation 13
4.1 Previous Investigations 13
4.1.1 *Lee Point Road Defence Site, NT – Environmental Site Assessment* (GHD, 2010) 13
4.1.2 *Contaminated Land Review – DOD Site Lee Point Road, NT* (SMEC, 2014) 13
4.1.3 Post Activity Report – Unexploded Ordnance Technical Survey, 2CRU Site (G-Tek, 2014) 14
4.1.4 *2CRU NT RAAF Transmission Facility Destructive Hazardous Building Materials Survey* (GHD, 2014a) 14
4.1.5 *Demolition Tender Specifications 2CRU NT Contamination Review* (GHD, 2014b) 14
4.2 Pre Remediation Conceptual Site Model 14
5.0 Remedial Action Plan (RAP) 17
5.1 Recommendations for Remediation 17
5.2 Remediation Goals 17
5.3 Overview of Remediation Works 17
6.0 Data Quality Objectives 18
7.0 Remediation and Validation Works 21
7.1 Remediation Works 21
7.1.1 Roles and Responsibility 21
7.1.2 Legislative Requirements 21
7.1.3 Summary of Remediation Works 22
7.2 Validation Sampling and Analysis Plan 23
7.2.1 Soil Validation Sampling and Analytical Suites 23
7.2.2 Asbestos Validation 25
7.2.3 Groundwater Validation 25
7.3 Remediation and Validation Acceptance Criteria 25
8.0 Results 27
8.1 QA/QC Summary 27
8.1.1 QA/QC Conclusions 28
8.2 Laboratory Analysis 28
8.3 APEC G – Electrical Transformer Results 29

8.4 APEC J – UPSS Results 29
8.5 APEC K – Septic System Results 29
8.6 Asbestos in near Surface Soils (APEC A to APEC F, APEC H, APEC I and APEC L to APEC Q) Results 30
8.7 Asbestos Pipeline Removal Results 31
8.8 Waste Disposal and or Re-use 31
9.0 Conclusions and Recommendations of the Validation Report 32
9.1 Consultant Conclusions 32
9.2 Ongoing Site Management 32
9.3 Consultant Recommendations 33
10.0 Auditor's Conclusions 34
11.0 Key References 35

Appendix A
Figures A

Appendix B
Extract from Lee Point Area Plan B

Appendix C
Relevant Correspondence and Documents C

Appendix D
Analytical Results Tables D

Statement of Environmental Audit

This statement provides a summary of the findings of a site audit of a portion of the former 2CRU NT RAAF Transmission Facility located on Lot 4873 Town of Nightcliff plan(s) S78/107, Northern Territory in accordance with Section 47 of the *Waste Management and Pollution Control Act* (NT).

Name of Auditor	Ross McFarland AECOM Australia Pty Ltd (AECOM) Level 2, St George Centre 60 Marcus Clarke Street Canberra ACT 2600 D +61 (0)2 8934 0772 M +61 413 833 811 ross.mcfarland@aecom.com
Date Audit Requested	23 September 2015
Owner of the Site	Commonwealth of Australia Director of Property Services, Defence Estate Organisation R4-2-008 Canberra ACT 2600
Person Requesting the Audit	Shaun Barber Defence Housing Authority
Consultancy	Site Environmental & Remediation Services Pty Ltd (SERS)
Municipality	Darwin
Local Government Authority	Darwin City Council
Site Identification	Former 2CRU NT RAAF Transmission Facility (See Figure 1) 577 Lee Point Road Lee Point NT 0810
Size of Area	20,000 m^2
Current Zoning	Commonwealth
Proposed Land Use	Residential Subdivision

The audit has had regard to, amongst other things:

- The Northern Territory *Waste Management and Pollution Control Act, 2006*
- The *National Environment Protection (Assessment of Site Contamination) Measure, revised 2013*
- Guidance provided by the *New South Wales Site Auditor Scheme, second Edition, 2006*.

Key Information Sources

Title of Reports reviewed:

- SERS (2016a), *Validation Report for Remedial Works, 2CRU Lee Point, Darwin*, prepared for Defence Housing Australia, issued 26 April 2016 (Ref. 150449/VR/CK/270116_rev2). This will hereafter be referred to as the "Validation Report"
- SERS (2016b), *Validation Report – Asbestos Pipe Removal, 2CRU Lee Point, Darwin*, prepared for Defence Housing Australia, issued May 2016 (Ref: 150449_CK_040516_rev1). This will hereafter be referred to as the "Asbestos Validation Report".

Other information reviewed (including remediation action plan, monitoring plans and previous investigations relating to the Site):

- SERS (2015a), *Remediation and Validation Action Plan, 2CRU Lee Point, Darwin*, prepared for Defence Housing Authority, 15 May 2015 (Ref: DAH_SAP_CK_130515). This will hereafter be referred to as the "RAP".
- SERS (2015b), *Environmental Management Plan, 2CRU Lee Point, Darwin*, prepared for Defence Housing Australia, issued 15 May 2015 (Ref: DHA_EMP_CK_130515).
- SERS (2015c), *Lee Point Remediation Project – Respirable Fibre (Asbestos) Control Monitoring Plan*, prepared for Defence Housing Australia, issued 5 September 2015 (Ref. 150449_RFMP_Lee_Point_MC_050915).
- Crassweller, C., (2010), *Heritage and Archaeological Investigations over Block 4873, Lee Point Road, Darwin*, report prepared for GHD on behalf of the Department of Defence, issued November 2010.
- AECOM, 2016, *EPA 1997 Reporting Guidelines Compliance Checklist – Validation, 2CRU NT RAAF Transmission Facility, Lee Point, Darwin, Northern Territory (Former)*, prepared for Defence Housing, issued 2 March 2016 (Ref: 60469416_AuditChecklist_20160314).

Site Audit Report

Title: *Site Audit Report, 2CRU Lee Point, Darwin*

Report no.: 60469416_SAR_2CRU_20160706 Date: 06 July 2016

Overall Comments

During the Site Audit, the Auditor noted the following key points, in relation to the 2CRU Site Validation Report (SERS, 2016a):

- The Site is a portion of the former 2CRU at Lee Point, defined by surveyor points, shown in Figure 1, Appendix A of the Site Audit Report (SAR). This auditor review is only for this surveyor identified portion of the Lee Point site.
- The methods employed in the validation work as reported in the 2CRU RAP and Validation Reports (SERS 2015a, 2016a and 2016b) by and large complied with the relevant NT EPA guidelines. Where deviations occurred, the Auditor is generally satisfied that these did not adversely impact on the outcome of the work conducted, and hence the proposed land use of the Site for Residential Use.
- The Auditor considers the documents generally followed an appropriate analytical methodology and, when taken as a whole, were sufficient for assessment and remediation or management of soil at the 2CRU Site.
- The Auditor considers that given the intended end use for Residential Subdivision, the adopted investigation criteria provided an appropriate level of protection to human health and ecological receptors.
- The Auditor considers that given the intended end use as a Residential Subdivision, and the close proximity of the site to sensitive ecological communities (i.e. Lee Point Reserve), the adopted environmental investigation criteria provides an appropriate level of protection to ecological receptors.
- The Auditor is satisfied that validation works were robust enough to establish remediation was undertaken to the extent practicable. Some uncertainty remains in relation to the potential for encountering Unexpected Finds such as small amounts of residual ACM and it is recommended that this be addressed by an effective Construction Environmental Management Plan (CEMP) – see below.

- The Auditor has reviewed the information presented by the consultant for considering the risk to groundwater from site activities was considered low. The auditor considers the decision that no further investigations on groundwater was necessary based on the previous NEPM (1999) schedule B(6) groundwater risk assessment, which allowed for an initial assessment of groundwater contamination. However, in accordance with ASC NEPM 2013, some uncertainty remains around the quality of groundwater on Site and therefore ,the use of site's groundwater for any beneficial uses be prohibited by the appropriate planning agencies until these groundwater quality uncertainties can be adequately addressed. If the local groundwater has the potential to be utilised in the future as a viable resource for potable uses, the auditor recommends that a monitoring and testing regime be undertaken – see below.

Auditor's Findings

I certify that, in my opinion, the site is SUITABLE for Residential Purposes

Subject to the following conditions:

1. Any future development of the Site would require the development of a Construction Environmental Management Plan (CEMP) to manage potential Unexpected Finds including ACM. The CEMP should include the methodology for carrying out ACM emu pick grid walks.
2. There should be no use of groundwater from the site, other than for the purposes of environmental monitoring.

Auditor's Declaration

This statement provides a summary of the findings of a site audit of a portion of the former 2CRU NT RAAF Transmission Facility located on Lot 4873 Town of Nightcliff plan(s) S78/107, Northern Territory in accordance with Section 47 of the *Waste Management and Pollution Control Act* (NT).

Further details regarding the condition of the site may be found in the environmental audit report (60469416_SAR_2CRU_0_20160706).

Signed:……Dated: 19 July 2016

Ross McFarland

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Contaminated Site Auditor (Accreditation No.9819) appointed pursuant with the NSW Site Auditor Scheme (*Contaminated Land Management [CLM] Act*, 1997) and recognised in the Northern Territory under section 68 of the NT *Waste Management and Pollution Control Act,* 2016.

1.0 Introduction

1.1 General

Mr Ross McFarland was appointed by Defence Housing Authority (DHA) in August 2015, to act as the Environmental Auditor for a portion of the former 2CRU NT RAAF Transmission Facility located on Block 4373 Lee Point Road, Darwin NT (the Site). The Site is proposed to be redeveloped for residential purposes. The Site location was provided in Figure 1 of the Validation Report (SERS, 2016a), and has been provided in Appendix A of this Site Audit Report (SAR).

DHA have requested that remediation and validation of the Site be reviewed by a Northern Territory Environmental Protection Authority (NT EPA) registered NSW accredited auditor under the New South Wales Site Auditor Scheme.

Mr Ross McFarland, employed by AECOM Australia Pty Ltd (AECOM), is a Northern Territory Environment Protection Authority (NT EPA) approved person in accordance with Part 6 of the NT's *Waste Management and Pollution Control Act* (*WMPC Act,* 2016). In accordance with S68 of the *WMPC Act* (2016), Ross is considered a Qualified Person as he is a NSW Environment Protection Authority (NSW EPA) Accredited Site Auditor (Accreditation No. 9819) under the NSW Site Auditor Scheme (*Contaminated Land Management [CLM] Act*, 1997) and follows Guidelines for the NSW Site Auditor Scheme (2nd edition) (NSW DEC, 2006) and subsequent guidance notes.

In June 2016, Mr Ross McFarland completed a review of the following audit reports prepared by Site Environmental and Remediation Services Pty Ltd (SERS) for the 2CRU Site:

- SERS (2016a), *Validation Report for Remedial Works, 2CRU Lee Point, Darwin*, prepared for Defence Housing Authority. Issued 26 April 2016.
- SERS (2016b), *Validation Report – Asbestos Pipe Removal, 2CRU Lee Point, Darwin*, prepared for Defence Housing Australia, issued May 2016.

The primary role of the contaminated sites auditor is to provide written Audit Reports and/or Audit Statement, after independently reviewing investigation, assessment, monitoring and remediation work undertaken by other professionals.

This includes carrying out reviews and providing interim audit advice on work undertaken in stages such as preliminary site investigations (PSI), detailed site investigations (DSI) or remediation of a site to determine one or more of the following prior to issuing an auditor's report:

a. the nature and extent of any contamination of the site
b. the nature and extent of the investigation or remediation of the site
c. whether any restrictions on the use of the site are required
d. the suitability of the land for a specific use, or a specific range of uses
e. whether any further investigation is required, recommended or necessary
f. whether any further investigation is required, recommended or necessary so that the site is suitable for all uses, or for a specific use, or a specific range of uses; and/or
g. the suitability or appropriateness of a management plan.

1.2 Site Identification

The Site associated for this audit is the portion of the area known as the former 2CRU NT RAAF Transmission Facility, which is located within a fenced compound on Block 4373 Lee Point Road, Darwin, NT (The Site). The former 2CRU Facility is a 100 m x 200 m area (20,000 m^2) located within the northern end of the larger block known as Lot 4873 which is approximately 836,650 m^2.

The area subject to the SAR and the focus of the remediation and validation works is provided in Figure 1 (GHD), presented in Appendix A.

2.0 The Site Audit Process

2.1 Purpose of the Site Audit

The purpose of this Site Audit was to:

- Review the environmental assessment, remediation and validation activities (including reporting) conducted by SERS at the 2CRU Site.
- Document compliance with the requirements of relevant guidelines endorsed by NT EPA and NSW EPA.
- Provide an opinion on the suitability of the Site for residential subdivision.
- Provide a Site Audit Statement (SAS) (this document) for the identified portion of the former 2CRU Site.

2.2 Parties Involved

Site Owner(s):	Commonwealth of Australia Director of Property Services, Defence Estate Organisation
Site Occupier(s)	None. Formerly used as Lee Point Radar Transmitting Station
Client	Defence Housing Australia
Project Manager	GHD
Environmental Site Assessor(s)	Site Environmental and Remediation Services (SERS)
Primary Laboratory Used by Assessor(s):	Envirolab/MPL Laboratories
Secondary Laboratory Used by Assessor(s):	ALS Environmental
Contractor(s):	Brajkovich Demolition and Salvage (WA) Pty Ltd

2.3 Summary of Audit Activities

The auditor was engaged on 31 August 2015. The auditor's role has included the following activities:

- Provision of advice on the proposed Remediation Action Plan (RAP) (received 29 September 2015).
- Provision of advice during the remediation activities, including water monitoring bore installation.
- Review of previous investigation reports and remediation and validation plans (RVAP (SERS, 2015a) and EMP (SERS, 2015b)).
- Site Audit Inspection by Kim Treglown, AECOM Environmental Scientist, during the Underground Storage Tank (UST) validation sampling event on 30 October 2015.
- Site Audit Inspection by Ross McFarland, AECOM Contaminated Land Auditor on 30 November 2015.
- Review of the Draft Validation Report and provision of Audit Checklist in accordance with the *NSW EPA 1997 Reporting Guidelines Compliance Checklist* (AECOM, 2016).
- Preparation of this Environmental Audit Report and associated Statement of Environmental Audit.

2.4 Documents Reviewed

The auditor has reviewed the following documentation:

- SERS (2016a), *Validation Report for Remedial Works, 2CRU Lee Point, Darwin*, prepared for Defence Housing Australia, issued 26 April 2016 (Ref. 150449/VR/CK/270116_rev2). This will hereafter be referred to as the "2CRU Validation Report"
- SERS (2016b), *Validation Report – Asbestos Pipe Removal, 2CRU Lee Point, Darwin*, prepared for Defence Housing Australia, issued May 2016 (Ref: 150449_CK_040516_rev1). This will hereafter be referred to as the "Asbestos Validation Report".

Other information reviewed (including remediation action plan, monitoring plans and previous investigations relating to the Site):

- SERS (2015a), *Remediation and Validation Action Plan, 2CRU Lee Point, Darwin*, prepared for Defence Housing Authority, 15 May 2015 (Ref: DAH_SAP_CK_130515). This will hereafter be referred to as the "RAP".
- SERS (2015b), *Environmental Management Plan, 2CRU Lee Point, Darwin*, prepared for Defence Housing Australia, issued 15 May 2015 (Ref: DHA_EMP_CK_130515). This will hereafter be referred to as the "EMP".
- SERS (2015c), *Lee Point Remediation Project – Respirable Fibre (Asbestos) Control Monitoring Plan*, prepared for Defence Housing Australia, issued 5 September 2015 (Ref. 150449_RFMP_Lee_Point_MC_050915). This will hereafter be referred to as the "ACMP".
- Crassweller, C., (2010), *Heritage and Archaeological Investigations over Block 4873, Lee Point Road, Darwin*, report prepared for GHD on behalf of the Department of Defence, issued November 2010.
- AECOM, 2016, *EPA 1997 Reporting Guidelines Compliance Checklist – Validation, 2CRU NT RAAF Transmission Facility, Lee Point, Darwin, Northern Territory (Former)*, prepared for Defence Housing, issued 2 March 2016 (Ref: 60469416_AuditChecklist_20160314).

2.5 Relevant Guidance Documents

The *WMPC Act* (2016) and regulation are the primary pieces of legislation in the Northern Territory for the assessment of contaminated sites and are administered by the NT EPA. Where contaminated sites pose or threaten to pose a serious or material environmental harm or human health harm, the NT EPA requires an assessment to be conducted in accordance with the *National Environment Protection Council (Northern Territory) Act 2004* which endorses the use of the *National Environmental (Assessment if Site Contamination) Protection Measure 2013* (ASC NEPM 2013) framework.

The NT EPA require "*the assessment of site contamination will require a Statement of Environmental Audit from an independent, accredited Auditor experienced in assessing land contamination as to the fitness of a site, in terms of risk to human health or the environment, for current or proposed uses and may include conditions specific to a proposed land use."*

The Auditor for the 2CRU Site is an NT EPA approved person accredited under the New South Wales Site Auditor Scheme. As such the Auditor must comply with the jurisdictional requirements from where the primary accreditation is held, being the *CLM Act* (1997).

The *CLM Act (*1997) defines a Site Audit as an independent review:

(a) that relates to management (whether under this Act or otherwise) of the actual or possible contamination of land, and

(b) that is conducted for the purpose of determining any one or more of the following matters:

  (i) the nature and extent of any contamination of the land

  (ii) the nature and extent of any management of actual or possible contamination of the land

  (iii) whether the land is suitable for any specified use or range of uses

  (iv) what management remains necessary before the land is suitable for any specified use or range of uses

  (v) the suitability and appropriateness of a plan of management, long-term management plan or a voluntary management proposal.

The Site Audit process is undertaken by an Auditor, accredited by NSW EPA under the *CLM Act* (1997) and comprises an independent review of reports prepared by an environmental consultant.

2.6 General Stages of a Site Audit

The Site Audit process generally includes review of assessment and investigation reports prepared by an environmental consultant pertaining to the environmental condition of the land and the suitability of the land for a given land use. The Site Audit may also include the review of a Remedial Action Plan (RAP) which, if conducted, may render the land suitable for a given land use(s). Until the RAP has been adequately implemented, the Auditor cannot certify the suitability of the land. The Site Audit may also review the Validation Plan, which is prepared by an environmental consultant to document the requirements for successful completion of the requirements of a RAP. At the conclusion of any remedial works, the Site Audit process also reviews the Validation Report, which documents the successful completion of the works outlined in the RAP and Validation Plan.

Site Audit Reports may also be completed throughout the site Audit process to document review of reports at project milestones. The Audit process is completed by preparation of a Site Audit Report (SAR), which independently reviews the report prepared by the consultant, and preparation of a Site Audit Statement (SAS), which certifies the suitability of the land for one or more uses, or certifies whether the extent of contamination has been appropriately determined and/or the appropriateness of an investigation/remedial action plan/management plan and/or the site can be made suitable for one or more uses if it is remediated/managed in accordance with a RAP/management plan.

The investigation of the environmental condition of the land and any required management is carried out by the environmental consultant by reference to guidelines endorsed by the NT EPA. If the report(s) prepared by the consultant are in substantial conformance with the guidelines, the Auditor is entitled to accept the results and conclusions stated therein and complete the Site Audit Report and issue a Site Audit Statement and the Auditor is entitled to form other opinions based on the results and conclusions stated in the report(s) by the consultant.

The Auditor does not normally carry out independent sampling or chemical analyses of soil, fill, groundwater or other media on the subject site, but relies on the testing and reporting that has been carried out by the consultant if it has been demonstrated to be of adequate reliability by reference to quality indicators listed in the endorsed guidelines.

It is expressly recognised that, even when a qualified environmental consulting firm has substantially followed guidelines endorsed by NT EPA, unidentified contamination or sub-surface structures may remain present. The processes of investigation, remediation and validation are statistically based and no liability is accepted by the Auditor for unidentified contamination or sub-surface structures subsequently found to be present on a site, which has been subjected to investigation, remediation and validation processes that are in substantial conformance to guidelines endorsed by NT EPA. In addition, this Site Audit has not addressed heritage, geotechnical, ecological or engineering suitability of the site, for which specialist advice is required to be obtained outside the Site Audit process.

3.0 Site Information

3.1 Site Identification and Description

The Site associated for this audit is a portion of the area known as the former 2CRU NT RAAF Transmission Facility, which is located on Block 4373 Lee Point Road, Darwin, NT (The Site).

The 2CRU Facility which is the subject of this Audit is a 100 m x 200 m area (20,000 m^2) located within the northern end of the larger block known as Lot 4873 which is approximately 836,650 m^2.

The following information in Table 1 was identified for the Site in the 2CRU Validation Report (SERS, 2016a) and provided by GHD.

Table 1 Site Identification Information

Item	Description
Site Address	Former 2CRU NT RAAF Transmission Facility 577 Lee Point Road Lee Point NT 0810
Legal Description	Lot 4873 Town of Nightcliff plan(s) S78/107
Site Owner	Commonwealth of Australia Director of Property Services, Defence Estate Organisation
Site Occupier	Unoccupied
Local Government Authority	Darwin City Council
Zoning	Commonwealth Land (no planning scheme controls)
Current Land Use	Commonwealth Land
Heritage	No historic heritage places and objects listed on Commonwealth or Northern Territory Cultural Heritage Lists and Registers, although the site has more than 60 years of Defence Activities.
Proposed Land Use	Residential Purposes
Site Elevation (m AHD)	Between 32 and 37 m AHD
Site Area	Total area of 2CRU at Lee Point: 836,650 m^2 Area of Investigation that is subject of this Audit: 20,000 m^2
Coordinates	The coordinates of the 2CRU Site were not provided in documentation provided by SERS; however; as per audit scope the site that is the subject of this Audit has the following corner point coordinates: **Easting Northing** 705470.8 8634634.0 705263.1 8634590.2 705409.2 8634709.6 705324.9 8634514.6
Site Location Plan and Site Layout	Figure 1 provided by GHD presents the area subject to this SAR. The site location was presented as Figure 1 in the 2CRU Validation Report. Both figures are presented in Appendix A of this SAR.

Site features that were known to be present prior to the commencement of the remediation works were described by SERS (2015a and 2016) as follows.

- a fenced compound (which is approximately 100 metres by 200 metres) containing office space, maintenance areas, ablutions blocks, septic facilities, observation towers and kitchens/preparation areas. There were also a number of transmitters, generators and other materials present on the Site. The site has not been in use for several years. Specific infrastructure known to exist on site included the following:
    - underground petroleum storage system (UPSS) comprising of two underground storage tanks (USTs) within a single pit;
    - former pits for transformers;
    - septic tank;
    - communications pit; and
    - 3 no. fire water above ground storage tanks (ASTs).
- the central portion of the site, in the vicinity of the fenced compound, was relatively flat. Beyond the interior, it slopes sharply towards the north northwest border to the Casuarina/Lee Point coastline.
- the area external to the fenced compound was predominantly bushland and appeared to be utilised for recreational activities, including recreational motorcyclists and small 4WDs, on dirt tracks that had been created, as well as foot traffic.

The Auditor considers that SERS (2016) Remediation and Validation Report provided the site description and details in general accordance with NT EPA approved guidelines, with the exception that geographic coordinates were not provided for the extent of the investigation area.

A site location plan was presented as Figure 1 of the 2CRU Validation Report (SERS, 2016a) and is provided in Appendix A of this SAR. Figure 2a of the 2CRU Validation Report (SERS, 2016a) presents the areas of potential environmental concern (APEC) and is also presented in Appendix A of this SAR. The site survey with coordinates of the site, as provided by GHD is provided as Figure 1 in Appendix A of this SAR.

The Auditor/Auditor Team have undertaken two site visits throughout the validation works and considers that the information presented adequately defines the subject site.

3.2 Surrounding Land Use and Zoning

Information relating to the surrounding land use was presented in the 2CRU RAP and Validation Report (SERS, 2015a and 2016a) and is summarised in Table 2.

Table 2 Surrounding Land Use

Direction	Description
North	Undeveloped bushland immediately north of the Site (Casuarina Coastal Reserve), beyond which lies the tip of Lee Point Peninsula and coastline.
East	An area of bushland beyond which lies Lee Point Road, with Lee Point Caravan Park located to the east of the Road. Bushland exists south of the Caravan Park, with what appears to be cleared vacant bushland beyond.
South	An area of bushland immediately south of the Site, beyond the Lyons residential estate.
West	An area of bushland beyond which contains a small area of wetland (mangroves) and sand dunes.

The Validation Report (SERS, 2016a) identified that the site is zoned as Commonwealth Land. It is noted that the revised NT Planning Scheme (2016) identifies Lot 4873 as zoned Future Development (FD). This zoning is an interim zone identifying an area that is intended for future re-zoning and development in accordance with an Area Plan (Lee Point Area Plan). The Lee Point Area Plan and associated planning principals provides for a mixed use development, including residential, commercial, community uses, tourism activity and public open space (planning scheme amendment, 2015). Excerpts from the Lee Point Area Plan, including a map showing the extent of the Future Development zone for Lots 4873, and a list of consent uses, is provided in Appendix B.

Under the current NT Planning Scheme (2016) zoning for the land immediately adjacent the site includes:

- north and west: Conservation (CN)
- south: Specific Use Darwin 17 (S D17) and Community Purpose (CP), and
- east: Future Development (FD) and Caravan Park (CV).

The Auditor considers that SERS (2016) Remediation and Validation Report provided sufficient information to identify the surrounding land uses and zoning, noting that the Auditor has provided additional zoning information above as it relates to this audit. SERS did not provide a site locality map in relation to the surrounding land use within the report.

3.3 Environmental Setting

3.3.1 Climate

The Auditor notes that no information was presented in the 2CRU Validation Report of the meteorology for Lee Point. Data from the Darwin Airport station (number 014015) indicates that the area experiences a mean minimum temperature in July with an average of 19.3 °C and an average maximum temperature in November of 33.3°C. The annual average rainfall for the area is 1727.5 mm, with the wettest month being January (mean of 423.7 mm) and the driest month July (mean of 1.2mm) (information accessed from www.bom.gov.au on 7 June 2016).

3.3.2 Topography and Drainage

The 2CRU Validation Report (SERS, 2016) described the Site as being relatively flat and ranges in elevation between 32 and 37 mAHD above sea level.

The Lee Point area is located on a peninsula, which opens out into the Casuarina coastal reserve to the east and Shoal Bay to the west. As such, surface water at the Site will naturally discharge both northwest from Sandy Creek to the coast and northeast to Buffalo Creek (Begnaze, November 2010). SERS (2016) noted various drainage lines present across the Site; the line of these drains indicates that surface water entering the drainage network would drain west towards the mangroves.

3.3.3 Geology and Hydrogeology

Information regarding the geology was summarised by SERS (2016), and sourced from GHD (2014).

Reference to the '1:250,000 Geological Survey of the Northern Territory '(2006 edition) (Northern Territory Geological Survey) indicates that the Site is located on fractured and weathered rock, which consists of shale, greywacke and sandstones and is part of the Cretaceous Darwin Formation. In addition, more recent Tertiary Laterite Gravel and Quaternary Coastal Alluvial (comprising mud, silt and clay) may also be present.

Reference to the 'Land Units of the Greater Darwin Area' (April 2007) and Geological Map of the Northern Territory (2006 edition) (Northern Territory Geological Survey)' indicates the Site is underlain by the following land units and groups.

- 1c: Short steep slopes and rises; gradient 5-15%; Shallow gravelly lithosols;
- 2bi: Gentle side slopes; gradient 2 -5%; moderately deep gravelly yellow massive earths, minor lithosols;
- 3d: Flat to gently undulating upland surface; gradient 1 - 3%; wet – season water table ; shallow gravelly lithosols;
- 3e: Flat to gently undulating upland surface; gradient 0.5 –2%; wet - season water table; hard setting deep mottled yellow massive earths;
- 4c: Gentle lower slopes; gradient 0.5 – 1.5 %; Wet - season water table; hard setting deep mottled yellow massive earths; and
- Money Shoal, Bonaparte, Arafura, Carpentaria, Pedirka and Eromanga Basins, which are indicative from the soil types within the land units.

Information regarding the hydrogeology was summarised by SERS (2016), and sourced from GHD (2010 and 2014).

Previous investigations undertaken by GHD (2010) have identified numerous existing registered groundwater bores within a one kilometre radius of the Site, three of which were located on site (RN008655, RN009097 and RN008656). No groundwater depth data is available for these onsite bores, and they were unable to be located by SERS (2016).

Information sourced by SERS (2016) on the Bureau of Meteorology, Australian Groundwater Explorer online application (http://www.bom.gov.au/water/groundwater/explorer/metadata.shtml) indicated that the closest active extraction bore is 8.8km southeast of the site boundary (RN025230) used for domestic purposes. The nearest irrigation, commercial/industrial, water supply bore is 27 km south of the site boundary.

An irrigation bore exists approximately 250 m east of the site situated within the Lee Point Caravan Park, drilled to a depth of 78 mbgl and with a reported groundwater depth of 50 mbgl during bore installation. SERS (2016) where unable to obtain any groundwater data in association with this bore.

GHD (2010) installed one groundwater bore within the vicinity of the UPSS, to a depth of 8 mbgs, this well has been recorded as dry during historically groundwater monitoring events. SERS (2016) also installed one groundwater bore within the site to a depth of 21 mbgs that was also monitored as dry indicating the groundwater at the site is at depths greater than 21 mbgs.

Given the proximity of the site to the Lee Point coastline, it is likely that ground water flows in a general north northwest direction.

3.3.4 Acid Sulfate Soils

The GHD (2014) report identified that although the Site is located close to the coastline, given the elevation is greater than 9 mAHD, acid sulfate soils (ASS) are not expected to be present at the site. SERS (2016) identified that the eastern boundary of the Site is defined as Non-tidal Zones, Sandplains, Dunes and Beach Ridge. The Lee Point Area is considered to have a low probability of occurrence of ASS (Hill, 2008). If present on the Site, ASS and potential acid sulfate soils (PASS) would generally occur below 1 m (refer to Hill, 2008).

3.3.5 Sensitive Local Environments

The Auditor notes that no information was presented in the 2CRU Validation Report regarding sensitive local environments. Previous investigations (HLA, 2001) identified that immediately surrounding the Site consists of a mostly cleared and heavily disturbed open woodland site, with army bunkers, storage dwellings, large bituminised areas and human rubbish. Sensitive environments are located in the surrounding areas of the Site, including:

- Mangrove habitat – located just outside of Lot 4873's western boundary within the Casuarina Coastal Reserve
- Monsoonal Vine Thicket - located just outside of Lot 4873's western boundary within the Casuarina Coastal Reserve and consisting of dominant vine species within a monsoon rainforest
- Rainforest – dominated by a mixture of rainforest species this site is situated on the edge of a small escarpment that runs through the Casuarina coastline (HLA, 2001).

Overall, the Auditor considers that SERS (2016) and previous investigations have adequately identified and reported the environmental setting, including topography, drainage, geology, hydrogeology and acid sulfate soils of the 2CRU Site in accordance with NT EPA approved guidelines.

3.4 History of Site

The SERS (2016) 2CRU Validation Report provided a summary of the site history. The Site was formerly used by the Royal Australian Air Force (RAAF) as a radar transmission facility. The Site was acquired by the Department of Defence in the early 1950s. By the 1960s there were numerous buildings surrounded by earth and sand embankments. Up until recently, the Site had been used as a radar facility by the Department of Defence, although was confirmed as abandoned in 2010 (SER, 2016).

There is little information available to describe the historical waste management practices for the Site. It is not clear if any historical landfills exist on the property external to the transmissions facility compound, although this area is considered by the Auditor to be out of the audited Site's boundary.

There was no evidence of intentional burning occurring at the Site given its proximity to residential dwellings at Lyons Estate to the south. An above ground Sewerage Treatment Plant (STP) existed on the Site, which was subsequently identified to be a simple septic tank. It is unclear where or if absorption trenches exist on the Site.

Two underground storage tanks (UST) exist within one pit on the Site inside the compound (removed as part of the remediation works). No dispensing bowser has been observed during the previous Site inspections. During the wider site's operation as a transmission facility SERS report that the following processes were undertaken:

- Storage of Fuel; and
- Treatment of waste water.

In addition, a Heritage Investigation was completed by Begnaze in 2010 and identified that it was highly unlikely that any unrecorded Aboriginal sites or objects are still intact on the Site as the area has been highly modified over many years.

3.4.1 Potential Sources of Contamination and Contaminants of Concern

SERS (2016) identified the following areas of potential environmental concern (APEC):

- APEC A – South Radar Tower
- APEC B – Communications Pit
- APEC C – Power House
- APEC D – Central Radar Tower
- APEC E – Concrete Pad
- APEC F – North Radar Tower
- APEC G – Electrical Transformer
- APEC H – Generator Shed
- APEC I – Administration Building
- APEC J – Underground Petroleum Storage System (UPSS)
- APEC K – Septic System
- APEC L – Water Tanks
- APEC M – Concrete Pad
- APEC N – Shed
- APEC O – Amenities Block
- APEC P – Guard House
- APEC Q – Concrete Pad.

Figure 2a of the 2CRU Validation Report (SERS, 2016a) provides the location of the APECs, a copy of which is provided in Appendix A of this SAR.

Contaminants of concern were reported by SERS (2016a) to include:

- Asbestos associated with the building structures
- Polychlorinated biphenyls (PCB) and pesticides associated with the transformer.
- Petroleum hydrocarbons and heavy metals associated with the UPSS and septic system.

The Auditor considers that SERS (2016a) generally presented the history of the 2CRU Site in accordance with NT EPA approved guidance.

SERS provided a 'Statement on the Desktop Study Information Adequacy' and given the ownership of the site prior to 1976 was not fully understood, the exact historical use of the site, prior to redevelopment for Defence purposes, has not been fully defined, there is a high degree of confidence that the site was a bushland site due to its location.

The Auditor considers that the information presented provided sufficient basis to identify the potential sources of contamination and the associated contaminants of concern.

4.0 Summary of Investigation

4.1 Previous Investigations

The SERS (2016a) 2CRU Validation report provided a summary of the previous investigations that included the area that is subject of this SAR, from the following sources:

- GHD (2010), *Lee Point Road Defence Site, NT - Environmental Site Assessment*, Department of Defence
- SMEC (2014), *Contaminated Land Review – DOD Site Lee Point Road, NT*, Defence Housing Australia.
- G-Tek (2014), *Post Activity Report – Unexploded Ordnance Technical Survey, 2CRU Site, Lee Point, Darwin, NT*, Defence Housing Australia.
- GHD (2014a), 2CRU NT RAAF Transmission Facility Destructive Hazardous Building Materials Survey, Defence Housing Australia.
- GHD (2014b), *Demolition Tender Specifications 2CRU NT Contamination Review*, Defence Housing Australia.

SERS (2016) summarised the results of assessments carried out at the site as follows.

4.1.1 *Lee Point Road Defence Site, NT – Environmental Site Assessment* (GHD, 2010)

The investigation undertaken by GHD (2010) recorded the following information:

- The soil sampling works included hand auguring, sediment sampling and soil boring and installation of groundwater monitoring wells. Imported fill materials were not identified during the Site works. No hydrocarbon odours or soil staining were observed during intrusive works. Groundwater was not observed within eight metres below surface level.
- Thirty-three analysed soil samples reported analyte concentrations of TPH and BTEXN less than the health-based assessment criteria. The investigation concluded that although some metal concentrations were identified within Site soils and some minor TPH impacts in the vicinity of the UST, nothing was identified that would render the Site unsuitable (from a contamination perspective) for a residential end use.
- The recommendations from the assessment included a current hazardous building materials survey be undertaken for the Site infrastructure, conducting a shallow soil assessment after transformer removal, decommissioning the UST and removing any identified impacted soils and undertaking groundwater monitoring when/if water is present within the installed groundwater wells. In addition, demolition of the on-site infrastructure may be beneficial before the Site is sold.

4.1.2 *Contaminated Land Review – DOD Site Lee Point Road, NT* (SMEC, 2014)

The investigation undertaken by SMEC (2014) recorded the following information:

- A limited soil sampling program was undertaken. A total of 11 soil samples were collected and analysed from eight locations by surface soil collection and test pitting to 3 mbgs. Samples were analysed for TPH, BTEX, PCBs, metals and asbestos.
- The presence of historic features potentially representing stockpiles was observed in the 1976 aerial photograph in the northern end of the compound. No concentrations of chemicals of concern were recorded greater than the investigation levels with the exception of vanadium concentrations (82-156 mg/kg) above the adopted PBIL criterion of 50 mg/kg in all soil samples tested across the site.
- Two USTs were observed at the site in a single tank pit. Dimensions determined by SMEC using ground penetrating radar techniques indicated approximately 10KL capacity, formerly containing diesel as indicated by residual fuel in the base. It is unclear from the report if this is capacity of one tank or both tanks. No signs of gross hydrocarbon contamination were identified in the vicinity of the two non-operational empty USTs.
- Hazardous building materials were observed in the Site compound buildings including asbestos containing materials (ACM). A positive lead test result was indicated on the under layer of paint on the internal walls of the main administrative building.
- SMEC identified underground service conduits inside the compound (e.g. telecommunications services pit) potentially containing asbestos and other contaminants such as residual pesticides.

- SMEC identified the battery room located adjacent to the generator room as a potential source of lead contamination.
- The GHD 2010 soil data was compared to the new updated NEPM 2013 criteria, however no further criteria exceedances were observed other than previously reported.
- The above ground STP reported by GHD was not sighted. Instead, a total of 3 large water storage tanks were observed (two inside the compound and one outside the compound). The sewage system for the site was observed to be potentially an underground sewage pump out system. No absorption trenches were encountered during the limited test pitting undertaken by SMEC.

4.1.3 Post Activity Report – Unexploded Ordnance Technical Survey, 2CRU Site (G-Tek, 2014)

The investigation undertaken by G-Tek (2014) recorded the following information:

- The Site had not been subjected to military activities that are known to have caused unexploded ordnance (UXO) or exploded ordnance (EO) contamination.
- The Site has been subjected to military/police activities that have caused small arms ammunition waste (SAAW) contamination.
- The Site has been subjected to military activity that has left remnant signs of occupation, including star pickets, barbed wire, drums and similar debris, with a potential for similar material to have been buried within the Site.
- The Site has been used for widespread public dumping of vehicles and general waste.
- No further UXO related works were considered necessary for the Site.

4.1.4 *2CRU NT RAAF Transmission Facility Destructive Hazardous Building Materials Survey* (GHD, 2014a)

GHD carried out a Hazardous Building Materials Survey for the structures located on the 2CRU site. The hazardous materials registered for the onsite infrastructure identified:

- chrysotile asbestos;
- lead based paints;
- lead dust; and
- PCB oils.

4.1.5 *Demolition Tender Specifications 2CRU NT Contamination Review* (GHD, 2014b)

Based on the information identified in the GHD (2010 and 2014) and SMEC (2014) investigation, GHD prepared the proposed remedial works tender specifications prior to the site being developed for residential purposes.

The Auditor considers that the 2CRU Validation Report (SERS, 2016) generally provided a suitable summary of the previous investigations undertaken on site, with appropriate reference to the documents that provided additional details and in a manner that was generally consistent with NT EPA approved guidelines..

4.2 Pre Remediation Conceptual Site Model

The 2CRU Validation Report (SERS, 2016) provided pre remediation conceptual site model (CSM) which assessed the sources, pathways and receptors for the identified contamination and hazardous materials.

A summary of the CSM is presented in Table 3 on the following page.

Table 3 Pre Remediation Conceptual Site Model

Sources	Potential Contaminants of Concern	Receptors	Transport mechanism and pathways	Likelihood of an Active Exposure Pathway
APEC A – South Radar Tower APEC B – Communications Pit APEC C – Power House APEC D – Central Radar Tower APEC E – Concrete Pad APEC F – North Radar Tower APEC H – Generator Shed APEC I – Administration Building APEC L – Water Tanks APEC M – Concrete Pad APEC N – Shed APEC O – Amenities Block APEC P – Guard House APEC Q – Concrete Pad.	Asbestos associated with structures	- Site Users (Future Residents) - Demolition Contractors - Construction Workers - Flora and Fauna	- Inhalation of contaminated soil, vapours, dust and fibres - Direct contact with contaminated soil and groundwater - Digestion of contaminated soils and groundwater	Yes
APEC G – Electrical Transformer	PCB Pesticides	- Site Users (Future Residents) - Demolition Contractors - Construction Workers - Recreational Users of Walking and Biking tracks outside of compound - Adjacent residents at Caravan Park - Flora and Fauna - Aquatic Ecosystems		Yes
APEC J – UPSS APEC K – Septic Tank	Petroleum Hydrocarbons Metals	- Site Users (Future Residents) - Demolition Contractors - Construction Workers - Recreational Users of Walking and Biking tracks outside of compound - Adjacent residents at Caravan Park - Flora and Fauna - Aquatic Ecosystems		Yes

After an independent review of the contamination investigations undertaken for the Site (both desktop and intrusive), together with site visits by the Auditor/Auditor Assistant, the Auditor is satisfied that SERS provided adequate assessment of the investigation findings and the CSM for the property in a manner consistent with NT EPA approved guidelines..

5.0 Remedial Action Plan (RAP)

5.1 Recommendations for Remediation

The SERS (2015a) RAP identified the following works to be undertaken:

- Excavation of previously identified contaminated areas and APECs.
- Analysis for asbestos (previously omitted from previous environmental assessments) within near surface soils.
- Disposal of contaminated material to an appropriately licensed and classed landfill facility.
- Disposal of ACM within buildings and structures, pipework and near surface soils.
- Classification and possible disposal of soils excavated at the base and walls of the UPSS, septic tank system and the electrical transformer locations (APEC G, APEC J and APEC K).

5.2 Remediation Goals

SERS (2015a) identified that the objectives of the Remedial Action Plan were to mitigate the risk to human health and the wider environment from the identified Areas of Potential Environmental Concern (APEC) to a condition where the land is considered suitable for proposed use (residential).

5.3 Overview of Remediation Works

The 2CRU RAP outlined the following key remediation tasks for the Site:

- Stage 1 – removal of all observed ACM prior to the demolition of the above ground structures (an Asbestos Removal Control Plan (ARCP) (refer to Appendix D of the SERS (2016) Validation Report) was prepared to identify required protocols for removing asbestos materials.
- Stage 2 – demolition of buildings and structures with the exception of APEC G, APEC J and APEC K.
- Stage 3 – removal of APEC G, APEC J and APEC K structures and associated contaminated soil.
- Stage 4 – removal of below ground structures and infrastructure
- Stage 5 – removal of residual near surface ACM post demolition
- Stage 6 – soil and groundwater sampling to confirm remedial works have achieved their objective of remediating the site to a condition suitable for residential development.

Further detail on the remediation and validation works undertaken is provided in Section 7.0.

The Auditor considered that the 2CRU RAP (SERS, 2015a) provided a suitable summary of the proposed remedial approach for the Site and was suitable for use to inform the proposed remediation works and the RAP was prepared in a manner consistent with NT EPA approved guidelines.

6.0 Data Quality Objectives

The 2CRU RAP and Validation Reports (SERS, 2015a, 2016a and 2016b) presented the results of the quality assurance and quality control program. The reports did not provide a specific section on the proposed Data Quality Objectives (DQOs) process to be followed for the remediation and validation works.

DQOs should be presented in the seven-step format outlined in the ASC NEPM (2013) and as per the US EPA guidance as follows:

1. Define the Problem
2. Identify the Decision
3. Identify Inputs to the Decision
4. Define the Study Boundaries
5. Specify an Action Level
6. Specify Tolerable Limits on Decision Errors
7. Optimise the Design for Collecting Data

Table 4 has been prepared from the information presented throughout the SERS RAP and Validation Reports (2015a, 2016a and 2016b) to provide the key components for a detailed assessment of the DQOs.

Table 4 Data Quality Objectives

Item	DQO
Step 1 – Define the Problem	
Project Drivers	The driver for the remedial works was to undertake works necessary to return the Site to a suitable condition to facilitate the future development as residential.
Objective	The overall goal for the remediation and validation works is to mitigate the risk to human health and the wider environment from the identified Areas of Potential Environmental Concern (APEC) to a condition where the land is considered suitable for proposed use (residential).
Key Issues	The presence of redundant buildings and infrastructure and the historical activities within the 2CRU Compound. The actual or potential presence of contamination resulting from such materials, activities, and/or infrastructure.
Project Team	DHA Project Manager: Angelique Brett (GHD Project Manager) SERS Project Director: Matt Campbell (Director) SERS Project Manager: Chris Kennedy (Senior Environmental Scientist) SERS Project Team: Paul Wallace (Environmental Scientist)
Conceptual Model	The conceptual site model (CSM) was included in the RAP as summarised in Section 4.2 of this SAR.
Resources & Project Timeframes	The SERS project team and resources are listed above. The remedial works were carried out between October 2015 and December 2015. The final emu pick was conducted on the 27 January 2016.
Community Concerns	Prior to commencement of the remedial work, SERS issued a letter to nearby residents detailing the proposed remediation of the site. An Environmental Management Plan was prepared for the remediation works to management Environment, Heritage and Community Issues.
Regulatory Authorities & Local Government	Commonwealth Department of Defence, Commonwealth Department of the Environment (DOTE), Northern Territory Department of Land and Resource Management (NT DLRM), NT Environment Protection Authority (NT EPA).
Step 2 - Identify the decision	
Media & Receptors	- Is there any soil that through olfactory and visual means is still impacted? - Is there waste material or redundant infrastructure still present at the Site? - Is there any surficial asbestos fragments remaining at the Site?

Item	DQO
Contaminants for Validation	- What were the contaminants targeted for remediation? - What is the background concentration of these contaminants?
Decision statements	- Are there any surficial waste materials or asbestos still present at the Site? - What validation activities are required to satisfy the objectives of validation? - Is the Site sufficiently remediated to the adopted validation criteria?
Step 3 - Identify the inputs	
Site Condition	- Visual survey for remaining miscellaneous waste materials and asbestos. - Visual observations of local flora and evidence of stress (caused by remedial works). - Visual observation of soil erosion or land instability (caused by remedial works). - Visual observations of road damage (caused by remedial works).
Aesthetic Condition	Field observations of waste material, remnant infrastructure, condition of soils that have aesthetic impacts within the 2CRU Compound (i.e. rubbish, odour, discolouration, stained materials).
Validation Criteria	The adopted validation criteria were outlined in the RAP, as summarised in Section 7.2.3 of this SAR.
Fieldwork-Sampling	Sampling should meet the minimum sampling frequencies outlined in RAP (SERS, 2015a) and be undertaken in accordance with AS4964-2004 (Standards Australia, 2004) and AS4482.1-2005 (Standards Australia, 2005).
Laboratory Methods	Laboratory analytical methods will be undertaken in accordance with NATA certification requirements.
Step 4 - Define the boundary of the study	
Geographical limit	The spatial boundary of the investigations will be the former 2CRU NT RAAF Transmission Facility, which is located within a fenced compound on Block 4373 Lee Point Road, Darwin, NT (The Site). The 2CRU Facility is a 100 m x 200 m area (20,000 m^2) located within the northern end of the larger block known as Lot 4873 which is approximately 836,650 m^2. (Refer Figure 1, Appendix A provided by GHD).
Validation limits	Limits on the identification, classification, and estimation of waste material and remnant infrastructure as defined by the geographical limits of 2CRU Compound.
Constraints	Not Applicable
Step 5 – Develop the decision rule	
Decision Statements	- Do soil samples meet the adopted validation criteria? - Is the 2CRU compound absent of miscellaneous waste materials? - Is the 2CRU compound absent of asbestos fragments?
Decision Rule	The decision rules have been developed based on the underlying project drivers and the corresponding objectives of the remediation and validation program. Criteria to be used to evaluate these decision rules are defined in Step 2. - If the concentration of contaminants in samples is greater than the validation criteria: • then further investigation and/or remediation should be undertaken. - If not, • then no further assessment, remediation or management works are required.
Step 6 – Specify tolerable limits on decision error	
Documentation and data completeness	- Site conditions properly described. - Waste material and remnant infrastructure identified and removed are logged, including location, photographs, physical description, material classification, and size and volume estimates. - Validation sampling locations properly described and located. - Completion of field records, chain of custody documentation, laboratory test certificates from NATA registered laboratories. - Visual inspection and logging of all remediated areas, including sample collection from all areas of identified contamination. - Samples are tested for all targeted contaminants.

Item	DQO
Data comparability	- Use of standardised and consistent logging techniques and observation descriptions. - Use of appropriate techniques for the sampling, storage and transportation of samples. - Use of laboratories with NATA certification for the analyses conducted and undertaken using NEPM procedures.
Data representativeness	- Collection of representative data and information to comprehensively describe the type, extent, and volume of waste material and remnant infrastructure (e.g. coordinates, photographs, descriptions). - Collection of minimum required samples from each sampling location as per AS4482.1 2005 (Standards Australia, 2005). - Use of appropriate techniques for the sampling, storage and transportation of samples.
Precision for sampling and analysis	- Achieve laboratory QC criteria. - Blanks returned with no contamination. - All matrix and surrogates returned acceptable results. - All laboratory duplicates within acceptable ranges. - All blind field duplicates within acceptable ranges. - All control results within acceptable ranges. - All laboratory LORs or practical quantification limits within acceptable ranges.
Accuracy for sampling and analysis	- Use of properly trained and qualified field personnel. - Use of blind field duplicate samples to be collected at a minimum rate of 1 in 20. - Relative percentage difference values for duplicate samples are less than specified criteria. - Acceptable quality of rinsate blanks (if required). - Acceptable quality of trip blank samples (if required). - Acceptable quality of trip spike samples (if required).
Sampling design	The sampling design strategy is based on systematic sampling from stockpiles as well as the base and sides of excavated areas.
Step 7 – Optimise the design for obtaining data	
Review of DQO outputs	The design of data collection activities was aimed at achieving the ultimate target outputs: - Validation of remediated areas to meet adopted validation criteria. - An inventory register of waste materials removed and the disposal method.

The Auditor considers that the DQOs presented in Table 6, above, are appropriate for the purpose of the remediation and validation works and generally in accordance with the requirements of the ASC NEPM (2013) and NT EPA approved guidelines.

7.0 Remediation and Validation Works

7.1 Remediation Works

7.1.1 Roles and Responsibility

The 2CRU Validation Report (SERS, 2016a) provided the role and responsibilities of the key stakeholders involved with the key components of the remediation works of which are presented in Table 5.

Table 5 Remediation Roles and Responsibilities

Organisation	Role	Key Responsibility
Defence Housing Authority	Client	Senior Development Manager for DHA who is responsible for the delivery of the remediation activities.
GHD	Project Manager and Contract Administrator (PMCA)	Overall management and delivery of the project for DHA.
AECOM	Contaminated Site Auditor (referred as Environmental, Site Auditor in the RAP)	Review key deliverables relating to the investigation and remediation works in accordance with NT and NSW EPA requirements. Preparation of Site Audit Report.
SERS	Environmental Consultant	Overall Consultant for delivery of the remediation and validation project, review and document remediation activities and implement remediation validation program. Monitor environmental performance of the remediation contractor. Preparation of the RAP and Validation Report.
Brajkovich Demolition and Salvage (WA) Pty Ltd (BDS)	Demolition Contractor	Implementation and execution of the demolition activities in accordance with the Remediation Contract Specification and under the direction of the Consultant.

7.1.2 Legislative Requirements

The 2CRU RAP (SERS, 2015a) identifies that the remediation works would be undertaken in accordance with licences, approvals and other specific regulatory requirements applicable for the various aspects of work involved. Specific mention was provided for the following:

- NT Work Health and Safety Acts and Regulations
- Work Health and Safety (National Uniform Legislation) Regulations
- Schedule 11 Hazardous Chemicals and Notification of the Abandonment of an underground, partially underground or fully mounded tank.
- Regulation 367 “Notification of Abandonment of Tank Form
- The National Environmental Protection (Assessment of Site Contamination) Measure (National Environmental Protection Council, 1999) as amended 2013 (ASC NEPM 2013)
- National Code of Practice for the Safe Removal of Asbestos (2nd Edition) 2005
- National Code of Practice for the Management and Control of Asbestos in Workplaces 2005
- Australian Standard 4482.1 *Guide to the Investigation and Sampling of Sites with potentially contaminated soil – non-volatile and semi-volatile compounds*
- Australian Standard 4482.2 *Guide to the Investigation and Sampling of Sites with potentially contaminated soil – Volatile Substances*
- Australian Standard 4976 (2008) *The removal and disposal of underground petroleum storage tanks*
- The *Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act).*

7.1.3 Summary of Remediation Works

The Validation Report summarised the remediation works undertaken by SERS and their nominated subcontractor BDS. The following presents a summary of the remediation works undertaken within the 2CRU compound:

- Stage 1 – removal of all observed ACM prior to the demolition of the above ground structures as per the Asbestos Removal Control Plan (ARCP) (refer to Appendix D of the SERS (2016a) Validation Report) protocols:
    - All ACM products present within the buildings were removed by licenced asbestos removalist in accordance with current legislation and Worksafe NT and Comcare procedures.
    - Any ACM observed was collected and placed in a plastic asbestos disposal bag and sealed with PCV tape then placed into another bag of same quality and sealed (double bagged)
    - Upon completion of the ACM removal works the building and structures were inspected by a qualified asbestos assessor and any open space grid walked three time in each axis to confirm successful removal of all ACM prior to demolition
    - Once asbestos assessor was satisfied that all ACM had been removed, a clearance certificate was issued and the demolition works proceeded.
- Stage 2 – demolition of buildings and structures with the exception of APEC G, APEC J and APEC K to the following protocols:
    - All demolition activities were carried out in accordance with specific NT and federal legislation.
    - Above ground structures were deconstructed first, followed by concrete slabs and hard standing areas.
    - All demolition works were notified to Worksafe NT and undertaken by SERS nominated subcontractor BDS in accordance with the safe work method statement (SWMS) provided in Appendix D of the SERS (2016a) Validation Report.
- Stage 3 – removal of APEC G (transformer), AEPC J (UPSS) and APEC K (Septic System) structures and associated contaminated soil under the supervision and direction of SERS as follows:
    - Prior to the remediation of the APEC's, SERS surveyed using a hand held GPS and pegged the site structures in preparation of demolition to ensure that all impacted areas would be addressed during the remediation.
    - Two steel twin skinned tanks were removed from APEC J (both tanks were noted to being empty prior to removal) and inspected for breaches prior to being loaded onto a truck for disposal at Shoal Bay Waste Facility.
    - Removal of one concrete dual chamber tank from APEC K. The chambers were excavated using the onsite excavator and placed on adjacent hard standing area for inspection prior to crushing. No liquid was noted as being present in the septic system prior to removal.
    - Excavation of contaminated soils from the relevant APEC (G, J and K) to a depth of 300 mm below any structure or observed visual or olfactory evidence of contamination. All excavated materials were placed on plastic sheeting lined hard stand and covered with plastic sheeting while laboratory analysis were performed on representative samples. Soils excavated from each APEC were stockpiled separately to prevent cross contamination.
    - Sampling and analysis of the excavations were performed from the base and side walls to validate that any potential contamination had been removed from the APEC. Upon completion of the remedial works, all final samples recorded concentrations below the adopted soil criteria.
    - Upon receipt of the chemical analysis, results for the stockpiled soils were compared to the ASC NEPM 2013 threshold values. Results determined:
        - Soils from APEC J (UPSS) and APEC K (Septic System) were considered suitable for reuse on site and used to back fill respective excavation pit.
        - Soils from APEC G (Transformer) were considered unsuitable and underwent waste classification and ultimately offsite disposal at Shoal Bay Waste Facility.

- Stage 4, Stage 5 and Stage 6 – upon demolition of the buildings and infrastructures, each APEC was cleared for near surface ACM to the following protocols:
    - The entire site was separated into seven areas to make asbestos remediation manageable as per Figure 1 Areas of Work presented in SERS (2016a) Appendix G Asbestos Clearance Certificates, a copy of which is presented in Appendix A of this SAR.
    - Each area in turn was grid walked three times in each axis in line formation by a team of no less than three competent asbestos removalist/assessors.
    - Any ACM observed was collected and placed within a plastic asbestos disposal bag and sealed with PVC tape and then placed into another bag of the same quality and sealed.
    - During the process, ACM recovered was weighed and aesthetic quality (colour, foreign material) were visually assessed. Once no ACM was observed, this stage of the asbestos remedial works was considered complete and validation sampling of exposed soils were undertaken.

The Validation Report identified that at completion of the remedial works, the surface of the site was graded and excavations backfilled.

During the decommissioning of the 2CRU Site, the demolition contractor BDS identified ACM piping which extended outside of the 2CRU compound. This instigated the Unexpected Finds Protocol for the works. Figure 2 from SERS (2016b) Asbestos Validation Report provides the location of where the ACM piping was removed from, of which a copy is presented in Appendix A of this SAR. The removal of the ACM piping was carried out by BDS under the supervision of SERS using the following method:

- Soils from above the ACM piping were carefully removed using an excavator and shovels and stockpiled adjacent to the sludge beds.
- All ACM pipes were then removed manually as to prevent breakages and placed directly into lined bins for removal from site and disposal to landfill.
- Approximately 98% of pipeline was removed with no minor breakages. IN case of minor breakages, which occurred in particular areas around the joints of the pipeline, BDS and SERS personnel manually removed any remaining fragments by hand picking and the area was inspected by SERS post removal of ACM fragments.
- In area where ACM pipeline came into direct contact with soil surrounding area was manually dug out to 300 mm below impacted area and disposed as asbestos waste.

The Auditor considers that the remediation works undertaken were generally in accordance with the RAP (SERS, 2015a) and the requirements of NT EPA endorsed guidelines, including the WA Department of Health, *Guidelines for the assessment, remediation and management of asbestos-contaminated sites in Western Australia*, May 2009.

7.2 Validation Sampling and Analysis Plan

7.2.1 Soil Validation Sampling and Analytical Suites

Soil laboratory analyses were undertaken by MPL Laboratories (Primary) and ALS Environmental (Secondary), who are all NATA accredited for the analyses conducted. Asbestos in soil laboratory analysis was carried out by SERS, who are NATA accredited for the analyses conducted.

The Validation Report indicated that samples were collected in accordance with Australian Standards (AS4482.1-2005 and AS4482-2-1999) from excavations associated with APEC's G, J and K and from near surface soils associated with APCE A to APEC F, APEC I and APEC L to Q. Table 6 provides a summary of the samples collected and the analytical suite for the analysis of the samples as reported in the Validation Report.

Table 6 Validation Sampling and Analytical Suites

Remediation Area	Size	Number of Samples[1]	Sample IDs	Analytical Suite
APEC A – South Radar Tower		5 Primary		Asbestos

Remediation Area	Size	Number of Samples[1]	Sample IDs	Analytical Suite
APEC B – Communication Pit		5 Primary		Asbestos
APEC C – Power House		5 Primary		Asbestos, PAHs, BTEX
APEC D – Central Radar Tower		5 Primary		Asbestos
APEC E – Concrete Pad		5 Primary		Asbestos
APEC F – North Radar Tower		5 Primary		Asbestos
APEC G – Electrical Transformer	50 m^3 (4.5 m x 6.5 m x 1.7 m)	5 Primary 3 QA/QC	G001 to G005 (collected 29/10/2015) APEC-G2-01 to APEC-G2-05 (collected 24/11/2015)	TPH, BTEX, PCBs, OC/OP, Naphthalene
APEC H – Generator Shed		5 Primary		Asbestos
APEC I – Administration Building		7 Primary		Asbestos
APEC J – Underground Petroleum Storage System	147.25 m^3 (5 m x 9.5 m x 3.1 m)	5 Primary 3 QA/QC	J001 to J010 (29/10/2015 to 30/10/2015)	Metals+, TPH, BTEX, Naphthalene
APEC K – Septic System	127.5 m^3 (8.2 m x 5.2 m x 3.1 m)	5 Primary 3 QA/QC	APEC-K-01 to APEC-K-10 (23/11/2015)	13 Metals+, TPH, BTEX, Naphthalene
APEC L – Water Tanks		5 Primary		Asbestos
APEC M – Concrete Pad		5 Primary		Asbestos
APEC N – Shed		5 Primary		Asbestos
APEC O – Amenities Block		5 Primary		Asbestos
APEC P – Guard House		5 Primary		Asbestos
APEC Q – Concrete Pad		5 Primary		Asbestos
Soil Classification Sampling: APEC G APEC J APEC K	 50 m^3 147.25 m^3 127.5 m^3	 4 Primary 5 Primary 5 Primary	 WC01 to WC04 WCA01 to WCA08 APEC-K-01 to APEC-K-03	13 Metals+, TRH, TPH, BTEXN. OC/OP, Phenols, Cyanide.

+ Metal Suite - Arsenic, Beryllium, Boron, Cadmium, Chromium, Cobalt, Copper, Lead, Manganese, Mercury, Nickel, Selenium and Zinc.

[1] Minimum sampling for excavations was based on NSW EPA *Sampling Design Guidelines* (NSW EPA, 1995) to detect circular hot spots with a radius of seven metres with 95% confidence using a grid sampling pattern.

7.2.2 Asbestos Validation

The Validation Report (SERS, 2016a) provided a summary of the asbestos validation methodology of the identified asbestos pipeline infrastructure which comprised the following key components:

- At completion of the ACM pipe removal works, SERS undertook a grid walk of the trench to ensure all possible ACM and potentially impacted soils were removed.
- Additional search area of 5 linear meters around the last visually observed ACM fragment was implemented to ensure all ACM fragments were recovered
- A total of 40 soil samples for asbestos analysis was collected along the length of the asbestos pipeline trench. Total length of 407.5 m which equates to a sample per 10.18 m in accordance with the WA Asbestos Guidelines (WA DoH, 2009) as follows:
    - A pit averaging a surface area 0.90 m^2 was hand excavated to a maximum depth of 0.3 mbgl. The excavated material was placed into a 7 mm spaced sieve and sieved through on to a clean black plastic sheet to allow the identification of asbestos fines. Upon completion of sieving the soil was placed in a laboratory supplied sample bag.
    - Samples of >500 ml strata were collected from areas identified as potentially impacted by hand and transferred into zip-lock bags. Samples were taken from 0 to 0.3 mbgl (ground level being the base of the excavation) to target the strata which had the greatest likelihood of containing ACM and asbestos fines.
    - All asbestos samples were analysed for %soil asbestos at a NATA accredited laboratory (SERS Laboratory, Northbridge, WA) using the ASC NEPM 2013 schedule B1 method.

7.2.3 Groundwater Validation

The Validation Report (SERS, 2016a) identified that no further groundwater monitoring or installation of monitoring bores were required due to the following reasons:

- Upon completion of the remedial works all potential mobile contamination and sources previously present onsite has been removed (APEC G (substation), APEC J (UPSS) and APEC K (septic system)).
- Laboratory results associated with the validation soil samples collected from the excavations associated with APEC G, APEC J and APEC K recorded potentially mobile contaminants (most notable hydrocarbons and PCBs) concentration below the laboratory level of detection and therefore below the selected threshold criteria values. Thus indicating that no residual contamination is present within the subject site boundary.
- No offsite contamination sources have been identified during the remedial works or previous environmental investigations.
- The underlying geology recorded during the construction of BH101 (total depth – 21 mbgl) comprised of clay and weathered siltstone which has a low permeability.
- During the construction of BH101 no moist strata was encountered and no water ingress noted
- No groundwater was recorded in the BH101 or the GHD installed LPH2 (total depth – 8 mbgl) from installation until the completion of the remedial works in December 2015.
- SERS tried to identify historical bore RN8469 (formed in 1974) to determine whether water was still present at depth of 4.9 m. SERS were unsuccessful in locating it, therefore it is reasonable to assume due to the age of the well it is likely damaged or backfilled.
- During the remedial works, no preferential pathways were identified to the underlying aquifer were observed.

7.3 Remediation and Validation Acceptance Criteria

The 2CRU Validation Report provided a summary of the Validation Criteria for soils, asbestos and waste classification.

The Validation Report stated that the remediation acceptance criteria (RAC) were based on the criteria defined in the ASC NEPM (2013) as follows:

- Health Investigation Levels (HILs) for residential use with garden/accessible soils (HIL-A).

- Health Screening Levels (HSLs) for residential use with garden/accessible soils (HSL-A) and residential with minimal accessible soils (HSL-B) for vapour intrusion.

The validation criteria for asbestos were compared to:

- WA Asbestos Guidelines (WA DoH, 2009) – 0.001%w/w for fibrous asbestos (FA) and asbestos fines (AF) – all site uses
- WA Asbestos Guidelines (WA DoH, 2009) – 0.01%w/w asbestos for ACM – Residential use, day care centres and schools etc.

The validation criteria for ecological significance were compared to:

- Ecological Investigation Levels (EILs) for lead, copper, nickel and zinc determined using the CEC of 21 meq/100g and a pH of 9.2.
- Ecological Screening Levels (EILS) were used for Urban Residential and Public Open Space, Fine.

Waste classification (associated with the excavated materials from APEC G were compared to the criteria presented in the *NSW EPA: Waste Classification Guidelines – Part 1 Classification of Waste (2014)* to determine the class of landfill for materials taken off site.

A waste disposal approval was provided by the City of Darwin's Waste and Recycling Department prior to disposal. A copy of the waste disposal receipts are provided in Appendix M of the Validation Report.

The Auditor considered that the 2CRU Validation Report (SERS, 2016a) provided a suitable summary of remediation and validation works and the remediation acceptance criteria.

The Auditor has reviewed the information presented by the consultant to identifying why the risk to groundwater from site activities was considered minimal, which resulted in no further groundwater assessment or monitoring being undertaken as part of the remediation and validation works.

Based on the findings from SERS remediation and validation activities, the Auditor considers that the groundwater conditions post remedial works comprised:

- no standing water detected within the two bores installed on Site (8 mbgl and 21 m bgl) since investigations commenced

- no sources of mobile contamination (removed and validated during remediation works)

- the underlying low permeability geology

- no preferential pathways to the underlying aquifer.

As such, it is considered that the risk to groundwater from contamination is low. As such, the auditor considers the decision that no further investigations on groundwater was necessary based on the previous NEPM (1999) schedule B(6) groundwater risk assessment, which allowed for an initial assessment of groundwater contamination.

However, in accordance with ASC NEPM 2013, some uncertainty remains around the quality of groundwater on Site. If the local groundwater has the potential to be utilised in the future as a viable resource for potable uses, the auditor recommends that groundwater not be used until a monitoring and testing regime be undertaken to confirm its suitability for any future uses.

8.0 Results

8.1 QA/QC Summary

The Validation Report (SERS, 2016a) stated the QA/QC program for the remediation and validation works were completed in general accordance with recommended good practice, standards and guidelines relevant to the investigation including USEPA, 1994: National Functional Guidelines for organic data review and the USEPA, 1994 National Functional Guidelines for inorganic data review.

The information presented in Table 7 and Table 8 below provides a summary of the QA/QC program as reported in the Validation Report.

Table 7 Field QA/QC

Protocol	Description
Sampling Team	The soil removal was overseen and redirected by an experienced Environmental Scientist and the asbestos validation works were undertaken by an Environmental Scientist with at least three years of asbestos in soil experience.
Suitability of sample matrix	Sampling methods used to collect samples were suitable for the compounds analysed.
Chain of Custody Forms	All samples were required to be logged and transferred under appropriately completed Chain of Custody (CoC) documentation. CoC documentation was provided in Appendix J of the Validation Report.
Preservation	The QA/QC program required that all samples be received at the laboratory in appropriately preserved containers and samples placed on ice in eskies. Laboratory sample receipts were presented with chain of custodies in Appendix J of the Validation Report.
Decontamination	All sample collection equipment was subjected to rigorous decontamination procedures to prevent cross contamination of samples. Reusable equipment (e.g. trowels) were cleaned with decontaminant solution (oxygen based, phosphate free detergent solution), rinsing in tap water and then rinsing in deionised water. Due to the loose structure of the soil, majority of samples were collected by clean nitrile gloved hand, significantly reducing the likelihood of sample cross contamination.
Rinsate Blanks	Rinsate blanks were to be taken during soil sampling where reusable equipment was used (stainless steel trowel). SERS states that as samples were collected either directly from the excavation or from undisturbed soils, no rinsate samples were collected. The absence of rinsate samples is not considered to affect the quality of the sampling/investigation undertaken. The Validation Report indicated that the potential for cross contamination between samples was considered unlikely given the sampling methodology followed which included use of fresh nitrile gloves for each sample.
Field & Trip Blanks	A total of four field blanks and four trip blank were analysed at rate of 1 per 11.75.
Duplicate (intra laboratory) and Split (inter laboratory) Samples	Results of primary and duplicate samples were within acceptable range. A total of 47 non QA samples were submitted to the laboratory between 29/10/2015 and 30/11/2015. Blind duplicates samples were analysed at a rate of 1 per 9.4 during the validation samples. Triplicate samples (inter laboratory) were analysed at a rate of 1 per 23.5. The inter-lab QA sampling rate of 1 per 20 was not achieved due to sample breakage during transportation. Two split (inter-laboratory duplicate) samples were collected during the field investigations. The split sample was analysed as part of the field QA/QC program to check the analytical proficiencies of the laboratories used. Relative percentage differences (RPD) were calculated between the primary and split samples. Exceedances of the required relative Percentage Difference (RPDs) were reported for selected metals and TRH fractions for some samples. SERS assessed that the exceedances did not affect the outcome of the assessment particularly as the results were less than the adopted validation criteria.

Table 8 Laboratory QA/QC

Protocol	Description
Holding Times	The QA/QC program required that all samples be kept in secure, chilled eskies and either transported to the primary laboratory directly or via courier under chain of custody procedures. Sample transfer and receipt details were provided with the Laboratory analytical results in the Validation Report. All samples were transported to the laboratory via courier within 48 hours of sampling and were analysed within appropriate holding times.
Laboratory Analytes limit of reporting	All laboratory analysis techniques used were within the NEPM 2013 guidelines. Limit of Report (LOR) were suitable for assessment values used within the validation process.
Laboratory QA Sample Results	24 Soil laboratory duplicates, 13 LCMs, 10 method blanks and 14 matrix spike samples were run by the laboratories. Results were acceptable range for all primary laboratory QA samples (70-130% for organics).
RPD for Laboratory Matrix duplicates and matrix spike recoveries	Within laboratory acceptance criteria. Sample method blanks and laboratory blanks were returned acceptable results of non-detect.
Frequency of laboratory cross contamination	There is no evidence to suggest sample cross contamination during the analysis process.

8.1.1 QA/QC Conclusions

The Validation Report stated that all QA/QC results were within the DQOs for the assessment. The quality of data produced is considered to be of an acceptable standard for interpretive use.

The Auditor considers that the QA/QC results were generally reported accordance with the requirements of NT EPA approved guidance. The Auditor has undertaken an independent review of the laboratory data provided by SERS and considers that the results are of an appropriate quality for the purposes of the remediation and validation works.

8.2 Laboratory Analysis

The Validation Report stated that the analysis of samples was undertaken by Eurofins (Oakleigh, Victoria) as the primary laboratory and Australian Laboratory Services (Springvale, Victoria) as the secondary laboratory, with analysis for asbestos undertaken by Eurofins (Sydney, NSW). The Validation Report stated that both laboratories are accredited by the National Association of Testing Authorities (NATA) for the analytical techniques required.

Laboratory reports were provided in Appendix J, of the Validation Report (SERS, 2016a). A summary of the Laboratory Certificates provided are detailed in Table 9.

Table 9 Laboratory Analysis

Laboratory	Date Received	Date Sampled	No. of Samples	Medium	Purpose
MPL Laboratories*	02/12/2015	30/11/2015	7	Soils	APEC G Electrical Transformer (PCBs and Pesticides)
MPL Laboratories*	25/11/2015	24/11/2015	5	Soils	APEC G Electrical Transformer (PCBs and Pesticides)
MPL Laboratories*	25/11/2015	23-24/11/2015	17	Soils	APEC K Septic System (Hydrocarbons and Metals)
MPL Laboratories*	02/11/2015	30/10/2015	31	Soils	APEC J UPSS (Hydrocarbons and Metals)
ALS Environmental	02/11/2015	02/11/2015		Soils	QA Sample

Laboratory	Date Received	Date Sampled	No. of Samples	Medium	Purpose
ALS Environmental	02/11/2015	29/10/2015		Soils	QA Sample
SERS	7/12/2015	20/11/2015 to 03/12/2015	11	Soils	Fibre Identification in Soils

* Envirolab Services (WA) Pty Ltd trading as MPL Laboratories

Detection limits and analytical methods performed by the analysing laboratories were referenced in the laboratory reports. The analytical results for the validation samples were presented in Appendix K of the Validation Report (SERS, 2016a), a copy of which is presented in Appendix D of this SAR.

8.3 APEC G – Electrical Transformer Results

The 2CRU RAP identified that APEC G required the excavation around the footprint of the electrical transformer and the transformer fluid (hydrocarbon based) impacted soils to a depth of 1.7 mbgl across a total area of 29.25 m^2. During the validation testing, a volume of 50 m^3 was excavated from the transformer footprint. No visual or olfactory signs of contamination were detected. The photoionization detector (PID) was used to record level of volatile organic carbon (VOC), which range from 0 to 0.8 ppm.

Four samples (APEC-G3-02 to APEC-G3-04) were obtained from the walls of the excavation and one from the base (APEC-G3-05). The laboratory analysis from samples APEC-G3-01 to APEC-G3-04 and APEC-G3-05 did not exceed the remediation action criteria (RACs). A number of analytes did report concentrations of chemicals of concern above the laboratory limit of report (LOR) for arsenic, chromium, copper, manganese, nickel, zinc and total recoverable hydrocarbon (TRH) fractions from APEC-G2-05 of C16-C34 and C10-C36.

The hydrocarbon contamination recorded within sample APEC-G2-05 (TRH C16-C34 for 570 mg/kg and TRH C10 to C36 of 625 mg/kg) were below the nominated screening value of 1,300 mg/kg for these fractions. Additional soils were excavated from the excavation face associated with APEC-G2-05.

Metal concentrations above the LOR but below the RAC are considered background levels associated with the geological profile of the site.

8.4 APEC J – UPSS Results

The 2CRU remediation works at APEC J consisted of the removal of two 10,000 L steel lined fuel storage tanks with approximate volumes of 147.25 m^3. The excavation pit displayed no visual or olfactory signs of contamination. Within the footprint of the tanks, soils were excavated to a minimum depth of 300 mm below the base of the tanks. A PID was used to record VOCs, however malfunctioned due to the high temperatures experienced on the day.

A total of 10 soil samples were obtained from the UPSS area, which included one sample from the base of each pit (at approximately 3.1 mbgl) and four from sides between 0.9 and 1.5 mbgl and four from 1.9 to 2.5 mbgl.

During transportation, samples J006 (2.1 to 2.5 mbgl) and J007 (1.0 to 1.6 mbgl) were broken and as such could not be analysed. The loss of the two samples was considered not to impact the findings of the validation works as no visual or olfactory signs of contamination were noted and results from the remaining samples. The laboratory analysis from samples (J001 to J010) did not indicate exceedances of the selected RACs.

Metal concentrations were reported above the laboratory LOR, including Arsenic, Lead, Nickel and Tin, however, were considered to be background levels associated with the geological profile.

8.5 APEC K – Septic System Results

The 2CRU remediation works at APEC K consisted of t

The 2CRU RAP identified that APEC K required the excavation around the footprint of the septic tank and infrastructure to a depth of 3.1 mbgl across a total area of 127.5 m^2. Within the footprint, the tank soils were excavated to a minimum depth of 300 mm below the base of the concrete tank. The excavation pit did not display visual or olfactory signs of contamination. A PID was used to record VOCs, these levels ranged from 0-0.5 ppm.

A total of ten samples (APEC-K-01 to APEC-K-10) were obtained with two samples taken from the base and two from each of the four walls of the excavation area. The laboratory results indicated no concentrations exceeding the RACs.

Metal concentrations were again reported above the laboratory LOR but below the RAC and as such were considered background concentrations.

8.6 Asbestos in near Surface Soils (APEC A to APEC F, APEC H, APEC I and APEC L to APEC Q) Results

The Validation Report stated that prior to demolition, all buildings and structures associated with APEC A to APEC F, APEC H, APEC I and APEC L to APEC Q contained ACM. Following the demolition of all hard standing and structures, SERS undertook a grid walk of each APEC by splitting the site into 7 work area (refer Figure 1 Remediation Work Area of the 2CRU Validation Report, a copy of which is presented in Appendix A of this SAR) to determine the presence of ACM.

The emu bob grid walk was undertaken on three occasions (27/11/2015, 02/12/2015 and 27/01/2016). A team of four comprising of asbestos assessors, asbestos removalists and environmental scientist emu bob across the site three times in each axis in line formation of each of the seven areas. ACM was encountered and appeared to originate from the demolition of the buildings.

Table 10.4 in the Validation Report presented a summary of the emu bon grid walks and has been replicated in Table x of this SAR.

Table 10 SERS Summary of Emu Bob Grid Walks

Date of Emu Bob	Approximate number of Fragments Recovered	General Condition of Fragments	Total weight of ACM recovered
27/11/2015	1,760	Highly Bonded	88 kg
02/12/2015	210	Highly Bonded	12 kg
27/01/2016	22	Highly Bonded	1 kg

In compliance with the WA DoH 2009 guidelines, SERS calculated the % Soil Asbestos. The results are as follows:

- First Grid Walk = 88 kg of ACM across approximate 836,650 m^2 equates to a % Soil Asbestos of 0.0000042%.
- Second Grid Walk = 12 kg of ACM across approximate 836,650 m^2 equates to a % Soil Asbestos of 0.00000057%.
- Third Grid Walk = 1 kg of ACM across approximate 836,650 m^2 equates to a % Soil Asbestos of 0.0000000478%.

Based on the above results for the % Soil Asbestos indicates that results are below the residential threshold value of 0.01% w/w stated in the WA DoH 2009 Guidelines and that the total ACM fragments recovered from the subject Site area had significantly dropped over time by 194.4988%.

The 101 kg of ACM produced over the three emu bob grid walks were disposed at a suitably licenced landfill site (Shoal Bay).

The validation testing of soils for concentrations of Asbestos Fines and Fibrous Asbestos did not detect asbestos (<0.0001%) and the condition of the collected ACM determine that the near surface soils across the site has been cleared of asbestos and risk to human health (in relation to asbestos) has been mitigated.

The Auditor notes that the consultant has used the total site area of 836,650 m^2 to calculate the % Soil Asbestos rather than the portion that was subject to this investigation. The results if used the area which is subject of the SAR (i.e. 20,000 m^2) would have resulted in the % Soil Asbestos being 42 times larger then what has been reported.

The Auditor notes that this does not affect the overall result, as the % Soil Asbestos results using the smaller area, would still be below the residential threshold value of 0.01% w/w stated in the WA DoH 2009.

8.7 Asbestos Pipeline Removal Results

The Validation Report (SERS, 2016a and 2016b) reported that prior to backfilling of the pipeline trenches, an emu bob grid walk was undertaken, as per the description provided in Section 8.6. Only minor ACM fragments were encountered at the pipe joints and were described as heavy bonded with no visible asbestos fibre bunds protruding from the ACM fragment.

A total of 6.94 tonnes of asbestos piping and fragments were recovered from the ACM pipeline removal works. All ACM material was disposed at the Shoal Bay Water Disposal Facility. Receipts from the landfill are presented in Appendix N of the SERS Validation Report.

In compliance with the WA DoH 2009 guidelines, SERS calculated the % Soil Asbestos. The results are as follows:

- Validation Grid Walk = 5 kg of ACM across approximate 203.75 m^3 equates to a % Soil Asbestos of 0.00023%.

Following final clearance inspection grid walk, validation sampling was conducted on the remaining insitu soil to ensure no asbestos fibres were present in the remaining soils exposed by the pipeline trenches.

The validation testing of soils for concentrations of Asbestos Fines and Fibrous Asbestos did not detect asbestos (<0.0001%) determine that soils remaining in the pipeline have been cleared of asbestos and risk to human health (in relation to asbestos) has been mitigated.

8.8 Waste Disposal and or Re-use

The Validation Report presented the waste classification laboratory analysis undertaken on the stockpile of excavated soils associated with APEC G, APEC J and APEC K. Results from the validation sample determined the end use of the soils removed from the APEC's. The following presents the outcome:

- A total of four soil samples (WC01 to WC04) were collected from APEC G stockpile which contained 50 m^3 of hydrocarbon impacted soils. Based on the results the stockpile of soil was classified as General Solid, in accordance with *NSW EPA: Waste Classification Guidelines – Part 1: Classification of Waste (2014)*. Soils from APEC G stockpile were disposed at the Shoal Bay Waste Management Facility (refer to Appendix M of the Validation Report for the Darwin City Council Waste Disposal Approval Certificate.
- A total of eight soil samples (WCA01 to WCA08) were collected from the APEC J stockpile. The laboratory results indicated no concentrations exceeding the RACs. Based on the results from the laboratory testing, the APEC J stockpile was considered suitable for re-use onsite and was used to backfill the excavation associated APEC J.
- A total of three samples (APEC-K-W01 to APEC-K-W03) were obtained from APEC K stockpile. The laboratory results indicated no concentrations exceeding the RACs.

The Auditor considers that the results summary provided in the Validation Report (SERS, 2016a and 2016b) were in general accordance with the requirements of NT EPA approved guidance and was appropriate for the purposes of the validation.

The Validation Report (SERS, 2016a) does not identify if clean fill was required to fill the voids of the excavations from APEC G, APEC J and APEC K. This uncertainty does not adversely impact on the suitability of the 2CRU Site or on the conclusions drawn by the Audit in the preparation of this Report.

9.0 Conclusions and Recommendations of the Validation Report

9.1 Consultant Conclusions

The Validation Report (SERS, 2016a) provided an overview of the remediation and validation works at the identified portion of the former 2CRU NT RAAF Transmission Facility, situated at Lee Point, Northern Territory, as shown in Figure 1 (GHD), Appendix A of this SAR.

The remedial works targeted all known potential sources of contamination as identified in the previous contaminated site investigations and hazardous materials survey. The remediation works included the removal of all asbestos materials, the underground petroleum storage system (UPSS), electrical transformer, a septic system and any associated contaminated soils.

The validation works included visual inspection of all surface soils, excavations associated with the removal of USTs and areas of excavation associated with the removal of ACM pipe and impacted soils. No further evidence (visual and/or olfactory) was identified during the remediation to suggest unknown sources of contamination (i.e. USTs, chambers, soil discolouration and pipework).

Post remediation the site was left in a clean and tidy condition with no signs of rubbish, chemical storage or structures. All underground structures (including ACM pipework) have been reported by SERS to have been removed.

SERS presented the following statements with respect to the current Site conditions:

- All potential sources of contamination have been successfully removed off the subject Site.
- During the remedial works no visual or olfactory evidence of mobile contamination was observed within the soil matrix.
- Chemical analysis of the soils taken post remediation did not record any exceedances of the selected remediation acceptance criteria. Therefore reasonable to conclude that the risk to the wider environment front contaminants originating from Site is negligible.
- No ACM or significant quantities of asbestos fibres were recorded within near surface soils post remediation.
- Groundwater underlying the site is at a depth greater than 21 mbgl and preferential pathways to the aquifer have been observed.

As result of the above statements, SERS concluded that:

Based on the completion of the remedial works and the successful validation program performed, no remaining potential contamination sources or potential pollutant linkages have been identified on the subject site area for the proposed residential end use within the underlying soils or groundwater which could be a risk to human health or the wider environment.

It is therefore SERS opinion that the site can be classified as uncontaminated and suitable for future residential development.

9.2 Ongoing Site Management

The Validation Report (SERS, 2016a) confirmed that no ACM fragments were observed onsite on the final emu grid walk undertaken on 28 January 2016. As a precautionary approach, it is suggested that until the site is developed, the following management protocols should be implemented:

- Emu Bob Grid Walk (in accordance with WA Asbestos Guidelines (WA DoH, 2009) on a monthly basis until no fragments are recovered.

SERS noted that although ongoing management protocols have been suggested, it should reiterated that the remedial works have been successful in remediating the subject site to a condition suitable for its intended end use (residential properties) and that the risk to human health and surrounding environment is considered negligible.

9.3 Consultant Recommendations

The Validation Report (SERS, 2016a) recommended that a Construction Environmental Management Plan be prepared prior to any future onsite development. The CEMP should detail procedures for managing Unexpected Finds, as well as methodology for carrying out ACM emu pick grid walks.

The Auditor considers that the conclusions and recommendations presented in the Validation Report (SERS, 2016a) were in accordance with the decision rules identified for the project and the stated objectives.

The Auditor has provided a discussion regarding overall conclusions of the Site Audit in Section 10.0 of this SAR.

10.0 Auditor's Conclusions

The methods employed in the investigation, remediation and validation work as reported in the Validation Reports (SERS, 2016a and 2016b) by and large complied with the relevant NT EPA approved guidelines. Where deviations occurred, the Auditor is generally satisfied that these did not adversely impact on the outcome of the work conducted, and hence the proposed land use of the Site for Residential use.

The Auditor considers the documents generally followed an appropriate analytical methodology and, when taken as a whole, were sufficient for the assessment, remediation and validation or management of soils at the subject Site, noting that the site is defined by survey coordinates within the wider, former 2CRU Lee Point Facility.

Concentrations of the potential contaminants of concern in soil were below the adopted site assessment criteria or the laboratory limit of report and as such did not present a risk to the receptors on or off the Site.

The Auditor considers that based on the information presented in the portion of the former 2CRU NT RAAF Transmission Facility, situated at Lee Point, Northern Territory Validation Report, identified by survey coordinates, sufficient evidence is provided that no further investigation and/or remediation and/or management is required and that the subject Site is in a suitable condition for Residential land use, subject to the following conditions:

1. Any future development of the Site would require the development of a Construction Environmental Management Plan (CEMP) to manage potential Unexpected Finds including ACM. The CEM P should include the methodology for carrying out ACM emu pick grid walks.
2. There should be no use of groundwater from the site, other than for the purposes of environmental monitoring.

The Auditor advises that due to conditions at the time of the remediation and validation works, groundwater was not encountered at the Former 2CRU Site and as such all owners and/or occupiers of the site (both current and future) should be made aware that groundwater should not be used for potable uses without further investigation.

11.0 Key References

AECOM, 2016, *EPA 1997 Reporting Guidelines Compliance Checklist – Validation*, 2CRU NT RAAF Transmission Facility, Lee Point, Darwin, Northern Territory (Former), prepared for Defence Housing, issued 2 March 2016 (Ref: 60469416_AuditChecklist_20160314).

ANZECC/ARMCANZ (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, October 2000.

Crassweller, C., (2010), *Heritage and Archaeological Investigations over Block 4873, Lee Point Road, Darwin*, report prepared for GHD on behalf of the Department of Defence, issued November 2010.

HLA Envirosciences Pty Ltd (HLA). 2001. Environmental Site Assessment of Defence Properties, Lot 4873 and Portion of Lot 4868, Lee Point, Darwin, Northern Territory. Unpublished report for the Department of Defence.

National Environment Protection Council (ASC NEPM, 2013), *National Environment Protection (Assessment of Site Contamination) Measure 1999* (as amended 2013).

NT EPA (2013), *Guidelines for Consultants Reporting on Environmental Issues*, Northern Territory Government, Darwin.

NSW DEC (2006) *Guidelines for the NSW Site Auditor Scheme (2nd edition),* NSW Department of Environment and Conservation.

NSW DEC (2007) *Guidelines for the Assessment and Management of Groundwater Contamination*, NSW Department of the Environment and Conservation

NSW EPA (1995) *Contaminated Sites: Sampling Design Guidelines*, NSW Environment Protection Authority.

NSW EPA (2011) *Contaminated Sites: Guidelines for Consultants Reporting on Contaminated Sites*, NSW Environment Protection Authority

SERS (2016a), *Validation Report for Remedial Works, 2CRU Lee Point, Darwin*, prepared for Defence Housing Australia, issued 26 April 2016 (Ref. 150449/VR/CK/270116_rev2).

SERS (2016b), *Validation Report – Asbestos Pipe Removal, 2CRU Lee Point, Darwin*, prepared for Defence Housing Australia, issued May 2016 (Ref: 150449_CK_040516_rev1).

SERS (2015a), *Remediation and Validation Action Plan, 2CRU Lee Point, Darwin*, prepared for Defence Housing Authority, 15 May 2015 (Ref: DAH_SAP_CK_130515).

SERS (2015b), *Environmental Management Plan, 2CRU Lee Point, Darwin*, prepared for Defence Housing Australia, issued 15 May 2015 (Ref: DHA_EMP_CK_130515).

SERS (2015c), *Lee Point Remediation Project – Respirable Fibre (Asbestos) Control Monitoring Plan*, prepared for Defence Housing Australia, issued 5 September 2015 (Ref. 150449_RFMP_Lee_Point_MC_050915).

Appendix A

Figures

Figure 1 - Site Location Plan (SERS, 2016a)

Figure 1 – Site Layout (GHD, 2014)

Figure 2a – Required Remedial Works (SERS, 2016a) – presents the APEC

Figure 2 – Location of ACM Pipework/Ducting (SERS, 2016b)

Figure 1 – Areas of Work (SERS, 2016a) – presents the seven areas for the asbestos remediation

Appendix A Figures

N

0km 2km 4km

DO NOT SCALE

NOTES:

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PROJECT: CRU LEE POINT, DARWIN

TITLE: Site Location Plan

SCALE@SIZE:	ISSUE:
NTS	FINAL
DESIGN/DRAWN:	DATE:
CK	MAY 2015
PROJECT No:	DRAWING No:
696	Figure 1

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1,000 @ A3

0 5 10 15 20

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 52

LEGEND

- Structure/Building
- Communications Cable
- Electrical Cable
- Drainage Feature
- Fence
- Water Supply

Defence Housing Australia
Civil Engineering Services

Job Number	43-22254
Revision	A
Date	20 Nov 2014

Site Layout

Figure 1

G:\43\22254\GIS\Maps\43222254_01.mxd

© 2014. Whilst every care has been taken to prepare this map, GHD, Nearmap and Department of Defence make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Data source: Nearmap - Imagery (date extracted: 17/10/2014); Site Layout - Department of Defence: 2014; ACM Fragment Areas - GHD: 2014. Created by: CW

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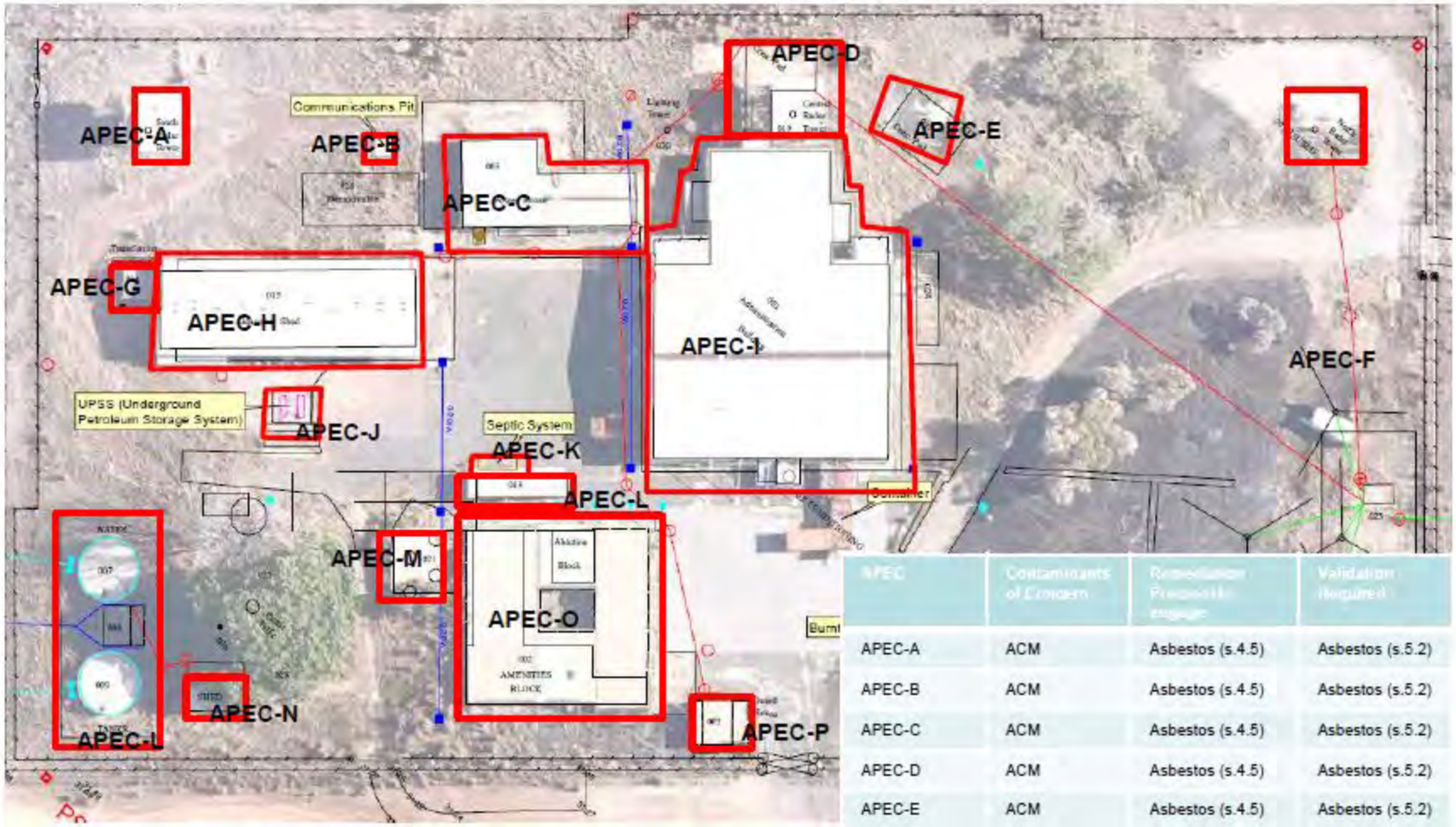

APEC	Contaminants of Concern	Remediation Proposed to engage	Validation Required
APEC-A	ACM	Asbestos (s.4.5)	Asbestos (s.5.2)
APEC-B	ACM	Asbestos (s.4.5)	Asbestos (s.5.2)
APEC-C	ACM	Asbestos (s.4.5)	Asbestos (s.5.2)
APEC-D	ACM	Asbestos (s.4.5)	Asbestos (s.5.2)
APEC-E	ACM	Asbestos (s.4.5)	Asbestos (s.5.2)
APEC-F	ACM	Asbestos (s.4.5)	Asbestos (s.5.2)
APEC-G	PCB, Pesticides	Soil (s.4.6)	Excavations (s.5.1)
APEC-H	ACM	Asbestos (s.4.5)	Asbestos (s.5.2)
APEC-I	ACM	Asbestos (s.4.5)	Asbestos (s.5.2)
APEC-J	TPH, Metals	Soil (s.4.6)	Excavations (s.5.1)
APEC-K	Metals, TPH	Soil (s.4.6)	Excavations (s.5.1)
APEC-L	ACM	Asbestos (s.4.5)	Asbestos (s.5.2)
APEC-M	ACM	Asbestos (s.4.5)	Asbestos (s.5.2)
APEC-N	ACM	Asbestos (s.4.5)	Asbestos (s.5.2)
APEC-O	ACM	Asbestos (s.4.5)	Asbestos (s.5.2)
APEC-P	ACM	Asbestos (s.4.5)	Asbestos (s.5.2)

N

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NOTES:

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PROJECT: CRU LEE POINT, DARWIN

TITLE: Required Remedial Works

SCALE@SIZE:	ISSUE:
NTS	FINAL
DESIGN/DRAWN: CK	DATE: MAY 2015
PROJECT No: 696	DRAWING No: Figure 2a

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FIGURE 2: Location of ACM pipework/Ducting

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E: admin@sers.net.au W: www.sers.net.au

Job No: 150449
Client:: DHA
Address: Lee Point, Darwin, NT

Scale: 1:1000
Original size: A3
Imagery from: 2015
Source: Nearmaps

Date drawn: Jan 2016
Revision: A
Drawn by: CK
Checked by: CK

N

Legend

- ACM Pipeline Removed
- Site Boundary

Note: Respirable fibre monitoring was also undertaken adjacent to asbestos pipe removal area during works. These locations moved on a daily basis.

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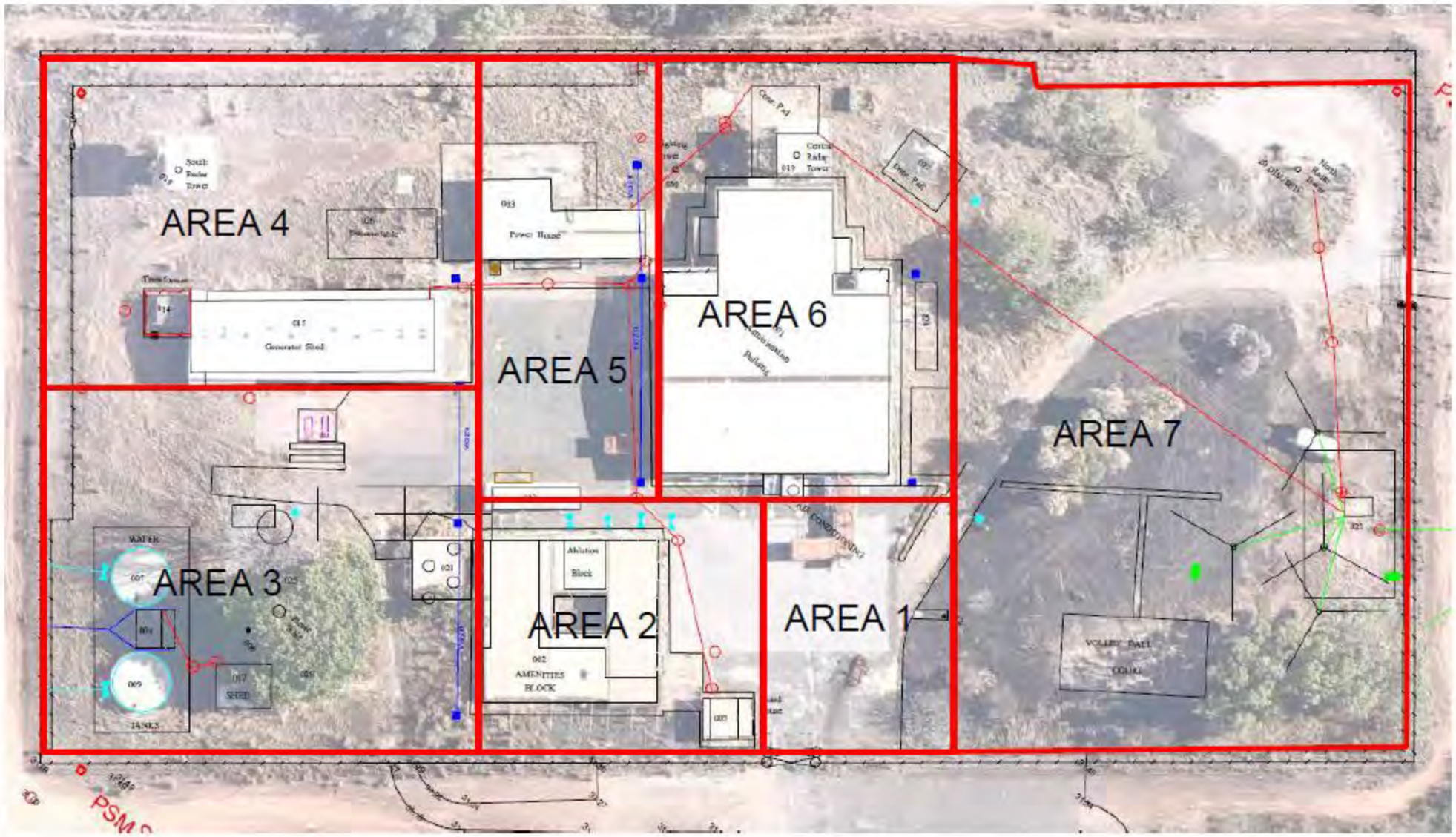
Appendix A

DO NOT SCALE

NOTES:

Work Area



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CLIENT: DHA Defence Housing Australia

PROJECT: CRU Lee Point, Darwin

TITLE: Areas of Work

SCALE@SIZE:	ISSUE:
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DESIGN/DRAWN:	DATE:
CK	Sept 15
PROJECT No:	DRAWING No:
	Fig 1

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Appendix B

Extract from Lee Point Area Plan

Appendix B Extract from Lee Point Area Plan

14.1.5 Planning Principles for the Lee Point Area Plan

Amendment No. 369 published in the NT News on 04.09.2015 introduces clause 14.1.5

Future development within the Lee Point area is to:

1. Preserve and integrate areas and items of environmental and heritage significance by:
   (a) limiting development below the escarpment to community uses, tourism activity and pedestrian / cycle tracks that protect the environmental values of the coastal reserve and adjoining vegetation types;
   (b) implementing appropriate environmental and engineering measures including but not limited to the application of principles of water sensitive urban design; and
   (c) adopting measures that acknowledge the role of Lot 4873 Town of Nightcliff in the Indonesia – Malaysia Confrontation including, where practicable, the retention of existing defence items or replacement with artistic/ cultural interpretive works that reflect the historical significance of the land.
2. Provide compact interconnected neighbourhoods as an extension to the existing northern suburbs that:
   (a) foster a distinct identity in the street layout and built form responding to the site's unique location, including its proximity to the Casuarina Coastal Reserve;
   (b) create a quality public realm and built form environment responsive to local climatic conditions through, but not limited to, the design of public areas and open space, the use of pedestrian shelters and landscaping, and the implementation of an energy-efficient built form;
   (c) facilitate access north from Lyons and Muirhead to future community, commercial and recreation facilities;
   (d) maintain a high level of public access to Lee Point and promote access to the Darwin Northern Suburbs and other major centres through a connected local road network, including access to public transport and key pedestrian / cycleways identified on the Area Plan;
   (e) include a lineal open space between development and the coastal reserve, and establish pedestrian connections to the Casuarina Coastal Reserve; and
   (f) promote walking and cycling as the preferred mode of travel for local trips.
3. Provide a mixed use village centre that integrates services to the local community while maximising opportunities for tourism by:
   (a) creating urban spaces that take advantage of the coastal location of the site;
   (b) providing a destination and focal point for visitors that is easily accessible to pedestrians, cyclists and vehicles travelling along Lee Point Road;
   (c) providing a mix of tourist accommodation, commercial development including tourism and recreation, and residential development along the main street;

(d) maximising opportunities for active street frontage in the main street;

(e) maximising accessibility to the centre by catering for all modes of transport;

(f) reducing traffic speed to create a pedestrian-friendly shared public environment with clearly identified key pedestrian access locations; and

(g) integrating development within the village centre with surrounding residential areas.

4. Provide a range of housing options and lot sizes to cater for diverse household types by:

(a) including the development of small lot housing to complement more traditional housing types;

(b) creating a mix of lot sizes for single and/ or multiple dwellings;

(c) associating medium and high density housing including townhouses and apartments with neighbourhood centres, public open space and/ or areas of high amenity; and

(d) providing larger rural residential lots as a further choice and to serve as buffers between urban residential development and potential biting insect areas.

5. Provide an appropriate built form that maximises site opportunities by:

(a) incorporating a range of building heights to maximise opportunities for coastal views while retaining appropriate built form character and residential scale;

(b) providing accommodation and residential development that is climatically appropriate, including appropriate solar orientation and natural ventilation; and

(c) respecting adjoining residential areas through appropriate transitions from commercial development and between residential areas of different densities, and by interfacing with Lyons and Muirhead at the same residential density.

6. Provide adequate land for education and community facilities that:

(a) allows for the shared use of community and active recreation facilities;

(b) is located close to public transport and supports a high level of neighbourhood accessibility through the encouragement of cycling and walking; and

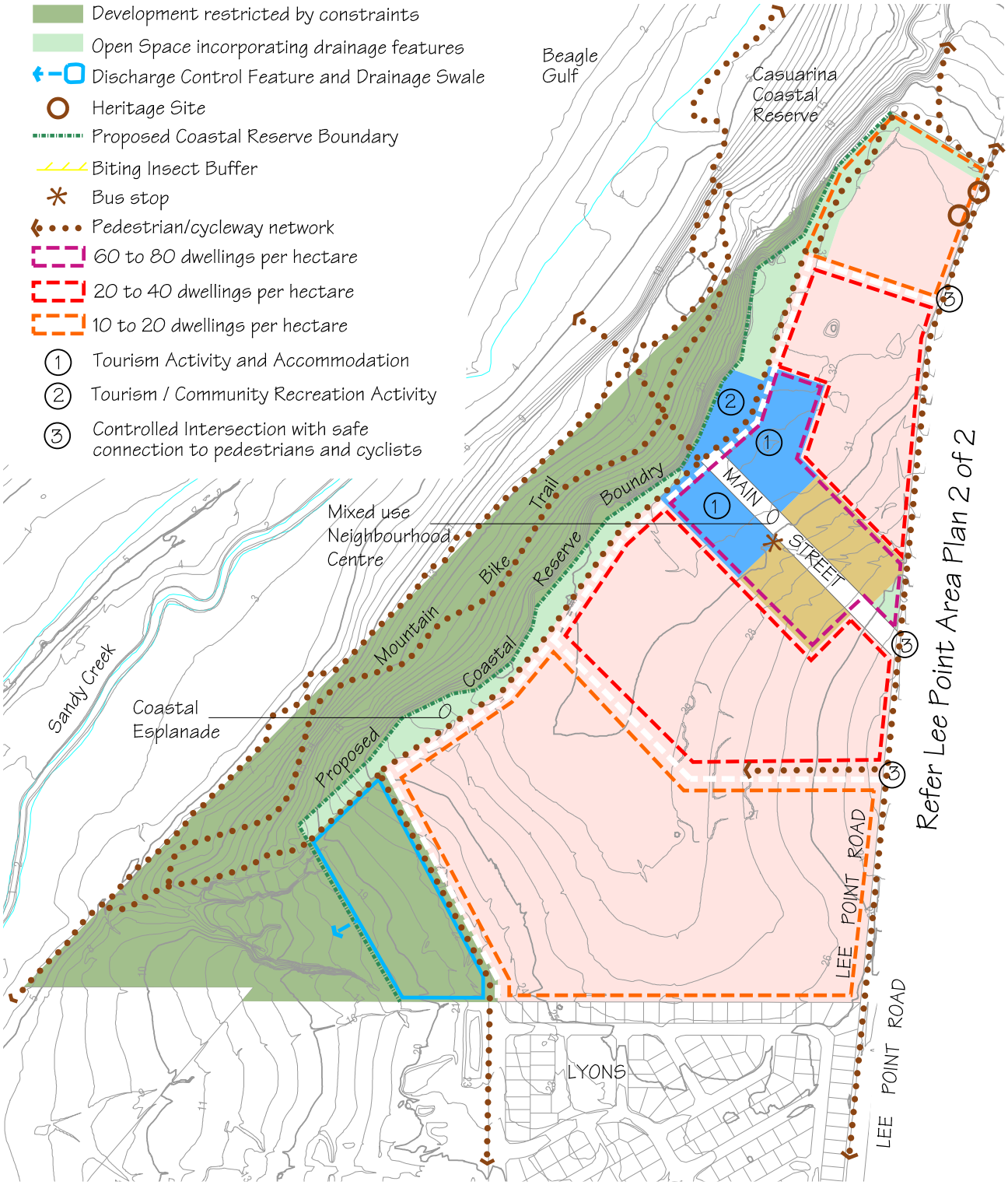
(c) facilitates safe and efficient access via the local road and pedestrian network to community services and facilities in the broader area, including the Royal Darwin Hospital.

Lee Point Area Plan 1 of 2

This plan must be read in conjunction with the associated planning principles

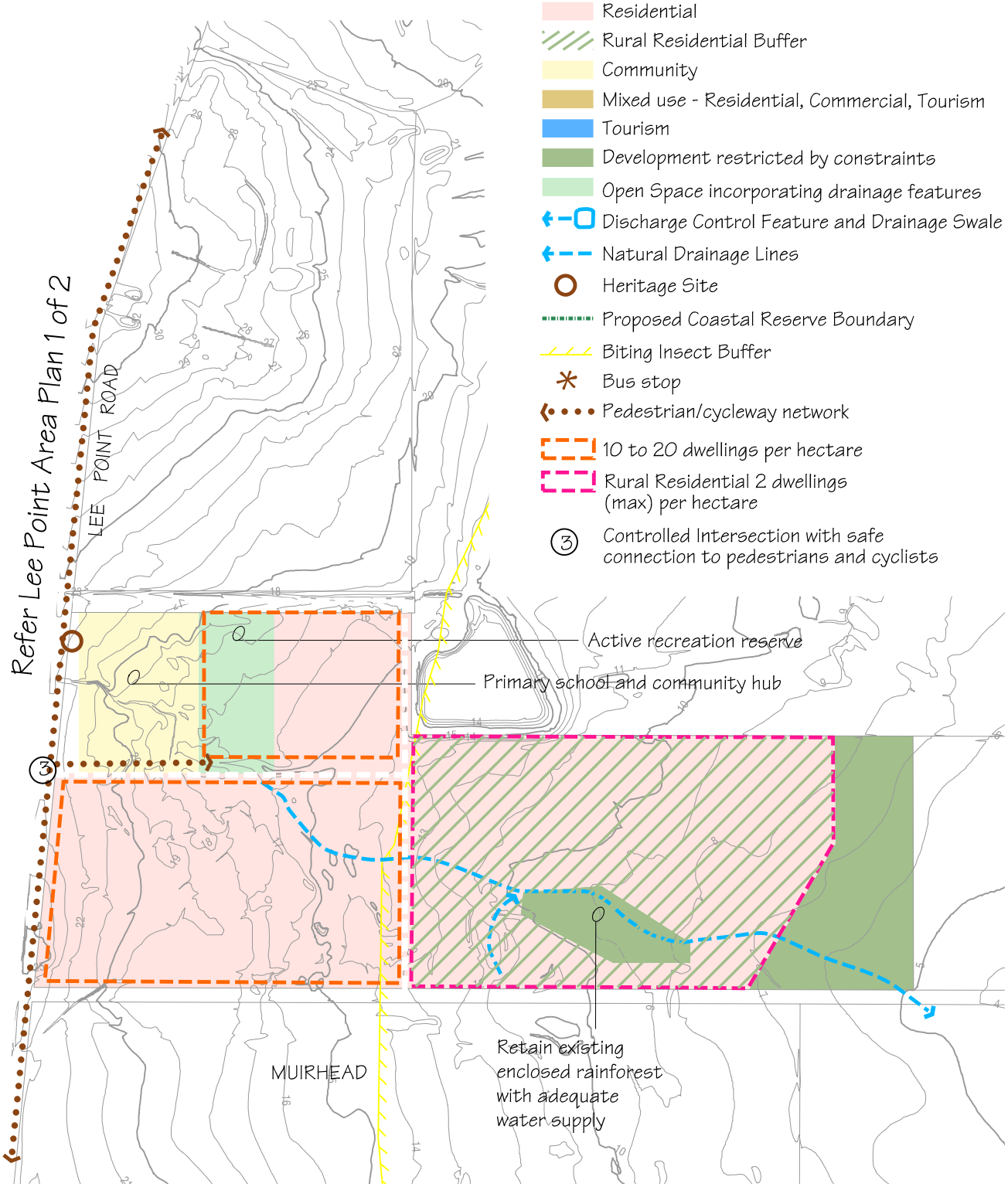
Legend

- Residential
- Rural Residential Buffer
- Community
- Mixed use - Residential, Commercial, Tourism
- Tourism
- Development restricted by constraints
- Open Space incorporating drainage features
- Discharge Control Feature and Drainage Swale
- Heritage Site
- Proposed Coastal Reserve Boundary
- Biting Insect Buffer
- Bus stop
- Pedestrian/cycleway network
- 60 to 80 dwellings per hectare
- 20 to 40 dwellings per hectare
- 10 to 20 dwellings per hectare
- (1) Tourism Activity and Accommodation
- (2) Tourism / Community Recreation Activity
- (3) Controlled Intersection with safe connection to pedestrians and cyclists



Lee Point Area Plan 2 of 2

This plan must be read in conjunction with the associated planning principles



Appendix C

Relevant Correspondence and Documents

SERS response to AECOM's EPA 1997 Reporting Guidelines Compliance Checklist – Validation

Appendix C Relevant Correspondence and Documents

SERS
Site Environmental and Remediation Services

Perth
ABN: 24 608 868 444
281 Newcastle St
Northbridge WA 6003
08 9220 2000

Brisbane
ABN: 24 608 868 444
95 Sandgate Road
Albion QLD 4010
07 3394 8234

Darwin
ABN: 24 608 868 444
Level 1, 48-50 Smith St
Darwin NT 0800
08 943 0636

26-Apr-16

Your Ref: 60469416_AuditChecklist_20160314
Our Ref: 150449_VR_CK_270116_rev2

Ross McFarland,
Chief Environmental Scientist – ANZ
AECOM
Level 2, St George Centre,
60 Marcus Clarke Street,
Canberra, ACT 2601

Validation Report for Remedial Works 2CRU Lee Point, Darwin – Revision 2

Ross,

Please find attached an electronic of the DSI report for 2CRU Lee Point, Darwin, NT.

Please find on the following pages SERS response to the Auditors comments relating to Revision 1 of the validation report.

We hope the amendments which have been undertaken upon the validation report satisfy the auditor's comments.

However, if you have any questions or queries please do not hesitate to contact us.

Kind Regards,

Chris Kennedy B.Sc. (Hons), CenvP, MEIANZ
Senior Environmental Scientist

DDI: :+61(0) 89220 2000

Section	Ref / Sec in Report	Auditor Comments	Overall Conclusion and Auditor requests	Consultants Reply / Section Amended
Executive Summary	**Pg. iii-iv**		Executive summary is limited to asbestos-related work. Given the Validation report is provided for overall landuse suitability, discussion on other potential contaminants of concern and the site's overall suitability is warranted. Simple summary of sampling and analysis are warranted. This conclusion requires justification in relation to potential contaminants other than asbestos.	
≠ Background	✓			
≠ Objectives of the Investigation	✓	Overarching Objective is to support management of risks associated with contam soil, groundwater and drainage residue associated with former site use. Specific Objectives: - the id and treatment of data gaps - the derivation of remedial object		No Action Undertaken
≠ Scope of work	✓	- Removal of haz building materials prior to demolition of structures - clearance certificates from qualified hygienist - Demolition of structures - Excavate Areas of Potential Environmental Concern (APEC) not previously investigated - Remove all sources of contamination associated with APEC - Validate by visual inspection and chemical analysis soils in walls and base of excavated APEC - Classify excavated soils to allow appropriate reuse onsite or waste disposal - mitigate environmental risks associated with Unexpected finds and oversee remedial works associated with the same - identify further sampling or management requirements - Validation Report - report findings in accordance with Statutory requirements.		Executive Summary has been updated to include all remedial and validation works undertaken.
≠ (Where appropriate) a summary of sampling results in tabulated format containing minimum, maximum, arithmetic average and 95% upper-confidence limit on arithmetic average for each		Not provided in ES of Validation Report		Executive Summary has been updated.
≠ Summary of conclusions and recommendations	✓	Conclusions in relation to current site condition: - During remedial work, no visual or olfactory evidence of contamination observed. - Chemical analysis of soil post remedial works did not record any exceedances of the selected guideline values. Conclude reasonable that the risk to the wider environment is negligible. - No ACM or asbestos fibres were recorded within near surface soils post remediation above Remediation Acceptance Criteria.		No Action Undertaken.
≠ Clear statement on land use suitability for the nominated landuse(s)	✓	Validation report concludes: No significant risk to human health or wider environment due to historical industrial legacy of the site and that validation works have been successful in demonstrating this.		No Action Undertaken.
Scope of Work and Objectives				
≠ A clear statement of the scope of work	✓ Section 1.4	Pg. 11 dot points identifying Scope of Works - Removal of hazardous building materials prior to demolition of structures - clearance certificates from hygienist certifying all hazardous materials been removed - demolition of structures		No Action Undertaken.

Section	Ref / Sec in Report	Auditor Comments	Overall Conclusion and Auditor requests	Consultants Reply / Section Amended
		- Excavate APEC, including tanks, septic systems, electrical transformers and contam soils. - Visually inspect excavations of potentially contam soils from previously identified APEC's (as per GHD 2014 report and SERS RAP 2015) - lab testing to validate APEC's and additional unexpected contamination finds - undertake classification testing of excavated soils to determine soils suitability - appropriate disposal of contaminated soils - production of validation report.		No Action Undertaken.
≠ A clear statement of the objectives.	✓ Section 1.3	Page 2 provides provision of general objectives of the remedial works. - Remove all haz building materials - determine contaminants (notably asbestos) were present in near surface soils within APEC. - Removal of all sources of contamination - validate, by visual and chemical analysis soils within base and walls of APEC areas - Classify excavated soils for appropriate reuse onsite or waste disposal. - mitigate environmental risks associated with unexpected finds and oversee remedial works. - identify further sampling and/or management - report findings		No Action Undertaken.
≠ A clear statement in relation to land use suitability, if relevant.	✓ Section 1.2	Pg. 2 Proposed development – DHA intends to divest the site to developers for residential purposes.		No Action Undertaken.
Site Identification ✓		**Site Details**		
≠ Street number, street name and suburb	Section 1.1 Table 1.1	Block 4373, Lee Point Road, Darwin, NT		No Action Undertaken.
≠ Lot number and Deposited Plan number		Lot 4873, Town of Night Cliff		No Action Undertaken.
≠ Geographic coordinates related to a nearby cadastral corner of a State Survey Control Mark		No geographic coordinates provided		
≠ Locality map		No specific site locality map in relation to surround land. Presents Figures of site boundary in Appendix A.		Included in Appendix A.
≠ Current site plan with scale bar, showing north, local water drainage and other local environmentally significant features	Appendix A	Figure 1 – Figure 6 present site. Includes scale bar, north reference. No figure presents local water drainage or other local environmentally significant features. Description provided of the surrounding land use.		No Action Undertaken.

Site History ✓ (S)	**S**			
≠ Summary of previous investigations	Section 4.1	Summary provided of four previous investigations: - GHD, 2010 - ESA - SMEC, 2014 - Contamination Land Review - G-Tek, 2014 - UXO - GHD, 2014 - Demolition Tender Specs		No Action Undertaken.
≠ Zoning-previous, present and proposed	Section 2 Table 2.1	Table identifies: Previous & Current Zoning: Commonwealth Land Proposed Zoning: Residential		No Action Undertaken.
≠ Land use-previous, present and proposed	Section 2 Table 2.1	Not in use. Formerly Lee Point Radar Transmitting Station		No Action Undertaken.
≠ Summary of Council rezoning and relevant	Section 3.4	LGA is Darwin City Council		No Action Undertaken.

Section	Ref / Sec in Report	Auditor Comments	Overall Conclusion and Auditor requests	Consultants Reply / Section Amended
development and building approvals records		Local Environment Plan- *NT Planning Scheme – Darwin and Surrounds – August 2010* indicates zone as Commonwealth Lands and that there are currently no planning scheme controls for this zone type. Certificate of Title Provided in Appendix B Section 1.1 identifies that as facility has been managed under Commonwealth Jurisdiction, any future development plans will need to be Territory legislation & regulations.		No Action Undertaken.
≠ Chronological list of site uses, indicating information gaps and unoccupied periods	Section 1.1	Paragraph stating: - RAAF Transmission Facility, acquired by DoD in 1950s - By 1960s buildings surrounded by earth and sand embankments - Until recently used as a Radar Facility by DoD.		No Action Undertaken.
≠ Review of aerial photographs	Section 3.3	Aerials from 1976 to 2010. Little change evident across the site since at the main compound over the years. Aerial Imagery provided in Appendix B.		No Action Undertaken.
≠ Site photographs (with date and location indicated on site maps)	Appendix E	Photographic Log showing Site Progress. Provides description with photos of Date, location, works, comments. No coordinates provided.	Provide co-ordinates	Coordinates provided in Appendix E
≠ Inventory of chemicals and wastes associated with site use and their on-site storage location	Section 4.2.1	No specific inventory. Although identifies APECs and contamination concerns. Contaminants include: - Asbestos associated with 14 structures - PCB and pesticides at Electrical Transformer - Hydrocarbons and Metals associated with UPSS and septic	Refer to Hazardous Materials Audit and associated inventory, if available	Section 4.4.1 Updated
≠ Possible contaminant sources and potential off-site effects including potential issues associated with migration of contaminants	Section 4.2	Provides pre-remediation CSM. 17 Areas of Potential Concern. Section 4.2.2 Identified potential receptors including site users (and future residents), demolition contractors, construction workers, adjacent residents, flora and fauna, underlying aquifer and nearby surface water receptors Transport mechanisms – inhalation, direct contact and digestion.		Section 4.2 Updated

≠ Site layout plans showing present and past industrial processes	Figure 2 Appendix B	Figure 2 presents Areas of Potential Env. Concern, description of APECs in Section 4.2.1	Clarify sewer system, including whether sorption trenches were used and their location, if relevant.	No Action Undertaken.
≠ Sewer and service plans	Section 2.1	Not provided, although Section 2.1 identified an above ground Sewerage Treatment Plant (STP) on site (i.e. Septic Tank). Not clear where or if there were absorption trenches.		Section 2.1 Updated
≠ Description of manufacturing processes		N/A		No Action Undertaken.
≠ Details and locations of current and former underground and aboveground storage tanks	Section 3	UPSS comprising two USTs within single pit. No coordinates, but highlighted APEC J on Figures.	Provide coordinates, if possible	Coordinates Provided in Appendix A
≠ Product spill and loss history		No specific detail provided.		No Action Undertaken.
≠ Discharges to land, water and air		None identified		No Action Undertaken.
≠ Disposal locations		None identified		No Action Undertaken.
≠ Relevant complaint history		None identified		No Action Undertaken.
≠ Local site knowledge of residents and staff-both present and former		None identified		No Action Undertaken.
≠ Summary of local literature about the site, including newspaper articles		None identified		No Action Undertaken.

Section	Ref / Sec in Report	Auditor Comments	Overall Conclusion and Auditor requests	Consultants Reply / Section Amended
≠ Details of building and related permits, licences, approvals and trade waste agreements		None identified		No Action Undertaken.
≠ Historical use of adjacent land		Outside RAP boundary (i.e. Radar Compound) is undeveloped bushland. - North is Casuarina Coastal Reserve and coastline - South Bushland separating Lyons Residential Estate - East Bushland and then Lee Point Caravan Park and further south of caravan is cleared vacant bushland - West mangroves and sand dunes		No Action Undertaken.
≠ Local usage of ground/surface waters, and locations of bores/pumps		Not identified. Identified 3 registered monitoring bores (RN008655, RN009097 and RN008656) Mentions the Lee Point Caravan Park bore (RN022618) which is 250 m east of site. No mention if in use/purpose.	Clarify status of bores.	Section 2.3 Updated.
≠ Integrity assessment (assessment of the accuracy of information)		Not provided	Provide statement of adequacy of site history, including any uncertainties that have been identified, if relevant in landuse suitability determination.	Section 3.7 Updated.

Site Condition and Surrounding Environment ✓ (S)	S			
≠ Topography	Section 2.1	Site relatively flat. Elevation range 32-37 m AHD. Overland water flows towards open drainage lines. No figure.		No Action Undertaken.
≠ Conditions at site boundary such as type and condition of fencing, soil stability and erosion	Section 2.1	Site History identifies: - Site Comprises of Fenced Compound with bushland surrounding which seems to be used by recreational uses (motorbikes/small 4WD) - Soil stability and erosion – not discussed		No Action Undertaken.
≠ Visible signs of contamination such as discolouration or staining of soil, bare soil patches-both on-site, and off-site adjacent to Site boundary	Section 4.1 – Previous Investigations	- No imported fill identified - No hydrocarbon odour or soil staining observed - No UXO risk - Hazardous Building Materials (asbestos) main risk.		No Action Undertaken.
≠ List potential contaminants of concern at or near the site	Section 4.2.1	- Asbestos associated with 14 structures - PCB and pesticides at Electrical Transformer - Hydrocarbons and Metals associated with UPSS and septic		No Action Undertaken.
≠ Visible signs of plant stress	Section 10.1 Section 10.3	APEC G Electrical Transformer – no plant stress identified at the site. APEC K Septic System – no plant stress identified at site		No Action Undertaken.
≠ Presence of drums, wastes and fill materials	Section 1.1.1 (error) Should be Section 2.3.3	G-Tek summary - Remnant WWII including star pickets, drums and other similar debris. Surrounding bushland has widespread public dumping of vehicles and other general waste.		No Action Undertaken.
≠ Odours	Section 2.3.1	GHD report – Imported Fill materials not identified.		No Action Undertaken.
≠ Condition of buildings and roads	Section 1.1 Section 4.1.2 Section 4.1.4	Built in ~1960s All building contained asbestos and lead test indicated positive result in main admin building. GHD Haz Material Survey – primarily Asbestos		No Action Undertaken.

Section	Ref / Sec in Report	Auditor Comments	Overall Conclusion and Auditor requests	Consultants Reply / Section Amended
≠ Quality of surface water	Section 2.4	Overland flow. Surface water naturally discharges NW from Sandy Creek to coast and NE to Buffalo Creek. Various drainage lines enter drainage network and would drain west towards mangroves. No mention that only flows in wet season. Not permanent water bodies on site	Provide simple statement on surface water and the potential impact(s) from the Site.	Section 2.4 updated.
≠ Flood potential	Section 2.1	Not identified specifically. States site is relatively flat between 32-37 m above sea level.		Section 2.4 updated.
≠ Details of relevant local sensitive environment-e.g Rivers, lakes, creeks, wetlands, local habitat areas, endangered flora and fauna.		Not specifically mentioned.	Nearby sensitive receptors (such as caravan park, and any protected areas/parks, if present) should be summarised.	Section 4.2 updated.
≠ Identification of sensitive receptors, e.g. kindergarten, parks, etc.		Adjacent Residents and surface water receptors.		Section 4.2 updated.
Geology and Hydrogeology ✓(S)	**S**			
≠ Soil stratigraphy using recognised classification methods, e.g. Australian Standard 1726, Unified Soil classification Table	Section 14 Appendix I – Field Records	References AS1726 Bore description presented Appendix I in table including: Date Sampled, sample number, location description and soil log (description of soils) No bore logs with Symbology provided.	Better presented in bore logs. Where is the PID results?	Included in Appendix I
≠ Location and extent of imported and locally derived fill	Section 4.1	Imported fill materials not identified.	Confirm that imported fill is not a significant issue for the proposed landuse. Was fill validated?	Section 4.2.2 updated.
≠ Site borehole logs or test pit logs showing stratigraphy	Appendix I	Only basic table provided in Appendix I Descriptions of geology provided in each APEC (Section 10)	Refer to well construction details	Included in Appendix I
≠ Detailed description of the location, design and construction of on-site wells.		Not detailed		Included in Appendix I
≠ Description and location of springs and wells in the vicinity		Not applicable		No Action Undertaken.
≠ Depth to groundwater table	Section 2.3	50 mbgl at Lee Point Caravan Park located 250 m from Site. 3 bores on site that did not record Standing Water Level	Can bore logs include standing water levels, if present? If not present should be noted.	Section 2.4 updated.
≠ Direction and rate of groundwater flow		Not provided	Indicate potential groundwater flow, if known, from historical bores?	Section 2.4 updated.
≠ Direction of surface water run-off	Section 2.4	Surface water naturally discharges NW from Sandy Creek to coast and NE to Buffalo Creek. Various drainage lines enter drainage network and would drain west towards mangroves.	Figure should provide surface water drainage.	No Drainage Plan made available to SERS prior to remedial works being undertaken.
≠ Background water quality		Not provided – except bore log from the Lee Point Caravan Park Bore.	Provide other background water quality, if available for the other identified bores.	No information available section 2.4 updated.
≠ Preferential water courses	Section 2.4			Section 2.4 updated.
≠ Summary of local meteorology		Not provided		Section 2.4 updated.

Acid Sulphate Soils ✓(S)				
≠ Identification of extent and potential for ASS	Section 2.2	GHD report state that although located close to coastline, given elevation greater than 9 m AHD, ASS not expected to be present. Greater Darwin Region ASS Risk Map (2009) indicates part of site not assessed and therefore unknown whether land management activities may be affected by ASS materials. Eastern boundary is non-tidal zones, sandplains,		No Action Undertaken.

Section	Ref / Sec in Report	Auditor Comments	Overall Conclusion and Auditor requests	Consultants Reply / Section Amended
		dunes and beach ridges. If present would be 1 mbgl.	Confirm that ASS does not require any special management.	Section 2.2.
≠ Assessment of management and remedial strategies to work with ASS		Not mentioned		Section 2.2.
Sampling and Analysis Plan and Sampling Methodology ✓				
≠ Sampling, analysis and data quality objectives (DQOS)	Section 6 Section 7	Presents the Remedial Works Undertaken by SERS and subcontractor. Validation Sampling and Analysis Plan Methodology		No Action Undertaken.
≠ Rationale for the selection of:		Validation Sampling and Analysis Plan was based on the Remediation Action Plan. RAP consisted of: - Opportunistic Sampling to Address Data Gaps and - Utilised previous investigations. - Selected strategy was to remove excavated soils from site and dispose off site. - Validation of excavation to below adopted HILA and HSL-A cleanup criteria. Asbestos Remediation carried out in two stages: 1. Removal of all observed ACM prior to demolition of above ground structures 2. Removal of residual near surface ACM post demolition. A licenced Asbestos removalist cleared APEC with Asbestos risk.		No Action Undertaken.

Section	Ref / Sec in Report	Auditor Comments	Overall Conclusion and Auditor requests	Consultants Reply / Section Amended
0 sampling pattern	Section 7.2 Sampling Methodology	Opportunistic and in accordance with AS4482.1-2005 and AS4482.2-1999 Timeline of Site Works presented in Section 6.1 APEC G Electrical Transformer – 50m^3 (4.5 x 6.5 x 1.7 m) – Figure 3A – 3 rounds of remedial works due to elevated TPH C16-C34. APEC J – UPSS – Two USTs in one pit removed from site. APEC K – Septic System – soils not risk based on sample results APEC C, APEC H, APEC I, APEC O, APEC P and APEC Q – removal of ACM Unexpected Finds: - Asbestos Pipe – located across entire site and removed as part of demolition. Air monitoring completed. - Site wide Near Surface ACM – Emu bob carried out by SERS. Validation - Site wide Near Surface Soils – soil samples taken between ground level and 300 mm bgl within APEC A to APEC F, APEC H, APEC I and APEC L to APEC Q for asbestos contamination. - Groundwater Quality – Newly installed well was Dry.	Noted that City of Darwin granted approval to dispose soil at SBWF. Were the tanks removed in accordance with Australian Standard AS-4976 – Removal and disposal of underground petroleum storage tank (2008)? If so provide commentary. Any sample taken from nearby bores? Need to provide some words regarding groundwater risks – Does the Caravan Park utilise the groundwater bore? Are the borelogs provided in the report for the groundwater wells?	Section 7.2.1 updated. Section 2.3 updated.
0 sampling density including an estimated size of the residual hot spots that may remain undetected		Dependent on type of APEC. Excavation focused on excavation base and walls.		No Action Undertaken.
0 sampling locations including locations shown on a site map		Shown in Figures		No Action Undertaken.
0 sampling depth		Ranged from 0.6 m to 3.4 m and stockpile samples.		No Action Undertaken.
0 samples for analysis and samples not analysed		Samples based on olfactory observations and results of PID.	PID results not included in the Validation Report/not seen.	Appendix I updated.
0 sampling of relevant environmental media (soil, air, water)	7.1.1	Validation from excavations and near surface soils		No Action Undertaken.
0 analytical methods	Appendix J	NATA Laboratory – Envirolab/MPL Laboratories		No Action Undertaken.

Section	Ref / Sec in Report	Auditor Comments	Overall Conclusion and Auditor requests	Consultants Reply / Section Amended
0 analytes for samples		Excavations and near surface: - Asbestos - PAH's - BTEX - PCBs - OC/OP - Naphthalene - Metals (As, Be, Bo, Cd, Cr, Co, Cu, Pb, Mn, Hg, Ni, Se, Zn) Soil Classification: - Metals (As, Be, Bo, Cd, Cr, Co, Cu, Pb, Mn, Hg, Ni, Se, Zn) - TPH - BTEX - Naphthalene - OC/OP - Phenols - Cyanide		No Action Undertaken.
≠ Detailed description of the sampling methods including:				
0 sample containers and type of seal used		Lab supplied sample jars		No Action Undertaken.
0 sampling devices and equipment e.g. auger type		Primarily sample directly into lab supplied jars using nitrile gloves. If trowel used or excavator bucket was decontam with deionised water and Decon 90		No Action Undertaken.
0 equipment decontamination procedures	Section 8.1	Decontamination procedures limited as sampled using lab supplied jar using new nitrile gloves each sample location.		No Action Undertaken.
0 sample handling and transport procedures		Soil jars labelled with Sample Id (location and depth), date and name of sampler		No Action Undertaken.
0 sample preservation methods and reference to recognised protocols, e.g. APHA or US EPA SW 846	Section 8.3	Table 8.3 describes Validation Data Quality. - samples stored in jars and ice was used to keep samples chilled during transport. Samples transported air freight within 48 hrs of sampling. Samples for asbestos not chilled. SERS evaluates analytical results and quality control in accordance with USEPA 1994 National Functional Guidelines for organic data review and USEPA national Functional Guidelines for inorganic data review.		No Action Undertaken.
≠ Detailed description of field screening protocols and validation of field measurements		Field screening with PID. Received table post activities on site in an email. Not in Validation report.		Presented within Appendix I

Field Quality Assurance and Quality Control (QA/QC) ✓				
≠ Details of sampling team	Section 8	CV's provided in Appendix 0 Team consisted of: Paul Wallace, Environmental Scientist – 4 yrs experience Chris Kennedy, Senior Environmental Scientist – 10 yrs experience Matt Campbell, Director/NATA signatory		No Action Undertaken.
≠ Decontamination procedures carried out between sampling events	Section 8.1	- All sampling equipment subjected to decontamination procedures - Sampling trowel subjected to the following decontam		No Action Undertaken.

Section	Ref / Sec in Report	Auditor Comments	Overall Conclusion and Auditor requests	Consultants Reply / Section Amended
		procedures: 1. removal of adhered soil using scrapers, brushes and sponges 2. washing with oxygen based phosphate free detergent soln 3. rising with de-ionised water. Majority of soils sampled were of loose nature and there for retrieved by scooping up with hand with nitrile gloves. Gloves replaced upon the collection of a new sample.		No Action Undertaken.
≠ Logs for each sample collected—including time, location, initials of sampler, duplicate locations, duplicate type, chemical analyses to be performed, site observations and weather conditions.	Appendix I	Logs provided in table format and include Date Sampled, Sample Number, Location and Soil Description. PID was taken and have seen table, or though not included in Validation Report. No comment on weather condition.		No Action Undertaken.
≠ Chain of custody fully identifying—for each sample—the sampler, nature of the sample, collection date, analyses to be performed, sample preservation method, departure time from the site and dispatch courier(s).	Appendix J	Envirolab – Paul Wallace, Soil, 23/11/2015, analytes listed, not listed, relinquished time, transported by courier ALS – Secondary lab??	Confirm ALS was secondary lab	Section 8.5 updated.
≠ Sample splitting techniques		Not mentioned?	Advise if any sample splitting was performed.	Section 8.3 updated.
≠ Statement of duplicate frequency		Blind Duplicate Frequency - 1 per 9.4 during validation sampling Triplicate samples (interlab) were 1 per 23.5 Interlab QA sampling rate 1 per 20 was not achieved due to sample breakage.		No Action Undertaken.
≠ Field blank results		4 field blanks results in 1 per 11.75		No Action Undertaken.
≠ Background sample results		Air Quality – background levels		No Action Undertaken.
≠ Rinsate sample results		Not mentioned.	Advise if rinsate samples were collected and reported.	
≠ Laboratory-prepared trip spike results for volatile analytes		Within expectable range (recover of 40%)		Section 8.2 updated.
≠ Trip blank results		4 trip blanks results in 1 per 11.75		No Action Undertaken.
≠ Field instrument calibrations (when used).		PID used – no mention of Calibration/Certificate of Cal provided.	Provide information on PID calibration.	Appendix I
≠ Acceptance limit for each calibration standard		N/A		No Action Undertaken.

Laboratory QA/QC ✓			Review Chain of custody forms to ensure that final forms are provided (with all relevant signatures as appropriate). If some CoCs were not completed, provide comments on the potential impacts of this QC non-conformance to data reliability.	
≠ A copy of signed chain-of-custody forms acknowledging receipt date and time, and identity of samples included in shipments		Copies provided. Signed by lab. Some with signatures and other without		CoCs included in Appendix J
≠ Record of holding times and a comparison with method specifications		Within 48 hrs of sampling were reported to be received by Lab.		No Action Undertaken.
≠ Analytical methods used		Refer to Lab Certificate of Analysis		No Action Undertaken.
≠ Laboratory accreditation for analytical methods used		Yes based on Certificate of Analysis for labs used	Advise if any non-standard methods were used.	Section 8.5 updated.
≠ Discussion of non-standard methods used		Not provided		Section 8.5 updated.
≠ Laboratory performance in inter-laboratory trials for the analytical methods used, where available				Section 8.5 updated.
≠ Description of surrogates and spikes used		Dup RPD and matrix spike recover within Acceptance Criteria		Section 8.5 updated.
≠ Per cent recoveries of spikes and surrogates		Dup		Section 8.5 updated.
≠ Instrument detection limits		Not provided	Provide simple summary statement in relation to Lab's internal QC protocols.	Section 8.5 updated.
≠ Method Detection Limits		Not provided		Section 8.5 updated.
≠ Matrix or practical quantification limits		Not provided		Section 8.5 updated.

Section	Ref / Sec in Report	Auditor Comments	Overall Conclusion and Auditor requests	Consultants Reply / Section Amended
≠ Standard solution results		Not provided		Section 8.5 updated.
≠ Reference sample results		Not provided		Section 8.5 updated.
≠ Reference check sample results		Not provided		Table 8.4
≠ Daily check sample results		Not provided		Table 8.4
≠ Laboratory duplicate results		Not provided		Table 8.4
≠ Laboratory blank results		Not provided		Table 8.4
≠ Laboratory standard charts.		Not provided		Table 8.4
QA/QC Data Evaluation ✓			Provide summary of Data Quality Evaluation, consistent with 2013 NEPM	
≠ Evaluation of all QA/QC information listed above against the stated DQOs, including a discussion of:		Not provided		Section 8.6 updated.
0 documentation completeness		Not provided		Section 8.6 updated.
0 data completeness		Not provided		Section 8.6 updated.
0 data comparability (see next point)		Not provided		Section 8.6 updated.
0 data representativeness		Not provided		Section 8.6 updated.
0 precision and accuracy for both sampling and analysis for each analyte in each environmental matrix informing data users of the reliability, unreliability, or qualitative value of the data		Not provided		Section 8.6 updated.
≠ Data comparability checks, which should include e.g. bias assessment – which may arise from various sources, including:		Not provided		Section 8.6 updated.
0 collection and analysis of samples by different personnel		Not provided		Section 8.6 updated.
0 use of different methodologies		Not provided		Section 8.6 updated.
0 collection and analysis by the same personnel using the same methods but at different times		Not provided		Section 8.6 updated.
0 spatial and temporal changes (because of the environmental dynamics)		Not provided		Section 8.6 updated.
≠ Relative per cent differences for intra-and inter-laboratory duplicates.		Not provided		Section 8.6 updated.

Basis for Assessment Criteria ✓	**Section 9**		Provide summary on assumptions and limitations	
≠ Table listing all selected assessment criteria and references	Table 9.1	**Soils** NEPM 2013 EIL NEPM 2013 Table 1A HILs Res A soil NEMP 2013 Table 1A(3) Res A/B Soil HSL for Vapour Intrusion Clay NEMP 2013 Table 1B ESLs for Urban Res Coarse Soil **Asbestos** WA DoH Guidelines for the Assessment, Remediation and Management of Asbestos Contaminated Sites in WA, May 2009		Section 9.1 updated.
≠ Rationale for and appropriateness of the selection of criteria		Due to future use as residential properties with garden/accessible soils.		No Action Undertaken.
≠ Assumptions and limitations of criteria.		Not provided		Section 9.1 updated.
≠ Compliance with Guidelines for Consultants Reporting on Contaminated Sites (1997)		Not provided		Section 9.1 updated.
Results ✓	Section 10		All sites reported below selected RACs. Tier 1 risk assessment table for the fuel tank (APEC-J) and transformer excavation (APEC-G).	
≠ Summary of previous results, if appropriate	Section 4	Presents discussion of previous investigations. Minor metal concentrations and potential TPH impact in vicinity of UST. Hazardous building Materials		No Action Undertaken.
≠ Summary of all results, in a table that:	Appendix K	Presents the assessment tables from ESDAT		No Action Undertaken.

Section	Ref / Sec in Report	Auditor Comments	Overall Conclusion and Auditor requests	Consultants Reply / Section Amended
0 shows all essential details such as sample numbers and sampling depth		Yes included	The results indicate that there is no residual contamination present within APEC-G and APEC-J. It should be noted that samples from each APEC (two from APEC-J - J006 and J007, one from APEC-G - APEC-G3-05) were broken in transit. These samples were to be replaced by resampling to ensure all walls of the excavation have been appropriately validated. Please advise status of this rework. With regards to APEC-G, all samples taken recorded concentrations below the nominated threshold values with the exception of G001 which recorded elevated TPH concentrations. SERS undertook to perform further excavation along this face of the transformer excavation (face closest to the generator shed floorslab to remove the identified residual contamination. Once the excavation works have been completed another validation sample was to be taken from this face to confirm that the remaining insitu soils are clean. Please advise status of this work.	No Action Undertaken.
0 shows assessment criteria		Yes		No Action Undertaken.
0 highlights all results exceeding the assessment criteria		Yes		No Action Undertaken.
≠ Site plan showing all sample locations, sample identification numbers and sampling depths		Yes		No Action Undertaken.
≠ Site plan showing the extent of soil and groundwater contamination exceeding selected assessment criteria for each sampling depth.		NA		No Action Undertaken.

Site Characterisation and Risk Assessment ✓S	**S**		Site Characterisation and Risk Assessment should be included in the report. A revised and updated Conceptual Site Model would provide a nice summary of the site at completion of remediation and validation.	
≠ Assessment of type of all environmental contamination, particularly soil and groundwater	Section 9.0	Presents Remediation Acceptance Criteria in Table 9.1. Considers HIL as per NEPM Schedule B1 (2013) and EIL. Table 9.2 presents WA DoH Guidelines Table 9.3 presents the waste classification thresholds		No Action Undertaken.
≠ Assessment of extent of soil and groundwater contamination, including off-site effects				No Action Undertaken.
≠ Assessment of the chemical degradation products				No Action Undertaken.
≠ Assessment of possible exposure routes and exposed populations (human, ecological).				Section 11 updated.
≠ Assessment of type of risks particularly to human health and the environment				Section 11 updated.
≠ Assessment of mathematical modelling or other method to justify conclusions of risk assessment				Section 11 updated.
≠ Detection limits for each chemical appropriate for risk assessment process				Section 11 updated.
≠ Appropriateness of site specific risk assessment				Section 11 updated.
≠ Compliance with requirements in Human Health Risk Assessment checklist				Section 11 updated.
≠ Confirmation of acid sulphate soil risk status		Agree not considered a concern due to elevation of the Subject site. May be issue in the broader area not covered by the remediation program.		No Action Undertaken.
Remedial Action Plan ✓(S)	**S**	Provided in Appendix K of the final Validation Report.		No Action Undertaken.
≠ Remediation goal				No Action Undertaken.
≠ Remediation category under SEPP55 (where applicable)				No Action Undertaken.
≠ Discussion of the extent of remediation required				No Action Undertaken.
≠ Discussion of possible remedial options and how risk can be reduced including consideration of vertical soil mixing and capping				No Action Undertaken.
≠ Where cap and contain is to be used:		Not Applicable		No Action Undertaken.
0 Maximises long term engineering security of the works		Not Applicable		No Action Undertaken.
0 Minimises leachate formation and volatilisation		Not Applicable		No Action Undertaken.
0 Notification mechanism to ensure protection of capped material		Not Applicable		No Action Undertaken.

Section	Ref / Sec in Report	Auditor Comments	Overall Conclusion and Auditor requests	Consultants Reply / Section Amended
0 Structures built n capped area will not pose a future significant risk of harm		Not Applicable		No Action Undertaken.
≠ Where bioremediation option is used:		Not Applicable		No Action Undertaken.
0 Consideration of local rather than foreign species		Not Applicable		No Action Undertaken.
0 Quarantine license and laboratory identification for foreign organisms		Not Applicable		No Action Undertaken.
0 Potential risks from release of organisms		Not Applicable		No Action Undertaken.
0 Monitoring and contingency measures		Not Applicable		No Action Undertaken.
≠ Consideration of chemical wastes subject to a Chemical Control Order (CCO) and compliance	Appendix N	Asbestos Waste disposed at Shoal Bay - Waste Acceptance Certificates provided for Shoal Bay		No Action Undertaken.
≠ Rationale for the selection of recommended remedial option including reference to ANZECC/ NHMRC preferred order of options for remediation				No Action Undertaken.
≠ Proposed testing to validate the site after remediation				No Action Undertaken.
≠ Contingency plan if the selected remedial strategy fails				No Action Undertaken.
≠ Interim site management plan (before remediation), including e.g. fencing, erection of warning signs, stormwater diversion				No Action Undertaken.
≠ Boundary conditions and extent of remediation				No Action Undertaken.
≠ Site management plan (operational phase):				No Action Undertaken.
0 site stormwater management plan				No Action Undertaken.
0 soil management plan				No Action Undertaken.
0 noise control plan				No Action Undertaken.
0 dust control plan, including wheel wash (where applicable)				No Action Undertaken.
0 odour control plan				No Action Undertaken.
0 occupational health and safety plan	Section 12	Site Management Protocol for ACM fragments required	Protocol not seen. Please provide summary	Appendix K updated
≠ Compliance with Part A in checklist (C1) for the EMP				Appendix K updated
≠ Remediation schedule				Appendix K updated
≠ Hour of operation				Appendix K updated
≠ Contingency plans to respond to site incidents, to obviate potential effects on surrounding environment and community				Appendix K updated
≠ Identification of regulatory compliance requirements such as licenses and approvals				Appendix K updated
≠ Names and phone numbers of appropriate personnel to contact during remediation				Appendix K updated
≠ Community relations plans, where applicable				Appendix K updated
≠ Staged progress reporting, where applicable				Appendix K updated
≠ Long-term site management plan				Appendix K updated

Validation ✓				
Rationale and justification for the validation strategy including:	Appendix C	The SERS Remediation and Validation Action Plan (2015) is provided in appendix C. Justification and rationale presented within this Plan. Not seen in the main Validation Report.		No Action Undertaken.
0 clean-up criteria and statistically based decision-making methodology		Site specific risk based clean-up levels (RBCLs) proposed for the 2CRU site.		No Action Undertaken.
0 validation sampling and analysis plan	Section 7	Section 7 presents description of the Validation Sampling and Analysis Plan. All validation samples were collected until no visual or		No Action Undertaken.

Section	Ref / Sec in Report	Auditor Comments	Overall Conclusion and Auditor requests	Consultants Reply / Section Amended
		olfactory evidence of contamination was apparent.		
≠ Details of a statistical analysis of validation results and evaluation against the clean-up criteria	Appendix K	Provision of statistical analysis of all results present beneath the Tier 1 Assessment Tables.		No Action Undertaken.
≠ Verification of compliance with regulatory requirements set forth by the EPA, WorkCover and local government		No comment provided		All works completed in accordance with EPA, WorkCover and local government
Ongoing site monitoring ✓			With the exception of the requirement for ongoing Emu Parade, no other on-site monitoring requirements were reported.	
≠ Scope of ongoing site monitoring requirements (if any), including monitoring parameters, targets and frequency		No additional ongoing site monitoring suggested by SERS.		No Action Undertaken.
≠ Results of monitoring analyses including all relevant QA/QC reporting requirements stated above		Not provided/Not required		No Action Undertaken.
≠ Corrective/preventative action taken (where monitoring has indicated that performance targets have not been met)		Not provided/Not required		No Action Undertaken.
≠ Ongoing site/equipment maintenance, e.g. containment cap integrity		Not provided/Not required		No Action Undertaken.
≠ Details of party(ies) responsible for maintenance and monitoring program		Not provided/Not required		No Action Undertaken.
≠ Maintenance records for plant and equipment		Not provided/Not required		No Action Undertaken.
≠ Data management – indicate where, for how long and by whom, monitoring and maintenance records will be kept		Not provided/Not required		No Action Undertaken.
≠ Regulatory compliance for ongoing monitoring		Not provided/Not required		No Action Undertaken.
≠ Attached ongoing management plan (if relevant) or reference to EMP		Not provided/Not required		No Action Undertaken.

Conclusions and Recommendations ✓	**Section 13**	Listed as Conclusions and Recommendations section of report. Note Section 11 provides conclusions relating to current site conditions.	Please provide a statement in relation to items identified as "not provided".	
≠ Brief summary of all findings	Section 11	Section 11 presents conclusions of validation: - All potential sources of contamination successfully removed off subject site - During remedial works no visual or olfactory evidence of mobile contamination in soil matrix - chemical analysis post remedial works did not record exceedances of selected RACs - No ACM or significant quantities asbestos fibre recorded in near soils post remediation - Groundwater is greater than 21 mbgl and preferential pathways to the aquifer have been observed No significant risk to human health and safety.		No Action Undertaken.
≠ Assumptions used in reaching the conclusions		Not provided		Section 14 updated
≠ Extent of uncertainties in the results		Not provided or there were no uncertainties – provide a statement in relation to this.		No Action Undertaken.
≠ Where remedial action has been taken, a list summarising the activities and physical changes to the site		Not provided		Section 14 updated
≠ A clear statement that the consultant considers the subject site to be suitable for the proposed use(s) (where applicable)	Section 13.2	SERS provides statement: *Based on completion of the remedial works and successful validation program performed, no remaining potential contamination sources or potential pollutant linkages have been identified across the subject site area for the proposed residential end use within the underlying soils or groundwater which could be a risk to human health or the wider environment. It is*		No Action Undertaken.

Section	Ref / Sec in Report	Auditor Comments	Overall Conclusion and Auditor requests	Consultants Reply / Section Amended
		therefore SERS opinion that the site can be classified as uncontaminated and suitable for future residential development.	Please clearly state that a CEMP will need to be prepared by the Contractor and an outline of the contents of this CEMP should be provided, including items noted in SERS report.	
≠ Reference to an ongoing management plan (e.g. during construction phase, operational phase, other?)	Section 12	Identifies the requirement for: - Emu Bob Grid Work (in accordance with the WA DoH Guidelines) on a monthly basis until no fragments of ACM are recovered. - Site Management Protocols have been devised with reference to industry standards.		Section 14 updated
≠ A statement detailing all limitations and constraints on the use of the site (where applicable)		Not included in conclusions and recommendations, although present a Disclaimer at the End of Report.		Section 14 updated
≠ Recommendations for further work, if appropriate.		As per section 12.1 – Emu Bob Grid Work		No Action Undertaken.

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Appendix D

Analytical Results Tables

Extract from SERS (2016a) Appendix K Tier 1 Assessment Tables and Appendix L QA/QC Laboratory Data Validation

Appendix D Analytical Results Tables

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	PAT Combined Compou			Hexavalent Chromium by Alkaline Digestion and DA F	Landfill Classification Metals											Moisture Content	Moisture	svTRH(C10-C36) in soil							Total Mercury by FIMS	Total Metals by ICP-AES						
	PAH (total, NSW Waste 2008)	+C10 - C36 (Sum of total)	Xylene Total	Chromium (hexavalent)	Arsenic	Cadmium	Copper	Lead	Mercury	Molybdenum	Nickel	Selenium	Silver	Tin	Zinc	Moisture	Moisture	C10-C16	C16-C34	C34-C40	F2-NAPHTHALENE	C10 - C14	C15 - C28	C29-C36	Mercury	Arsenic	Beryllium	Cadmium	Lead	Molybdenum	Nickel	Selenium
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL					2	0.4	1	1	0.1	1	1	2	1	1	1		0.1	50	100	100	50	50	100	100								
NEPM 2013 EIL				1	40	3	80	470			50				230											40		3	470		50	
NEPM 2013 Table 1A(1) HILs Res A Soil				100	100	20	6000	300	40		400	200			7400										40	100	60	20	300		400	200
NEPM 2013 Table 1A(3) Res A/B Soil HSL for Vapour Intrusion, Clay																					280											
0-1m			110																		NL											
1-2m			310																		NL											
2-4m			NL																													
NEPM 2013 Table 1B(6) ESLs for Urban Res, Fine Soil																			1300	5600	120											
0-2m			45																													
NEPM 2013 Table 1B(7) Management Limits in Res / Parkland, Fine Soil																		1000	2500	10000												

Field_ID	LocCode	Sample_Depth_Range	Sampled_Date-Time	Matrix_Description																													
APEC-J-01	J001	1-1.8	30/10/2015	Soil	<1	<250	<3	<1	5	<0.4	<1	7	<0.1	<1	<1	<2	<1	2	<1	-	17	<50	<100	<100	<50	<50	<100	<100	<0.1	-	-	-	-	-	-	-
APEC-J-02	J002	2.1-2.6	30/10/2015	Soil	<1	<250	<3	<1	3	<0.4	<1	5	<0.1	<1	1	<2	<1	2	<1	-	17	<50	<100	<100	<50	<50	<100	<100	<0.1	-	-	-	-	-	-	-
APEC-J-03	J003	1-1.7	30/10/2015	Soil	<1	<250	<3	<1	9	<0.4	<1	8	0.1	<1	<1	<2	<1	1	<1	-	15	<50	<100	<100	<50	<50	<100	<100	0.1	-	-	-	-	-	-	-
APEC-J-04	J004	2.1-3.1	30/10/2015	Soil	<1	<250	<3	<1	5	<0.4	<1	6	<0.1	<1	<1	<2	<1	1	<1	-	15	<50	<100	<100	<50	<50	<100	<100	<0.1	-	-	-	-	-	-	-
APEC-J-05	J005	0.9-1.5	30/10/2015	Soil	<1	<250	<3	<1	4	<0.4	<1	5	<0.1	<1	<1	<2	<1	1	<1	-	12	<50	<100	<100	<50	<50	<100	<100	<0.1	-	-	-	-	-	-	-
APEC-J-08	J008	1.9-2.5	30/10/2015	Soil	<1	<250	<3	<1	5	<0.4	<1	6	<0.1	<1	<1	<2	<1	1	<1	-	16	<50	<100	<100	<50	<50	<100	<100	<0.1	-	-	-	-	-	-	-
APEC-J-09	J009	2.5-2.6	30/10/2015	Soil	<1	<250	<3	<1	<2	<0.4	<1	<1	<0.1	<1	<1	<2	<1	1	<1	-	16	<50	<100	<100	<50	<50	<100	<100	<0.1	-	-	-	-	-	-	-
APEC-J-10	J010	3-3.1	30/10/2015	Soil	<1	<250	<3	<1	<2	<0.4	<1	1	<0.1	<1	<1	<2	<1	<1	<1	-	16	<50	<100	<100	<50	<50	<100	<100	<0.1	-	-	-	-	-	-	-
J QA2	J QA2		2/11/2015	Soil	<1	<50	-	<0.5	<5	<1	-	5	-	<2	<2	<5	-	-	<2	17.6	17.6	-	-	-	-	-	-	-	<0.1	<5	<1	<1	5	<2	<2	<5
JQA1	J001	1-1.8	30/10/2015	Soil	<1	<250	<3	<1	5	<0.4	<1	6	<0.1	<1	<1	<2	<1	1	<1	-	15	<50	<100	<100	<50	<50	<100	<100	<0.1	-	-	-	-	-	-	-

Statistical Summary																																
Number of Results	10	10	9	10	10	10	9	10	9	10	10	10	9	9	10	1	10	9	9	9	9	9	9	9	10	1	1	1	1	1	1	1
Number of Detects	0	0	0	0	7	0	0	9	1	0	1	0	0	8	0	1	10	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
Minimum Concentration	<1	<50	<3	<0.5	<2	<0.4	<1	<1	<0.1	<1	<1	<2	<1	<1	<1	17.6	12	<50	<100	<100	<50	<50	<100	<100	<0.1	<5	<1	<1	5	<2	<2	<5
Minimum Detect	ND	ND	ND	ND	3	ND	ND	1	0.1	ND	1	ND	ND	1	ND	17.6	12	ND	ND	ND	ND	ND	ND	ND	0.1	ND	ND	ND	5	ND	ND	ND
Maximum Concentration	<1	<250	<3	<1	9	<1	<1	8	0.1	<2	<2	<5	<1	2	<2	17.6	17.6	<50	<100	<100	<50	<50	<100	<100	0.1	<5	<1	<1	5	<2	<2	<5
Maximum Detect	ND	ND	ND	ND	9	ND	ND	8	0.1	ND	1	ND	ND	2	ND	17.6	17.6	ND	ND	ND	ND	ND	ND	ND	0.1	ND	ND	ND	5	ND	ND	ND
Average Concentration	0.5	115	1.5	0.48	4.1	0.23	0.5	5	0.056	0.55	0.6	1.2	0.5	1.2	0.55		16	25	50	50	25	25	50	50	0.055							
Median Concentration	0.5	125	1.5	0.5	4.5	0.2	0.5	5.5	0.05	0.5	0.5	1	0.5	1	0.5	17.6	16	25	50	50	25	25	50	50	0.05	2.5	0.5	0.5	5	1	1	2.5
Standard Deviation	0	32	0	0.079	2.4	0.095	0	2.4	0.017	0.16	0.21	0.47	0	0.5	0.16		1.6	0	0	0	0	0	0	0	0.016							
Number of Guideline Exceedances	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

					TRH - Semivolatile Fraction							TRH Volatiles/BTEX												vTRH(C6-C10)/MBTEXN in soil									
				Silver	C10-C16	C16-C34	C34-C40	F2-NAPHTHALENE	C10 - C14	C15 - C28	C29-C36	+C10 - C36 (Sum of total)	C10 - C40 (Sum of total)	Benzene	Ethylbenzene	Naphthalene	Toluene	Total BTEX	C6 - C9	Xylene (m & p)	Xylene (o)	Xylene Total	C6-C10 less BTEX (F1)	C6-C10	Benzene	Ethylbenzene	MTBE	Naphthalene	Toluene	C6 - C9	Xylene (m & p)	Xylene (o)	C6-C10 less BTEX (F1)	C6-C10
EQL				mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
NEPM 2013 EIL																10								0.2	1	0.5	1	0.5	25	2	1	25	25
NEPM 2013 Table 1A(1) HILs Res A Soil																											10						
NEPM 2013 Table 1A(3) Res A/B Soil HSL for Vapour Intrusion, Clay																																	
0-1m								280						0.7	NL	5	480					110	50		0.7	NL		5	480				50	
1-2m								NL						1	NL	NL	NL					310	90		1	NL		NL	NL				90	
2-4m								NL						2	NL	NL	NL					NL	150		2	NL		NL	NL				150	
NEPM 2013 Table 1B(6) ESLs for Urban Res, Fine Soil						1300	5600	120						65			105						180		65				105				180	
0-2m															125							45				125								
NEPM 2013 Table 1B(7) Management Limits in Res / Parkland, Fine Soil					1000	3500	10000																	700										700
Field_ID	LocCode	Sample_Depth_Range	Sampled_Date-Time	Matrix_Descri																														
APEC-J-01	J001	1-1.8	30/10/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-J-02	J002	2.1-2.6	30/10/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-J-03	J003	1-1.7	30/10/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-J-04	J004	2.1-3.1	30/10/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-J-05	J005	0.9-1.5	30/10/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-J-08	J008	1.9-2.5	30/10/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-J-09	J009	2.5-2.6	30/10/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-J-10	J010	3-3.1	30/10/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
J QA2	J QA2		2/11/2015	Soil	<2	<50	<100	<100	<50	<50	<100	<100	<50	<50	<0.2	<0.5	<1	<0.5	<0.2	<10	<0.5	<0.5	<0.5	<10	<10	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
JQA1	J001	1-1.8	30/10/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<0.5	<1	<0.5	<10	<0.5	<0.5	<0.5	<10	<10
Statistical Summary																																		
Number of Results				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	10	10	10	10	10	10	10	10	10	10
Number of Detects				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum Concentration				<2	<50	<100	<100	<50	<50	<100	<100	<50	<50	<0.2	<0.5	<1	<0.5	<0.2	<10	<0.5	<0.5	<0.5	<10	<10	<0.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<10	<10
Minimum Detect				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Maximum Concentration				<2	<50	<100	<100	<50	<50	<100	<100	<50	<50	<0.2	<0.5	<1	<0.5	<0.2	<10	<0.5	<0.5	<0.5	<10	<10	<0.2	<1	<1	<1	<10	<25	<2	<1	<25	<25
Maximum Detect				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Average Concentration																																		
Median Concentration				1	25	50	50	25	25	50	50	25	25	0.1	0.25	0.5	0.25	0.1	5	0.25	0.25	0.25	5	5	0.1	0.48	0.28	0.48	0.73	11	0.93	0.48	12	12
Standard Deviation																									0.1	0.5	0.25	0.5	0.25	12.5	1	0.5	12.5	12.5
Number of Guideline Exceedances				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.079	0.079	0.079	1.5	3.9	0.24	0.079	2.4	2.4
Number of Guideline Exceedances(Detects Only)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0
																									0	5	0	0	0	0	0	0	0	0

					Acid Herbicides in Soil																							ESI		
					2-(2-Methyl-1,4-chlorophenoxy) propionic acid	2,4,5-Trichlorophenoxy Acetic Acid	2,4,5-TP (Silvex)	2,4,6-trichlorophenol	Hedonal	2,4-Dichlorprop	4-(2,4-Dichlorophenoxy)butyric Acid (2,4-DB)	2-Chlorophenoxyacetic acid	4-Chlorophenoxy acetic acid	3,5-Dichlorobenzoic acid	Acifluorfen	Actril (loxynil)	Bromoxynil	Clopyralid	Dacthal	Dicamba	Dinoseb	2-Methyl-4-chlorophenoxyacetic acid	2-Methyl-4-Chlorophenoxy Butanoic Acid	Mecoprop	Picloram	Triclopyr	PAH (total, NSW Waste 2008)	Pesticides (total, NSW Waste 2008)	Plasticiser Compounds
					mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL					0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2	1	0.5	0.5	0.5	0.5	1	0.5	0.5	0.5	0.5	0.5			
NEPM 2013 EIL																													
NEPM 2013 Table 1A(1) HILs Res A Soil						600			900													600	600	600	4500				
NEPM 2013 Table 1A(3) Res A/B Soil HSL for Vapour Intrusion, Clay																													
0-1m																													
NEPM 2013 Table 1B(6) ESLs for Urban Res, Fine Soil																													
0-2m																													
NEPM 2013 Table 1B(7) Management Limits in Res / Parkland, Fine Soil																													
Field_ID	**LocCode**	**Sample_Depth_Range**	**Sampled_Date-Time**	**Matrix_Description**																									
APEC-K-W01	APEC-K	Stockpile Sample	23/11/2015	Soil	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<1	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<1.35	<5.6	<5
APEC-K-W02	APEC-K	Stockpile Sample	23/11/2015	Soil	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<1	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<1.35	<5.6	<5
APEC-K-W03	APEC-K	Stockpile Sample	23/11/2015	Soil	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<1	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<1.35	<5.6	<5
WCA01	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<1	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<1.35	<5.6	<5
WCA02	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<1	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<1.35	<5.6	<5
WCA03	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<1	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<1.35	<5.6	<5
WCA04	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<1	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<1.35	<5.6	<5
WCA05	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<1	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<1.35	<5.6	<5
WCA06	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<1	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<1.35	<5.6	<5
WCA07	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<1	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<1.35	<5.6	<5
WCA08	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<1	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<1.35	<5.6	<5
Statistical Summary																													
Number of Results					8	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Number of Detects					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum Concentration					<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<1	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<1.35	<5.6	<5
Minimum Detect					ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Maximum Concentration					<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<1	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<1.35	<5.6	<5
Maximum Detect					ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Average Concentration					0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	1	0.5	0.25	0.25	0.25	0.25	0.5	0.25	0.25	0.25	0.25	0.25	0.68	2.8	2.5
Median Concentration					0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	1	0.5	0.25	0.25	0.25	0.25	0.5	0.25	0.25	0.25	0.25	0.25	0.675	2.8	2.5
Standard Deviation					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

					DAT Combined Compounds						Landfill Classification Metals												aneous Organi		Moisture						
					Scheduled chemicals (NSW Waste 2008)	Aldrin + Dieldrin	Carcinogenic PAHs as B(a)P TPE	DDT+DDE+DDD	+C10 - C36 (Sum of total)	Xylene Total	Arsenic	Cadmium	Copper	Lead	Mercury	Molybdenum	Nickel	Selenium	Silver	Tin	Zinc	2,4-Dinitrotoluene	Nitrobenzene	Moisture	a-BHC	Aldrin	b-BHC	Chlordane (cis)	Chlordane (trans)	
EQL					mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	
NEPM 2013 EIL											2	0.4	1	1	0.1	1	1	2	1	1	1	1	1	0.1	0.1	0.1	0.1	0.1	0.1	
NEPM 2013 Table 1A(1) HILs Res A Soil						6	3	240			40	3	80	470			50				230									
NEPM 2013 Table 1A(3) Res A/B Soil HSL for Vapour Intrusion, Clay											100	20	6000	300	40		400	200			7400									
0-1m										110																				
NEPM 2013 Table 1B(6) ESLs for Urban Res, Fine Soil																														
0-2m										45																				
NEPM 2013 Table 1B(7) Management Limits in Res / Parkland, Fine Soil																														
Field_ID	**LocCode**	**Sample_Depth_Range**	**Sampled_Date-Time**	**Matrix_Description**																										
APEC-K-W01	APEC-K	Stockpile Sample	23/11/2015	Soil	<7.6	<0.2	<0.172	<0.3	<250	<3	8	<0.4	2	9	<0.1	1	2	<2	<1	1	11	<1	<1	8.7	<0.1	<0.1	<0.1	<0.1	<0.1	
APEC-K-W02	APEC-K	Stockpile Sample	23/11/2015	Soil	<7.6	<0.2	<0.172	<0.3	<250	<3	10	<0.4	2	10	<0.1	1	3	<2	<1	1	10	<1	<1	13	<0.1	<0.1	<0.1	<0.1	<0.1	
APEC-K-W03	APEC-K	Stockpile Sample	23/11/2015	Soil	<7.6	<0.2	<0.172	<0.3	<250	<3	11	<0.4	4	13	<0.1	1	3	<2	<1	3	35	<1	<1	8.4	<0.1	<0.1	<0.1	<0.1	<0.1	
WCA01	APEC-J	Stockpile Sample	4/11/2015	Soil	<7.6	<0.2	<0.172	<0.3	<250	<3	2	<0.4	<1	2	<0.1	<1	<1	<2	<1	<1	4	<1	<1	1.1	<0.1	<0.1	<0.1	<0.1	<0.1	
WCA02	APEC-J	Stockpile Sample	4/11/2015	Soil	<7.6	<0.2	<0.172	<0.3	<250	<3	4	<0.4	1	4	<0.1	<1	<1	<2	<1	<1	4	<1	<1	7.7	<0.1	<0.1	<0.1	<0.1	<0.1	
WCA03	APEC-J	Stockpile Sample	4/11/2015	Soil	<7.6	<0.2	<0.172	<0.3	245	<3	5	<0.4	1	10	<0.1	<1	1	<2	<1	<1	5	<1	<1	7	<0.1	<0.1	<0.1	<0.1	<0.1	
WCA04	APEC-J	Stockpile Sample	4/11/2015	Soil	<7.6	<0.2	<0.172	<0.3	<250	<3	3	<0.4	2	3	<0.1	<1	1	<2	<1	<1	4	<1	<1	4	<0.1	<0.1	<0.1	<0.1	<0.1	
WCA05	APEC-J	Stockpile Sample	4/11/2015	Soil	<7.6	<0.2	<0.172	<0.3	<250	<3	7	<0.4	1	9	<0.1	1	2	<2	<1	1	6	<1	<1	11	<0.1	<0.1	<0.1	<0.1	<0.1	
WCA06	APEC-J	Stockpile Sample	4/11/2015	Soil	<7.6	<0.2	<0.172	<0.3	<250	<3	8	<0.4	<1	11	<0.1	1	2	<2	<1	1	2	<1	<1	13	<0.1	<0.1	<0.1	<0.1	<0.1	
WCA07	APEC-J	Stockpile Sample	4/11/2015	Soil	<7.6	<0.2	<0.172	<0.3	<250	<3	7	<0.4	1	11	<0.1	<1	2	<2	<1	1	3	<1	<1	6.7	<0.1	<0.1	<0.1	<0.1	<0.1	
WCA08	APEC-J	Stockpile Sample	4/11/2015	Soil	<7.6	<0.2	<0.172	<0.3	<250	<3	6	<0.4	1	8	<0.1	<1	2	<2	<1	1	4	<1	<1	10	<0.1	<0.1	<0.1	<0.1	<0.1	
Statistical Summary																														
Number of Results					11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	
Number of Detects					0	0	0	0	1	0	11	0	9	11	0	5	9	0	0	7	11	0	0	11	0	0	0	0	0	
Minimum Concentration					<7.6	<0.2	<0.172	<0.3	245	<3	2	<0.4	<1	2	<0.1	<1	<1	<2	<1	<1	2	<1	<1	1.1	<0.1	<0.1	<0.1	<0.1	<0.1	
Minimum Detect					ND	ND	ND	ND	245	ND	2	ND	1	2	ND	1	1	ND	ND	1	2	ND	ND	1.1	ND	ND	ND	ND	ND	
Maximum Concentration					<7.6	<0.2	<0.172	<0.3	<250	<3	11	<0.4	4	13	<0.1	1	3	<2	<1	3	35	<1	<1	13	<0.1	<0.1	<0.1	<0.1	<0.1	
Maximum Detect					ND	ND	ND	ND	245	ND	11	ND	4	13	ND	1	3	ND	ND	3	35	ND	ND	13	ND	ND	ND	ND	ND	
Average Concentration					3.8	0.1	0.086	0.15	136	1.5	6.5	0.2	1.5	8.2	0.05	0.73	1.7	1	0.5	1	8	0.5	0.5	8.2	0.05	0.05	0.05	0.05	0.05	
Median Concentration					3.8	0.1	0.086	0.15	125	1.5	7	0.2	1	9	0.05	0.5	2	1	0.5	1	4	0.5	0.5	8.4	0.05	0.05	0.05	0.05	0.05	
Standard Deviation					0	0	0	0	36	0	2.8	0	1	3.6	0	0.26	0.88	0	0	0.71	9.4	0	0	3.6	0	0	0	0	0	
Number of Guideline Exceedances					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Number of Guideline Exceedances(Detects Only)					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

	Organochlorine Pesticides																Organophosphorus Pesticides								
	a-BHC	DDD	DDE	DDT	Dieldrin	Endosulfan I	Endosulfan II	Endosulfan sulphate	Endrin	Endrin aldehyde	Endrin ketone	g-BHC (Lindane)	Heptachlor	Heptachlor epoxide	Hexachlorobenzene	Methoxychlor	Azinophos methyl	Bromophos-ethyl	Chlorpyrifos	Chlorpyrifos-methyl	Diazinon	Dichlorvos	Dimethoate	Ethion	Fenitrothion
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
NEPM 2013 EIL				3																					
NEPM 2013 Table 1A(1) HILs Res A Soil									10				6		10	300			160						
NEPM 2013 Table 1A(3) Res A/B Soil HSL for Vapour Intrusion, Clay																									
0-1m																									
NEPM 2013 Table 1B(6) ESLs for Urban Res, Fine Soil																									
0-2m																									
NEPM 2013 Table 1B(7) Management Limits In Res / Parkland, Fine Soil																									

Field_ID	LocCode	Sample_Depth_Range	Sampled_Date-Time	Matrix_Description																								
APEC-K-W01	APEC-K	Stockpile Sample	23/11/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
APEC-K-W02	APEC-K	Stockpile Sample	23/11/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
APEC-K-W03	APEC-K	Stockpile Sample	23/11/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
WCA01	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
WCA02	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
WCA03	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
WCA04	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
WCA05	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
WCA06	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
WCA07	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
WCA08	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Statistical Summary

Number of Results	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Number of Detects	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum Concentration	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Minimum Detect	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Maximum Concentration	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Maximum Detect	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Average Concentration	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Median Concentration	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Standard Deviation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

					Other Inorganic Species				PAHs in Soil																		
					Malathion	Parathion	Ronnel	Chromium (hexavalent)	Cyanide (Free)	Cyanide Total	Fluoride	B(a)P Total Potency Equivalent	Acenaphthene	Acenaphthylene	Anthracene	Benz[a]anthracene	Benzo(a) pyrene	Benzo(b)&(k)fluoranthene	Benzo(g,h,i)perylene	Chrysene	Dibenz[a,h]anthracene	Fluoranthene	Fluorene	Indeno(1,2,3-c,d)pyrene	Naphthalene	PAHs (Sum of total)	Phenanthrene	Pyrene	Bis(2-ethylhexyl) phthalate
EQL					mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
NEPM 2013 EIL					0.1	0.1	0.1	1	0.5	0.5	50	0.5	0.1	0.1	0.1	0.1	0.05	0.2	0.1	0.1	0.1	0.1	0.1	0.1		0.1	0.1	5
NEPM 2013 Table 1A(1) HILs Res A Soil								1																10				
NEPM 2013 Table 1A(3) Res A/B Soil HSL for Vapour Intrusion, Clay								100	250																300			
0-1m																												
NEPM 2013 Table 1B(6) ESLs for Urban Res, Fine Soil																								5				
0-2m																	0.7											
NEPM 2013 Table 1B(7) Management Limits in Res / Parkland, Fine Soil																												
Field_ID	**LocCode**	**Sample_Depth_Range**	**Sampled_Date-Time**	**Matrix_Description**																								
APEC-K-W01	APEC-K	Stockpile Sample	23/11/2015	Soil	<0.1	<0.1	<0.1	<1	<0.5	<0.5	<50	<0.5	<0.1	<0.1	<0.1	<0.1	<0.05	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0	<0.1	<0.1	<5
APEC-K-W02	APEC-K	Stockpile Sample	23/11/2015	Soil	<0.1	<0.1	<0.1	<1	<0.5	<0.5	<50	<0.5	<0.1	<0.1	<0.1	<0.1	<0.05	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0	<0.1	<0.1	<5
APEC-K-W03	APEC-K	Stockpile Sample	23/11/2015	Soil	<0.1	<0.1	<0.1	<1	<0.5	<0.5	<50	<0.5	<0.1	<0.1	<0.1	<0.1	<0.05	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0	<0.1	<0.1	<5
WCA01	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.1	<0.1	<0.1	<1	<0.5	<0.5	<50	<0.5	<0.1	<0.1	<0.1	<0.1	<0.05	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0	<0.1	<0.1	<5
WCA02	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.1	<0.1	<0.1	<1	<0.5	<0.5	<50	<0.5	<0.1	<0.1	<0.1	<0.1	<0.05	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0	<0.1	<0.1	<5
WCA03	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.1	<0.1	<0.1	<1	<0.5	<0.5	<50	<0.5	<0.1	<0.1	<0.1	<0.1	<0.05	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0	<0.1	<0.1	<5
WCA04	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.1	<0.1	<0.1	<1	<0.5	<0.5	<50	<0.5	<0.1	<0.1	<0.1	<0.1	<0.05	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0	<0.1	<0.1	<5
WCA05	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.1	<0.1	<0.1	<1	<0.5	<0.5	<50	<0.5	<0.1	<0.1	<0.1	<0.1	<0.05	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0	<0.1	<0.1	<5
WCA06	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.1	<0.1	<0.1	<1	<0.5	<0.5	60	<0.5	<0.1	<0.1	<0.1	<0.1	<0.05	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0	<0.1	<0.1	<5
WCA07	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.1	<0.1	<0.1	<1	<0.5	<0.5	<50	<0.5	<0.1	<0.1	<0.1	<0.1	<0.05	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0	<0.1	<0.1	<5
WCA08	APEC-J	Stockpile Sample	4/11/2015	Soil	<0.1	<0.1	<0.1	<1	<0.5	<0.5	<50	<0.5	<0.1	<0.1	<0.1	<0.1	<0.05	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0	<0.1	<0.1	<5
Statistical Summary																												
Number of Results					11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Number of Detects					0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0
Minimum Concentration					<0.1	<0.1	<0.1	<1	<0.5	<0.5	<50	<0.5	<0.1	<0.1	<0.1	<0.1	<0.05	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0	<0.1	<0.1	<5
Minimum Detect					ND	ND	ND	ND	ND	ND	60	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Maximum Concentration					<0.1	<0.1	<0.1	<1	<0.5	<0.5	60	<0.5	<0.1	<0.1	<0.1	<0.1	<0.05	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0	<0.1	<0.1	<5
Maximum Detect					ND	ND	ND	ND	ND	ND	60	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Average Concentration					0.05	0.05	0.05	0.5	0.25	0.25	28	0.25	0.05	0.05	0.05	0.05	0.025	0.1	0.05	0.05	0.05	0.05	0.05	0.05	0	0.05	0.05	2.5
Median Concentration					0.05	0.05	0.05	0.5	0.25	0.25	25	0.25	0.05	0.05	0.05	0.05	0.025	0.1	0.05	0.05	0.05	0.05	0.05	0.05	0	0.05	0.05	2.5
Standard Deviation					0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	Phthalates in Soil					Speciated Phenols in Soil																svTRH(C10-C36			
	Butyl benzyl phthalate	Diethylphthalate	Dimethyl phthalate	Di-n-butyl phthalate	Di-n-octyl phthalate	2,3,4,6-tetrachlorophenol	2,4,5-trichlorophenol	2,4,6-trichlorophenol	2,4-dichlorophenol	2,4-dimethylphenol	2,4-dinitrophenol	2,6-dichlorophenol	2-chlorophenol	2-methylphenol	2-nitrophenol	4,6-Dinitro-2-methylphenol	4-chloro-3-methylphenol	4-methylphenol	4-nitrophenol	Pentachlorophenol	Phenol	C10-C16	C16-C34	C34-C40	F2-NAPHTHALENE
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL	1	1	1	5	1	0.2	0.2	0.2	0.2	0.2	4	0.2	0.2	0.2	0.2	10	5	0.4	4	5	0.2	50	100	100	50
NEPM 2013 EIL																									
NEPM 2013 Table 1A(1) HILs Res A Soil																				100	3000				
NEPM 2013 Table 1A(3) Res A/B Soil HSL for Vapour Intrusion, Clay																									
0-1m																									280
NEPM 2013 Table 1B(6) ESLs for Urban Res, Fine Soil																							1300	5600	120
0-2m																									
NEPM 2013 Table 1B(7) Management Limits in Res / Parkland, Fine Soil																						1000	2500	10000	
Field_ID	**LocCode**	**Sample_Depth_Range**	**Sampled_Date-Time**	**Matrix_Description**																					
APEC-K-W01	APEC-K	Stockpile Sample	23/11/2015	Soil	<1	<1	<1	<5	<1	<0.2	<0.2	<0.2	<0.2	<0.2	<4	<0.2	<0.2	<0.2	<0.2	<10	<5	<0.4	<4	<5	<0.2	<50	<100	<100	<50
APEC-K-W02	APEC-K	Stockpile Sample	23/11/2015	Soil	<1	<1	<1	<5	<1	<0.2	<0.2	<0.2	<0.2	<0.2	<4	<0.2	<0.2	<0.2	<0.2	<10	<5	<0.4	<4	<5	<0.2	<50	<100	<100	<50
APEC-K-W03	APEC-K	Stockpile Sample	23/11/2015	Soil	<1	<1	<1	<5	<1	<0.2	<0.2	<0.2	<0.2	<0.2	<4	<0.2	<0.2	<0.2	<0.2	<10	<5	<0.4	<4	<5	<0.2	<50	<100	<100	<50
WCA01	APEC-J	Stockpile Sample	4/11/2015	Soil	<1	<1	<1	<5	<1	<0.2	<0.2	<0.2	<0.2	<0.2	<4	<0.2	<0.2	<0.2	<0.2	<10	<5	<0.4	<4	<5	<0.2	<50	<100	<100	<50
WCA02	APEC-J	Stockpile Sample	4/11/2015	Soil	<1	<1	<1	<5	<1	<0.2	<0.2	<0.2	<0.2	<0.2	<4	<0.2	<0.2	<0.2	<0.2	<10	<5	<0.4	<4	<5	<0.2	<50	<100	<100	<50
WCA03	APEC-J	Stockpile Sample	4/11/2015	Soil	<1	<1	<1	<5	<1	<0.2	<0.2	<0.2	<0.2	<0.2	<4	<0.2	<0.2	<0.2	<0.2	<10	<5	<0.4	<4	<5	<0.2	64	130	<100	64
WCA04	APEC-J	Stockpile Sample	4/11/2015	Soil	<1	<1	<1	<5	<1	<0.2	<0.2	<0.2	<0.2	<0.2	<4	<0.2	<0.2	<0.2	<0.2	<10	<5	<0.4	<4	<5	<0.2	<50	<100	<100	<50
WCA05	APEC-J	Stockpile Sample	4/11/2015	Soil	<1	<1	<1	<5	<1	<0.2	<0.2	<0.2	<0.2	<0.2	<4	<0.2	<0.2	<0.2	<0.2	<10	<5	<0.4	<4	<5	<0.2	<50	<100	<100	<50
WCA06	APEC-J	Stockpile Sample	4/11/2015	Soil	<1	<1	<1	<5	<1	<0.2	<0.2	<0.2	<0.2	<0.2	<4	<0.2	<0.2	<0.2	<0.2	<10	<5	<0.4	<4	<5	<0.2	<50	<100	<100	<50
WCA07	APEC-J	Stockpile Sample	4/11/2015	Soil	<1	<1	<1	<5	<1	<0.2	<0.2	<0.2	<0.2	<0.2	<4	<0.2	<0.2	<0.2	<0.2	<10	<5	<0.4	<4	<5	<0.2	<50	<100	<100	<50
WCA08	APEC-J	Stockpile Sample	4/11/2015	Soil	<1	<1	<1	<5	<1	<0.2	<0.2	<0.2	<0.2	<0.2	<4	<0.2	<0.2	<0.2	<0.2	<10	<5	<0.4	<4	<5	<0.2	<50	<100	<100	<50
Statistical Summary																									
Number of Results						11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Number of Detects						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1
Minimum Concentration						<0.2	<0.2	<0.2	<0.2	<0.2	<4	<0.2	<0.2	<0.2	<0.2	<10	<5	<0.4	<4	<5	<0.2	<50	<100	<100	<50
Minimum Detect						ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	64	130	ND	64
Maximum Concentration						<0.2	<0.2	<0.2	<0.2	<0.2	<4	<0.2	<0.2	<0.2	<0.2	<10	<5	<0.4	<4	<5	<0.2	64	130	<100	64
Maximum Detect						ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	64	130	ND	64
Average Concentration						0.1	0.1	0.1	0.1	0.1	2	0.1	0.1	0.1	0.1	5	2.5	0.2	2	2.5	0.1	29	57	50	29
Median Concentration						0.1	0.1	0.1	0.1	0.1	2	0.1	0.1	0.1	0.1	5	2.5	0.2	2	2.5	0.1	25	50	50	25
Standard Deviation						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	24	0	12
Number of Guideline Exceedances						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	) in soil																										
	C10 - C14	C15 - C28	C29-C36	1,1,1,2-tetrachloroethane	1,1,1-trichloroethane	1,1,2,2-tetrachloroethane	1,1,2-trichloroethane	1,1-dichloroethane	1,1-dichloroethene	1,1-dichloropropene	1,2,3-trichlorobenzene	1,2,3-trichloropropane	1,2,4-trichlorobenzene	1,2,4-trimethylbenzene	1,2-dibromo-3-chloropropane	1,2-dibromoethane	1,2-dichlorobenzene	1,2-dichloroethane	1,2-dichloropropane	1,3,5-trimethylbenzene	1,3-dichlorobenzene	1,3-dichloropropane	1,4-dichlorobenzene	2,2-dichloropropane	2-chlorotoluene
EQL	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
	50	100	100	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
NEPM 2013 EIL																											
NEPM 2013 Table 1A(1) HILs Res A Soil																											
NEPM 2013 Table 1A(3) Res A/B Soil HSL for Vapour Intrusion, Clay																											
0-1m																											
NEPM 2013 Table 1B(6) ESLs for Urban Res, Fine Soil																											
0-2m																											
NEPM 2013 Table 1B(7) Management Limits in Res / Parkland, Fine Soil																											

Field_ID	LocCode	Sample_Depth_Range	Sampled_Date-Time	Matrix_Description																								
APEC-K-W01	APEC-K	Stockpile Sample	23/11/2015	Soil	<50	<100	<100	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
APEC-K-W02	APEC-K	Stockpile Sample	23/11/2015	Soil	<50	<100	<100	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
APEC-K-W03	APEC-K	Stockpile Sample	23/11/2015	Soil	<50	<100	<100	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
WCA01	APEC-J	Stockpile Sample	4/11/2015	Soil	<50	<100	<100	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
WCA02	APEC-J	Stockpile Sample	4/11/2015	Soil	<50	<100	<100	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
WCA03	APEC-J	Stockpile Sample	4/11/2015	Soil	<50	170	<100	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
WCA04	APEC-J	Stockpile Sample	4/11/2015	Soil	<50	<100	<100	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
WCA05	APEC-J	Stockpile Sample	4/11/2015	Soil	<50	<100	<100	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
WCA06	APEC-J	Stockpile Sample	4/11/2015	Soil	<50	<100	<100	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
WCA07	APEC-J	Stockpile Sample	4/11/2015	Soil	<50	<100	<100	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
WCA08	APEC-J	Stockpile Sample	4/11/2015	Soil	<50	<100	<100	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

Statistical Summary

Number of Results	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Number of Detects	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum Concentration	<50	<100	<100	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Minimum Detect	ND	170	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Maximum Concentration	<50	170	<100	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Maximum Detect	ND	170	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Average Concentration	25	61	50	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Median Concentration	25	50	50	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Standard Deviation	0	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

VOCs in soil

	4-chlorotoluene	Benzene	Bromobenzene	Bromochloromethane	Bromodichloromethane	Bromoform	Bromomethane	Carbon tetrachloride	Chlorobenzene	Chlorodibromomethane	Chloroethane	Chloroform	Chloromethane	cis-1,2-dichloroethene	cis-1,3-dichloropropene	Cyclohexane	Dibromomethane	Dichlorodifluoromethane	Ethylbenzene	Hexachlorobutadiene	Isopropylbenzene	MTBE	n-butylbenzene	n-propylbenzene	p-isopropyltoluene
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL	1	0.2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.5	1	1	1
NEPM 2013 EIL																									
NEPM 2013 Table 1A(1) HILs Res A Soil																									
NEPM 2013 Table 1A(3) Res A/B Soil HSL for Vapour Intrusion, Clay																									
0-1m		0.7																	NL						
NEPM 2013 Table 1B(6) ESLs for Urban Res, Fine Soil		65																							
0-2m																			125						
NEPM 2013 Table 1B(7) Management Limits in Res / Parkland, Fine Soil																									

Field_ID	LocCode	Sample_Depth_Range	Sampled_Date-Time	Matrix_Description																								
APEC-K-W01	APEC-K	Stockpile Sample	23/11/2015	Soil	<1	<0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1
APEC-K-W02	APEC-K	Stockpile Sample	23/11/2015	Soil	<1	<0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1
APEC-K-W03	APEC-K	Stockpile Sample	23/11/2015	Soil	<1	<0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1
WCA01	APEC-J	Stockpile Sample	4/11/2015	Soil	<1	<0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1
WCA02	APEC-J	Stockpile Sample	4/11/2015	Soil	<1	<0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1
WCA03	APEC-J	Stockpile Sample	4/11/2015	Soil	<1	<0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1
WCA04	APEC-J	Stockpile Sample	4/11/2015	Soil	<1	<0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1
WCA05	APEC-J	Stockpile Sample	4/11/2015	Soil	<1	<0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1
WCA06	APEC-J	Stockpile Sample	4/11/2015	Soil	<1	<0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1
WCA07	APEC-J	Stockpile Sample	4/11/2015	Soil	<1	<0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1
WCA08	APEC-J	Stockpile Sample	4/11/2015	Soil	<1	<0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1

Statistical Summary

Number of Results	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Number of Detects	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum Concentration	<1	<0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1
Minimum Detect	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Maximum Concentration	<1	<0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1
Maximum Detect	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Average Concentration	0.5	0.1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.25	0.5	0.5	0.5
Median Concentration	0.5	0.1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.25	0.5	0.5	0.5
Standard Deviation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

														vTRH(C6-C10)/MBTEXN in soil										
							sec-butylbenzene	Styrene	Trichloroethene	tert-butylbenzene	Tetrachloroethene	Toluene	trans-1,2-dichloroethene	trans-1,3-dichloropropene	Trichlorofluoromethane	Vinyl chloride	Xylene (m & p)	Xylene (o)	Benzene	Ethylbenzene	MTBE	Naphthalene	Toluene	C6 - C9	Xylene (m & p)	Xylene (o)	C6-C10 less BTEX (F1)	C6-C10
EQL							mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
							1	1	1	1	1	0.5	1	1	1	1	2	1	0.2	1	0.5	1	0.5	25	2	1	25	25
NEPM 2013 EIL																												
NEPM 2013 Table 1A(1) HILs Res A Soil																						10						
NEPM 2013 Table 1A(3) Res A/B Soil HSL for Vapour Intrusion, Clay																												
0-1m												480							0.7	NL		5	480				50	
NEPM 2013 Table 1B(6) ESLs for Urban Res, Fine Soil												105							65				105				180	
0-2m																				125								700
NEPM 2013 Table 1B(7) Management Limits in Res / Parkland, Fine Soil																												
Field_ID	**LocCode**	**Sample_Depth_Range**	**Sampled_Date-Time**	**Matrix_Description**																								
APEC-K-W01	APEC-K	Stockpile Sample	23/11/2015	Soil			<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<2	<1	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-K-W02	APEC-K	Stockpile Sample	23/11/2015	Soil			<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<2	<1	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-K-W03	APEC-K	Stockpile Sample	23/11/2015	Soil			<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<2	<1	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
WCA01	APEC-J	Stockpile Sample	4/11/2015	Soil			<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<2	<1	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
WCA02	APEC-J	Stockpile Sample	4/11/2015	Soil			<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<2	<1	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
WCA03	APEC-J	Stockpile Sample	4/11/2015	Soil			<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<2	<1	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
WCA04	APEC-J	Stockpile Sample	4/11/2015	Soil			<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<2	<1	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
WCA05	APEC-J	Stockpile Sample	4/11/2015	Soil			<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<2	<1	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
WCA06	APEC-J	Stockpile Sample	4/11/2015	Soil			<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<2	<1	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
WCA07	APEC-J	Stockpile Sample	4/11/2015	Soil			<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<2	<1	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
WCA08	APEC-J	Stockpile Sample	4/11/2015	Soil			<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<2	<1	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
Statistical Summary																												
Number of Results							11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Number of Detects							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum Concentration							<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<2	<1	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
Minimum Detect							ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Maximum Concentration							<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<2	<1	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
Maximum Detect							ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Average Concentration							0.5	0.5	0.5	0.5	0.5	0.25	0.5	0.5	0.5	0.5	1	0.5	0.1	0.5	0.25	0.5	0.25	13	1	0.5	13	13
Median Concentration							0.5	0.5	0.5	0.5	0.5	0.25	0.5	0.5	0.5	0.5	1	0.5	0.1	0.5	0.25	0.5	0.25	12.5	1	0.5	12.5	12.5
Standard Deviation							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	ESDAT Combined Compounds							Moisture Content	Moisture	NEPM Suite 1 - Metals													
	PAH (total, NSW Waste 2008)	Pesticides (total, NSW Waste 2008)	Scheduled chemicals (NSW Waste 2008)	Aldrin + Dieldrin	DDT+DDE+DDD	+C10 - C36 (Sum of total)	Xylene Total	Moisture	Moisture	Arsenic	Beryllium	Boron	Cadmium	Chromium (III+VI)	Cobalt	Copper	Lead	Manganese	Mercury	Nickel	Selenium	Zinc	a-BHC
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL									0.1	2	1	3	0.4	1	1	1	1	1	0.1	1	2	1	0.1
NEPM 2013 EIL										40			3			80	470			50		230	
NEPM 2013 Table 1A(1) HILs Res A Soil				6	240					100	60	4500	20		100	6000	300	3800	40	400	200	7400	
NEPM 2013 Table 1A(3) Res A/B Soil HSL for Vapour Intrusion, Clay																							
0-1m							110																
1-2m							310																
NEPM 2013 Table 1B(6) ESLs for Urban Res, Fine Soil																							
0-2m							45																
NEPM 2013 Table 1B(7) Management Limits in Res / Parkland, Fine Soil																							

Field_ID	LocCode	Sample_Depth	Sampled_Date-Time	Matrix_Description																					
APEC-G-01	G001	0.5	29/10/2015	Soil	<1	<0.6	<1.4	<0.2	<0.3	1875	<3	-	4.4	-	-	-	-	-	-	-	-	-	-	-	-	<0.1
APEC-G-02	G002	0.5	29/10/2015	Soil	<1	<0.6	<1.4	<0.2	<0.3	<250	<3	-	1.3	-	-	-	-	-	-	-	-	-	-	-	-	<0.1
APEC-G-03	G003	0.5	29/10/2015	Soil	<1	<0.6	<1.4	<0.2	<0.3	<250	<3	-	6.3	-	-	-	-	-	-	-	-	-	-	-	-	<0.1
APEC-G-04	G004	0.5	29/10/2015	Soil	<1	<0.6	<1.4	<0.2	<0.3	<250	<3	-	6.2	-	-	-	-	-	-	-	-	-	-	-	-	<0.1
APEC-G-05	G005	1.2	29/10/2015	Soil	<1	<0.6	<1.4	<0.2	<0.3	<250	<3	-	4.8	-	-	-	-	-	-	-	-	-	-	-	-	<0.1
APEC-G2-01	APEC-G2-01	1.3	24/11/2015	Soil	<1	<0.6	-	-	-	275	<3	-	2.8	10	<1	<3	<0.4	37	2	8	14	130	<0.1	3	<2	66	-
APEC-G2-02	APEC-G2-02	0.6	24/11/2015	Soil	<1	<0.6	-	-	-	1475	<3	-	3.8	9	<1	<3	<0.4	52	2	15	33	100	<0.1	3	<2	170	-
APEC-G2-03	APEC-G2-03	0.6	24/11/2015	Soil	<1	<0.6	-	-	-	225	<3	-	3.8	11	<1	<3	<0.4	59	2	9	17	120	<0.1	2	<2	72	-
APEC-G2-04	APEC-G2-04	0.6	24/11/2015	Soil	<1	<0.6	-	-	-	325	<3	-	3.8	10	<1	<3	<0.4	68	2	9	28	110	<0.1	3	<2	100	-
APEC-G2-05	APEC-G2-05	0.6	24/11/2015	Soil	<1	<0.6	-	-	-	625	<3	-	3.1	9	<1	<3	<0.4	61	2	10	22	96	<0.1	3	<2	96	-
APEC-G3-01	APEC-G3-01	1.7	30/11/2015	Soil	<1	<0.6	-	-	-	<250	<3	-	6.5	10	<1	3	<0.4	83	2	2	11	42	<0.1	2	<2	20	-
APEC-G3-02	APEC-G3-02	0.6	30/11/2015	Soil	<1	<0.6	-	-	-	<250	<3	-	6.4	10	<1	<3	<0.4	100	2	2	13	39	<0.1	3	<2	27	-
APEC-G3-03	APEC-G3-03	0.6	30/11/2015	Soil	<1	<0.6	-	-	-	<250	<3	-	19	11	<1	<3	<0.4	94	2	4	13	49	<0.1	3	<2	170	-
APEC-G3-04	APEC-G3-04	0.6	30/11/2015	Soil	<1	<0.6	-	-	-	<250	<3	-	21	10	<1	<3	<0.4	85	2	3	11	42	<0.1	3	<2	12	-
APEC-G3-QA1	APEC-G3-01	1.7	30/11/2015	Soil	<1	<0.6	-	-	-	<250	<3	-	7	10	<1	<3	<0.4	85	2	2	13	44	<0.1	2	<2	9	-
QA1	G001	0.5	29/10/2015		<1	<0.6	<1.4	<0.2	<0.3	<250	<3	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1
QA2	QA2		29/10/2015		<1	<0.5	<0.85	-	-	-	-	5.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.05

Statistical Summary																								
Number of Results	17	17	7	6	6	16	16	1	16	10	10	10	10	10	10	10	10	10	10	10	10	10	10	7
Number of Detects	0	0	0	0	0	6	0	1	16	10	0	1	0	10	10	10	10	10	0	10	0	10	0	0
Minimum Concentration	<1	<0.5	<0.85	<0.2	<0.3	225	<3	5.8	1.3	9	<1	<3	<0.4	37	2	2	11	39	<0.1	2	<2	9	<0.05	
Minimum Detect	ND	ND	ND	ND	ND	225	ND	5.8	1.3	9	ND	3	ND	37	2	2	11	39	ND	2	ND	9	ND	
Maximum Concentration	<1	<0.6	<1.4	<0.2	<0.3	1875	<3	5.8	21	11	<1	3	<0.4	100	2	15	33	130	<0.1	3	<2	170	<0.1	
Maximum Detect	ND	ND	ND	ND	ND	1875	ND	5.8	21	11	ND	3	ND	100	2	15	33	130	ND	3	ND	170	ND	
Average Concentration	0.5	0.3	0.66	0.1	0.15	378	1.5		6.5	10	0.5	1.7	0.2	72	2	6.4	18	77	0.05	2.7	1	74	0.046	
Median Concentration	0.5	0.3	0.7	0.1	0.15	125	1.5	5.8	4.6	10	0.5	1.5	0.2	75.5	2	6	13.5	72.5	0.05	3	1	69	0.05	
Standard Deviation	0	0.012	0.1	0	0	528	0		5.5	0.67	0	0.47	0	20	0	4.5	7.7	37	0	0.48	0	60	0.009	
Number of Guideline Exceedances	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Number of Guideline Exceedances(Detects Only)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

					Organochlorine Pesticides																				Organc				
					Aldrin	b-BHC	Chlordane (cis)	Chlordane (trans)	d-BHC	DDD	DDE	DDT	Dieldrin	Endosulfan I	Endosulfan II	Endosulfan sulphate	Endrin	Endrin aldehyde	Endrin ketone	g-BHC (Lindane)	Heptachlor	Heptachlor epoxide	Hexachlorobenzene	Methoxychlor	Azinophos methyl	Bromophos-ethyl	Chlorpyrifos	Chlorpyrifos-methyl	Diazinon
					mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL					0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
NEPM 2013 EIL												3																	
NEPM 2013 Table 1A(1) HILs Res A Soil																	10				6		10	300			160		
NEPM 2013 Table 1A(3) Res A/B Soil HSL for Vapour Intrusion, Clay																													
0-1m																													
1-2m																													
NEPM 2013 Table 1B(6) ESLs for Urban Res, Fine Soil																													
0-2m																													
NEPM 2013 Table 1B(7) Management Limits in Res / Parkland, Fine Soil																													
Field_ID	LocCode	Sample_Depth	Sampled_Date-Time	Matrix_Descri																									
APEC-G-01	G001	0.5	29/10/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
APEC-G-02	G002	0.5	29/10/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
APEC-G-03	G003	0.5	29/10/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
APEC-G-04	G004	0.5	29/10/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
APEC-G-05	G005	1.2	29/10/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
APEC-G2-01	APEC-G2-01	1.3	24/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1
APEC-G2-02	APEC-G2-02	0.6	24/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1
APEC-G2-03	APEC-G2-03	0.6	24/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1
APEC-G2-04	APEC-G2-04	0.6	24/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1
APEC-G2-05	APEC-G2-05	0.6	24/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1
APEC-G3-01	APEC-G3-01	1.7	30/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1
APEC-G3-02	APEC-G3-02	0.6	30/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1
APEC-G3-03	APEC-G3-03	0.6	30/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1
APEC-G3-04	APEC-G3-04	0.6	30/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1
APEC-G3-QA1	APEC-G3-01	1.7	30/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1
QA1	G001	0.5	29/10/2015		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
QA2	QA2		29/10/2015		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Statistical Summary																													
Number of Results					7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	17	17	17	17	17
Number of Detects					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum Concentration					<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Minimum Detect					ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Maximum Concentration					<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Maximum Detect					ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Average Concentration					0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.057	0.046	0.046	0.046	0.046	0.049	0.049	0.049	0.049	0.049
Median Concentration					0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Standard Deviation					0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.019	0.009	0.009	0.009	0.009	0.006	0.006	0.006	0.006	0.006
Number of Guideline Exceedances					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

[Filter]

									Phosphorus Pesticides							PCBs in Soil																
									Dichlorvos	Dimethoate	Ethion	Fenitrothion	Malathion	Parathion	Ronnel	Arochlor 1016	Arochlor 1221	Arochlor 1232	Arochlor 1242	Arochlor 1248	Arochlor 1254	Arochlor 1260	4,4-DDE	a-BHC	Aldrin	Aldrin + Dieldrin	Azinophos methyl	b-BHC	Bromophos-ethyl	Carbophenothion	chlordane	Chlordane (cis)	Chlordane (trans)
					mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL					0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1											
NEPM 2013 EIL																															
NEPM 2013 Table 1A(1) HILs Res A Soil																										6				50		
NEPM 2013 Table 1A(3) Res A/B Soil HSL for Vapour Intrusion, Clay																															
0-1m																															
1-2m																															
NEPM 2013 Table 1B(6) ESLs for Urban Res, Fine Soil																															
0-2m																															
NEPM 2013 Table 1B(7) Management Limits in Res / Parkland, Fine Soil																															
Field_ID	**LocCode**	**Sample_Depth**	**Sampled_Date-Time**	**Matrix_Descrip**																											
APEC-G-01	G001	0.5	29/10/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G-02	G002	0.5	29/10/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G-03	G003	0.5	29/10/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G-04	G004	0.5	29/10/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G-05	G005	1.2	29/10/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G2-01	APEC-G2-01	1.3	24/11/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G2-02	APEC-G2-02	0.6	24/11/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G2-03	APEC-G2-03	0.6	24/11/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G2-04	APEC-G2-04	0.6	24/11/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G2-05	APEC-G2-05	0.6	24/11/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G3-01	APEC-G3-01	1.7	30/11/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G3-02	APEC-G3-02	0.6	30/11/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G3-03	APEC-G3-03	0.6	30/11/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G3-04	APEC-G3-04	0.6	30/11/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G3-QA1	APEC-G3-01	1.7	30/11/2015	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
QA1	G001	0.5	29/10/2015		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
QA2	QA2		29/10/2015		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	-	<0.2	<0.2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Statistical Summary																															
Number of Results					17	17	17	17	17	17	17	16	16	16	16	16	16	16	16	1	1	1	1	1	1	1	1	1	1	1	1
Number of Detects					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum Concentration					<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Minimum Detect					ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Maximum Concentration					<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Maximum Detect					ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Average Concentration					0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05													
Median Concentration					0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.1	0.1	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Standard Deviation					0.006	0.006	0.006	0.006	0.006	0.006	0.006	0	0	0	0	0	0	0	0													
Number of Guideline Exceedances					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	Pesticides by GCMS																										
	Chlorfenvinphos	Chlorpyrifos	Chlorpyrifos-methyl	d-BHC	DDD	DDT	DDT+DDE+DDD	Demeton-S-methyl	Diazinon	Dichlorvos	Dieldrin	Dimethoate	Endosulfan	Endosulfan I	Endosulfan II	Endosulfan sulphate	Endrin	Endrin aldehyde	Endrin ketone	Ethion	Fenamiphos	Fenthion	g-BHC (Lindane)	Heptachlor	Heptachlor epoxide
EQL	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
NEPM 2013 EIL						3																			
NEPM 2013 Table 1A(1) HILs Res A Soil		160					240						270				10							6	
NEPM 2013 Table 1A(3) Res A/B Soil HSL for Vapour Intrusion, Clay																									
0-1m																									
1-2m																									
NEPM 2013 Table 1B(6) ESLs for Urban Res, Fine Soil																									
0-2m																									
NEPM 2013 Table 1B(7) Management Limits in Res / Parkland, Fine Soil																									

Field_ID	LocCode	Sample_Depth	Sampled_Date-Time	Matrix_Descri																								
APEC-G-01	G001	0.5	29/10/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G-02	G002	0.5	29/10/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G-03	G003	0.5	29/10/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G-04	G004	0.5	29/10/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G-05	G005	1.2	29/10/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G2-01	APEC-G2-01	1.3	24/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G2-02	APEC-G2-02	0.6	24/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G2-03	APEC-G2-03	0.6	24/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G2-04	APEC-G2-04	0.6	24/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G2-05	APEC-G2-05	0.6	24/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G3-01	APEC-G3-01	1.7	30/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G3-02	APEC-G3-02	0.6	30/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G3-03	APEC-G3-03	0.6	30/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G3-04	APEC-G3-04	0.6	30/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
APEC-G3-QA1	APEC-G3-01	1.7	30/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
QA1	G001	0.5	29/10/2015		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
QA2	QA2		29/10/2015		<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Statistical Summary

Number of Results	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Number of Detects	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum Concentration	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Minimum Detect	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Maximum Concentration	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Maximum Detect	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Average Concentration																											
Median Concentration	0.025	0.025	0.025	0.025	0.025	0.1	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Standard Deviation																											
Number of Guideline Exceedances	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

[Filter]

										Polychlorinated Biphenyls (PCB)	svTRH(C10-C36) in soil							TRH - Semivolatile Fracti								

	on			TRH Volatiles/BTEX											vTRH(C6-C10)/MBTEXN in soil									
	C29-C36	+C10 - C36 (Sum of total)	C10 - C40 (Sum of total)	Benzene	Ethylbenzene	Naphthalene	Toluene	Total BTEX	C6 - C9	Xylene (m & p)	Xylene (o)	Xylene Total	C6-C10 less BTEX (F1)	C6-C10	Benzene	Ethylbenzene	MTBE	Naphthalene	Toluene	C6 - C9	Xylene (m & p)	Xylene (o)	C6-C10 less BTEX (F1)	C6-C10
EQL	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
NEPM 2013 EIL						10									0.2	1	0.5	1	0.5	25	2	1	25	25
NEPM 2013 Table 1A(1) HILs Res A Soil																		10						
NEPM 2013 Table 1A(3) Res A/B Soil HSL for Vapour Intrusion, Clay																								
0-1m				0.7	NL	5	480					110	50		0.7	NL		5	480				50	
1-2m				1	NL	NL	NL					310	90		1	NL		NL	NL				90	
NEPM 2013 Table 1B(6) ESLs for Urban Res, Fine Soil				65			105						180		65				105				180	
0-2m					125							45				125								
NEPM 2013 Table 1B(7) Management Limits in Res / Parkland, Fine Soil														700										700

Field_ID	LocCode	Sample_Depth	Sampled_Date-Time	Matrix_Descri																					
APEC-G-01	G001	0.5	29/10/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-G-02	G002	0.5	29/10/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-G-03	G003	0.5	29/10/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-G-04	G004	0.5	29/10/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-G-05	G005	1.2	29/10/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-G2-01	APEC-G2-01	1.3	24/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-G2-02	APEC-G2-02	0.6	24/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-G2-03	APEC-G2-03	0.6	24/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-G2-04	APEC-G2-04	0.6	24/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-G2-05	APEC-G2-05	0.6	24/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-G3-01	APEC-G3-01	1.7	30/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-G3-02	APEC-G3-02	0.6	30/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-G3-03	APEC-G3-03	0.6	30/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-G3-04	APEC-G3-04	0.6	30/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
APEC-G3-QA1	APEC-G3-01	1.7	30/11/2015	Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
QA1	G001	0.5	29/10/2015		-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
QA2	QA2		29/10/2015		<100	140	130	<0.2	<0.5	<1	<0.5	<0.2	<10	<0.5	<0.5	<0.5	<10	<10	<0.2	<0.5		<1	<0.5	<10	<0.5	<0.5	<10	<10

Statistical Summary																									
Number of Results	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17	17	16	17	17	17	17	17	17	17
Number of Detects	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum Concentration	<100	140	130	<0.2	<0.5	<1	<0.5	<0.2	<10	<0.5	<0.5	<0.5	<10	<10	<0.2	<0.5	<0.5	<1	<0.5	<10	<0.5	<0.5	<10	<10
Minimum Detect	ND	140	130	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Maximum Concentration	<100	140	130	<0.2	<0.5	<1	<0.5	<0.2	<10	<0.5	<0.5	<0.5	<10	<10	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
Maximum Detect	ND	140	130	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Average Concentration															0.1	0.49	0.25	0.5	0.25	12	0.96	0.49	12	12
Median Concentration	50	140	130	0.1	0.25	0.5	0.25	0.1	5	0.25	0.25	0.25	5	5	0.1	0.5	0.25	0.5	0.25	12.5	1	0.5	12.5	12.5
Standard Deviation															0	0.061	0	0	0	1.8	0.18	0.061	1.8	1.8
Number of Guideline Exceedances	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

					Acid Herbicides in Soil																							Cyanides in Soi		
					2-(2-Methyl-1,4-chlorophenoxy) propionic acid	2,4,5-Trichlorophenoxy Acetic Acid	2,4,5-TP (Silvex)	2,4,6-trichlorophenol	Hedonal	2,4-Dichlorprop	4-(2,4-Dichlorophenoxy)butyric Acid (2,4-DB)	2-Chlorophenoxyacetic acid	4-Chlorophenoxy acetic acid	3,5-Dichlorobenzoic acid	Acifluorfen	Actril (loxynil)	Bromoxynil	Clopyralid	Dacthal	Dicamba	Dinoseb	2-Methyl-4-chlorophenoxyacetic acid	2-Methyl-4-Chlorophenoxy Butanoic Acid	Mecoprop	Picloram	Triclopyr	Cyanide (Free)	Cyanide Total	PAH (total, NSW Waste 2008)
					mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL					0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2	1	0.5	0.5	0.5	0.5	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	
NSW 2008 General Solid Waste (No Leaching)								40	200																60	40		320	
NSW 2008 General Solid Waste (with leached)								72	360																110	75		5900	200
NSW 2008 Restricted Solid Waste (No Leaching)								160	800																240	160		1280	
NSW 2008 Restricted Solid Waste (with leached)								288	1440																440	300		23600	800
Field_ID	**LocCode**	**Sample_Depth_Range**	**Sampled_Date-Time**	**Matrix_Description**																										
WC01	APEC-G		3/11/2015	Soil	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<1	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5	<0.5	<0.5	**<0.5**	**<0.5**	<6.75
WC02	APEC-G		3/11/2015	Soil	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<1	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5	<0.5	<0.5	**<0.5**	**<0.5**	<6.75
WC03	APEC-G		3/11/2015	Soil	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<1	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5	<0.5	<0.5	**<0.5**	**<0.5**	<6.75
WC04	APEC-G		3/11/2015	Soil	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<1	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5	<0.5	<0.5	**<0.5**	**<0.5**	<6.75
Statistical Summary																														
Number of Results					4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Number of Detects					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum Concentration					<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<1	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<6.75
Minimum Detect					ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Maximum Concentration					<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2	<1	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<6.75
Maximum Detect					ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Average Concentration					0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	1	0.5	0.25	0.25	0.25	0.25	0.5	0.25	0.25	0.25	0.25	0.25	0.25	0.25	3.4
Median Concentration					0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	1	0.5	0.25	0.25	0.25	0.25	0.5	0.25	0.25	0.25	0.25	0.25	0.25	0.25	3.375
Standard Deviation					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

					ESDAT Combined Compounds								Landfill Classification Metals													Miscellaneous Inorg -		Miscellaneous Organ	
					Pesticides (total, NSW Waste 2008)	Plasticiser Compounds	Scheduled chemicals (NSW Waste 2008)	Aldrin + Dieldrin	Carcinogenic PAHs as B(a)P TPE	DDT+DDE+DDD	+C10 - C36 (Sum of total)	Xylene Total	Arsenic	Cadmium	Copper	Lead	Mercury	Molybdenum	Nickel	Selenium	Silver	Tin	Zinc	Zinc	Chromium (hexavalent)	Fluoride	2,4-Dinitrotoluene	Nitrobenzene
EQL					mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
NSW 2008 General Solid Waste (No Leaching)						20						1000	100	20		100	4	100	40	20	100				100	3000	2.6	40
NSW 2008 General Solid Waste (with leached)					250	600	50				10000	1800	500	100		1500	50	1000	1050	50	180				1900	10000	4.68	72
NSW 2008 Restricted Solid Waste (No Leaching)						80						4000	400	80		400	16	400	160	80	400				400	12000	10.4	160
NSW 2008 Restricted Solid Waste (with leached)					1000	2400	50				40000	7200	2000	400		6000	200	4000	4200	200	720				7600	40000	18.7	288
Field_ID	**LocCode**	**Sample_Depth_Range**	**Sampled_Date-Time**	**Matrix_Description**																									
WC01	APEC-G		3/11/2015	Soil	<28	<5	<34	<1	<0.86	<1.5	7666	<3	7	<0.4	100	46	<0.1	1	4	<2	<1	2	280	-	4	<50	<1	<1
WC02	APEC-G		3/11/2015	Soil	<28	<5	<34	<1	<0.86	<1.5	3325	<3	8	<0.4	44	27	<0.1	1	2	<2	<1	1	230	-	2	<50	<1	<1
WC03	APEC-G		3/11/2015	Soil	<28	<5	<34	<1	<0.86	<1.5	12,640	<3	10	<0.4	150	66	<0.1	1	4	<2	<1	2	660	-	2	<50	<1	<1
WC04	APEC-G		3/11/2015	Soil	<28	<5	<34	<1	<0.86	<1.5	17,910	<3	11	<0.4	190	83	<0.1	1	4	<2	<1	2	390	-	9	<50	<1	<1
Statistical Summary																													
Number of Results					4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	0	4	4	4	4
Number of Detects					0	0	0	0	0	0	4	0	4	0	4	4	0	4	4	0	0	4	4	0	4	0	0	0
Minimum Concentration					<28	<5	<34	<1	<0.86	<1.5	3325	<3	7	<0.4	44	27	<0.1	1	2	<2	<1	1	230	99999	2	<50	<1	<1
Minimum Detect					ND	ND	ND	ND	ND	ND	3325	ND	7	ND	44	27	ND	1	2	ND	ND	1	230	ND	2	ND	ND	ND
Maximum Concentration					<28	<5	<34	<1	<0.86	<1.5	17910	<3	11	<0.4	190	83	<0.1	1	4	<2	<1	2	660	0	9	<50	<1	<1
Maximum Detect					ND	ND	ND	ND	ND	ND	17910	ND	11	ND	190	83	ND	1	4	ND	ND	2	660	ND	9	ND	ND	ND
Average Concentration					14	2.5	17	0.5	0.43	0.75	10385	1.5	9	0.2	121	56	0.05	1	3.5	1	0.5	1.8	390		4.3	25	0.5	0.5
Median Concentration					14	2.5	17	0.5	0.43	0.75	10153	1.5	9	0.2	125	56	0.05	1	4	1	0.5	2	335		3	25	0.5	0.5
Standard Deviation					0	0	0	0	0	0	6297	0	1.8	0	63	24	0	0	1	0	0	0.5	192		3.3	0	0	0
Number of Guideline Exceedances					0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)					0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

					Moisture	Organochlorine Pesticides																								
					Moisture	a-BHC	Aldrin	b-BHC	Chlordane (cis)	Chlordane (trans)	d-BHC	DDD	DDE	DDT	Dieldrin	Endosulfan I	Endosulfan II	Endosulfan sulphate	Endrin	Endrin aldehyde	Endrin ketone	g-BHC (Lindane)	Heptachlor	Heptachlor epoxide	Hexachlorobenzene	Methoxychlor	Azinophos methyl	Bromophos-ethyl	Chlorpyrifos
					%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL					0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
NSW 2008 General Solid Waste (No Leaching)																													4
NSW 2008 General Solid Waste (with leached)																													7.5
NSW 2008 Restricted Solid Waste (No Leaching)																													16
NSW 2008 Restricted Solid Waste (with leached)																													30
Field_ID	**LocCode**	**Sample_Depth_Range**	**Sampled_Date-Time**	**Matrix_Description**																									
WC01	APEC-G		3/11/2015	Soil	3.9	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
WC02	APEC-G		3/11/2015	Soil	5.3	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
WC03	APEC-G		3/11/2015	Soil	5.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
WC04	APEC-G		3/11/2015	Soil	6.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Statistical Summary																													
Number of Results					4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Number of Detects					4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum Concentration					3.9	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Minimum Detect					3.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Maximum Concentration					6.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Maximum Detect					6.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Average Concentration					5.2	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Median Concentration					5.2	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Standard Deviation					1.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

					Organophosphorus Pesticides									Other Inorganic Species				PAHs in Soil											
					Chlorpyrifos-methyl	Diazinon	Dichlorvos	Dimethoate	Ethion	Fenitrothion	Malathion	Parathion	Ronnel	Chromium (hexavalent)	Cyanide (Free)	Cyanide Total	Fluoride	B(a)P Total Potency Equivalent	Acenaphthene	Acenaphthylene	Anthracene	Benz(a)anthracene	Benzo(a) pyrene	Benzo(b)&(k)fluoranthene	Benzo(g,h,i)perylene	Chrysene	Dibenz(a,h)anthracene	Fluoranthene	Fluorene
EQL					mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
					0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1	0.5	0.5	50	0.5	0.1	0.1	0.1	0.1	0.05	0.2	0.1	0.1	0.1	0.1	0.1
NSW 2008 General Solid Waste (No Leaching)														100		320	3000						0.8						
NSW 2008 General Solid Waste (with leached)														1900		5900	10000						10						
NSW 2008 Restricted Solid Waste (No Leaching)														400		1280	12000						3.2						
NSW 2008 Restricted Solid Waste (with leached)														7600		23600	40000						23						
Field_ID	**LocCode**	**Sample_Depth_Range**	**Sampled_Date-Time**	**Matrix_Description**																									
WC01	APEC-G		3/11/2015	Soil	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<50	<0.5	<0.5	<0.5	<0.5	<0.5	<0.25	<1	<0.5	<0.5	<0.5	<0.5	<0.5
WC02	APEC-G		3/11/2015	Soil	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2	<0.5	<0.5	<50	<0.5	<0.5	<0.5	<0.5	<0.5	<0.25	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
WC03	APEC-G		3/11/2015	Soil	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2	<0.5	<0.5	<50	<0.5	<0.5	<0.5	<0.5	<0.5	<0.25	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
WC04	APEC-G		3/11/2015	Soil	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	9	<0.5	<0.5	<50	<0.5	<0.5	<0.5	<0.5	<0.5	<0.25	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Statistical Summary																													
Number of Results					4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Number of Detects					0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum Concentration					<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2	<0.5	<0.5	<50	<0.5	<0.5	<0.5	<0.5	<0.5	<0.25	<1	<0.5	<0.5	<0.5	<0.5	<0.5
Minimum Detect					ND	ND	ND	ND	ND	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Maximum Concentration					<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	9	<0.5	<0.5	<50	<0.5	<0.5	<0.5	<0.5	<0.5	<0.25	<1	<0.5	<0.5	<0.5	<0.5	<0.5
Maximum Detect					ND	ND	ND	ND	ND	ND	ND	ND	ND	9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Average Concentration					0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	4.3	0.25	0.25	25	0.25	0.25	0.25	0.25	0.25	0.13	0.5	0.25	0.25	0.25	0.25	0.25
Median Concentration					0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	3	0.25	0.25	25	0.25	0.25	0.25	0.25	0.25	0.125	0.5	0.25	0.25	0.25	0.25	0.25
Standard Deviation					0	0	0	0	0	0	0	0	0	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

									PCBs in Soil							Phthalates in Soil													Spec
					Indeno(1,2,3-c,d)pyrene	Naphthalene	PAHs (Sum of total)	Phenanthrene	Pyrene	Arochlor 1016	Arochlor 1221	Arochlor 1232	Arochlor 1242	Arochlor 1248	Arochlor 1254	Arochlor 1260	Bis(2-ethylhexyl) phthalate	Butyl benzyl phthalate	Diethylphthalate	Dimethyl phthalate	Di-n-butyl phthalate	Di-n-octyl phthalate	2,3,4,6-tetrachlorophenol	2,4,5-trichlorophenol	2,4,6-trichlorophenol	2,4-dichlorophenol	2,4-dimethylphenol	2,4-dinitrophenol	2,6-dichlorophenol
					mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL					0.1	0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	5	1	1	1	5	1	0.2	0.2	0.2	0.2	0.2	4	0.2
NSW 2008 General Solid Waste (No Leaching)																								8000	40				
NSW 2008 General Solid Waste (with leached)																								14400	72				
NSW 2008 Restricted Solid Waste (No Leaching)																								32000	160				
NSW 2008 Restricted Solid Waste (with leached)																								57600	288				
Field_ID	**LocCode**	**Sample_Depth_Range**	**Sampled_Date-Time**	**Matrix_Description**																									
WC01	APEC-G		3/11/2015	Soil	<0.5	<0.5	0	<0.5	<0.5	<0.2	<0.2	<0.2	<0.2	<0.2	0.4	<0.2	<5	<1	<1	<1	<5	<1	<1	<1	<1	<1	<1	<20	<1
WC02	APEC-G		3/11/2015	Soil	<0.5	<0.5	0	<0.5	<0.5	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<5	<1	<1	<1	<5	<1	<1	<1	<1	<1	<1	<20	<1
WC03	APEC-G		3/11/2015	Soil	<0.5	<0.5	0	<0.5	<0.5	<0.2	<0.2	<0.2	<0.2	<0.2	0.3	<0.2	<5	<1	<1	<1	<5	<1	<1	<1	<1	<1	<1	<20	<1
WC04	APEC-G		3/11/2015	Soil	<0.5	<0.5	0	<0.5	<0.5	<0.2	<0.2	<0.2	<0.2	<0.2	0.4	<0.2	<5	<1	<1	<1	<5	<1	<1	<1	<1	<1	<1	<20	<1
Statistical Summary																													
Number of Results					4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Number of Detects					0	0	4	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum Concentration					<0.5	<0.5	0	<0.5	<0.5	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<5	<1	<1	<1	<5	<1	<1	<1	<1	<1	<1	<20	<1
Minimum Detect					ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Maximum Concentration					<0.5	<0.5	0	<0.5	<0.5	<0.2	<0.2	<0.2	<0.2	<0.2	0.4	<0.2	<5	<1	<1	<1	<5	<1	<1	<1	<1	<1	<1	<20	<1
Maximum Detect					ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Average Concentration					0.25	0.25	0	0.25	0.25	0.088	0.088	0.088	0.088	0.088	0.33	0.088	2.5	0.5	0.5	0.5	2.5	0.5	0.5	0.5	0.5	0.5	0.5	10	0.5
Median Concentration					0.25	0.25	0	0.25	0.25	0.1	0.1	0.1	0.1	0.1	0.35	0.1	2.5	0.5	0.5	0.5	2.5	0.5	0.5	0.5	0.5	0.5	0.5	10	0.5
Standard Deviation					0	0	0	0	0	0.025	0.025	0.025	0.025	0.025	0.096	0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	iated Phenols in Soil									svTRH(C10-C36) in soil																		
	2-chlorophenol	2-methylphenol	2-nitrophenol	4,6-Dinitro-2-methylphenol	4-chloro-3-methylphenol	4-methylphenol	4-nitrophenol	Pentachlorophenol	Phenol	C10-C16	C16-C34	C34-C40	F2-NAPHTHALENE	C10 - C14	C15 - C28	C29-C36	1,1,1,2-tetrachloroethane	1,1,1-trichloroethane	1,1,2,2-tetrachloroethane	1,1,2-trichloroethane	1,1-dichloroethane	1,1-dichloroethene	1,1-dichloropropene	1,2,3-trichlorobenzene	1,2,3-trichloropropane
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL	0.2	0.2	0.2	10	5	0.4	4	5	0.2	50	100	100	50	50	100	100	1	1	1	1	1	1	1	1	1
NSW 2008 General Solid Waste (No Leaching)		4000				4000											200	600	26	24		14			
NSW 2008 General Solid Waste (with leached)		7200				7200			518								360	1080	46.8	43.2		25			
NSW 2008 Restricted Solid Waste (No Leaching)		16000				16000											800	2400	104	96		56			
NSW 2008 Restricted Solid Waste (with leached)		28800				28800			2073								1440	4320	187.2	172.8		100			
WC01	<1	<1	<1	<50	<25	<2	<20	<25	<1	550	7300	<100	550	76	7300	290	<1	<1	<1	<1	<1	<1	<1	<1	<1
WC02	<1	<1	<1	<50	<25	<2	<20	<25	<1	240	3100	<100	240	<50	3200	100	<1	<1	<1	<1	<1	<1	<1	<1	<1
WC03	<1	<1	<1	<50	<25	<2	<20	<25	<1	990	12,000	<100	990	160	12,000	480	<1	<1	<1	<1	<1	<1	<1	<1	<1
WC04	<1	<1	<1	<50	<25	<2	<20	<25	<1	1300	17,000	<100	1300	220	17,000	690	<1	<1	<1	<1	<1	<1	<1	<1	<1
Statistical Summary																									
Number of Results	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Number of Detects	0	0	0	0	0	0	0	0	0	4	4	0	4	3	4	4	0	0	0	0	0	0	0	0	0
Minimum Concentration	<1	<1	<1	<50	<25	<2	<20	<25	<1	240	3100	<100	240	<50	3200	100	<1	<1	<1	<1	<1	<1	<1	<1	<1
Minimum Detect	ND	ND	ND	ND	ND	ND	ND	ND	ND	240	3100	ND	240	76	3200	100	ND	ND	ND	ND	ND	ND	ND	ND	ND
Maximum Concentration	<1	<1	<1	<50	<25	<2	<20	<25	<1	1300	17000	<100	1300	220	17000	690	<1	<1	<1	<1	<1	<1	<1	<1	<1
Maximum Detect	ND	ND	ND	ND	ND	ND	ND	ND	ND	1300	17000	ND	1300	220	17000	690	ND	ND	ND	ND	ND	ND	ND	ND	ND
Average Concentration	0.5	0.5	0.5	25	13	1	10	13	0.5	770	9850	50	770	120	9875	390	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Median Concentration	0.5	0.5	0.5	25	12.5	1	10	12.5	0.5	770	9650	50	770	118	9650	385	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Standard Deviation	0	0	0	0	0	0	0	0	0	469	5995	0	469	87	5957	253	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Field_ID	LocCode	Sample_Depth_Range	Sampled_Date-Time	Matrix_Description
WC01	APEC-G		3/11/2015	Soil
WC02	APEC-G		3/11/2015	Soil
WC03	APEC-G		3/11/2015	Soil
WC04	APEC-G		3/11/2015	Soil

					VOCs in soil																						
					1,2,4-trichlorobenzene	1,2,4-trimethylbenzene	1,2-dibromo-3-chloropropane	1,2-dibromoethane	1,2-dichlorobenzene	1,2-dichloroethane	1,2-dichloropropane	1,3,5-trimethylbenzene	1,3-dichlorobenzene	1,3-dichloropropane	1,4-dichlorobenzene	2,2-dichloropropane	2-chlorotoluene	4-chlorotoluene	Benzene	Bromobenzene	Bromochloromethane	Bromodichloromethane	Bromoform	Bromomethane	Carbon tetrachloride	Chlorobenzene	Chlorodibromomethane	Chloroethane	Chloroform
					mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL					1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.2	1	1	1	1	1	1	1	1	1	1
NSW 2008 General Solid Waste (No Leaching)									86	10					150				10						10	2000			120
NSW 2008 General Solid Waste (with leached)									155	18					270				18						18	3600			216
NSW 2008 Restricted Solid Waste (No Leaching)									344	40					600				40						40	8000			480
NSW 2008 Restricted Solid Waste (with leached)									620	72					1080				72						72	14400			864
Field_ID	**LocCode**	**Sample_Depth_Range**	**Sampled_Date-Time**	**Matrix_Description**																									
WC01	APEC-G		3/11/2015	Soil	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
WC02	APEC-G		3/11/2015	Soil	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
WC03	APEC-G		3/11/2015	Soil	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
WC04	APEC-G		3/11/2015	Soil	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Statistical Summary																													
Number of Results					4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Number of Detects					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum Concentration					<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Minimum Detect					ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Maximum Concentration					<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Maximum Detect					ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Average Concentration					0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Median Concentration					0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Standard Deviation					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	Chloromethane	cis-1,2-dichloroethene	cis-1,3-dichloropropene	Cyclohexane	Dibromomethane	Dichlorodifluoromethane	Ethylbenzene	Hexachlorobutadiene	Isopropylbenzene	MTBE	n-butylbenzene	n-propylbenzene	p-isopropyltoluene	sec-butylbenzene	Styrene	Trichloroethene	tert-butylbenzene	Tetrachloroethene	Toluene	trans-1,2-dichloroethene	trans-1,3-dichloropropene	Trichlorofluoromethane	Vinyl chloride	Xylene (m & p)	Xylene (o)
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL	1	1	1	1	1	1	1	1	1	0.5	1	1	1	1	1	1	1	1	0.5	1	1	1	1	2	1
NSW 2008 General Solid Waste (No Leaching)							600								60	10		14	288				4		
NSW 2008 General Solid Waste (with leached)							1080								108	18		25.2	518				7.2		
NSW 2008 Restricted Solid Waste (No Leaching)							2400								240	40		56	1152				16		
NSW 2008 Restricted Solid Waste (with leached)							4320								432	72		100.8	2073				28.8		

Field_ID	LocCode	Sample_Depth_Range	Sampled_Date-Time	Matrix_Description																								
WC01	APEC-G		3/11/2015	Soil	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<2	<1
WC02	APEC-G		3/11/2015	Soil	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<2	<1
WC03	APEC-G		3/11/2015	Soil	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<2	<1
WC04	APEC-G		3/11/2015	Soil	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<2	<1

Statistical Summary

Number of Results	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Number of Detects	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum Concentration	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<2	<1	
Minimum Detect	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Maximum Concentration	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<2	<1	
Maximum Detect	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Average Concentration	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.25	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.25	0.5	0.5	0.5	0.5	1	0.5	
Median Concentration	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.25	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.25	0.5	0.5	0.5	0.5	1	0.5	
Standard Deviation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Number of Guideline Exceedances	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Number of Guideline Exceedances(Detects Only)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

	vTRH(C6-C10)/MBTEXN in soil									
	Benzene	Ethylbenzene	MTBE	Naphthalene	Toluene	C6 - C9	Xylene (m & p)	Xylene (o)	C6-C10 less BTEX (F1)	C6-C10
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL	0.2	1	0.5	1	0.5	25	2	1	25	25
NSW 2008 General Solid Waste (No Leaching)	10	600			288					
NSW 2008 General Solid Waste (with leached)	18	1080			518	650				
NSW 2008 Restricted Solid Waste (No Leaching)	40	2400			1152					
NSW 2008 Restricted Solid Waste (with leached)	72	4320			2073	2600				

Field_ID	LocCode	Sample_Depth_Range	Sampled_Date-Time	Matrix_Description									
WC01	APEC-G		3/11/2015	Soil	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
WC02	APEC-G		3/11/2015	Soil	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
WC03	APEC-G		3/11/2015	Soil	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
WC04	APEC-G		3/11/2015	Soil	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25

Statistical Summary

Number of Results	4	4	4	4	4	4	4	4	4	4
Number of Detects	0	0	0	0	0	0	0	0	0	0
Minimum Concentration	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
Minimum Detect	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Maximum Concentration	<0.2	<1	<0.5	<1	<0.5	<25	<2	<1	<25	<25
Maximum Detect	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Average Concentration	0.1	0.5	0.25	0.5	0.25	13	1	0.5	13	13
Median Concentration	0.1	0.5	0.25	0.5	0.25	12.5	1	0.5	12.5	12.5
Standard Deviation	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)	0	0	0	0	0	0	0	0	0	0

Appendix L – QA/QC Laboratory Data Validation

ESDAT QA Checker
Project:150449.mdb
Filter: ALL

Overview Summary
- Count of Samples
- Summary By Compound
- Count of Results

Holding Times
- Holding Time Errors (0)

Blanks
- Field Blanks
- Detects in Lab Blanks (6)
- SDG's without Storage Blanks (5)
- SDG's without Method Blanks (1)

Duplicates
- Field and Interlab Duplicates
- Lab Duplicates with high RPDs (9)
- Duplicate Samples with incorrect or missing Parent Samples (0)
- Samples at the same Location/Depth/Time not specified as duplicates (0)

Surrogates
- Surrogate Variation > 30% or outside lab LCL or UCL (21)

Lab Control Samples
- SDG's without a Laboratory Control Sample (0)
- Laboratory Control Samples, Error > 30% (12)

Certified and Standard Reference Materials
- Certified Reference Materials - Error > 30% (0)

Matrix Spikes
- SDG's without a Matrix Spike (0)
- Trip Spikes with invalid Control Sample (0)
- Less than 1 matrix spike in 20 samples, or less than 1 matrix duplicate in 20 samples (2)
- Matrix Spike Recoveries less than 30% or greater than 150% or outside lab LCL or UCL (1)
- Trip Spike Recoveries (30% - 150% is acceptable) (0)

Inorganic
- Na + CL > TDS (0)
- BOD > COD (0)
- BOD > COD (0)

Other
- Unit Conversion Problems (1)
- OriginalChemNames Requiring Validation (5)
- Samples with no Results (0)
- Samples associated with Wells which are not specified in the Well Table (0)
- Aborted Analysis (0)

			Num Results	Holding Times (days)			Lab Control Samples			Method and Storage Blanks			Laboratory Duplicates			Surrogates		
Method_Type	ChemName	Range	Non QA (Normal + Composite)	Volatility Group	Sample to Extraction	Sample to Analysis	Acceptable	Recovery %	Num Reported	Acceptable	Range	Num Reported	Acceptable	Max RPD > EQL x 1	Num Reported	Acceptable	Recovery %	Num Reported	Acceptable
Acid Herbicides in Soil	2-(2-Methyl-1,4-chlorophenoxy) propionic acid	0.5 mg/kg	12	SVOC			Y		0		ND	1	Y		1	Y		0	
	2,4,5-TP (Silvex)	0.5 mg/kg	15	SVOC	3	4	Y		0		ND	2	Y		2	Y		0	
	2,4,5-Trichlorophenoxy Acetic Acid	0.5 mg/kg	15	SVOC	3	4	Y	81 to 88	2	Y	ND	2	Y		2	Y		0	
	2,4,6-trichlorophenol	0.5 mg/kg	15	SVOC	3	4	Y		0		ND	2	Y		2	Y		0	
	2,4-Dichlorophenyl Acetic Acid		0	SVOC			Y	80 to 89	2	Y		0			0	N	75 to 100	22	Y
	2,4-Dichlorprop	0.5 mg/kg	15	SVOC	3	4	Y		0		ND	2	Y		2	Y		0	
	2-Chlorophenoxyacetic acid	0.5 mg/kg	15	SVOC	3	4	Y		0		ND	2	Y		2	Y		0	
	2-Methyl-4-Chlorophenoxy Butanoic Acid	0.5 mg/kg	15	SVOC	3	4	Y		0		ND	2	Y		2	Y		0	
	2-Methyl-4-chlorophenoxyacetic acid	0.5 mg/kg	15	SVOC	3	4	Y	86 to 90	2	Y	ND	2	Y		2	Y		0	
	3,5-Dichlorobenzoic acid	0.5 mg/kg	15	SVOC	3	4	Y		0		ND	2	Y		2	Y		0	
	4-(2,4-Dichlorophenoxy)butyric Acid (2,4-DB)	0.5 mg/kg	15	SVOC	3	4	Y		0		ND	2	Y		2	Y		0	
	4-Chlorophenoxy acetic acid	0.5 mg/kg	15	SVOC	3	4	Y		0		ND	2	Y		2	Y		0	
	Acifluorfen	2 mg/kg	15	SVOC	3	4	Y		0		ND	2	Y		2	Y		0	
	Actril (loxynil)	1 mg/kg	15	SVOC	3	4	Y		0		ND	2	Y		2	Y		0	
	Bromoxynil	0.5 mg/kg	15	SVOC	3	4	Y		0		ND	2	Y		2	Y		0	
	Clopyralid	0.5 mg/kg	15	SVOC	3	4	Y		0		ND	2	Y		2	Y		0	
	Dacthal	0.5 mg/kg	15	SVOC	3	4	Y		0		ND	2	Y		2	Y		0	
	Dicamba	0.5 mg/kg	15	SVOC	3	4	Y	96 to 101	2	Y	ND	2	Y		2	Y		0	
	Dinoseb	1 mg/kg	15	SVOC	3	4	Y		0		ND	2	Y		2	Y		0	
	Hedonal	0.5 mg/kg	15	SVOC	3	4	Y	101 to 122	2	Y	ND	2	Y		2	Y		0	
	Mecoprop	0.5 mg/kg	15	SVOC	3	4	Y	110 to 113	2	Y	ND	2	Y		2	Y		0	
	Picloram	0.5 mg/kg	15	SVOC	3	4	Y		0		ND	2	Y		2	Y		0	
	Triclopyr	0.5 mg/kg	15	SVOC	3	4	Y		0		ND	2	Y		2	Y		0	
Cyanides in Soil	Cyanide (Free)	0.5 mg/kg	3	Low_Stability	3	4	Y	102 to 102	1	Y	ND	1	Y		1	Y		0	
	Cyanide Total	0.5 mg/kg	3	Low_Stability	3	4	Y	100 to 100	1	Y	ND	1	Y		1	Y		0	
Hexavalent Chromium by Alkaline Digestion and DA F	Chromium (hexavalent)		0	Other	4444444444444444		Y	86.1 to 86.1	1	Y	ND	1	Y	1	2	Y		0	
Landfill Classification Metals	Arsenic	2 mg/kg	20	Other	5	5	Y	109 to 109	2	Y	ND	1	Y	35	3	Y		0	
	Cadmium	0.4 mg/kg	20	Other	5	5	Y	116 to 116	2	Y	ND	1	Y		3	Y		0	
	Copper	1 mg/kg	20	Other	5	5	Y	106 to 106	2	Y	ND	1	Y	17	3	Y		0	
	Lead	1 mg/kg	20	Other	5	5	Y	111 to 111	2	Y	ND	1	Y	82	3	N		0	
	Mercury	0.1 mg/kg	20	Specific	5	5	Y	94 to 94	2	Y	ND	1	Y		3	Y		0	
	Molybdenum	1 mg/kg	20	Other	5	5	Y	108 to 108	2	Y	ND	1	Y	0	3	Y		0	
	Nickel	1 mg/kg	20	Other	5	5	Y	109 to 109	2	Y	ND	1	Y	22	3	Y		0	
	Selenium	2 mg/kg	20	Other	5	5	Y	109 to 109	2	Y	ND	1	Y		3	Y		0	
	Silver	1 mg/kg	20	Other	5	5	Y	106 to 106	2	Y	ND	1	Y		3	Y		0	
	Tin	1 mg/kg	20	Other	5	5	Y	107 to 107	2	Y	ND	1	Y	0	3	Y		0	
	Zinc	1 mg/kg	20	Other	5	5	Y	113 to 113	2	Y	ND	1	Y	38	3	N		0	
Metals - soil	Arsenic	2 mg/kg	3	Other	3	4	Y		0			0		22	1	Y		0	
	Cadmium	0.4 mg/kg	3	Other	3	4	Y		0			0			1	Y		0	
	Copper	1 mg/kg	3	Other	3	4	Y		0			0		0	1	Y		0	
	Lead	1 mg/kg	3	Other	3	4	Y		0			0		0	1	Y		0	
	Mercury	0.1 mg/kg	3	Specific	3	4	Y		0			0			1	Y		0	
	Molybdenum	1 mg/kg	3	Other	3	4	Y	102 to 102	1	Y	ND	1	Y	0	1	Y		0	
	Nickel	1 mg/kg	3	Other	3	4	Y		0			0		0	1	Y		0	
	Selenium	2 mg/kg	3	Other	3	4	Y		0			0			1	Y		0	
	Silver	1 mg/kg	3	Other	3	4	Y	100 to 100	1	Y	ND	1	Y		1	Y		0	
	Tin	1 mg/kg	3	Other	3	4	Y	102 to 102	1	Y	ND	1	Y	0	1	Y		0	
	Zinc	1 mg/kg	3	Other	3	4	Y		0			0		24	1	Y		0	
Miscellaneous Inorg - soil	Chromium (hexavalent)	1 mg/kg	3	Other	3	4	Y	105 to 105	1	Y	ND	1	Y		1	Y		0	
	Fluoride	50 mg/kg	3	Low_Stability	3	4	Y	87 to 87	1	Y	ND	1	Y		0	N		0	
Miscellaneous Organics - Soil	2,4-Dinitrotoluene	1 mg/kg	15	SVOC	2	4	Y		0		ND	2	Y		3	Y		0	
	Nitrobenzene	1 mg/kg	15	SVOC	2	4	Y	92 to 92	1	Y	ND	2	Y		3	Y		0	
Moisture	Moisture	0.1 %	47	Other	2 to 5	2 to 6	Y		0		ND	3	Y		0	N		0	
Moisture Content	Moisture		0	Other	1.3444444444467		Y		0			0		2	2	Y		0	
NEPM Suite 1 - Metals	Arsenic	2 mg/kg	19	Other	2 to 3	2 to 4	Y	104 to 110	3	Y	ND	3	Y	11	3	Y		0	
	Beryllium	1 mg/kg	19	Other	2 to 3	2 to 4	Y	103 to 110	3	Y	ND	3	Y		3	Y		0	
	Boron	3 mg/kg	19	Other	2 to 3	2 to 4	Y	99 to 110	3	Y	ND	3	Y	0	3	Y		0	
	Cadmium	0.4 mg/kg	19	Other	2 to 3	2 to 4	Y	106 to 120	3	Y	ND	3	Y		3	Y		0	
	Chromium (III+VI)	1 mg/kg	19	Other	2 to 3	2 to 4	Y	101 to 110	3	Y	ND	3	Y	13	3	Y		0	
	Cobalt	1 mg/kg	19	Other	2 to 3	2 to 4	Y	103 to 110	3	Y	ND	3	Y	0	3	Y		0	
	Copper	1 mg/kg	19	Other	2 to 3	2 to 4	Y	102 to 110	3	Y	ND	3	Y	67	3	N		0	
	Lead	1 mg/kg	19	Other	2 to 3	2 to 4	Y	104 to 110	3	Y	ND	3	Y	13	3	Y		0	
	Manganese	1 mg/kg	19	Other	2 to 3	2 to 4	Y	102 to 110	3	Y	ND	3	Y	34	3	N		0	
	Mercury	0.1 mg/kg	19	Specific	2 to 3	2 to 4	Y	93 to 96	3	Y	ND	3	Y		3	Y		0	

	Nickel	1 mg/kg	19	Other	2 to 3	2 to 4	Y	104 to 110	3	Y	ND	3	Y	0	3	Y		0	
	Selenium	2 mg/kg	19	Other	2 to 3	2 to 4	Y	105 to 110	3	Y	ND	3	Y		3	Y		0	
	Zinc	1 mg/kg	19	Other	2 to 3	2 to 4	Y	106 to 110	3	Y	ND	3	Y	30	3	Y		0	
Organochlorine Pesticides	a-BHC	0.1 mg/kg	20	SVOC	2 to 5	4 to 6	Y	104 to 105	2	Y	ND	2	Y		4	Y		0	
	Aldrin	0.1 mg/kg	20	SVOC	2 to 5	4 to 6	Y	106 to 119	2	Y	ND	2	Y		4	Y		0	
	b-BHC	0.1 mg/kg	20	SVOC	2 to 5	4 to 6	Y	94 to 113	2	Y	ND	2	Y		4	Y		0	
	Chlordane (cis)	0.1 mg/kg	20	SVOC	2 to 5	4 to 6	Y		0		ND	2	Y		4	Y		0	
	Chlordane (trans)	0.1 mg/kg	20	SVOC	2 to 5	4 to 6	Y		0		ND	2	Y		4	Y		0	
	d-BHC	0.1 mg/kg	20	SVOC	2 to 5	4 to 6	Y		0		ND	2	Y		4	Y		0	
	DDD	0.1 mg/kg	20	SVOC	2 to 5	4 to 6	Y	106 to 106	1	Y	ND	2	Y		4	Y		0	
	DDE	0.1 mg/kg	20	SVOC	2 to 5	4 to 6	Y	101 to 127	2	Y	ND	2	Y		4	Y		0	
	DDT	0.1 mg/kg	20	SVOC	2 to 5	4 to 6	Y		0		ND	2	Y		4	Y		0	
	Dieldrin	0.1 mg/kg	20	SVOC	2 to 5	4 to 6	Y	105 to 119	2	Y	ND	2	Y		4	Y		0	
	Endosulfan I	0.1 mg/kg	20	SVOC	2 to 5	4 to 6	Y		0		ND	2	Y		4	Y		0	
	Endosulfan II	0.1 mg/kg	20	SVOC	2 to 5	4 to 6	Y		0		ND	2	Y		4	Y		0	
	Endosulfan sulphate	0.1 mg/kg	20	SVOC	2 to 5	4 to 6	Y	97 to 120	2	Y	ND	2	Y		4	Y		0	
	Endrin	0.1 mg/kg	20	SVOC	2 to 5	4 to 6	Y	116 to 132	2	N	ND	2	Y		4	Y		0	
	Endrin aldehyde	0.1 mg/kg	20	SVOC	2 to 5	4 to 6	Y		0		ND	2	Y		4	Y		0	
	Endrin ketone	0.1 mg/kg	20	SVOC	2 to 5	4 to 6	Y		0		ND	2	Y		4	Y		0	
	g-BHC (Lindane)	0.1 mg/kg	20	SVOC	2 to 5	4 to 6	Y		0		ND	2	Y		4	Y		0	
	Heptachlor	0.1 mg/kg	20	SVOC	2 to 5	4 to 6	Y	80 to 122	2	Y	ND	2	Y		4	Y		0	
	Heptachlor epoxide	0.1 mg/kg	20	SVOC	2 to 5	4 to 6	Y	101 to 129	2	Y	ND	2	Y		4	Y		0	
	Hexachlorobenzene	0.1 mg/kg	20	SVOC	2 to 5	4 to 6	Y		0		ND	2	Y		4	Y		0	
	Methoxychlor	0.1 mg/kg	20	SVOC	2 to 5	4 to 6	Y		0		ND	2	Y		4	Y		0	
Organophosphorus Pesticides	Azinophos methyl	0.1 mg/kg	29	SVOC	1 to 5	2 to 6	Y		0		ND	4	Y		6	Y		0	
	Bromophos-ethyl	0.1 mg/kg	29	SVOC	1 to 5	2 to 6	Y		0		ND	4	Y		6	Y		0	
	Chlorpyrifos	0.1 mg/kg	29	SVOC	1 to 5	2 to 6	Y	96 to 122	4	Y	ND	4	Y		6	Y		0	
	Chlorpyrifos-methyl	0.1 mg/kg	29	SVOC	1 to 5	2 to 6	Y	96 to 113	4	Y	ND	4	Y		6	Y		0	
	Diazinon	0.1 mg/kg	29	SVOC	1 to 5	2 to 6	Y		0		ND	4	Y		6	Y		0	
	Dichlorvos	0.1 mg/kg	29	SVOC	1 to 5	2 to 6	Y		0		ND	4	Y		6	Y		0	
	Dimethoate	0.1 mg/kg	29	SVOC	1 to 5	2 to 6	Y		0		ND	4	Y		6	Y		0	
	Ethion	0.1 mg/kg	29	SVOC	1 to 5	2 to 6	Y	88 to 130	4	N	ND	4	Y		6	Y		0	
	Fenitrothion	0.1 mg/kg	29	SVOC	1 to 5	2 to 6	Y	84 to 92	3	Y	ND	4	Y		6	Y		0	
	Malathion	0.1 mg/kg	29	SVOC	1 to 5	2 to 6	Y		0		ND	4	Y		6	Y		0	
	Parathion	0.1 mg/kg	29	SVOC	1 to 5	2 to 6	Y		0		ND	4	Y		6	Y		0	
	p-Terphenyl		29	SVOC	1 to 5	2 to 6	Y	94 to 117	4	Y	92 to 115	4	N		6	Y		0	
	Ronnel	0.1 mg/kg	29	SVOC	1 to 5	2 to 6	Y		0		ND	4	Y		6	Y		0	
Other Inorganic Species	Chromium (hexavalent)	1 mg/kg	12	Other			Y	109 to 109	1	Y	ND	1	Y	0	2	Y		0	
	Cyanide (Free)	0.5 mg/kg	12	Low_Stability			Y	99 to 99	1	Y		0			2	Y		0	
	Cyanide Total	0.5 mg/kg	12	Low_Stability			Y	105 to 105	1	Y		0			2	Y		0	
	Fluoride	50 mg/kg	12	Low_Stability			Y	82 to 82	1	Y	ND	1	Y		2	Y		0	
PAHs in Soil	Acenaphthene	0.1 mg/kg	15	SVOC	2	4	Y		0		ND	2	Y		3	Y		0	
	Acenaphthylene	0.1 mg/kg	15	SVOC	2	4	Y		0		ND	2	Y		3	Y		0	
	Anthracene	0.1 mg/kg	15	SVOC	2	4	Y		0		ND	2	Y		3	Y		0	
	B(a)P Total Potency Equivalent	0.5 mg/kg	15	SVOC	2	4	Y		0			0			3	Y		0	
	Benz(a)anthracene	0.1 mg/kg	15	SVOC	2	4	Y		0		ND	2	Y		3	Y		0	
	Benzo(a) pyrene	0.05 mg/kg	15	SVOC	2	4	Y	98 to 109	2	Y	ND	2	Y		3	Y		0	
	Benzo(b)&(k)fluoranthene	0.2 mg/kg	15	SVOC	2	4	Y		0		ND	2	Y		3	Y		0	
	Benzo(g,h,i)perylene	0.1 mg/kg	15	SVOC	2	4	Y		0		ND	2	Y		3	Y		0	
	Chrysene	0.1 mg/kg	15	SVOC	2	4	Y	101 to 104	2	Y	ND	2	Y		3	Y		0	
	Dibenz(a,h)anthracene	0.1 mg/kg	15	SVOC	2	4	Y		0		ND	2	Y		3	Y		0	
	Fluoranthene	0.1 mg/kg	15	SVOC	2	4	Y	102 to 122	2	Y	ND	2	Y		3	Y		0	
	Fluorene	0.1 mg/kg	15	SVOC	2	4	Y	98 to 102	2	Y	ND	2	Y		3	Y		0	
	Indeno(1,2,3-c,d)pyrene	0.1 mg/kg	15	SVOC	2	4	Y		0		ND	2	Y		3	Y		0	
	Naphthalene	0.1 mg/kg	15	SVOC	2	4	Y	100 to 101	2	Y	ND	2	Y		3	Y		0	
	PAHs (Sum of total)		15	SVOC	2	4	Y		0			0			3	Y		0	
	Phenanthrene	0.1 mg/kg	15	SVOC	2	4	Y	98 to 100	2	Y	ND	2	Y		3	Y		0	
	p-Terphenyl		15	SVOC	2	4	Y	102 to 117	2	Y	97 to 115	2	N		3	Y		0	
	Pyrene	0.1 mg/kg	15	SVOC	2	4	Y	104 to 129	2	Y	ND	2	Y		3	Y		0	
PCBs in Soil	Arochlor 1016	0.1 mg/kg	18	SVOC	1 to 5	1 to 7	Y		0		ND	4	Y		4	Y		0	
	Arochlor 1221	0.1 mg/kg	18	SVOC	1 to 5	1 to 7	Y		0		ND	4	Y		4	Y		0	
	Arochlor 1232	0.1 mg/kg	18	SVOC	1 to 5	1 to 7	Y		0		ND	4	Y		4	Y		0	
	Arochlor 1242	0.1 mg/kg	18	SVOC	1 to 5	1 to 7	Y		0		ND	4	Y		4	Y		0	
	Arochlor 1248	0.1 mg/kg	18	SVOC	1 to 5	1 to 7	Y		0		ND	4	Y		4	Y		0	
	Arochlor 1254	0.1 mg/kg	18	SVOC	1 to 5	1 to 7	Y	102 to 110	4	Y	ND	4	Y	29	4	Y		0	
	Arochlor 1260	0.1 mg/kg	18	SVOC	1 to 5	1 to 7	Y		0		ND	4	Y		4	Y		0	
Pesticides by GCMS	4,4-DDE		0	SVOC	5.375	6.375	Y	91 to 91	1	Y	ND	1	Y		2	Y		0	
	a-BHC		0	SVOC	5.375	6.375	Y	87 to 87	1	Y	ND	1	Y		2	Y		0	
	Aldrin		0	SVOC	5.375	6.375	Y	87.5 to 87.5	1	Y	ND	1	Y		2	Y		0	
	Aldrin + Dieldrin		0	SVOC	5.375	6.375	Y		0		ND	1	Y		2	Y		0	
	Azinophos methyl		0	SVOC	5.375	6.375	Y	21.8 to 21.8	1	N	ND	1	Y		2	Y		0	
	b-BHC		0	SVOC	5.375	6.375	Y	88.3 to 88.3	1	Y	ND	1	Y		2	Y		0	
	Bromophos-ethyl		0	SVOC	5.375	6.375	Y	82.1 to 82.1	1	Y	ND	1	Y		2	Y		0	
	Carbophenothion		0	SVOC	5.375	6.375	Y	80.6 to 80.6	1	Y	ND	1	Y		2	Y		0	

	chlordane		0	SVOC	5.375	6.375	Y		0		ND	1	Y		2	Y		0	
	Chlordane (cis)		0	SVOC	5.375	6.375	Y	85.6 to 85.6	1	Y	ND	1	Y		2	Y		0	
	Chlordane (trans)		0	SVOC	5.375	6.375	Y	85.3 to 85.3	1	Y	ND	1	Y		2	Y		0	
	Chlorfenvinphos		0	SVOC	5.375	6.375	Y	102 to 102	1	Y	ND	1	Y		2	Y		0	
	Chlorpyrifos		0	SVOC	5.375	6.375	Y	84.8 to 84.8	1	Y	ND	1	Y		2	Y		0	
	Chlorpyrifos-methyl		0	SVOC	5.375	6.375	Y	78.8 to 78.8	1	Y	ND	1	Y		2	Y		0	
	d-BHC		0	SVOC	5.375	6.375	Y	85.4 to 85.4	1	Y	ND	1	Y		2	Y		0	
	DDD		0	SVOC	5.375	6.375	Y	89 to 89	1	Y	ND	1	Y		2	Y		0	
	DDT		0	SVOC	5.375	6.375	Y	86.3 to 86.3	1	Y	ND	1	Y		2	Y		0	
	DDT+DDE+DDD		0	SVOC	5.375	6.375	Y		0		ND	1	Y		2	Y		0	
	DEF		0	SVOC			Y	97 to 97	1	Y		0			0	N	91.8 to 123	7	Y
	Demeton-S-methyl		0	SVOC	5.375	6.375	Y	79.9 to 79.9	1	Y	ND	1	Y		2	Y		0	
	Diazinon		0	SVOC	5.375	6.375	Y	88.5 to 88.5	1	Y	ND	1	Y		2	Y		0	
	Dibromo-DDE		0	SVOC			Y	107 to 107	1	Y		0			0	N	95.2 to 108	7	Y
	Dichlorvos		0	SVOC	5.375	6.375	Y	87.9 to 87.9	1	Y	ND	1	Y		2	Y		0	
	Dieldrin		0	SVOC	5.375	6.375	Y	85.5 to 85.5	1	Y	ND	1	Y		2	Y		0	
	Dimethoate		0	SVOC	5.375	6.375	Y	60.9 to 60.9	1	N	ND	1	Y		2	Y		0	
	Endosulfan		0	SVOC	5.375	6.375	Y		0		ND	1	Y		2	Y		0	
	Endosulfan I		0	SVOC	5.375	6.375	Y	92.7 to 92.7	1	Y	ND	1	Y		2	Y		0	
	Endosulfan II		0	SVOC	5.375	6.375	Y	90.6 to 90.6	1	Y	ND	1	Y		2	Y		0	
	Endosulfan sulphate		0	SVOC	5.375	6.375	Y	88.2 to 88.2	1	Y	ND	1	Y		2	Y		0	
	Endrin		0	SVOC	5.375	6.375	Y	81.3 to 81.3	1	Y	ND	1	Y		2	Y		0	
	Endrin aldehyde		0	SVOC	5.375	6.375	Y	66.3 to 66.3	1	N	ND	1	Y		2	Y		0	
	Endrin ketone		0	SVOC	5.375	6.375	Y	102 to 102	1	Y	ND	1	Y		2	Y		0	
	Ethion		0	SVOC	5.375	6.375	Y	73.8 to 73.8	1	Y	ND	1	Y		2	Y		0	
	Fenamiphos		0	SVOC	5.375	6.375	Y	66 to 66	1	N	ND	1	Y		2	Y		0	
	Fenthion		0	SVOC	5.375	6.375	Y	79.6 to 79.6	1	Y	ND	1	Y		2	Y		0	
	g-BHC (Lindane)		0	SVOC	5.375	6.375	Y	87.6 to 87.6	1	Y	ND	1	Y		2	Y		0	
	Heptachlor		0	SVOC	5.375	6.375	Y	78.8 to 78.8	1	Y	ND	1	Y		2	Y		0	
	Heptachlor epoxide		0	SVOC	5.375	6.375	Y	85.4 to 85.4	1	Y	ND	1	Y		2	Y		0	
	Hexachlorobenzene		0	SVOC	5.375	6.375	Y	84.7 to 84.7	1	Y	ND	1	Y		2	Y		0	
	Malathion		0	SVOC	5.375	6.375	Y	75 to 75	1	Y	ND	1	Y		2	Y		0	
	Methoxychlor		0	SVOC	5.375	6.375	Y	79.4 to 79.4	1	Y	ND	1	Y		2	Y		0	
	Methyl parathion		0	SVOC	5.375	6.375	Y	64.2 to 64.2	1	N	ND	1	Y		2	Y		0	
	Monocrotophos		0	SVOC	5.375	6.375	Y	35.1 to 35.1	1	N	ND	1	Y		2	Y		0	
	Parathion		0	SVOC	5.375	6.375	Y	74 to 74	1	Y	ND	1	Y		2	Y		0	
	Pirimphos-ethyl		0	SVOC	5.375	6.375	Y	88.4 to 88.4	1	Y	ND	1	Y		2	Y		0	
	Prothiofos		0	SVOC	5.375	6.375	Y	80.6 to 80.6	1	Y	ND	1	Y		2	Y		0	
Phthalates in Soil																				
	Bis(2-ethylhexyl) phthalate	5 mg/kg	15	SVOC	2	4	Y		0		ND	2	Y		3	Y		0	
	Butyl benzyl phthalate	1 mg/kg	15	SVOC	2	4	Y	70 to 70	1	N	ND	2	Y		3	Y		0	
	Diethylphthalate	1 mg/kg	15	SVOC	2	4	Y	100 to 100	1	Y	ND	2	Y		3	Y		0	
	Dimethyl phthalate	1 mg/kg	15	SVOC	2	4	Y		0		ND	2	Y		3	Y		0	
	Di-n-butyl phthalate	5 mg/kg	15	SVOC	2	4	Y	97 to 97	1	Y	ND	2	Y		3	Y		0	
	Di-n-octyl phthalate	1 mg/kg	15	SVOC	2	4	Y		0		ND	2	Y		3	Y		0	
	p-Terphenyl		0	SVOC			Y	86 to 86	1	Y		0			0	N	0 to 124	22	N
Polychlorinated Biphenyls (PCB)																				
	Decachlorobiphenyl		0	SVOC			Y	106 to 106	1	Y		0			0	N	52 to 106	4	N
	PCBs (Sum of total)		0	SVOC	5.375	6.375	Y	95.4 to 95.4	1	Y	ND	1	Y		1	Y		0	
Speciated Phenols in Soil																				
	2,3,4,6-tetrachlorophenol	0.2 mg/kg	15	SVOC	2	4	Y		0			0			3	Y		0	
	2,4,5-trichlorophenol	0.2 mg/kg	15	SVOC	2	4	Y		0			0			3	Y		0	
	2,4,6-Tribromophenol		0	SVOC			Y	127 to 132	2	N		0			0	N	0 to 136	23	N
	2,4,6-trichlorophenol	0.2 mg/kg	15	SVOC	2	4	Y		0			0			3	Y		0	
	2,4-dichlorophenol	0.2 mg/kg	15	SVOC	2	4	Y		0			0			3	Y		0	
	2,4-dimethylphenol	0.2 mg/kg	15	SVOC	2	4	Y		0			0			3	Y		0	
	2,4-dinitrophenol	4 mg/kg	15	SVOC	2	4	Y		0			0			3	Y		0	
	2,6-dichlorophenol	0.2 mg/kg	15	SVOC	2	4	Y		0			0			3	Y		0	
	2-chlorophenol	0.2 mg/kg	15	SVOC	2	4	Y		0			0			3	Y		0	
	2-methylphenol	0.2 mg/kg	15	SVOC	2	4	Y		0			0			3	Y		0	
	2-nitrophenol	0.2 mg/kg	15	SVOC	2	4	Y		0			0			3	Y		0	
	4,6-Dinitro-2-methylphenol	10 mg/kg	15	SVOC	2	4	Y		0			0			3	Y		0	
	4-chloro-3-methylphenol	5 mg/kg	15	SVOC	2	4	Y		0			0			3	Y		0	
	4-methylphenol	0.4 mg/kg	15	SVOC	2	4	Y		0			0			3	Y		0	
	4-nitrophenol	4 mg/kg	15	SVOC	2	4	Y		0			0			3	Y		0	
	Pentachlorophenol	5 mg/kg	15	SVOC	2	4	Y		0			0			3	Y		0	
	Phenol	0.2 mg/kg	15	SVOC	2	4	Y		0			0			3	Y		0	
	Phenol-D6		0	SVOC			Y	102 to 103	2	Y		0			0	N	69 to 105	23	N
svTRH(C10-C36) in soil																				
	C10 - C14	50 mg/kg	47	SVOC	2 to 5	2 to 6	Y	88 to 116	5	Y	ND	4	Y	1	8	Y		0	
	C10-C16	50 mg/kg	47	SVOC	2 to 5	2 to 6	Y	86 to 120	5	Y	ND	4	Y	20	8	Y		0	
	C15 - C28	100 mg/kg	47	SVOC	2 to 5	2 to 6	Y	87 to 97	5	Y	ND	4	Y	4	8	Y		0	
	C16-C34	100 mg/kg	47	SVOC	2 to 5	2 to 6	Y	87 to 97	5	Y	ND	4	Y	5	8	Y		0	
	C29-C36	100 mg/kg	47	SVOC	2 to 5	2 to 6	Y	95 to 106	5	Y	ND	4	Y	11	8	Y		0	
	C34-C40	100 mg/kg	47	SVOC	2 to 5	2 to 6	Y	100 to 111	5	Y	ND	4	Y		8	Y		0	
	F2-NAPHTHALENE	50 mg/kg	47	SVOC	2 to 5	2 to 6	Y		0			0			4	Y		0	
	o-Terphenyl		0	SVOC			Y	86 to 99	5	Y		0			0	N	0 to 99	81	N
Total Mercury by FIMS																				
	Mercury		0	Specific	44444444	44444444	Y	95.9 to 95.9	1	Y	ND	1	Y		2	Y		0	

Total Metals by ICP-AES	Arsenic		0	Other	44444444	44444444	Y	92.9 to 92.9	1	Y	ND	1	Y		2	Y		0	
	Beryllium		0	Other	44444444	44444444	Y		0		ND	1	Y		2	Y		0	
	Cadmium		0	Other	44444444	44444444	Y	92.5 to 92.5	1	Y	ND	1	Y		2	Y		0	
	Lead		0	Other	44444444	44444444	Y	96.5 to 96.5	1	Y	ND	1	Y	0	2	Y		0	
	Molybdenum		0	Other	44444444	44444444	Y		0		ND	1	Y		2	Y		0	
	Nickel		0	Other	44444444	44444444	Y	93.6 to 93.6	1	Y	ND	1	Y		2	Y		0	
	Selenium		0	Other	44444444	44444444	Y		0		ND	1	Y		2	Y		0	
	Silver		0	Other	44444444	44444444	Y		0		ND	1	Y		2	Y		0	
TRH - Semivolatile Fraction	+C10 - C36 (Sum of total)		0	SVOC	44444444	4444467	Y		0			0			0	N		0	
	C10 - C14		0	SVOC	44444444	4444467	Y	99.9 to 99.9	2	Y	ND	2	Y		2	Y		0	
	C10 - C40 (Sum of total)		0	SVOC	44444444	4444467	Y		0			0			0	N		0	
	C10-C16		0	SVOC	44444444	4444467	Y	103 to 103	2	Y	ND	2	Y		2	Y		0	
	C15 - C28		0	SVOC	44444444	4444467	Y	102 to 102	2	Y	ND	2	Y	90	2	N		0	
	C16-C34		0	SVOC	44444444	4444467	Y	96.6 to 96.6	2	Y	ND	2	Y	94	2	N		0	
	C29-C36		0	SVOC	44444444	4444467	Y	75 to 75	2	Y	ND	2	Y		2	Y		0	
	C34-C40		0	SVOC	44444444	4444467	Y	50.2 to 50.2	2	N	ND	2	Y		2	Y		0	
	F2-NAPHTHALENE		0	SVOC	44444444	4444467	Y		0			0			0	N		0	
TRH Volatiles/BTEX	1,2-Dichloroethane-d4		0	VOC			Y	118 to 118	2	Y		0			0	N	102 to 119	15	Y
	4-Bromofluorobenzene		0	VOC			Y	98.6 to 98.6	2	Y		0			0	N	77.6 to 98.6	15	Y
	Benzene		0	VOC	4444467	4444467	Y	108 to 108	2	Y	ND	2	Y		4	Y		0	
	C6 - C9		0	VOC	4444467	4444467	Y	77.9 to 77.9	2	Y	ND	2	Y		4	Y		0	
	C6-C10		0	SVOC	4444467	4444467	Y	69.6 to 69.6	2	N	ND	2	Y		4	Y		0	
	C6-C10 less BTEX (F1)		0	SVOC	4444467	4444467	Y		0			0			0	N		0	
	Ethylbenzene		0	VOC	4444467	4444467	Y	91.2 to 91.2	2	Y	ND	2	Y		4	Y		0	
	Naphthalene		0	SVOC	4444467	4444467	Y	108 to 108	2	Y	ND	2	Y		4	Y		0	
	Toluene		0	VOC	4444467	4444467	Y	103 to 103	2	Y	ND	2	Y		4	Y		0	
	Toluene-D8		0	VOC			Y	98.2 to 98.2	2	Y		0			0	N	81.3 to 98.2	15	Y
	Total BTEX		0	SVOC	4444467	4444467	Y		0			0			0	N		0	
	Xylene (m & p)		0	VOC	4444467	4444467	Y	86.8 to 86.8	2	Y	ND	2	Y		4	Y		0	
	Xylene (o)		0	VOC	4444467	4444467	Y	94.5 to 94.5	2	Y	ND	2	Y		4	Y		0	
	Xylene Total		0	VOC	4444467	4444467	Y		0			0			0	N		0	
VOCs in soil	1,1,1,2-tetrachloroethane	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	1,1,1-trichloroethane	1 mg/kg	15	VOC	3	4	Y	85 to 93	2	Y	ND	2	Y		3	Y		0	
	1,1,2,2-tetrachloroethane	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	1,1,2-trichloroethane	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	1,1-dichloroethane	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	1,1-dichloroethene	1 mg/kg	15	VOC	3	4	Y	88 to 91	2	Y	ND	2	Y		3	Y		0	
	1,1-dichloropropene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	1,2,3-trichlorobenzene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	1,2,3-trichloropropane	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	1,2,4-trichlorobenzene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	1,2,4-trimethylbenzene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	1,2-dibromo-3-chloropropane	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	1,2-dibromoethane	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	1,2-dichlorobenzene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	1,2-dichloroethane	1 mg/kg	15	VOC	3	4	Y	86 to 88	2	Y	ND	2	Y		3	Y		0	
	1,2-dichloropropane	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	1,3,5-trimethylbenzene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	1,3-dichlorobenzene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	1,3-dichloropropane	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	1,4-dichlorobenzene	1 mg/kg	15	VOC	3	4	Y	83 to 88	2	Y	ND	2	Y		3	Y		0	
	2,2-dichloropropane	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	2-chlorotoluene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	4-Bromofluorobenzene		0	VOC			Y	100 to 102	2	Y		0			0	N	95 to 105	24	Y
	4-chlorotoluene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	Benzene	0.2 mg/kg	15	VOC	3	4	Y	89 to 94	2	Y	ND	2	Y		3	Y		0	
	Bromobenzene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	Bromochloromethane	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	Bromodichloromethane	1 mg/kg	15	VOC	3	4	Y	90 to 95	2	Y	ND	2	Y		3	Y		0	
	Bromoform	1 mg/kg	15	VOC	3	4	Y	84 to 88	2	Y	ND	2	Y		3	Y		0	
	Bromomethane	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	Carbon tetrachloride	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	Chlorobenzene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	Chlorodibromomethane	1 mg/kg	15	VOC	3	4	Y	87 to 92	2	Y	ND	2	Y		3	Y		0	
	Chloroethane	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	Chloroform	1 mg/kg	15	VOC	3	4	Y	85 to 91	2	Y	ND	2	Y		3	Y		0	
	Chloromethane	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	cis-1,2-dichloroethene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	cis-1,3-dichloropropene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	Cyclohexane	1 mg/kg	15	SVOC	3	4	Y		0		ND	2	Y		3	Y		0	
	Dibromofluoromethane		0	SVOC			Y	99 to 100	2	Y		0			0	N	90 to 108	24	Y
	Dibromomethane	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	Dichlorodifluoromethane	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	Ethylbenzene	1 mg/kg	15	VOC	3	4	Y	85 to 86	2	Y	ND	2	Y		3	Y		0	
	Hexachlorobutadiene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	Isopropylbenzene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	MTBE	0.5 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	

	n-butylbenzene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	n-propylbenzene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	p-isopropyltoluene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	sec-butylbenzene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	Styrene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	tert-butylbenzene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	Tetrachloroethene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	Toluene	0.5 mg/kg	15	VOC	3	4	Y	86 to 96	2	Y	ND	2	Y		3	Y		0	
	Toluene-D8		0	VOC			Y	87 to 94	2	Y	ND	2	Y		3	Y		0	
	trans-1,2-dichloroethene	1 mg/kg	15	VOC	3	4	Y	103 to 103	2	Y		0			0	N	97 to 107	24	Y
	trans-1,3-dichloropropene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	Trichloroethene	1 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	Trichlorofluoromethane	1 mg/kg	15	VOC	3	4	Y	87 to 97	2	Y	ND	2	Y		3	Y		0	
	Trifluorotoluene		0	SVOC			Y		0		ND	2	Y		3	Y		0	
	Vinyl chloride	1 mg/kg	15	VOC	3	4	Y	99 to 114	2	Y		0			0	N	88 to 116	24	Y
	Xylene (m & p)	2 mg/kg	15	VOC	3	4	Y		0		ND	2	Y		3	Y		0	
	Xylene (o)	1 mg/kg	15	VOC	3	4	Y	83 to 84	2	Y	ND	2	Y		3	Y		0	
								83 to 85	2	Y	ND	2	Y		3	Y		0	
vTRH(C6-C10)/MBTEXN in soil	Benzene	0.2 mg/kg	47	VOC	2 to 5	2 to 6	Y												
	C6 - C9	25 mg/kg	47	VOC	2 to 5	2 to 6	Y	89 to 110	5	Y	ND	4	Y		8	Y		0	
	C6-C10	25 mg/kg	47	SVOC	2 to 5	2 to 6	Y	86 to 107	5	Y	ND	4	Y		8	Y		0	
	C6-C10 less BTEX (F1)	25 mg/kg	47	SVOC	2 to 5	2 to 6	Y	86 to 107	5	Y	ND	4	Y		8	Y		0	
	Ethylbenzene	1 mg/kg	47	VOC	2 to 5	2 to 6	Y		0			0			8	Y		0	
	MTBE	0.5 mg/kg	47	VOC	2 to 5	2 to 6	Y	85 to 105	5	Y	ND	4	Y		8	Y		0	
	Naphthalene	1 mg/kg	47	SVOC	2 to 5	2 to 6	Y		0		ND	4	Y		8	Y		0	
	Toluene	0.5 mg/kg	47	VOC	2 to 5	2 to 6	Y		0		ND	4	Y		8	Y		0	
	Trifluorotoluene		0	SVOC			Y	87 to 110	5	Y	ND	4	Y		8	Y		0	
	Xylene (m & p)	2 mg/kg	47	VOC	2 to 5	2 to 6	Y	99 to 114	5	Y		0			0	N	80 to 123	81	Y
	Xylene (o)	1 mg/kg	47	VOC	2 to 5	2 to 6	Y	83 to 108	5	Y	ND	4	Y		8	Y		0	
								83 to 107	5	Y	ND	4	Y		8	Y		0	
Speciated Phenols in Soil	2,3,4,6-tetrachlorophenol		0	SVOC			Y												
	2,4,5-trichlorophenol		0	SVOC			Y		0		ND	2	Y		0	N		0	
	2,4,6-trichlorophenol		0	SVOC			Y		0		ND	2	Y		0	N		0	
	2,4-dichlorophenol		0	SVOC			Y		0		ND	2	Y		0	N		0	
	2,4-dimethylphenol		0	SVOC			Y		0		ND	2	Y		0	N		0	
	2,4-dinitrophenol		0	SVOC			Y		0		ND	2	Y		0	N		0	
	2,6-dichlorophenol		0	SVOC			Y		0		ND	2	Y		0	N		0	
	2-chlorophenol		0	SVOC			Y	117 to 122	2	Y	ND	2	Y		0	N		0	
	2-methylphenol		0	SVOC			Y	110 to 112	2	Y	ND	2	Y		0	N		0	
	2-nitrophenol		0	SVOC			Y	102 to 102	2	Y	ND	2	Y		0	N		0	
	4,6-Dinitro-2-methylphenol		0	SVOC			Y		0		ND	2	Y		0	N		0	
	4-chloro-3-methylphenol		0	SVOC			Y		0		ND	2	Y		0	N		0	
	4-methylphenol		0	SVOC			Y		0		ND	2	Y		0	N		0	
	4-nitrophenol		0	SVOC			Y		0		ND	2	Y		0	N		0	
	Pentachlorophenol		0	SVOC			Y		0		ND	2	Y		0	N		0	
	Phenol		0	SVOC			Y		0		ND	2	Y		0	N		0	
								98 to 101	2	Y	ND	2	Y		0	N		0	

Matrix,Trip and Compound Spikes			Field,Rinsate and Trip Blanks			Field Duplicates		
Recovery %	Num Reported	Acceptable	Range	Num Reported	Acceptable	Max RPD > EQL x 1	Num Reported	Acceptable
	0			0			0	N
	0			0			0	N
80 to 80	1	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
86 to 86	1	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
110 to 110	1	Y		0			0	N
	0			0			0	N
81 to 81	1	Y		0			0	N
126 to 126	1	Y		0			0	N
	0			0			0	N
	0			0			0	N
102 to 102	1	Y		0			0	N
117 to 117	1	Y		0			0	N
91.1 to 91.1	1	Y		0			0	N
95 to 96	2	Y	ND	1	Y	0	1	Y
98 to 107	2	Y	ND	1	Y		1	Y
87 to 105	2	Y	ND	1	Y		1	Y
94 to 101	2	Y	ND	1	Y	15	1	Y
94 to 94	2	Y	ND	1	Y		1	Y
74 to 75	2	Y	ND	1	Y		1	Y
95 to 103	2	Y	ND	1	Y		1	Y
89 to 89	1	Y	ND	1	Y		1	Y
101 to 103	2	Y	ND	1	Y		1	Y
92 to 101	2	Y	ND	1	Y	67	1	Y
105 to 105	1	Y	ND	1	Y		1	Y
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
81 to 81	1	Y		0			0	N
	0			0			0	N
	0			0			0	N
98 to 98	1	Y		0			0	N
93 to 93	1	Y		0			0	N
	0			0			0	N
106 to 106	1	Y		0			0	N
	0			0			0	N
	0			0			0	N
90 to 90	1	Y		0			0	N
	0		0.27 to 17 %	6	N	14	5	Y
	0			0			0	N
100 to 104	3	Y	ND	4	Y	13	3	Y
94 to 99	3	Y	ND	4	Y		3	Y
82 to 88	3	Y	ND	4	Y	0	3	Y
92 to 100	3	Y	ND	4	Y		3	Y
	0		ND	4	Y	19	3	Y
93 to 98	3	Y	ND	4	Y	0	3	Y
93 to 110	3	Y	ND	4	Y	67	3	Y
75 to 100	3	Y	ND	4	Y	17	3	Y
96 to 110	2	Y	ND	4	Y	51	3	N
98 to 98	3	Y	ND	4	Y		3	Y

94 to 97	3	Y	ND	4	Y	67	3	Y
80 to 81	3	Y	ND	4	Y		3	Y
71 to 105	2	Y	ND	4	Y	167	3	N
92 to 92	1	Y		0			1	Y
118 to 118	1	Y		0			1	Y
	0			0			1	Y
	0			0			1	Y
	0			0			1	Y
	0			0			1	Y
120 to 120	1	Y		0			1	Y
103 to 103	1	Y		0			1	Y
	0			0			1	Y
125 to 125	1	Y		0			1	Y
	0			0			1	Y
	0			0			1	Y
94 to 94	1	Y		0			1	Y
105 to 105	1	Y		0			1	Y
	0			0			1	Y
	0			0			1	Y
	0			0			1	Y
74 to 74	1	Y		0			1	Y
113 to 113	1	Y		0			1	Y
	0			0			1	Y
	0			0			1	Y
	0		ND	4	Y		2	Y
	0		ND	4	Y		2	Y
94 to 100	2	Y	ND	4	Y		2	Y
78 to 97	2	Y	ND	4	Y		2	Y
	0		ND	4	Y		2	Y
	0		ND	4	Y		2	Y
	0		ND	4	Y		2	Y
92 to 109	2	Y	ND	4	Y		2	Y
70 to 83	2	Y	ND	4	Y		2	Y
	0		ND	4	Y		2	Y
	0		ND	4	Y		2	Y
96 to 112	2	Y	92 to 131	4	N		2	Y
	0		ND	4	Y		2	Y
100 to 100	1	Y		0			0	N
	0			0			0	N
	0			0			0	N
81 to 81	1	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
113 to 113	1	Y		0			0	N
	0			0			0	N
	0			0			0	N
109 to 109	1	Y		0			0	N
	0			0			0	N
115 to 115	1	Y		0			0	N
92 to 92	1	Y		0			0	N
	0			0			0	N
96 to 96	1	Y		0			0	N
	0			0			0	N
	0			0			0	N
112 to 112	1	Y		0			0	N
112 to 112	1	Y		0			0	N
	0		ND	4	Y		2	Y
	0		ND	4	Y		2	Y
	0		ND	4	Y		2	Y
	0		ND	4	Y		2	Y
	0		ND	4	Y		2	Y
110 to 125	2	Y	ND	4	Y		2	Y
	0		ND	4	Y		2	Y
	0			0			0	N
	0			0			0	N
88.4 to 88.4	1	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
83.1 to 83.1	1	Y		0			0	N
	0			0			0	N

	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
76.9 to 76.9	1	Y		0			0	N
	0			0			0	N
	0			0			0	N
87.1 to 87.1	1	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
86.3 to 86.3	1	Y		0			0	N
	0			0			0	N
	0			0			0	N
86.1 to 86.1	1	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
87 to 87	1	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
85.4 to 85.4	1	Y		0			0	N
78.8 to 78.8	1	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
89.2 to 89.2	1	Y		0			0	N
82.8 to 82.8	1	Y		0			0	N
	0			0			0	N
83 to 83	1	Y		0			0	N
83 to 83	1	Y		0			0	N
	0			0			0	N
99 to 99	1	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
92 to 92	1	Y		0			0	N
62 to 62	1	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
95 to 95	1	Y		0			0	N
	0			0			0	N
85 to 122	4	Y	ND	8	Y		5	Y
84 to 120	4	Y	ND	8	Y	95	5	N
85 to 98	4	Y	ND	8	Y	179	5	N
86 to 99	4	Y	ND	8	Y	179	5	N
95 to 120	4	Y	ND	8	Y		5	Y
89 to 110	4	Y	ND	8	Y		5	Y
	0		ND	8	Y	95	5	N
	0			0			0	N
83 to 83	1	Y		0			0	N

75.1 to 75.1	1	Y		0			0	N
109 to 109	1	Y		0			0	N
99.4 to 99.4	1	Y		0			0	N
97.8 to 97.8	1	Y		0			0	N
76 to 76	1	Y		0			0	N
102 to 102	1	Y		0			0	N
40.3 to 40.3	1	Y		0			0	N
103 to 103	1	Y		0			0	N
	0			0			0	N
112 to 112	2	Y		0			0	N
	0			0			0	N
113 to 113	2	Y		0			0	N
115 to 115	2	Y		0			0	N
112 to 112	2	Y		0			0	N
95.1 to 95.1	2	Y		0			0	N
91.7 to 91.7	2	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
88 to 88	2	Y		0			0	N
88.1 to 88.1	2	Y		0			0	N
88.2 to 88.2	2	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
92.8 to 92.8	2	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
90 to 95	2	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
94 to 94	2	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
91 to 93	2	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
85 to 91	2	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
94 to 97	2	Y		0			0	N
	0			0			0	N
	0			0			0	N
95 to 98	2	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
93 to 94	2	Y		0			0	N
	0			0			0	N
91 to 94	2	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
82 to 94	2	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N

	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
93 to 97	2	Y		0			0	N
93 to 96	2	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
93 to 102	2	Y		0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
83 to 92	2	Y		0			0	N
82 to 92	2	Y		0			0	N
94 to 107	4	Y	ND	8	Y		5	Y
86 to 101	4	Y	ND	8	Y		5	Y
86 to 101	4	Y	ND	8	Y		5	Y
	0		ND	8	Y		5	Y
82 to 100	4	Y	ND	8	Y		5	Y
	0		ND	8	Y		5	Y
	0		ND	8	Y		5	Y
93 to 107	4	Y	ND	8	Y		5	Y
	0			0			0	N
83 to 103	4	Y	ND	8	Y		5	Y
82 to 101	4	Y	ND	8	Y		5	Y
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N
	0			0			0	N

Field Duplicates (SOIL)
Filter: ALL

Method_T	ChemNam	Units	EQL	SDG	ENVIROLAB 2015-11-02T00:00:00	ENVIROLAB 2015-11-02T00:00:00	RPD	ENVIROLAB 2015-11-02T00:00:00	ENVIROLAB 2015-11-02T00:00:00	RPD	ENVIROLAB 2015-11-25T00:00:00	ENVIROLAB 2015-11-25T00:00:00	RPD	ENVIROLAB 2015-11-25T00:00:00	ENVIROLAB 2015-11-25T00:00:00
				Field ID	APEC-J-01	JQA1		APEC-G-01	QA1		APEC-K-01	APEC-K-QA1		APEC-K-03	APEC-K-QA2
				Sampled Date/Time	30/10/2015	30/10/2015		29/10/2015	29/10/2015		23/11/2015	23/11/2015		23/11/2015	23/11/2015
vTRH(C6-	Benzene	mg/kg	0.2		<0.2	<0.2	0	<0.2	<0.2	0	<0.2	<0.2	0	<0.2	<0.2
	Ethylbenze	mg/kg	1 (Primary): 0.5 (Interlab		<1.0	<1.0	0	<1.0	<1.0	0	<1.0	<1.0	0	<1.0	<1.0
	Toluene	mg/kg	0.5		<0.5	<0.5	0	<0.5	<0.5	0	<0.5	<0.5	0	<0.5	<0.5
	Xylene (m	mg/kg	2 (Primary): 0.5 (Interlab		<2.0	<2.0	0	<2.0	<2.0	0	<2.0	<2.0	0	<2.0	<2.0
	Xylene (o)	mg/kg	1 (Primary): 0.5 (Interlab		<1.0	<1.0	0	<1.0	<1.0	0	<1.0	<1.0	0	<1.0	<1.0
	C6-C10 les	mg/kg	25 (Primary): 10 (Interlat		<25.0	<25.0	0	<25.0	<25.0	0	<25.0	<25.0	0	<25.0	<25.0
C10)/MBTEXN in soil															
Organochl	Hexachlor	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
orine Pesticides															
Moisture	Moisture	%	0.1 (Primary): 1 (Interlab		17.0	15.0	13	4.4	4.0	10	16.0	16.0	0	13.0	15.0
Landfill Cla	Lead	mg/kg	1 (Primary): 5 (Interlab)		7.0	6.0	15								
ssification Metals															
NEPM Suit	Lead	mg/kg	1								8.0	9.0	12	11.0	10.0
e 1 - Metals															
Landfill Cla	Arsenic	mg/kg	2 (Primary): 5 (Interlab)		5.0	5.0	0								
	Cadmium	mg/kg	0.4 (Primary): 1 (Interlab		<0.4	<0.4	0								
	Copper	mg/kg	1		<1.0	<1.0	0								
	Mercury	mg/kg	0.1		<0.1	<0.1	0								
	Molybdenu	mg/kg	1 (Primary): 2 (Interlab)		<1.0	<1.0	0								
	Nickel	mg/kg	1 (Primary): 2 (Interlab)		<1.0	<1.0	0								
	Selenium	mg/kg	2 (Primary): 5 (Interlab)		<2.0	<2.0	0								
	Silver	mg/kg	1 (Primary): 2 (Interlab)		<1.0	<1.0	0								
	Tin	mg/kg	1		2.0	1.0	67								
	Zinc	mg/kg	1		<1.0	<1.0	0								
ssification Metals															
NEPM Suit	Arsenic	mg/kg	2								7.0	8.0	13	11.0	10.0
	Beryllium	mg/kg	1								<1.0	<1.0	0	<1.0	<1.0
	Boron	mg/kg	3								<3.0	<3.0	0	<3.0	<3.0
	Cadmium	mg/kg	0.4								<0.4	<0.4	0	<0.4	<0.4
	Chromium	mg/kg	1								70.0	85.0	19	88.0	94.0
	Cobalt	mg/kg	1								2.0	2.0	0	2.0	2.0
	Copper	mg/kg	1								<1.0	<1.0	0	2.0	<1.0
	Manganes	mg/kg	1								27.0	19.0	35	**52.0**	**31.0**
	Mercury	mg/kg	0.1								<0.1	<0.1	0	<0.1	<0.1
	Nickel	mg/kg	1								2.0	1.0	67	3.0	2.0
	Selenium	mg/kg	2								<2.0	<2.0	0	<2.0	<2.0
	Zinc	mg/kg	1								1.0	<1.0	0	**11.0**	**1.0**
e 1 - Metals															
Organochl	a-BHC	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	Aldrin	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	b-BHC	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	Chlordane	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	Chlordane	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	d-BHC	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	DDD	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	DDE	mg/kg	0.1					<0.1	<0.1	0					
	DDT	mg/kg	0.1 (Primary): 0.2 (Interlab)					<0.1	<0.1	0					
	Dieldrin	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	Endosulfar	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	Endosulfar	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	Endosulfar	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	Endrin	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	Endrin ald	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	Endrin ket	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	g-BHC (Lir	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	Heptachlor	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	Heptachlor	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	Methoxych	mg/kg	0.1 (Primary): 0.2 (Interlab)					<0.1	<0.1	0					
orine Pesticides															
Organopho	Azinophos	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	Bromopho	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	Chlorpyrifo	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	Chlorpyrifo	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	Diazinon	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	Dichlorvos	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	Dimethoat	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	Ethion	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	Fenitrothio	mg/kg	0.1					<0.1	<0.1	0					
	Malathion	mg/kg	0.1 (Primary): 0.05 (Interlab)					<0.1	<0.1	0					
	Ronnel	mg/kg	0.1					<0.1	<0.1	0					
sphorus Pesticides															
vTRH(C6-	Naphthale	mg/kg	1		<1.0	<1.0	0	<1.0	<1.0	0	<1.0	<1.0	0	<1.0	<1.0
C10)/MBTEXN in soil															
Organoph	Parathion	mg/kg	0.1 (Primary): 0.2 (Interlab)					<0.1	<0.1	0					
sphorus Pesticides															
PCBs in S	Arochlor 1	mg/kg	0.1					<0.1	<0.1	0					
	Arochlor 1	mg/kg	0.1					<0.1	<0.1	0					
	Arochlor 1	mg/kg	0.1					<0.1	<0.1	0					

Field Duplicates (SOIL)
Filter: ALL

				SDG	ENVIROLAB 2015-11-02T00:00:00	ENVIROLAB 2015-11-02T00:00:00		ENVIROLAB 2015-11-02T00:00:00	ENVIROLAB 2015-11-02T00:00:00		ENVIROLAB 2015-11-25T00:00:00	ENVIROLAB 2015-11-25T00:00:00		ENVIROLAB 2015-11-25T00:00:00	ENVIROLAB 2015-11-25T00:00:00
				Field ID	APEC-J-01	JQA1	RPD	APEC-G-01	QA1	RPD	APEC-K-01	APEC-K-QA1	RPD	APEC-K-03	APEC-K-QA2
				Sampled Date/Time	30/10/2015	30/10/2015		29/10/2015	29/10/2015		23/11/2015	23/11/2015		23/11/2015	23/11/2015
	Arochlor 1	mg/kg	0.1				<0.1	<0.1	0					
	Arochlor 1	mg/kg	0.1				<0.1	<0.1	0					
	Arochlor 1	mg/kg	0.1				<0.1	<0.1	0					
	Arochlor 1	mg/kg	0.1				<0.1	<0.1	0					
oil															
vTRH(C6-(	MTBE	mg/kg	0.5	<0.5	<0.5	0	<0.5	<0.5	0	<0.5	<0.5	0	<0.5	<0.5
C10)/MBTEXN in soil															
svTRH(C1	C10-C16	mg/kg	50	<50.0	<50.0	0	**140.0**	**<50.0**	**95**	<50.0	<50.0	0	<50.0	<50.0
	C16-C34	mg/kg	100	<100.0	<100.0	0	**1800.0**	**<100.0**	**179**	<100.0	<100.0	0	<100.0	<100.0
	C34-C40	mg/kg	100	<100.0	<100.0	0	<100.0	<100.0	0	<100.0	<100.0	0	<100.0	<100.0
	F2-NAPHT	mg/kg	50	<50.0	<50.0	0	**140.0**	**<50.0**	**95**	<50.0	<50.0	0	<50.0	<50.0
	C10 - C14	mg/kg	50	<50.0	<50.0	0	<50.0	<50.0	0	<50.0	<50.0	0	<50.0	<50.0
	C15 - C28	mg/kg	100	<100.0	<100.0	0	**1800.0**	**<100.0**	**179**	<100.0	<100.0	0	<100.0	<100.0
	C29-C36	mg/kg	100	<100.0	<100.0	0	<100.0	<100.0	0	<100.0	<100.0	0	<100.0	<100.0
)-C36) in soil															
vTRH(C6-(	C6 - C9	mg/kg	25 (Primary): 10 (Interlat	<25.0	<25.0	0	<25.0	<25.0	0	<25.0	<25.0	0	<25.0	<25.0
	C6-C10	mg/kg	25 (Primary): 10 (Interlat	<25.0	<25.0	0	<25.0	<25.0	0	<25.0	<25.0	0	<25.0	<25.0

*RPDs have only been considered where a concentration is greater than 1 times the EQL.
**High RPDs are in bold (Acceptable RPDs for each EQL multiplier range are: 80 (1-10 x EQL); 50 (10-30 x EQL); 30 (> 30 x EQL))
***Interlab Duplicates are matched on a per compound basis as methods vary between laboratories. Any methods in the row header relate to those used in the primary laboratory

Field Duplicates (SOIL)
Filter: ALL

				SDG		174217	174217		ENVIROLAB 2015-11-02T00:00:00	Interlab_D		ENVIROLAB 2015-11-02T00:00:00	Interlab_D	
				Field ID	RPD	APEC-G3-01	APEC-G3-QA1	RPD	APEC-G-01	QA2	RPD	APEC-J-01	J QA2	RPD
				Sampled Date/Time		30/11/2015	30/11/2015		29/10/2015	29/10/2015		30/10/2015	30/10/2015	
Method_T	ChemNam	Units	EQL											
vTRH(C6-	Benzene	mg/kg	0.2	0	<0.2	<0.2	0	<0.2	<0.2	0	<0.2	<0.2	0	
	Ethylbenze	mg/kg	1 (Primary): 0.5 (Interlab	0	<1.0	<1.0	0	<1.0	<0.5	0	<1.0	<0.5	0	
	Toluene	mg/kg	0.5	0	<0.5	<0.5	0	<0.5	<0.5	0	<0.5	<0.5	0	
	Xylene (m	mg/kg	2 (Primary): 0.5 (Interlab	0	<2.0	<2.0	0	<2.0	<0.5	0	<2.0	<0.5	0	
	Xylene (o)	mg/kg	1 (Primary): 0.5 (Interlab	0	<1.0	<1.0	0	<1.0	<0.5	0	<1.0	<0.5	0	
	C6-C10 les	mg/kg	25 (Primary): 10 (Interlat	0	<25.0	<25.0	0	<25.0	<10.0	0	<25.0	<10.0	0	
210)/MBTEXN in soil														
Organochl	Hexachlor	mg/kg	0.1 (Primary): 0.05 (Inter					<0.1	<0.05	0				
orine Pesticides														
Moisture	Moisture	%	0.1 (Primary): 1 (Interlab	14	6.5	7.0	7	4.4	5.8	27	17.0	17.6	3	
Landfill Cla	Lead	mg/kg	1 (Primary): 5 (Interlab)								7.0	5.0	33	
ssification Metals														
NEPM Sui	Lead	mg/kg	1	10	11.0	13.0	17							
e 1 - Metals														
Landfill Cla	Arsenic	mg/kg	2 (Primary): 5 (Interlab)								5.0	<5.0	0	
	Cadmium	mg/kg	0.4 (Primary): 1 (Interlab								<0.4	<1.0	0	
	Copper	mg/kg	1								<1.0			
	Mercury	mg/kg	0.1								<0.1	<0.1	0	
	Molybdenu	mg/kg	1 (Primary): 2 (Interlab)								<1.0	<2.0	0	
	Nickel	mg/kg	1 (Primary): 2 (Interlab)								<1.0	<2.0	0	
	Selenium	mg/kg	2 (Primary): 5 (Interlab)								<2.0	<5.0	0	
	Silver	mg/kg	1 (Primary): 2 (Interlab)								<1.0	<2.0	0	
	Tin	mg/kg	1								2.0			
	Zinc	mg/kg	1								<1.0			
ssification Metals														
NEPM Sui	Arsenic	mg/kg	2	10	10.0	10.0	0							
	Beryllium	mg/kg	1	0	<1.0	<1.0	0							
	Boron	mg/kg	3	0	3.0	<3.0	0							
	Cadmium	mg/kg	0.4	0	<0.4	<0.4	0							
	Chromium	mg/kg	1	7	83.0	85.0	2							
	Cobalt	mg/kg	1	0	2.0	2.0	0							
	Copper	mg/kg	1	67	2.0	2.0	0							
	Manganes	mg/kg	1	51	42.0	44.0	5							
	Mercury	mg/kg	0.1	0	<0.1	<0.1	0							
	Nickel	mg/kg	1	40	2.0	2.0	0							
	Selenium	mg/kg	2	0	<2.0	<2.0	0							
	Zinc	mg/kg	1	167	20.0	9.0	76							
e 1 - Metals														
Organochl	a-BHC	mg/kg	0.1 (Primary): 0.05 (Inter					<0.1	<0.05	0				
	Aldrin	mg/kg	0.1 (Primary): 0.05 (Inter					<0.1	<0.05	0				
	b-BHC	mg/kg	0.1 (Primary): 0.05 (Inter					<0.1	<0.05	0				
	Chlordane	mg/kg	0.1 (Primary): 0.05 (Inter					<0.1	<0.05	0				
	Chlordane	mg/kg	0.1 (Primary): 0.05 (Inter					<0.1	<0.05	0				
	d-BHC	mg/kg	0.1 (Primary): 0.05 (Inter					<0.1	<0.05	0				
	DDD	mg/kg	0.1 (Primary): 0.05 (Inter					<0.1	<0.05	0				
	DDE	mg/kg	0.1					<0.1						
	DDT	mg/kg	0.1 (Primary): 0.2 (Interla					<0.1	<0.2	0				
	Dieldrin	mg/kg	0.1 (Primary): 0.05 (Inter					<0.1	<0.05	0				
	Endosulfar	mg/kg	0.1 (Primary): 0.05 (Inter					<0.1	<0.05	0				
	Endosulfar	mg/kg	0.1 (Primary): 0.05 (Inter					<0.1	<0.05	0				
	Endosulfar	mg/kg	0.1 (Primary): 0.05 (Inter					<0.1	<0.05	0				
	Endrin	mg/kg	0.1 (Primary): 0.05 (Inter					<0.1	<0.05	0				
	Endrin ald	mg/kg	0.1 (Primary): 0.05 (Inter					<0.1	<0.05	0				
	Endrin ket	mg/kg	0.1 (Primary): 0.05 (Inter					<0.1	<0.05	0				
	g-BHC (Lir	mg/kg	0.1 (Primary): 0.05 (Inter					<0.1	<0.05	0				
	Heptachlor	mg/kg	0.1 (Primary): 0.05 (Inter					<0.1	<0.05	0				
	Heptachlo	mg/kg	0.1 (Primary): 0.05 (Inter					<0.1	<0.05	0				
	Methoxych	mg/kg	0.1 (Primary): 0.2 (Interla					<0.1	<0.2	0				
orine Pesticides														
Organoph	Azinophos	mg/kg	0.1 (Primary): 0.05 (Inter		<0.1	<0.1	0	<0.1	<0.05	0				
	Bromopho	mg/kg	0.1 (Primary): 0.05 (Inter		<0.1	<0.1	0	<0.1	<0.05	0				
	Chlorpyrifo	mg/kg	0.1 (Primary): 0.05 (Inter		<0.1	<0.1	0	<0.1	<0.05	0				
	Chlorpyrifo	mg/kg	0.1 (Primary): 0.05 (Inter		<0.1	<0.1	0	<0.1	<0.05	0				
	Diazinon	mg/kg	0.1 (Primary): 0.05 (Inter		<0.1	<0.1	0	<0.1	<0.05	0				
	Dichlorvos	mg/kg	0.1 (Primary): 0.05 (Inter		<0.1	<0.1	0	<0.1	<0.05	0				
	Dimethoat	mg/kg	0.1 (Primary): 0.05 (Inter		<0.1	<0.1	0	<0.1	<0.05	0				
	Ethion	mg/kg	0.1 (Primary): 0.05 (Inter		<0.1	<0.1	0	<0.1	<0.05	0				
	Fenitrothio	mg/kg	0.1		<0.1	<0.1	0	<0.1						
	Malathion	mg/kg	0.1 (Primary): 0.05 (Inter		<0.1	<0.1	0	<0.1	<0.05	0				
	Ronnel	mg/kg	0.1		<0.1	<0.1	0	<0.1						
sphorus Pesticides														
vTRH(C6-	Naphthale	mg/kg	1	0	<1.0	<1.0	0	<1.0	<1.0	0	<1.0	<1.0	0	
210)/MBTEXN in soil														
Organoph	Parathion	mg/kg	0.1 (Primary): 0.2 (Interla		<0.1	<0.1	0	<0.1	<0.2	0				
sphorus Pesticides														
PCBs in S	Arochlor 1	mg/kg	0.1		<0.1	<0.1	0	<0.1						
	Arochlor 1	mg/kg	0.1		<0.1	<0.1	0	<0.1						
	Arochlor 1	mg/kg	0.1		<0.1	<0.1	0	<0.1						

Field Duplicates (SOIL)
Filter: ALL

				SDG		174217	174217		ENVIROLAB 2015-11-02T00:00:00	Interlab_D		ENVIROLAB 2015-11-02T00:00:00	Interlab_D	
				Field ID	RPD	APEC-G3-01	APEC-G3-QA1	RPD	APEC-G-01	QA2	RPD	APEC-J-01	J QA2	RPD
				Sampled Date/Time		30/11/2015	30/11/2015		29/10/2015	29/10/2015		30/10/2015	30/10/2015	
	Arochlor 1	mg/kg	0.1		<0.1	<0.1	0	<0.1						
	Arochlor 1	mg/kg	0.1		<0.1	<0.1	0	<0.1						
	Arochlor 1	mg/kg	0.1		<0.1	<0.1	0	<0.1						
	Arochlor 1	mg/kg	0.1		<0.1	<0.1	0	<0.1						
oil														
vTRH(C6-(	MTBE	mg/kg	0.5	0	<0.5	<0.5	0	<0.5				<0.5		
C10)/MBTEXN in soil														
svTRH(C1	C10-C16	mg/kg	50	0	<50.0	<50.0	0	**140.0**	**<50.0**	**95**		<50.0	<50.0	0
	C16-C34	mg/kg	100	0	<100.0	<100.0	0	**1800.0**	**130.0**	**173**		<100.0	<100.0	0
	C34-C40	mg/kg	100	0	<100.0	<100.0	0	<100.0	<100.0	0		<100.0	<100.0	0
	F2-NAPHT	mg/kg	50	0	<50.0	<50.0	0	**140.0**	**<50.0**	**95**		<50.0	<50.0	0
	C10 - C14	mg/kg	50	0	<50.0	<50.0	0	<50.0	<50.0	0		<50.0	<50.0	0
	C15 - C28	mg/kg	100	0	<100.0	<100.0	0	**1800.0**	**140.0**	**171**		<100.0	<100.0	0
	C29-C36	mg/kg	100	0	<100.0	<100.0	0	<100.0	<100.0	0		<100.0	<100.0	0
0-C36) in soil														
vTRH(C6-(	C6 - C9	mg/kg	25 (Primary): 10 (Interlat	0	<25.0	<25.0	0	<25.0	<10.0	0		<25.0	<10.0	0
	C6-C10	mg/kg	25 (Primary): 10 (Interlat	0	<25.0	<25.0	0	<25.0	<10.0	0		<25.0	<10.0	0

*RPDs have only been considered where a concentratic
**High RPDs are in bold (Acceptable RPDs for each EC
***Interlab Duplicates are matched on a per compound

Field Blanks (SOIL)
Filter: ALL

SDG	ENVIROLAB 2015-11-02T00:00:00	ENVIROLAB 2015-11-02T00:00:00	ENVIROLAB 2015-11-25T00:00:00	174217	ENVIROLAB 2015-11-02T00:00:00
Field ID	Field Blank 2	Field Blank	Field Blank	Field Blank	Trip Blank
Sampled_Date/Time	30/10/2015	29/10/2015	24/11/2015	30/11/2015	
Sample Type	Field_B	Field_B	Field_B	Field_B	Trip_B

Method_Type	ChemName	Units	EQL					
Acid Herbicides in Soil	2-(2-Methyl-1,4-chlorophenoxy) propionic acid	mg/kg	0.5					
	2,4,5-Trichlorophenoxy Acetic Acid	mg/kg	0.5					
	2,4,5-TP (Silvex)	mg/kg	0.5					
	2,4,6-trichlorophenol	mg/kg	0.5					
	Hedonal	mg/kg	0.5					
	2,4-Dichlorprop	mg/kg	0.5					
	4-(2,4-Dichlorophenoxy)butyric Acid (2,4-DB)	mg/kg	0.5					
	2-Chlorophenoxyacetic acid	mg/kg	0.5					
	4-Chlorophenoxy acetic acid	mg/kg	0.5					
	3,5-Dichlorobenzoic acid	mg/kg	0.5					
	Acifluorfen	mg/kg	2					
	Actril (loxynil)	mg/kg	1					
	Bromoxynil	mg/kg	0.5					
	Clopyralid	mg/kg	0.5					
	Dacthal	mg/kg	0.5					
	Dicamba	mg/kg	0.5					
	Dinoseb	mg/kg	1					
	2-Methyl-4-chlorophenoxyacetic acid	mg/kg	0.5					
	2-Methyl-4-Chlorophenoxy Butanoic Acid	mg/kg	0.5					
	Mecoprop	mg/kg	0.5					
	Picloram	mg/kg	0.5					
	Triclopyr	mg/kg	0.5					
Cyanides in Soil	Cyanide (Free)	mg/kg	0.5					
	Cyanide Total	mg/kg	0.5					
Hexavalent Chromium by Alkaline Digestion and DA F	Chromium (hexavalent)	mg/kg	0.5					
Landfill Classification Metals	Arsenic	mg/kg	2	<2				
	Cadmium	mg/kg	0.4	<0.4				
	Copper	mg/kg	1	<1				
	Lead	mg/kg	1	<1				
	Mercury	mg/kg	0.1	<0.1				
	Molybdenum	mg/kg	1	<1				
	Nickel	mg/kg	1	<1				
	Selenium	mg/kg	2	<2				
	Silver	mg/kg	1	<1				
	Tin	mg/kg	1	<1				
	Zinc	mg/kg	1	<1				
Metals - soil	Arsenic	mg/kg	2					
	Cadmium	mg/kg	0.4					
	Copper	mg/kg	1					
	Lead	mg/kg	1					
	Mercury	mg/kg	0.1					
	Molybdenum	mg/kg	1					
	Nickel	mg/kg	1					
	Selenium	mg/kg	2					
	Silver	mg/kg	1					
	Tin	mg/kg	1					
	Zinc	mg/kg	1					
Miscellaneous Inorg - soil	Chromium (hexavalent)	mg/kg	1					
	Fluoride	mg/kg	50					
Miscellaneous Organics - Soil	2,4-Dinitrotoluene	mg/kg	1					
	Nitrobenzene	mg/kg	1					
Moisture	Moisture	%	0.1	**1.4**		**0.31**	**0.54**	**1.2**
Moisture Content	Moisture	%	1					
NEPM Suite 1 - Metals	Arsenic	mg/kg	2			<2	<2	
	Beryllium	mg/kg	1			<1	<1	

Field Blanks (SOIL)
Filter: ALL

			SDG	ENVIROLAB 2015-11-02T00:00:00	ENVIROLAB 2015-11-02T00:00:00	ENVIROLAB 2015-11-25T00:00:00	174217	ENVIROLAB 2015-11-02T00:00:00
			Field ID	Field Blank 2	Field Blank	Field Blank	Field Blank	Trip Blank
			Sampled_Date/Time	30/10/2015	29/10/2015	24/11/2015	30/11/2015	
			Sample Type	Field_B	Field_B	Field_B	Field_B	Trip_B
	Boron	mg/kg	3			<3	<3	
	Cadmium	mg/kg	0.4			<0.4	<0.4	
	Chromium (III+VI)	mg/kg	1			<1	<1	
	Cobalt	mg/kg	1			<1	<1	
	Copper	mg/kg	1			<1	<1	
	Lead	mg/kg	1			<1	<1	
	Manganese	mg/kg	1			<1	<1	
	Mercury	mg/kg	0.1			<0.1	<0.1	
	Nickel	mg/kg	1			<1	<1	
	Selenium	mg/kg	2			<2	<2	
	Zinc	mg/kg	1			<1	<1	
Organochlorine Pesticides	a-BHC	mg/kg	0.1					
	Aldrin	mg/kg	0.1					
	b-BHC	mg/kg	0.1					
	Chlordane (cis)	mg/kg	0.1					
	Chlordane (trans)	mg/kg	0.1					
	d-BHC	mg/kg	0.1					
	DDD	mg/kg	0.1					
	DDE	mg/kg	0.1					
	DDT	mg/kg	0.1					
	Dieldrin	mg/kg	0.1					
	Endosulfan I	mg/kg	0.1					
	Endosulfan II	mg/kg	0.1					
	Endosulfan sulphate	mg/kg	0.1					
	Endrin	mg/kg	0.1					
	Endrin aldehyde	mg/kg	0.1					
	Endrin ketone	mg/kg	0.1					
	g-BHC (Lindane)	mg/kg	0.1					
	Heptachlor	mg/kg	0.1					
	Heptachlor epoxide	mg/kg	0.1					
	Hexachlorobenzene	mg/kg	0.1					
	Methoxychlor	mg/kg	0.1					
Organophosphorus Pesticides	Azinophos methyl	mg/kg	0.1			<0.1	<0.1	
	Bromophos-ethyl	mg/kg	0.1			<0.1	<0.1	
	Chlorpyrifos	mg/kg	0.1			<0.1	<0.1	
	Chlorpyrifos-methyl	mg/kg	0.1			<0.1	<0.1	
	Diazinon	mg/kg	0.1			<0.1	<0.1	
	Dichlorvos	mg/kg	0.1			<0.1	<0.1	
	Dimethoate	mg/kg	0.1			<0.1	<0.1	
	Ethion	mg/kg	0.1			<0.1	<0.1	
	Fenitrothion	mg/kg	0.1			<0.1	<0.1	
	Malathion	mg/kg	0.1			<0.1	<0.1	
	Parathion	mg/kg	0.1			<0.1	<0.1	
	Ronnel	mg/kg	0.1			<0.1	<0.1	
Other Inorganic Species	Chromium (hexavalent)	mg/kg	1					
	Cyanide (Free)	mg/kg	0.5					
	Cyanide Total	mg/kg	0.5					
	Fluoride	mg/kg	50					
PAHs in Soil	B(a)P Total Potency Equivalent	mg/kg	0.5					
	Acenaphthene	mg/kg	0.1					
	Acenaphthylene	mg/kg	0.1					
	Anthracene	mg/kg	0.1					
	Benz(a)anthracene	mg/kg	0.1					
	Benzo(a) pyrene	mg/kg	0.05					
	Benzo(b)&(k)fluoranthene	mg/kg	0.2					
	Benzo(g,h,i)perylene	mg/kg	0.1					
	Chrysene	mg/kg	0.1					
	Dibenz(a,h)anthracene	mg/kg	0.1					
	Fluoranthene	mg/kg	0.1					
	Fluorene	mg/kg	0.1					
	Indeno(1,2,3-c,d)pyrene	mg/kg	0.1					
	Naphthalene	mg/kg	0.1					

Field Blanks (SOIL)
Filter: ALL

				SDG Field ID Sampled_Date/Time Sample Type	ENVIROLAB 2015-11-02T00:00:00 Field Blank 2 30/10/2015 Field_B	ENVIROLAB 2015-11-02T00:00:00 Field Blank 29/10/2015 Field_B	ENVIROLAB 2015-11-25T00:00:00 Field Blank 24/11/2015 Field_B	174217 Field Blank 30/11/2015 Field_B	ENVIROLAB 2015-11-02T00:00:00 Trip Blank Trip_B
	PAHs (Sum of total)	mg/kg							
	Phenanthrene	mg/kg	0.1						
	Pyrene	mg/kg	0.1						
PCBs in Soil	Arochlor 1016	mg/kg	0.1						
	Arochlor 1221	mg/kg	0.1				<0.1	<0.1	
	Arochlor 1232	mg/kg	0.1				<0.1	<0.1	
	Arochlor 1242	mg/kg	0.1				<0.1	<0.1	
	Arochlor 1248	mg/kg	0.1				<0.1	<0.1	
	Arochlor 1254	mg/kg	0.1				<0.1	<0.1	
	Arochlor 1260	mg/kg	0.1				<0.1	<0.1	
Pesticides by GCMS	4,4-DDE	mg/kg	0.05						
	a-BHC	mg/kg	0.05						
	Aldrin	mg/kg	0.05						
	Aldrin + Dieldrin	mg/kg	0.05						
	Azinophos methyl	mg/kg	0.05						
	b-BHC	mg/kg	0.05						
	Bromophos-ethyl	mg/kg	0.05						
	Carbophenothion	mg/kg	0.05						
	chlordane	mg/kg	0.05						
	Chlordane (cis)	mg/kg	0.05						
	Chlordane (trans)	mg/kg	0.05						
	Chlorfenvinphos	mg/kg	0.05						
	Chlorpyrifos	mg/kg	0.05						
	Chlorpyrifos-methyl	mg/kg	0.05						
	d-BHC	mg/kg	0.05						
	DDD	mg/kg	0.05						
	DDT	mg/kg	0.2						
	DDT+DDE+DDD	mg/kg	0.05						
	Demeton-S-methyl	mg/kg	0.05						
	Diazinon	mg/kg	0.05						
	Dichlorvos	mg/kg	0.05						
	Dieldrin	mg/kg	0.05						
	Dimethoate	mg/kg	0.05						
	Endosulfan	mg/kg	0.05						
	Endosulfan I	mg/kg	0.05						
	Endosulfan II	mg/kg	0.05						
	Endosulfan sulphate	mg/kg	0.05						
	Endrin	mg/kg	0.05						
	Endrin aldehyde	mg/kg	0.05						
	Endrin ketone	mg/kg	0.05						
	Ethion	mg/kg	0.05						
	Fenamiphos	mg/kg	0.05						
	Fenthion	mg/kg	0.05						
	g-BHC (Lindane)	mg/kg	0.05						
	Heptachlor	mg/kg	0.05						
	Heptachlor epoxide	mg/kg	0.05						
	Hexachlorobenzene	mg/kg	0.05						
	Malathion	mg/kg	0.05						
	Methoxychlor	mg/kg	0.2						
	Methyl parathion	mg/kg	0.2						
	Monocrotophos	mg/kg	0.2						
	Parathion	mg/kg	0.2						
	Pirimphos-ethyl	mg/kg	0.05						
	Prothiofos	mg/kg	0.05						
Phthalates in Soil	Bis(2-ethylhexyl) phthalate	mg/kg	5						
	Butyl benzyl phthalate	mg/kg	1						
	Diethylphthalate	mg/kg	1						
	Dimethyl phthalate	mg/kg	1						
	Di-n-butyl phthalate	mg/kg	5						
	Di-n-octyl phthalate	mg/kg	1						
Polychlorinated Biphenyls (PCB)	PCBs (Sum of total)	mg/kg	0.1						

Field Blanks (SOIL)
Filter: ALL

			SDG	ENVIROLAB 2015-11-02T00:00:00	ENVIROLAB 2015-11-02T00:00:00	ENVIROLAB 2015-11-25T00:00:00	174217	ENVIROLAB 2015-11-02T00:00:00
			Field ID	Field Blank 2	Field Blank	Field Blank	Field Blank	Trip Blank
			Sampled_Date/Time	30/10/2015	29/10/2015	24/11/2015	30/11/2015	
			Sample Type	Field_B	Field_B	Field_B	Field_B	Trip_B
Speciated Phenols in Soil	2,3,4,6-tetrachlorophenol	mg/kg	0.2					
	2,4,5-trichlorophenol	mg/kg	0.2					
	2,4,6-trichlorophenol	mg/kg	0.2					
	2,4-dichlorophenol	mg/kg	0.2					
	2,4-dimethylphenol	mg/kg	0.2					
	2,4-dinitrophenol	mg/kg	4					
	2,6-dichlorophenol	mg/kg	0.2					
	2-chlorophenol	mg/kg	0.2					
	2-methylphenol	mg/kg	0.2					
	2-nitrophenol	mg/kg	0.2					
	4,6-Dinitro-2-methylphenol	mg/kg	10					
	4-chloro-3-methylphenol	mg/kg	5					
	4-methylphenol	mg/kg	0.4					
	4-nitrophenol	mg/kg	4					
	Pentachlorophenol	mg/kg	5					
	Phenol	mg/kg	0.2					
svTRH(C10-C36) in soil	C10-C16	mg/kg	50	<50	<50	<50	<50	<50
	C16-C34	mg/kg	100	<100	<100	<100	<100	<100
	C34-C40	mg/kg	100	<100	<100	<100	<100	<100
	F2-NAPHTHALENE	mg/kg	50	<50	<50	<50	<50	<50
	C10 - C14	mg/kg	50	<50	<50	<50	<50	<50
	C15 - C28	mg/kg	100	<100	<100	<100	<100	<100
	C29-C36	mg/kg	100	<100	<100	<100	<100	<100
Total Mercury by FIMS	Mercury	mg/kg	0.1					
Total Metals by ICP-AES	Arsenic	mg/kg	5					
	Beryllium	mg/kg	1					
	Cadmium	mg/kg	1					
	Lead	mg/kg	5					
	Molybdenum	mg/kg	2					
	Nickel	mg/kg	2					
	Selenium	mg/kg	5					
	Silver	mg/kg	2					
TRH - Semivolatile Fraction	C10-C16	mg/kg	50					
	C16-C34	mg/kg	100					
	C34-C40	mg/kg	100					
	F2-NAPHTHALENE	mg/kg	50					
	C10 - C14	mg/kg	50					
	C15 - C28	mg/kg	100					
	C29-C36	mg/kg	100					
	+C10 - C36 (Sum of total)	mg/kg	50					
	C10 - C40 (Sum of total)	mg/kg	50					
TRH Volatiles/BTEX	Benzene	mg/kg	0.2					
	Ethylbenzene	mg/kg	0.5					
	Naphthalene	mg/kg	1					
	Toluene	mg/kg	0.5					
	Total BTEX	mg/kg	0.2					
	C6 - C9	mg/kg	10					
	Xylene (m & p)	mg/kg	0.5					
	Xylene (o)	mg/kg	0.5					
	Xylene Total	mg/kg	0.5					
	C6-C10 less BTEX (F1)	mg/kg	10					
	C6-C10	mg/kg	10					
VOCs in soil	1,1,1,2-tetrachloroethane	mg/kg	1					
	1,1,1-trichloroethane	mg/kg	1					
	1,1,2,2-tetrachloroethane	mg/kg	1					
	1,1,2-trichloroethane	mg/kg	1					
	1,1-dichloroethane	mg/kg	1					
	1,1-dichloroethene	mg/kg	1					
	1,1-dichloropropene	mg/kg	1					
	1,2,3-trichlorobenzene	mg/kg	1					

Field Blanks (SOIL)
Filter: ALL

				SDG	ENVIROLAB 2015-11-02T00:00:00	ENVIROLAB 2015-11-02T00:00:00	ENVIROLAB 2015-11-25T00:00:00	174217	ENVIROLAB 2015-11-02T00:00:00
				Field ID	Field Blank 2	Field Blank	Field Blank	Field Blank	Trip Blank
				Sampled_Date/Time	30/10/2015	29/10/2015	24/11/2015	30/11/2015	
				Sample Type	Field_B	Field_B	Field_B	Field_B	Trip_B
	1,2,3-trichloropropane	mg/kg	1						
	1,2,4-trichlorobenzene	mg/kg	1						
	1,2,4-trimethylbenzene	mg/kg	1						
	1,2-dibromo-3-chloropropane	mg/kg	1						
	1,2-dibromoethane	mg/kg	1						
	1,2-dichlorobenzene	mg/kg	1						
	1,2-dichloroethane	mg/kg	1						
	1,2-dichloropropane	mg/kg	1						
	1,3,5-trimethylbenzene	mg/kg	1						
	1,3-dichlorobenzene	mg/kg	1						
	1,3-dichloropropane	mg/kg	1						
	1,4-dichlorobenzene	mg/kg	1						
	2,2-dichloropropane	mg/kg	1						
	2-chlorotoluene	mg/kg	1						
	4-chlorotoluene	mg/kg	1						
	Benzene	mg/kg	0.2						
	Bromobenzene	mg/kg	1						
	Bromochloromethane	mg/kg	1						
	Bromodichloromethane	mg/kg	1						
	Bromoform	mg/kg	1						
	Bromomethane	mg/kg	1						
	Carbon tetrachloride	mg/kg	1						
	Chlorobenzene	mg/kg	1						
	Chlorodibromomethane	mg/kg	1						
	Chloroethane	mg/kg	1						
	Chloroform	mg/kg	1						
	Chloromethane	mg/kg	1						
	cis-1,2-dichloroethene	mg/kg	1						
	cis-1,3-dichloropropene	mg/kg	1						
	Cyclohexane	mg/kg	1						
	Dibromomethane	mg/kg	1						
	Dichlorodifluoromethane	mg/kg	1						
	Ethylbenzene	mg/kg	1						
	Hexachlorobutadiene	mg/kg	1						
	Isopropylbenzene	mg/kg	1						
	MTBE	mg/kg	0.5						
	n-butylbenzene	mg/kg	1						
	n-propylbenzene	mg/kg	1						
	p-isopropyltoluene	mg/kg	1						
	sec-butylbenzene	mg/kg	1						
	Styrene	mg/kg	1						
	Trichloroethene	mg/kg	1						
	tert-butylbenzene	mg/kg	1						
	Tetrachloroethene	mg/kg	1						
	Toluene	mg/kg	0.5						
	trans-1,2-dichloroethene	mg/kg	1						
	trans-1,3-dichloropropene	mg/kg	1						
	Trichlorofluoromethane	mg/kg	1						
	Vinyl chloride	mg/kg	1						
	Xylene (m & p)	mg/kg	2						
	Xylene (o)	mg/kg	1						
vTRH(C6-C10)/MBTEXN in soil	Benzene	mg/kg	0.2		<0.2	<0.2	<0.2	<0.2	<0.2
	Ethylbenzene	mg/kg	1		<1	<1	<1	<1	<1
	MTBE	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
	Naphthalene	mg/kg	1		<1	<1	<1	<1	<1
	Toluene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
	C6 - C9	mg/kg	25		<25	<25	<25	<25	<25
	Xylene (m & p)	mg/kg	2		<2	<2	<2	<2	<2
	Xylene (o)	mg/kg	1		<1	<1	<1	<1	<1
	C6-C10 less BTEX (F1)	mg/kg	25		<25	<25	<25	<25	<25
	C6-C10	mg/kg	25		<25	<25	<25	<25	<25

Field Blanks (SOIL)
Filter: ALL

SDG	ENVIROLAB 2015-11-02T00:00:00	ENVIROLAB 2015-11-25T00:00:00	174217
Field ID	Trip Blank	Field Trip	Field Trip
Sampled_Date/Time	29/10/2015	24/11/2015	30/11/2015
Sample Type	Trip_B	Trip_B	Trip_B

Method_Type	ChemName	Units	EQL			
Acid Herbicides in Soil	2-(2-Methyl-1,4-chlorophenoxy) propionic acid	mg/kg	0.5			
	2,4,5-Trichlorophenoxy Acetic Acid	mg/kg	0.5			
	2,4,5-TP (Silvex)	mg/kg	0.5			
	2,4,6-trichlorophenol	mg/kg	0.5			
	Hedonal	mg/kg	0.5			
	2,4-Dichlorprop	mg/kg	0.5			
	4-(2,4-Dichlorophenoxy)butyric Acid (2,4-DB)	mg/kg	0.5			
	2-Chlorophenoxyacetic acid	mg/kg	0.5			
	4-Chlorophenoxy acetic acid	mg/kg	0.5			
	3,5-Dichlorobenzoic acid	mg/kg	0.5			
	Acifluorfen	mg/kg	2			
	Actril (loxynil)	mg/kg	1			
	Bromoxynil	mg/kg	0.5			
	Clopyralid	mg/kg	0.5			
	Dacthal	mg/kg	0.5			
	Dicamba	mg/kg	0.5			
	Dinoseb	mg/kg	1			
	2-Methyl-4-chlorophenoxyacetic acid	mg/kg	0.5			
	2-Methyl-4-Chlorophenoxy Butanoic Acid	mg/kg	0.5			
	Mecoprop	mg/kg	0.5			
	Picloram	mg/kg	0.5			
	Triclopyr	mg/kg	0.5			
Cyanides in Soil	Cyanide (Free)	mg/kg	0.5			
	Cyanide Total	mg/kg	0.5			
Hexavalent Chromium by Alkaline Digestion and DA F	Chromium (hexavalent)	mg/kg	0.5			
Landfill Classification Metals	Arsenic	mg/kg	2			
	Cadmium	mg/kg	0.4			
	Copper	mg/kg	1			
	Lead	mg/kg	1			
	Mercury	mg/kg	0.1			
	Molybdenum	mg/kg	1			
	Nickel	mg/kg	1			
	Selenium	mg/kg	2			
	Silver	mg/kg	1			
	Tin	mg/kg	1			
	Zinc	mg/kg	1			
Metals - soil	Arsenic	mg/kg	2			
	Cadmium	mg/kg	0.4			
	Copper	mg/kg	1			
	Lead	mg/kg	1			
	Mercury	mg/kg	0.1			
	Molybdenum	mg/kg	1			
	Nickel	mg/kg	1			
	Selenium	mg/kg	2			
	Silver	mg/kg	1			
	Tin	mg/kg	1			
	Zinc	mg/kg	1			
Miscellaneous Inorg - soil	Chromium (hexavalent)	mg/kg	1			
	Fluoride	mg/kg	50			
Miscellaneous Organics - Soil	2,4-Dinitrotoluene	mg/kg	1			
	Nitrobenzene	mg/kg	1			
Moisture	Moisture	%	0.1		**0.27**	**17**
Moisture Content	Moisture	%	1			
NEPM Suite 1 - Metals	Arsenic	mg/kg	2		<2	<2
	Beryllium	mg/kg	1		<1	<1

Field Blanks (SOIL)
Filter: ALL

			SDG	ENVIROLAB 2015-11-02T00:00:00	ENVIROLAB 2015-11-25T00:00:00	174217
			Field ID	Trip Blank	Field Trip	Field Trip
			Sampled_Date/Time	29/10/2015	24/11/2015	30/11/2015
			Sample Type	Trip_B	Trip_B	Trip_B
	Boron	mg/kg	3		<3	<3
	Cadmium	mg/kg	0.4		<0.4	<0.4
	Chromium (III+VI)	mg/kg	1		<1	<1
	Cobalt	mg/kg	1		<1	<1
	Copper	mg/kg	1		<1	<1
	Lead	mg/kg	1		<1	<1
	Manganese	mg/kg	1		<1	<1
	Mercury	mg/kg	0.1		<0.1	<0.1
	Nickel	mg/kg	1		<1	<1
	Selenium	mg/kg	2		<2	<2
	Zinc	mg/kg	1		<1	<1
Organochlorine Pesticides	a-BHC	mg/kg	0.1			
	Aldrin	mg/kg	0.1			
	b-BHC	mg/kg	0.1			
	Chlordane (cis)	mg/kg	0.1			
	Chlordane (trans)	mg/kg	0.1			
	d-BHC	mg/kg	0.1			
	DDD	mg/kg	0.1			
	DDE	mg/kg	0.1			
	DDT	mg/kg	0.1			
	Dieldrin	mg/kg	0.1			
	Endosulfan I	mg/kg	0.1			
	Endosulfan II	mg/kg	0.1			
	Endosulfan sulphate	mg/kg	0.1			
	Endrin	mg/kg	0.1			
	Endrin aldehyde	mg/kg	0.1			
	Endrin ketone	mg/kg	0.1			
	g-BHC (Lindane)	mg/kg	0.1			
	Heptachlor	mg/kg	0.1			
	Heptachlor epoxide	mg/kg	0.1			
	Hexachlorobenzene	mg/kg	0.1			
	Methoxychlor	mg/kg	0.1			
Organophosphorus Pesticides	Azinophos methyl	mg/kg	0.1		<0.1	<0.1
	Bromophos-ethyl	mg/kg	0.1		<0.1	<0.1
	Chlorpyrifos	mg/kg	0.1		<0.1	<0.1
	Chlorpyrifos-methyl	mg/kg	0.1		<0.1	<0.1
	Diazinon	mg/kg	0.1		<0.1	<0.1
	Dichlorvos	mg/kg	0.1		<0.1	<0.1
	Dimethoate	mg/kg	0.1		<0.1	<0.1
	Ethion	mg/kg	0.1		<0.1	<0.1
	Fenitrothion	mg/kg	0.1		<0.1	<0.1
	Malathion	mg/kg	0.1		<0.1	<0.1
	Parathion	mg/kg	0.1		<0.1	<0.1
	Ronnel	mg/kg	0.1		<0.1	<0.1
Other Inorganic Species	Chromium (hexavalent)	mg/kg	1			
	Cyanide (Free)	mg/kg	0.5			
	Cyanide Total	mg/kg	0.5			
	Fluoride	mg/kg	50			
PAHs in Soil	B(a)P Total Potency Equivalent	mg/kg	0.5			
	Acenaphthene	mg/kg	0.1			
	Acenaphthylene	mg/kg	0.1			
	Anthracene	mg/kg	0.1			
	Benz(a)anthracene	mg/kg	0.1			
	Benzo(a) pyrene	mg/kg	0.05			
	Benzo(b)&(k)fluoranthene	mg/kg	0.2			
	Benzo(g,h,i)perylene	mg/kg	0.1			
	Chrysene	mg/kg	0.1			
	Dibenz(a,h)anthracene	mg/kg	0.1			
	Fluoranthene	mg/kg	0.1			
	Fluorene	mg/kg	0.1			
	Indeno(1,2,3-c,d)pyrene	mg/kg	0.1			
	Naphthalene	mg/kg	0.1			

Field Blanks (SOIL)
Filter: ALL

			SDG	ENVIROLAB 2015-11-02T00:00:00	ENVIROLAB 2015-11-25T00:00:00	174217
			Field ID	Trip Blank	Field Trip	Field Trip
			Sampled_Date/Time	29/10/2015	24/11/2015	30/11/2015
			Sample Type	Trip_B	Trip_B	Trip_B
	PAHs (Sum of total)	mg/kg				
	Phenanthrene	mg/kg	0.1			
	Pyrene	mg/kg	0.1			
PCBs in Soil	Arochlor 1016	mg/kg	0.1		<0.1	<0.1
	Arochlor 1221	mg/kg	0.1		<0.1	<0.1
	Arochlor 1232	mg/kg	0.1		<0.1	<0.1
	Arochlor 1242	mg/kg	0.1		<0.1	<0.1
	Arochlor 1248	mg/kg	0.1		<0.1	<0.1
	Arochlor 1254	mg/kg	0.1		<0.1	<0.1
	Arochlor 1260	mg/kg	0.1		<0.1	<0.1
Pesticides by GCMS	4,4-DDE	mg/kg	0.05			
	a-BHC	mg/kg	0.05			
	Aldrin	mg/kg	0.05			
	Aldrin + Dieldrin	mg/kg	0.05			
	Azinophos methyl	mg/kg	0.05			
	b-BHC	mg/kg	0.05			
	Bromophos-ethyl	mg/kg	0.05			
	Carbophenothion	mg/kg	0.05			
	chlordane	mg/kg	0.05			
	Chlordane (cis)	mg/kg	0.05			
	Chlordane (trans)	mg/kg	0.05			
	Chlorfenvinphos	mg/kg	0.05			
	Chlorpyrifos	mg/kg	0.05			
	Chlorpyrifos-methyl	mg/kg	0.05			
	d-BHC	mg/kg	0.05			
	DDD	mg/kg	0.05			
	DDT	mg/kg	0.2			
	DDT+DDE+DDD	mg/kg	0.05			
	Demeton-S-methyl	mg/kg	0.05			
	Diazinon	mg/kg	0.05			
	Dichlorvos	mg/kg	0.05			
	Dieldrin	mg/kg	0.05			
	Dimethoate	mg/kg	0.05			
	Endosulfan	mg/kg	0.05			
	Endosulfan I	mg/kg	0.05			
	Endosulfan II	mg/kg	0.05			
	Endosulfan sulphate	mg/kg	0.05			
	Endrin	mg/kg	0.05			
	Endrin aldehyde	mg/kg	0.05			
	Endrin ketone	mg/kg	0.05			
	Ethion	mg/kg	0.05			
	Fenamiphos	mg/kg	0.05			
	Fenthion	mg/kg	0.05			
	g-BHC (Lindane)	mg/kg	0.05			
	Heptachlor	mg/kg	0.05			
	Heptachlor epoxide	mg/kg	0.05			
	Hexachlorobenzene	mg/kg	0.05			
	Malathion	mg/kg	0.05			
	Methoxychlor	mg/kg	0.2			
	Methyl parathion	mg/kg	0.2			
	Monocrotophos	mg/kg	0.2			
	Parathion	mg/kg	0.2			
	Pirimphos-ethyl	mg/kg	0.05			
	Prothiofos	mg/kg	0.05			
Phthalates in Soil	Bis(2-ethylhexyl) phthalate	mg/kg	5			
	Butyl benzyl phthalate	mg/kg	1			
	Diethylphthalate	mg/kg	1			
	Dimethyl phthalate	mg/kg	1			
	Di-n-butyl phthalate	mg/kg	5			
	Di-n-octyl phthalate	mg/kg	1			
Polychlorinated Biphenyls (PCB)	PCBs (Sum of total)	mg/kg	0.1			

Field Blanks (SOIL)
Filter: ALL

			SDG	ENVIROLAB 2015-11-02T00:00:00	ENVIROLAB 2015-11-25T00:00:00	174217
			Field ID	Trip Blank	Field Trip	Field Trip
			Sampled_Date/Time	29/10/2015	24/11/2015	30/11/2015
			Sample Type	Trip_B	Trip_B	Trip_B
	1,2,3-trichloropropane	mg/kg	1			
	1,2,4-trichlorobenzene	mg/kg	1			
	1,2,4-trimethylbenzene	mg/kg	1			
	1,2-dibromo-3-chloropropane	mg/kg	1			
	1,2-dibromoethane	mg/kg	1			
	1,2-dichlorobenzene	mg/kg	1			
	1,2-dichloroethane	mg/kg	1			
	1,2-dichloropropane	mg/kg	1			
	1,3,5-trimethylbenzene	mg/kg	1			
	1,3-dichlorobenzene	mg/kg	1			
	1,3-dichloropropane	mg/kg	1			
	1,4-dichlorobenzene	mg/kg	1			
	2,2-dichloropropane	mg/kg	1			
	2-chlorotoluene	mg/kg	1			
	4-chlorotoluene	mg/kg	1			
	Benzene	mg/kg	0.2			
	Bromobenzene	mg/kg	1			
	Bromochloromethane	mg/kg	1			
	Bromodichloromethane	mg/kg	1			
	Bromoform	mg/kg	1			
	Bromomethane	mg/kg	1			
	Carbon tetrachloride	mg/kg	1			
	Chlorobenzene	mg/kg	1			
	Chlorodibromomethane	mg/kg	1			
	Chloroethane	mg/kg	1			
	Chloroform	mg/kg	1			
	Chloromethane	mg/kg	1			
	cis-1,2-dichloroethene	mg/kg	1			
	cis-1,3-dichloropropene	mg/kg	1			
	Cyclohexane	mg/kg	1			
	Dibromomethane	mg/kg	1			
	Dichlorodifluoromethane	mg/kg	1			
	Ethylbenzene	mg/kg	1			
	Hexachlorobutadiene	mg/kg	1			
	Isopropylbenzene	mg/kg	1			
	MTBE	mg/kg	0.5			
	n-butylbenzene	mg/kg	1			
	n-propylbenzene	mg/kg	1			
	p-isopropyltoluene	mg/kg	1			
	sec-butylbenzene	mg/kg	1			
	Styrene	mg/kg	1			
	Trichloroethene	mg/kg	1			
	tert-butylbenzene	mg/kg	1			
	Tetrachloroethene	mg/kg	1			
	Toluene	mg/kg	0.5			
	trans-1,2-dichloroethene	mg/kg	1			
	trans-1,3-dichloropropene	mg/kg	1			
	Trichlorofluoromethane	mg/kg	1			
	Vinyl chloride	mg/kg	1			
	Xylene (m & p)	mg/kg	2			
	Xylene (o)	mg/kg	1			
vTRH(C6-C10)/MBTEXN in soil	Benzene	mg/kg	0.2	<0.2	<0.2	<0.2
	Ethylbenzene	mg/kg	1	<1	<1	<1
	MTBE	mg/kg	0.5	<0.5	<0.5	<0.5
	Naphthalene	mg/kg	1	<1	<1	<1
	Toluene	mg/kg	0.5	<0.5	<0.5	<0.5
	C6 - C9	mg/kg	25	<25	<25	<25
	Xylene (m & p)	mg/kg	2	<2	<2	<2
	Xylene (o)	mg/kg	1	<1	<1	<1
	C6-C10 less BTEX (F1)	mg/kg	25	<25	<25	<25
	C6-C10	mg/kg	25	<25	<25	<25

Lee Point

Field Blanks (SOIL)
Filter: ALL

				SDG	ENVIROLAB 2015-11-02T00:00:00	ENVIROLAB 2015-11-25T00:00:00	174217
				Field ID	Trip Blank	Field Trip	Field Trip
				Sampled_Date/Time	29/10/2015	24/11/2015	30/11/2015
				Sample Type	Trip_B	Trip_B	Trip_B
Speciated Phenols in Soil	2,3,4,6-tetrachlorophenol	mg/kg	0.2				
	2,4,5-trichlorophenol	mg/kg	0.2				
	2,4,6-trichlorophenol	mg/kg	0.2				
	2,4-dichlorophenol	mg/kg	0.2				
	2,4-dimethylphenol	mg/kg	0.2				
	2,4-dinitrophenol	mg/kg	4				
	2,6-dichlorophenol	mg/kg	0.2				
	2-chlorophenol	mg/kg	0.2				
	2-methylphenol	mg/kg	0.2				
	2-nitrophenol	mg/kg	0.2				
	4,6-Dinitro-2-methylphenol	mg/kg	10				
	4-chloro-3-methylphenol	mg/kg	5				
	4-methylphenol	mg/kg	0.4				
	4-nitrophenol	mg/kg	4				
	Pentachlorophenol	mg/kg	5				
	Phenol	mg/kg	0.2				
svTRH(C10-C36) in soil	C10-C16	mg/kg	50		<50	<50	<50
	C16-C34	mg/kg	100		<100	<100	<100
	C34-C40	mg/kg	100		<100	<100	<100
	F2-NAPHTHALENE	mg/kg	50		<50	<50	<50
	C10 - C14	mg/kg	50		<50	<50	<50
	C15 - C28	mg/kg	100		<100	<100	<100
	C29-C36	mg/kg	100		<100	<100	<100
Total Mercury by FIMS	Mercury	mg/kg	0.1				
Total Metals by ICP-AES	Arsenic	mg/kg	5				
	Beryllium	mg/kg	1				
	Cadmium	mg/kg	1				
	Lead	mg/kg	5				
	Molybdenum	mg/kg	2				
	Nickel	mg/kg	2				
	Selenium	mg/kg	5				
	Silver	mg/kg	2				
TRH - Semivolatile Fraction	C10-C16	mg/kg	50				
	C16-C34	mg/kg	100				
	C34-C40	mg/kg	100				
	F2-NAPHTHALENE	mg/kg	50				
	C10 - C14	mg/kg	50				
	C15 - C28	mg/kg	100				
	C29-C36	mg/kg	100				
	+C10 - C36 (Sum of total)	mg/kg	50				
	C10 - C40 (Sum of total)	mg/kg	50				
TRH Volatiles/BTEX	Benzene	mg/kg	0.2				
	Ethylbenzene	mg/kg	0.5				
	Naphthalene	mg/kg	1				
	Toluene	mg/kg	0.5				
	Total BTEX	mg/kg	0.2				
	C6 - C9	mg/kg	10				
	Xylene (m & p)	mg/kg	0.5				
	Xylene (o)	mg/kg	0.5				
	Xylene Total	mg/kg	0.5				
	C6-C10 less BTEX (F1)	mg/kg	10				
	C6-C10	mg/kg	10				
VOCs in soil	1,1,1,2-tetrachloroethane	mg/kg	1				
	1,1,1-trichloroethane	mg/kg	1				
	1,1,2,2-tetrachloroethane	mg/kg	1				
	1,1,2-trichloroethane	mg/kg	1				
	1,1-dichloroethane	mg/kg	1				
	1,1-dichloroethene	mg/kg	1				
	1,1-dichloropropene	mg/kg	1				
	1,2,3-trichlorobenzene	mg/kg	1				

APPENDIX S

Muirhead North: Stage 1 Preliminary Site Investigation

Appendix I – Muirhead North Stage 1 Preliminary Site Investigation (EcOz 2015)

Muirhead North:

Stage 1 Preliminary Site Investigation

Prepared for: Defence Housing Australia

Prepared by: EcOz Environmental Consultants

2015

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APPROVED COMPANY
ISO 9001 Quality Management Systems
QMS Certification Services

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Executive Summary

A Stage 1 Preliminary Site Investigation was undertaken on behalf of Defence Housing Australia (DHA) to assess the potential for the presence of soil contamination on a 'greenfield' site intended for future residential development. The site, referred to as Muirhead North, comprises Lot 9370, Town of Nightcliff.

The primary objective of the assessment was to identify the potential for site contamination, identify and quantify likely risks, and recommend further investigations (if necessary). In accordance with the National Environment Protection (Assessment of Site Contamination) Measure (NEPM) and Australian Standard AS4482.1-2005, EcOz undertook the following scope of works:

- *Development of a site history including review of historical aerial photographs, historical titles, planning certificates and contaminated land register*
- *Discussions with local people familiar with the site and surrounding site uses*
- *Desktop review of local hydrogeological and geological conditions*
- *Detailed site inspection and description, including confirmation of adjacent land use and potential offsite sources of contamination.*

EcOz undertook a site inspection on 1 April 2015 to collate as much visual and documentary (i.e. site-based records) information as possible regarding the site and immediately surrounding properties. The following factors were assessed:

- *Local topography*
- *Surface water flow direction(s), surface water bodies and/or areas of ponding*
- *Current and remnant site infrastructure*
- *Site use activities*
- *Evidence of surface soil contamination, imported fill material(s), stockpiles, waste and/or stressed vegetation*
- *Presence of asbestos building materials*

The desktop review revealed that the site has always been Vacant Crown Land. A large proportion of the project area was cleared and borrowed prior to 1970, which has largely re-grown and the remainder is relatively undisturbed bush land. There have been no known significant developments, with the main potential sources of contamination being from illegally dumped materials (e.g. hydrocarbons, asbestos).

Illegally dumped household rubbish, car bodies, soil piles and building materials (i.e. steel, concrete, etc) were observed in some areas, which were mainly concentrated near access tracks, particularly in the western section of the site. A small amount of asbestos containing material (ACM) was observed at one location.

Based on a review of the available desktop information and observations made during the site inspection, it is concluded that:

- *It is unlikely that there is any extensive contamination with ACM as only a few small fragments were observed at a single location*
- *It is possible that additional areas of minor ACM contamination could be present that were not identified due to the heavily-vegetated state of the site at the time of the inspection*
- *There was no evidence of hydrocarbon contamination associated with dumped vehicles and rubbish, and no other potential contaminants were identified*
- *There is no indication or evidence of likely contamination within the project area and therefore a Stage 2 Detailed Site Investigation is not considered necessary.*

It is recommended that in the event ACM is uncovered during the development of the site, a suitably qualified asbestos removal contractor be engaged.

Table of Contents

1 Introduction 1
1.1 Purpose 1
1.2 Scope 1
2 Site Identification 2
3 Site Setting 3
3.1 Topography and hydrology 3
3.2 Geology 3
3.3 Hydrogeology 3
3.4 Acid sulfate soils 3
4 Site History 6
4.1 Land tenure and zoning 6
4.2 Maps and aerial photography 7
4.3 Previous and current land uses 9
4.4 Potential contamination sources 9
5 Site Inspection 10
5.1 Areas inspected 10
5.2 Infrastructure 10
5.3 Wastes and fill materials 10
5.4 Staining and odours 11
5.5 Land uses 11
5.6 Other site observations 11
6 Conclusions and Recommendations 12
7 References 13

Figures

Figure 2-1. Map showing location of Muirhead North 2
Figure 3-1. Map showing local topography and drainage 4
Figure 3-2. Map showing local geology 4
Figure 3-3. Map showing local aquifers and historic groundwater bore locations 5
Figure 3-4. Map showing locations of potential occurrence of acid sulfate soils 5
Figure 4-1. Map showing land tenure within and surrounding the site 6
Figure 4-2. Map showing NT Planning Scheme zoning within and surrounding the site 7
Figure 4-3. Historical aerial photography of the site 8
Figure 5-1. Map showing areas inspected and location of asbestos fragments 10

Appendices

Appendix A – Site Photographs

1 Introduction

1.1 Purpose

This Stage 1 Preliminary Site Investigation was undertaken on behalf of the Defence Housing Australia (DHA) to assess the potential for the presence of soil contamination on a 'greenfield' site intended for future residential development. Referred to as 'the site' throughout this report, the Muirhead North proposed development area comprises Lot 9370, Town of Nightcliff.

The primary objective of this Stage 1 Preliminary Site Investigation was to identify the potential for site contamination, identify and quantify likely risks, and recommend further investigations (if necessary).

1.2 Scope

The first step of the contaminated land assessment process, as specified by the *National Environment Protection (Assessment of Site Contamination) Measure (NEPM)* and *Australian Standard AS4482.1-2005*, involves the completion of a site history review (also identified as a Preliminary Site Investigation or Phase 1 Environmental Site Assessment).

Under the guidance of the NEPM, EcOz undertook the following scope of works:

- Development of a site history including review of historical aerial photographs and contaminated land register
- Discussions with local people familiar with the site and surrounding site uses
- Desktop review of local hydrogeological and geological conditions
- Detailed site inspection and description, including confirmation of adjacent land use and potential offsite sources of contamination.

A site inspection was undertaken by EcOz on 1 April 2015, to collate as much visual and documentary (i.e. site-based records) information as possible regarding the site and immediately surrounding properties. The following factors were assessed:

- Local topography
- Surface water flow direction(s), surface water bodies and/or areas of ponding
- Current and remnant site infrastructure
- Site use activities
- Evidence of surface soil contamination, imported fill material(s), stockpiles, waste and/or stressed vegetation
- Presence of asbestos building materials (ACM)

2 Site Identification

The Muirhead North site is legally identified as Lot 9370, Town of Nightcliff.

The area proposed for future residential development comprises 51 ha of land on the Lee Point peninsula, approximately 13 km north of the Darwin CBD (Figure 2-1). The area is bounded by Lee Point Road to the west, Buffalo Creek to the east, Lee Point Caravan Park to the north and the existing suburb of Muirhead to the south.

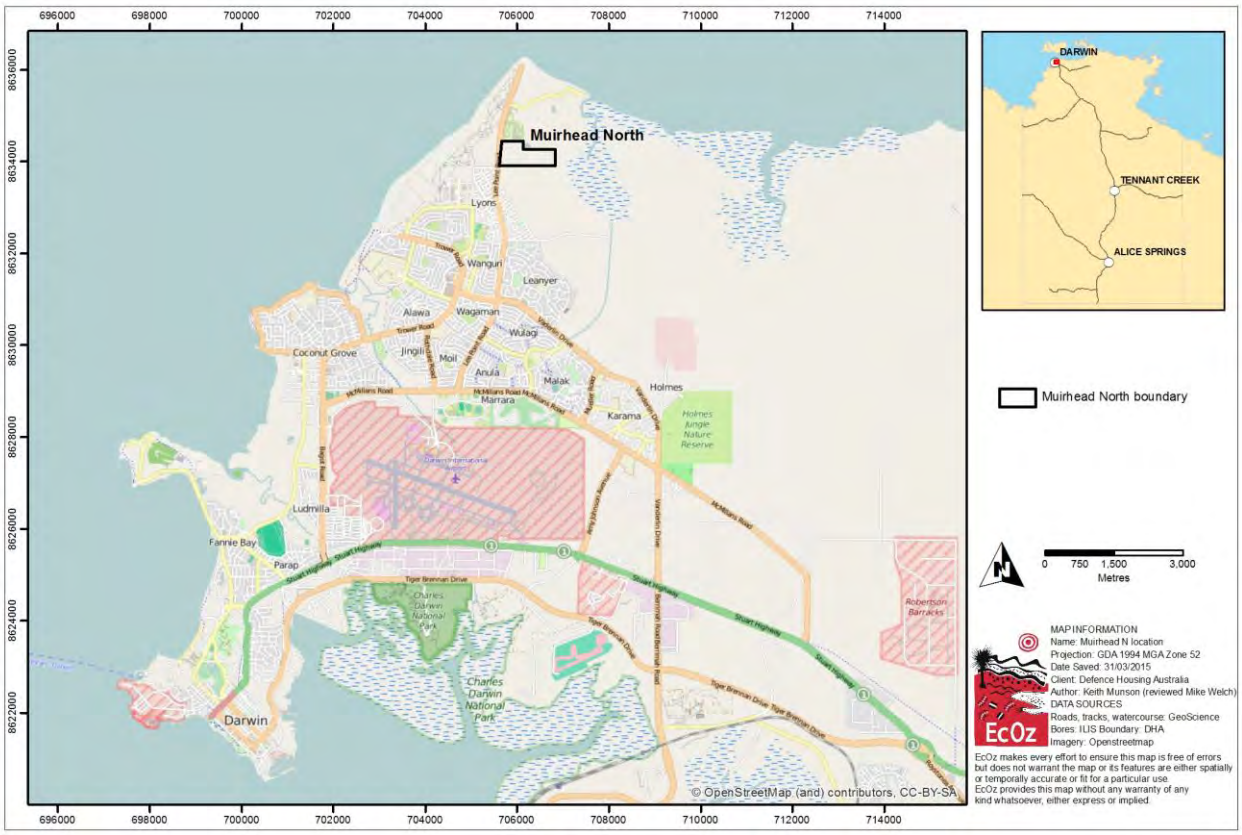


Figure 2-1. Map showing location of Muirhead North

3 Site Setting

3.1 Topography and hydrology

The western section of the site comprises gentle lower slopes (0.5-1.5 % slope), which drain in a south-easterly direction into broad lowland plains (<0.5 – 1.0 % slope). A drainage line enters the site in the north-west corner and flows to the south-east into the Buffalo Creek catchment and into Shoal Bay (Darwin Harbour) (Figure 3-1).

3.2 Geology

The 1:250,000 Geological Survey of the Northern Territory (2006 edition) (Northern Territory Geological Survey) indicates that the site is located on fractured and weathered rock, which consists of shale, greywacke and sandstones and is part of the Cretaceous Darwin Formation. In addition, more recent Tertiary Laterite Gravel and Quaternary Coastal Alluvial (comprising mud, silt and clay) may also be present (Figure 3-2).

3.3 Hydrogeology

Aquifers underlying the site occur in fractured and weathered rock (Figure 3-3), and groundwater flow paths would likely follow the land contours, which is generally towards the south-east. There are several historical groundwater bores located within 1 km of the site (Figure 3-3), and bore logs downloaded from the NT Governments 'NR Maps' online database indicate that groundwater quality is slightly saline, with circum-neutral pH and high concentrations of dissolved ions. Bore logs indicate that groundwater strikes generally occur at a depth of around 50 m below ground level, although no information on standing water levels is available.

3.4 Acid sulfate soils

Acid sulfate soils in the Darwin region are generally located within coastal zones associated with tidal estuaries (Hill and Edmeades 2008). According to acid sulfate soil risk mapping the nearest potential occurrence of acid sulfate soils would be in the Buffalo Creek catchment, approximately 300 m from the eastern boundary of the site (Figure 3-4).

The QLD ASS Technical Manual (QLD Government 2014) (referenced by the *NT Land Suitability Assessment Guidelines*) indicates that "all disturbances to soils, groundwater hydrology or surface water drainage patterns in coastal areas below 5 m AHD should be investigated, designed and managed to avoid potential adverse effects from ASS." This applies to areas where the ground level is above 5 m AHD but where excavation may occur to depths below 5 m AHD.

The contour data for the proposed development area indicates that the elevation ranges from 6 m AHD at the eastern boundary of the Muirhead North lot to a high point of 25 m AHD near Lee Point Road. On the lower lying eastern section of the Muirhead North lot elevations vary between 7 m to 13 m AHD approximately.

The risk of exposing ASS is considered to be low as no earthworks are proposed that will require excavation below 5 m AHD in any part of the proposed development area. Site assessment of ASS was not deemed necessary based on this information provided by SMEC (DHA's engineering contractor).

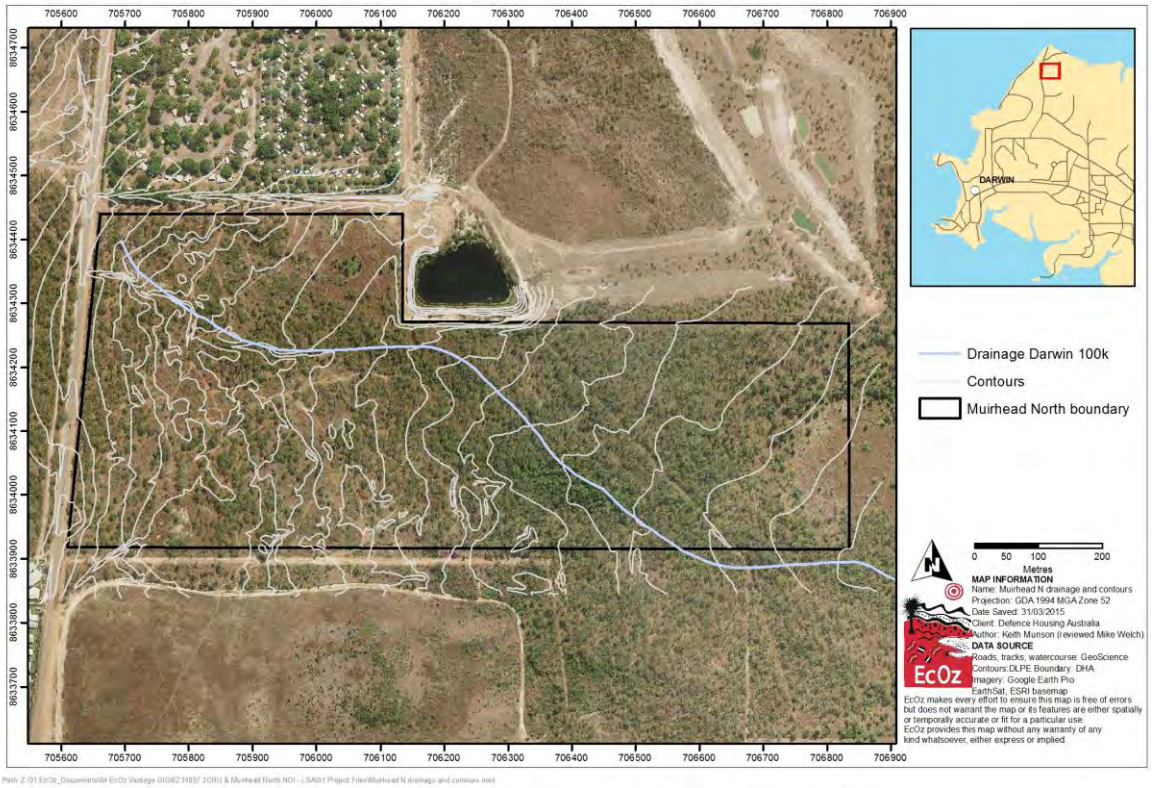


Figure 3-1. Map showing local topography and drainage

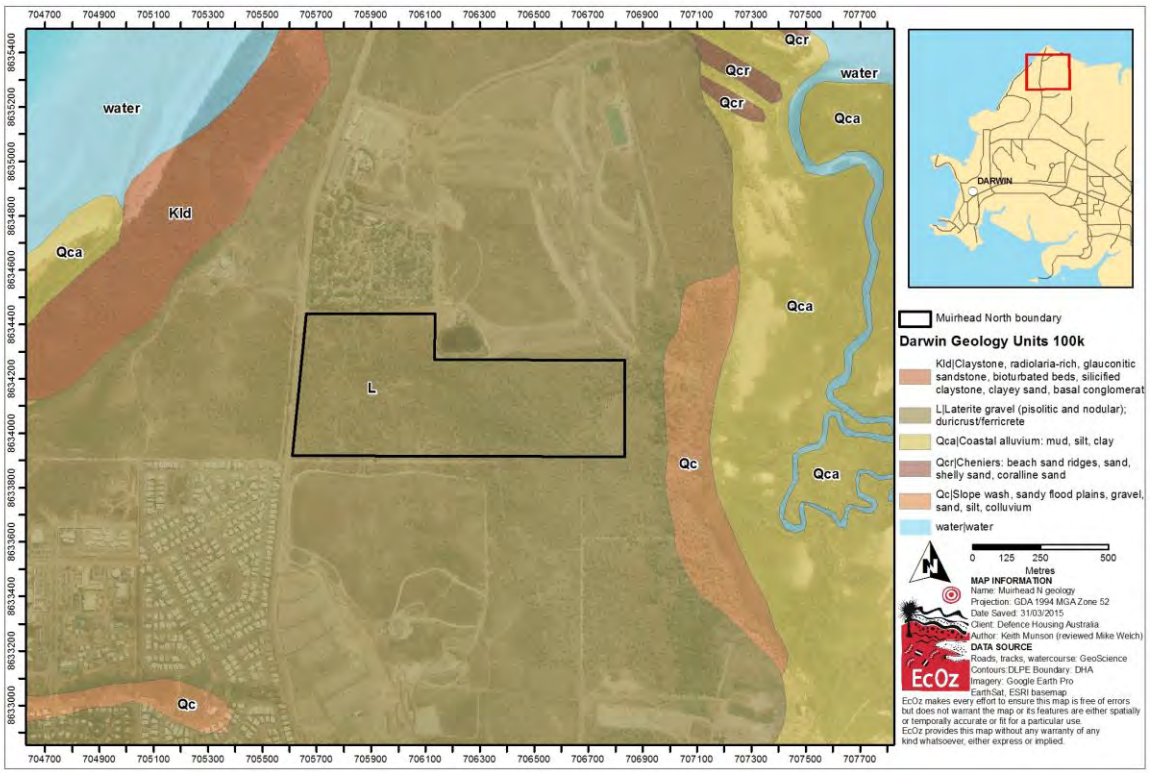


Figure 3-2. Map showing local geology

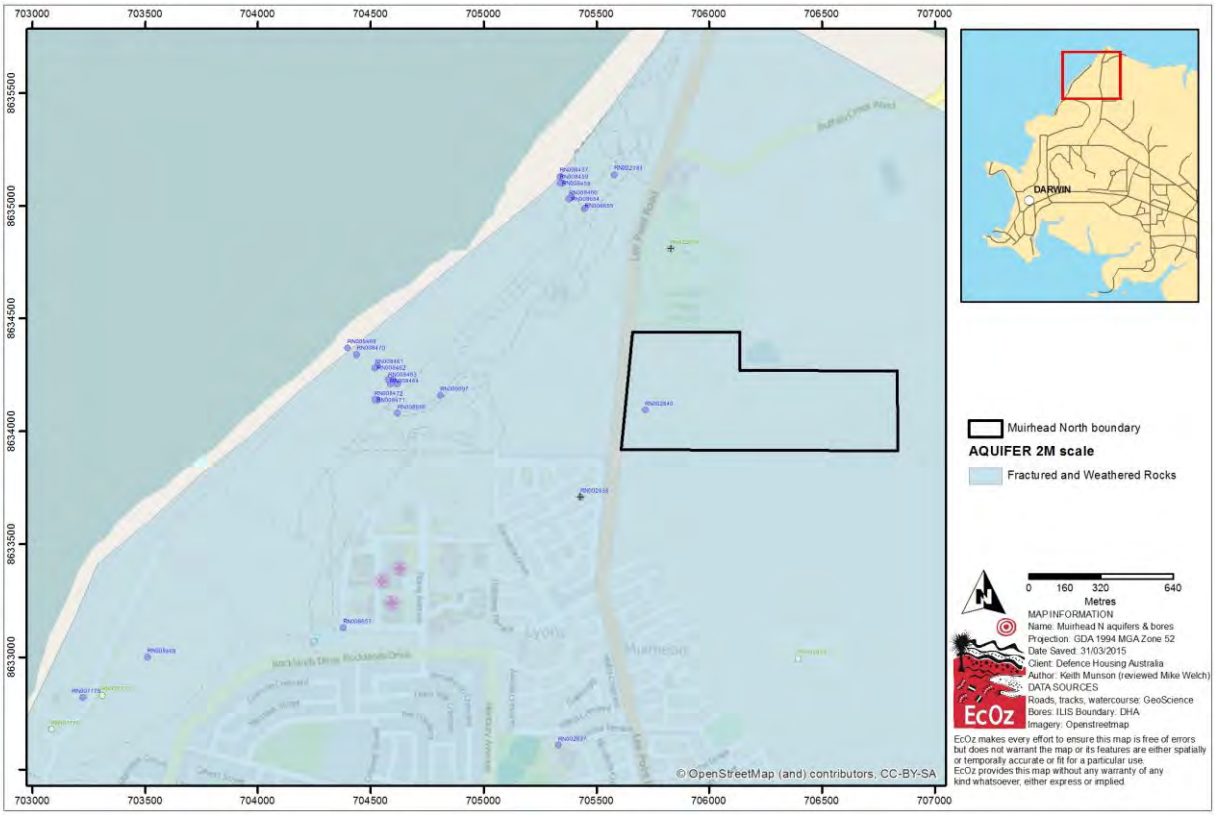


Figure 3-3. Map showing local aquifers and historic groundwater bore locations

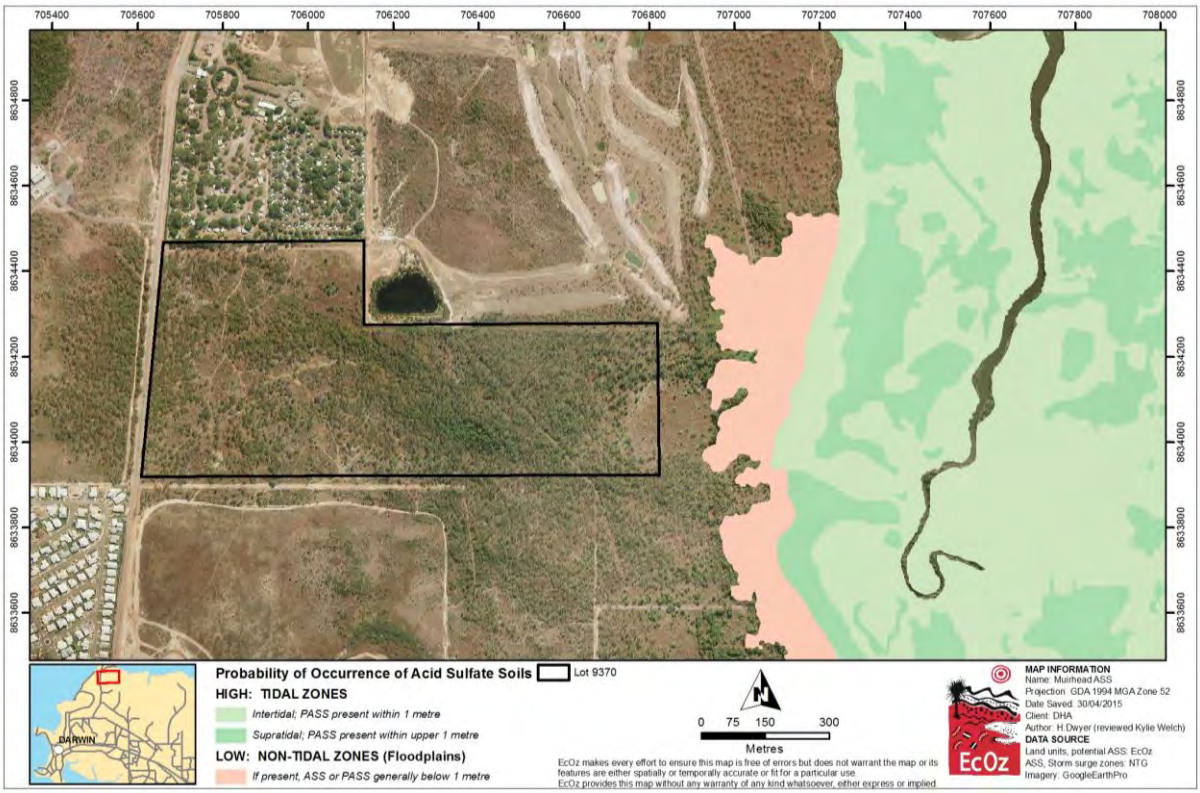


Figure 3-4. Map showing locations of potential occurrence of acid sulfate soils

4 Site History

4.1 Land tenure and zoning

The site is classified as Vacant Crown Land (Figure 4-1) and under an amendment to the NT Planning Scheme in October 2009, Lot 9370 Town of Nightcliff was zoned as Specific Use '…to facilitate the subdivision, use and development of the land as a residential estate…'(Figure 4-2).

Land to the north of the site includes Freehold land zoned as Caravan Park (CV) and Crown Lease Term zoned as Organised Recreation (OR). Land to the west includes Freehold land zoned as Commonwealth Land (no planning scheme – adjacent '2CRU' site) and to the east includes Vacant Crown Land zone as Public Open Space (PS). Land to the south is Freehold land zoned as Specific Use, similar to the site.

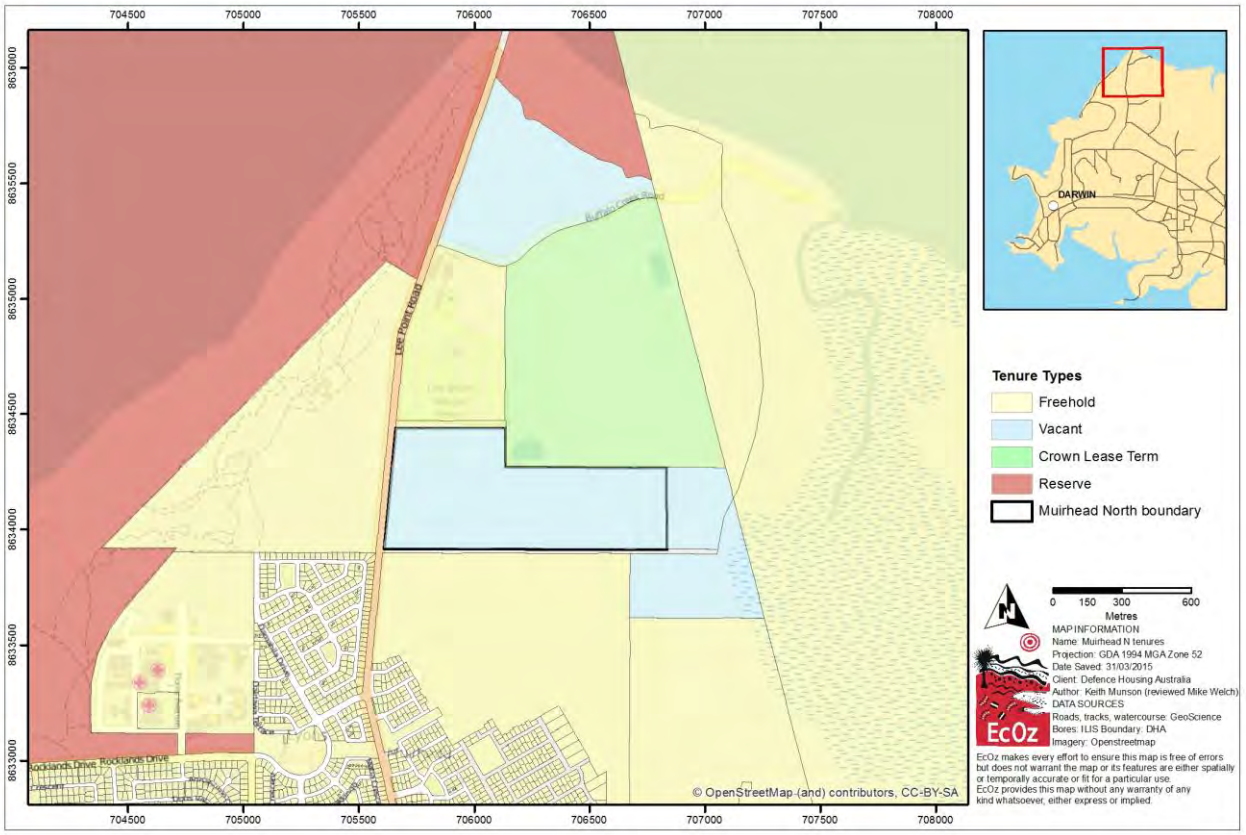


Figure 4-1. Map showing land tenure within and surrounding the site

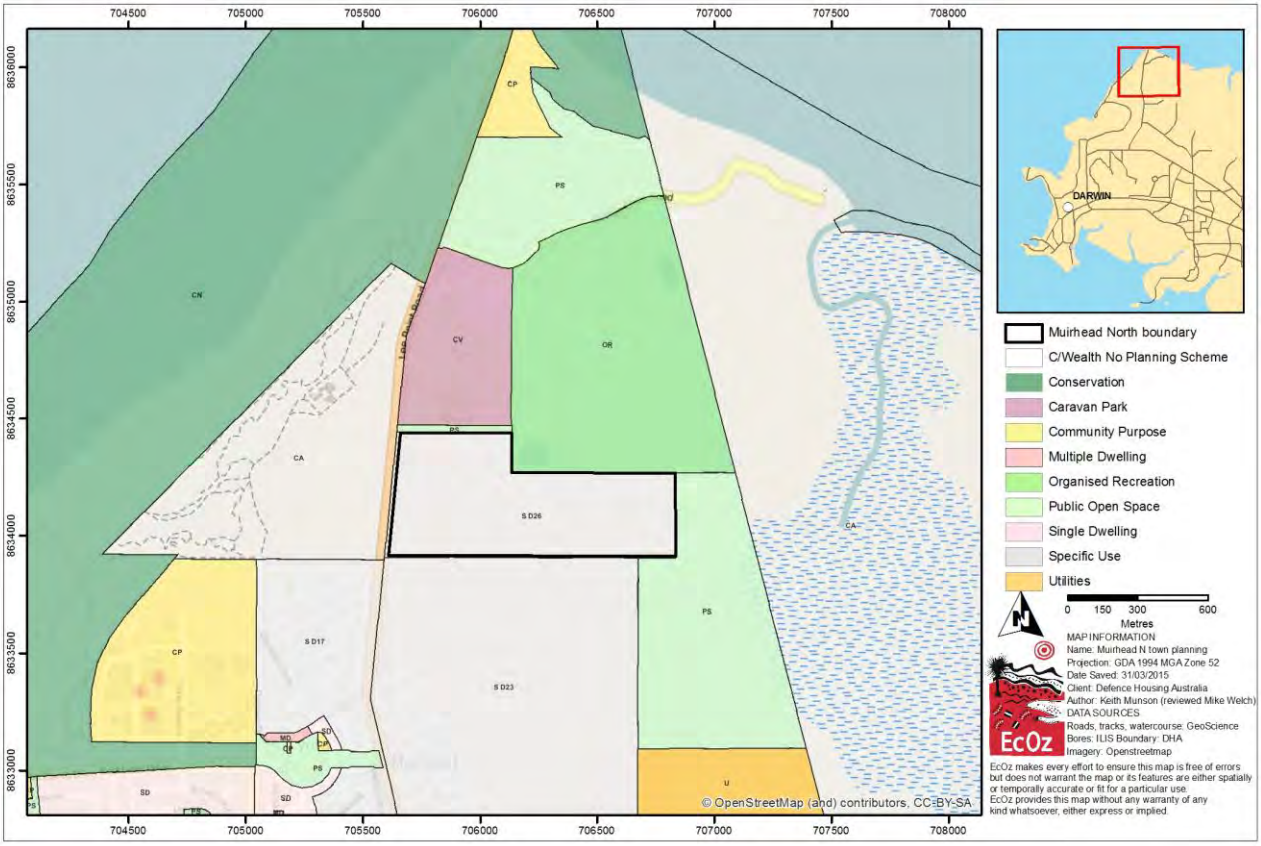


Figure 4-2. Map showing NT Planning Scheme zoning within and surrounding the site

4.2 Maps and aerial photography

Available aerial photography was interrogated in order to determine the site history, with available images including 1944, 1970, 1987 and 2012 (Figure 4-3). From the available aerial photography and topographic mapping (1:250 000), the following historical site land use observations can be made:

- Vegetation largely cleared and extensive borrowing of soil materials circa 1970, which has gradually re-grown without further substantial disturbance since that time. Appears from aerial photography that borrowed material was probably utilised in construction of Leanyer sewage treatment ponds, to the south-east of the site
- Informal access tracks throughout
- No obvious infrastructure (e.g. buildings, concrete slabs) at any time.

Figure 4-3. Historical aerial photography of the site

4.3 Previous and current land uses

4.3.1 Within site

The existing land use within the site is undeveloped bush land, and it is understood that the area has always been Vacant Crown Land, with no formal land use. An inspection of the site (see below) indicated that the informal tracks within the site are used regularly for recreational off-road activities and illegal dumping (i.e. household rubbish, car bodies). As indicated in aerial photos, the site has been extensively borrowed in the past but has not been used for this purpose for some time, as evident in significant regrowth of native trees.

Military remnants in the form of several steel drums are located in the north-west corner of the site and a concurrent heritage assessment indicates that the site, referred to as the 'Konfrontasi AA Site 1' (KAS-1), was built ca1963 for stationing of the No. 121 light Anti-Aircraft Battery (Jung 2015).

4.3.2 Surrounding areas

Until recently, the land surrounding the site has had limited development. A caravan park was constructed to the north of the site in the mid 1980's. Up until the 1990's parcels of Commonwealth land to the west and south were used as air force communications facilities. This included a RAAF Transmission Facility to the west (i.e. known as '2CRU' site) and aerial farm to the south, where the suburb of Muirhead has recently been developed.

4.4 Potential contamination sources

A search of the NT Environmental Protection Authority's contaminated site register indicates that there are no recognised contaminated sites in the vicinity of the site.

Based on the surrounding land use (i.e. predominantly bush land, no heavy industry) and local drainage pathways, the only potential off-site sources of contamination could be the caravan park to the north and former defence communications facility to the west (2CRU). There is unlikely to be any sources of contamination entering the site from the caravan park and a previous site contamination assessment of the adjacent 2CRU parcel of land land did not identify anything that would render the site unsuitable (from a contamination perspective) for a residential end use (GHD 2010).

The main potential sources of contamination on site would be from illegally dumped materials (e.g. fill, hydrocarbons, asbestos).

5 Site Inspection

5.1 Areas inspected

A site inspection was carried out on 1 April 2015, which focussed on areas identified in the site history review as having had historical disturbance (i.e. borrow areas) and within 100 m of any informal access tracks, which are extensive throughout the site. Observations were made both on foot and from vehicle; driving slowly along the access tracks (Figure 5-1).

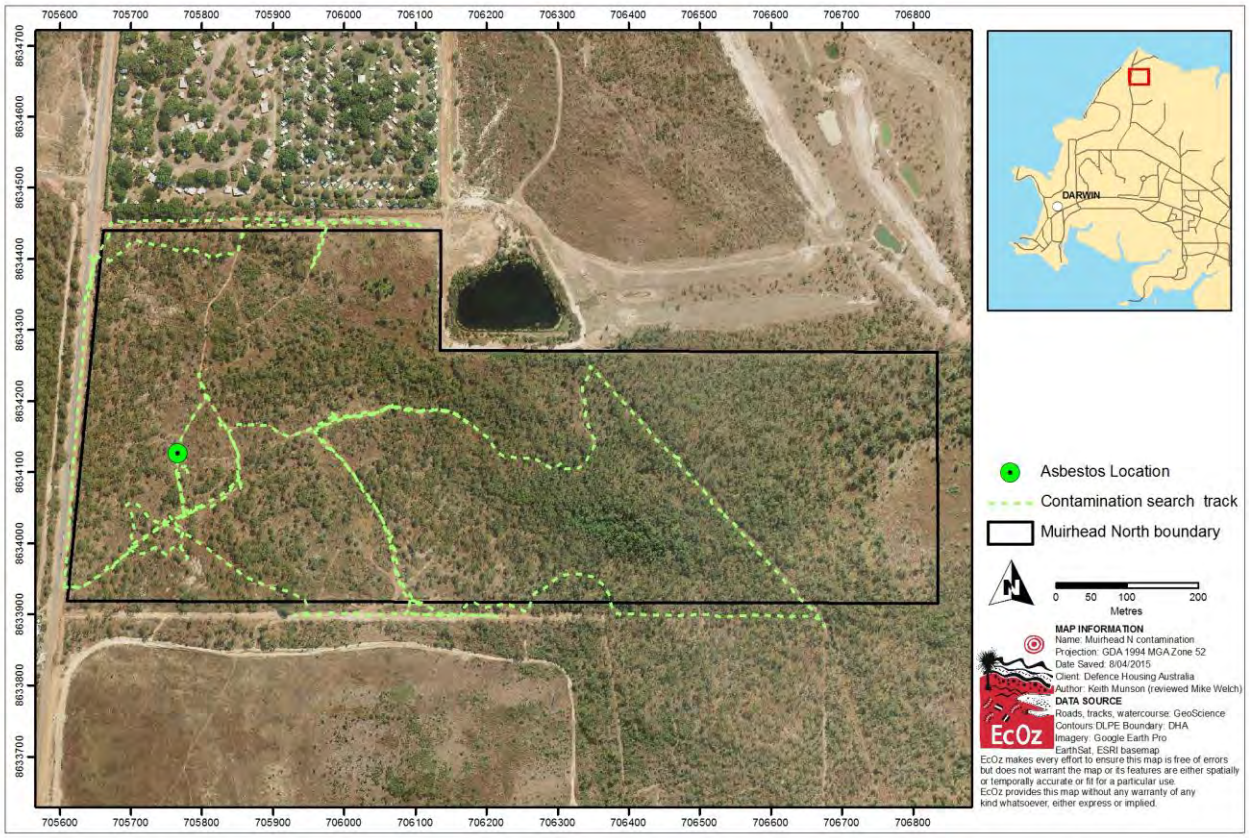


Figure 5-1. Map showing areas inspected and location of asbestos fragments

5.2 Infrastructure

No evidence of current or previous infrastructure was observed on site (e.g. concrete slabs), apart from the historic military gun emplacement at the north-western corner of the site, which consists of some steel drums and a small excavated area (see Section 4.3.1 for historical detail).

5.3 Wastes and fill materials

Some illegally dumped building materials were observed (i.e. concrete), including household rubbish (fridge, washing machine, etc) and car bodies observed in the western section of the site (i.e. closest to Lee Point Rd), where the majority informal access tracks are present (see Appendix A: Figures A1, A2, A7 and A12).

Extensive areas of mounded soil were observed on site, with many mounds having vegetation re-growth indicating a long period since the disturbance occurred (see Appendix A: Figure A8). In conjunction with reviewed historical aerial photos, it appears that most of the soil mounds are likely to be overburden material from when the majority of the site was probably utilised for borrowed materials in the early 1970's. However, it was generally not possible to distinguish between soil material originating at the site and fill material that may have been imported to the site, with only one instance of recently-placed soil observed that may have been imported (see Appendix A: Figure A6).

The site was heavily vegetated with grass (native and weeds) at the time of the inspection, which meant that most soil piles were covered and therefore difficult to determine whether they may have contained any contaminated materials. Vegetation was pushed to the side to expose the soil on at least one location for most soil piles observed and whilst all material appeared to be 'clean', it is possible that potentially contaminated soils could have gone un-noticed during this preliminary investigation.

Particular attention was focussed on identifying any asbestos-containing materials (ACM) present on site, as the illegal dumping of this material (and possibly debris from Cyclone Tracy) is relatively common in bush land adjacent to urban areas around Darwin. ACM was only observed at one location (Figure 5-1), which consisted of several small fragments (see Appendix A: Figures A4 and A5). A thorough search of the immediate area did not identify any further ACM materials.

5.4 Staining and odours

No staining or odours indicating potential contamination (e.g. hydrocarbons) were observed during the site inspection.

5.5 Land uses

The site inspection confirmed the adjacent land uses identified in Section 0. There was no visual evidence observed of potential contamination migrating onto the site from adjacent properties.

Numerous informal vehicle tracks were observed on site, indicating that the area is regularly used for recreational four wheel driving.

5.6 Other site observations

At the time of the inspection during the wet season, the drainage line was flowing and areas of waterlogged soils and ponding were observed across the majority of the eastern section of the Muirhead North (see Appendix A: Figure A3)[1].

[1] It is noted that the geotechnical investigation undertaken by SMEC in January 2015 encountered no groundwater or seepage and the subsurface conditions encountered were amenable to good subsurface drainage. Follow-up inspections of the site undertaken by SMEC in early May 2015 found generally dry conditions; however evidence of where water had ponded in depressions during the wet season was noted.

6 Conclusions and Recommendations

Based on a review of the available desktop search data and observations made during the site inspection, it is concluded that:

- Only one location within the site observed with asbestos containing materials (ACM) indicates that it is unlikely that there is any extensive contamination of ACM.
- Although we are confident that the site inspection identified that it is unlikely to be extensive ACM contamination within the site, there may be some additional areas that were not identified due to the heavily-vegetated state of the site at the time of the inspection.
- There were no other potential sources of soil contamination identified, in either the site history review or site inspection.
- Other than the observed and potential contamination sources specified above, there is no evidence or likely presence of any other contamination within the project area and therefore a Stage 2 Detailed Site Investigation is not required.

It is recommended that in the event that ACM (or other potentially hazardous material) is uncovered during construction a suitably qualified asbestos removal contractor be engaged. The following should be noted in relation to NT WorkSafe requirements for asbestos removal work:

- Licensed businesses engaged in the removal of asbestos require a licensed asbestos assessor during Class A asbestos removal work. The licensed asbestos assessor is required to conduct air monitoring, a clearance inspection and to issue a clearance certificate.
- The clearance inspection must be completed by an *independent* licensed asbestos assessor. To be *independent*, the licensed asbestos assessor or competent person must not be involved in the removal of asbestos for that specific job and is not involved in a business or undertaking involved in the removal of the asbestos for that specific job.
- From 1 January 2015, the air monitoring for Class A asbestos removal work and the removal of friable asbestos must be conducted by an *independent* licensed asbestos assessor.

The risk of exposing ASS is considered to be low as no earthworks are proposed that will require excavation below 5 m AHD in any part of the proposed development area. Service trenching in the low lying areas in the east of Muirhead North is expected to be relatively shallow and not extend below 5 m AHD. Stormwater attenuation basins proposed in the south-east corner of the Muirhead North lot will need to be constructed above the natural surface allowing free-draining discharge of stormwater from the site to the natural drainage channels, and therefore should not disturb any ASS. Should the details of the proposed development change and require excavation below 5 m AHD then ASS risk should be re-assessed at that time.

7 References

EcOz Environmental Consultants 2015, Site Characteristics Assessment for Lot 9370 Town of Nighcliff, Report to Defence Housing Australia, April 2015.

GHD 2010, Report for Lee Point Road Defence Site, NT: Environmental Site Assessment, Report to Department of Defence, December 2010.

Hill, J and Edmeades, B 2008, *Acid Sulfate Soils of the Darwin Region,* Land and Water Division, Department of Natural Resources, Environment, the Arts and Sport, Palmerston, NT.

Jung, S 2015, Muirhead North (Lot 9370 Town of Nightlciff) – Archaeological Survey Report, Report to Ecoz Environmental Consultants, April 2015.

Appendix A – Site Photographs

Figure A1. Dumped household rubbish

Figure A2. Dumped car body

Figure A3. Waterlogged area in eastern section of site

Figure A4. Small fragment of asbestos

Figure A5. Area surrounding observed asbestos

Figure A6. Recent dumped/excavated material

Figure A7. Dumped building materials (concrete)

Figure A8. Historical dumped/excavated soil

Figure A9. Historical dumped/excavated soil

Figure A10. Cleared area on NE boundary

Figure A11. Drain entering site from west

Figure A12. Informal access track

APPENDIX T

Water Discharge Licence WDL 147-05 Annual Audit and Compliance Report (December 2014)

Northern Territory Government

ANNUAL AUDIT AND COMPLIANCE REPORT
WASTE DISCHARGE LICENCE

LICENCE NO.	WDL 147-05
REPORTING PERIOD	28 November 2013 to 2 December 2014

Please email a copy of your completed AACR to pollution@nt.gov.au.

Licensee Details

Legal Entity Name:	Power and Water Corporation
ABN:	15 947 352 360
Registered Business Address:	15 Iliffe Street STUART PARK NT 0820
Postal Address:	PO BOX 37471 WINNELLIE NT 0821
Contact Person:	Water Services Executive Group
Contact Details:	
b/h:	08 8985 7123
mobile:	0401 117 644
email:	waterservicesexecutive@powerwater.com.au

Location of Premises

Name:	Leanyer Sanderson Wastewater Treatment Plant
Address:	141 Fitzmaurice Drive LEANYER NT 0812 Section 3388 Hundred of Bagot
Telephone Numbers:	
b/h:	08 8941 7218
mobile:	0401 114 461

24 hour emergency response

Contact Person:	Power and Water Corporation Emergency Response Line
Telephone Number(s):	1800 245 090

1. Compliance with Licence Conditions

Condition	Action	How	Evidence	When (Date)	Status
1.	The Licensee must notify the NT EPA within 24 hours if there are changes to the details of the 24-hour emergency contact as provided on page one of this Licence.	No changes that required notification	NA	On-going	NA
2.	The Licensee must notify the NT EPA within 14 days if there are changes to the Licensee details shown on page one of this Licence.	No changes that required notification	NA	On-going	NA
3.	The Licensee must notify the NT EPA within 14 days after ceasing to conduct the activity to which this Licence relates.	No changes that required notification	NA	On-going	NA
4.	The Licensee must notify the NT EPA prior to making any operational change that will cause, or is likely to cause, an increase in the potential for environmental harm, environmental nuisance, material environmental harm or serious environmental harm.	Penstocks opening to prevent further overflow from Sanderson 2	D2014/32757	20/1/2014	Compliant (notified prior to change)
		Penstock trial for TDT	D2014/111570	3/3/2014	
		NTEPA provided with factsheet and TDT schedule	D2014/262759	20/5/2014	
		Leanyer Pond 3 and 4 offline for channel works prior to TDT	D2014/290647	4/6/2014	
		Change to wet season operating mode to prevent overflow	D2014/482773	22/9/2014	
5.	The Licensee must cause a copy of this Licence to be available at all times:				
	5.1. on the Licensee's Australian website; and	PWC Internet	Web link	Ongoing	Compliant
	5.2. at the Registered business address.	PWC Aquanet (intranet)	D2013/29734 ; D2013/424331	18/1/2013 Ongoing	Compliant
6.	Where this Licence requires the provision of any	PWC provides all	Refer to evidence with	Ongoing	Compliant

Condition	Action	How	Evidence	When (Date)	Status
	notice, document or other correspondence to the NT EPA, the relevant contact is:	notifications to pollution@nt.gov.au	respect to specific notifications in this AACR		[redacted]
	Pollution Control NT EPA				
	Physical Address: Level 2 Darwin Plaza, 41 Smith Street Mall, Darwin NT 0800				
	Postal Address: GPO Box 3675, Darwin NT 0801				
	Email: pollution@nt.gov.au				
7.	All notices, documents or other correspondence required to be provided pursuant to this Licence must be provided in both hard and electronic form unless otherwise specified as a condition of this Licence.	PWC requested that a concession to submit electronic as opposed to hardcopies for WDL 150-03 be considered for WDL 147-05, 151-04 and 159-04 as well	D2013/653494	11/12/2013	[redacted]
		NTEPA advised PWC they no longer requires hard copies for WDL 147-05	D2014/222734	20/12/2013	
	OPERATIONAL				

Condition	Action	How	Evidence	When (Date)	Status
8.	The Licensee must, without limiting any other condition of this Licence in conducting the Activity do all things reasonable and practicable to ensure the Activity does not adversely affect the Declared Beneficial Uses and Objectives as declared from time to time, including those applying to:	PWC does all things reasonable and practical to protect BUs within the constraints of the existing WSP technology and for a discharge in this location i.e. poorly flushed estuary (legacy issue for over 40 years). The WwTP performs well in reduction of loads and prevention of direct faecal contamination. PWC periodically undertakes necessary operational changes to ensure the optimum capacity and functioning of the WSPs. Major operational changes such as desludging of ponds are accompanied by task specific ERAs prior to commencement to prevent environmental harm. No such	Position paper on SSTVs – D2012/645803	14/2/2012	Compliant
			2014 Monitoring Report – D2014/496849	3/11/2014	

Condition	Action	How	Evidence	When (Date)	Status
		activities such as desludging were undertaken within the period of this AACR. Buffalo Creek is considered a highly disturbed aquatic ecosystem and likely to remain in this state without significant infrastructure investment that will require government/public consultation. The protection of Beneficial Uses is not typically applied in mixing zones in accordance with ANZECC and ARMCANZ (2000).			
	• The Darwin Harbour Region.				
9.	The Licensee must maintain and implement a communication plan which includes a strategy for communicating with members of the public who are likely to have a genuine interest in or be affected by the Activity.	**Maintenance** - approved WDL communication strategy is being updated in conjunction with PWC Corporate Comms	Approved strategy is under revision Email from Jane Dellow D2014/446957, Corporate Communications	Ongoing	Non-compliant
		Implementation – (only partial implementation	Provision of data to AHU D2014/451238 and contribution of	4/9/2014	

Condition	Action	How	Evidence	When (Date)	Status
		while strategy under review). Additional task specific communication plan for TDT developed and implemented inclusive of signage, public notices, fact sheets etc.	ARC Project Summary D2014/440713 for Darwin Harbour Report Card PWC Internet Site – News regarding continuous improvement at Leanyer Sanderson TDT Comms Plan D2014/191138	28/8/2014 6/3/2013 20/5/2014	
		NTEPA advised of non-compliance	D2014/607187	2/12/2014	
10.	The Licensee must keep a legible record of each complaint made to the Licensee or any employee or agent of the Licensee in relation to the Licensed Action(s). The record of a complaint must include details of the following:	Complaint log recorded in both PWC database MAXIMO and in the PWC WQ Complaints Tracking Worksheet	Complaints Tracking Worksheet in Compliance Matrix Tracking file; MAXIMO Search Results for this period – D2014/607982	Ongoing	
	• the date and time of the complaint;	Recorded in MAXIMO and WQ Tracking	Refer above	Refer above	
	• the contact details of the complainant if known;	Recorded in MAXIMO and WQ Tracking	Refer above	Refer above	
	• the nature of the complaint and events giving rise to the complaint;	Recorded in MAXIMO and WQ Tracking	Refer above	Refer above	
	• prevailing weather conditions at the time of	Not recorded in	Refer above	Refer above	

Condition	Action	How	Evidence	When (Date)	Status
	the complaint;	MAXIMO but recorded in WQ Tracking			
	• the action taken in relation to the complaint;	Recorded in MAXIMO and WQ Tracking	Refer above	Refer above	
	• any conclusions the Licensee made regarding the cause of the complaint; and	Recorded in MAXIMO and WQ Tracking	Refer above	Refer above	
	• any preventative measure put in place to prevent reoccurrence.	Recorded in MAXIMO and WQ Tracking	Refer above	Refer above	
11.	During the term of this Licence the Licensee will improve its complaint management system to enable the following details to be recorded:	Complaint Tracking Worksheet captures all relevant fields	Refer Condition 10	Ongoing	Compliant
	• where contact details of the complainant are incomplete, a note or flag to that effect;				
	• methods, other than telephone calls, by which complaints are received;				
	• details of follow-up contact with the complainant; and				
	• if no action was taken by the Licensee in relation to the complaint, the reasons why no action was taken.				
	DISCHARGES AND EMISSIONS				
12.	This Licence authorises wastewater to be discharged from the Authorised Discharge Point(s) identified in Table 1, and in Appendix 1. **Table 1** **Authorised Discharge Point** / **Description** / **Location**	Overflow from Sanderson 2 in wet season (heavy rain)	Non-compliance notification to NTEPA - D2014/32757 Overflow log sheet -D2014/36306	20/1/2014	Non-compliant

Condition	Action	How	Evidence	When (Date)	Status
	SLe100 / End of outfall pipe at the headwaters of Buffalo Creek. / Longitude: 130.91057 Latitude: -12.35888				
13.	Wastewater(s) discharged from the Authorised Discharge Point in Table 1 must not:	Qualitative discharge limits assessed during routine monitoring and recorded on site notes for each sampling day and/or field sheets for each site	Site notes and field sheets with QDL observations stored in F2011/6237	Ongoing	
	• contain any visible matter, floating oil and grease or petroleum hydrocarbon sheen or scum, or litter or other objectionable matter;	Qualitative discharge limit complied with	Refer above	Refer above	Compliant
	• cause or generate odours which would adversely affect the use of surrounding waters;	Qualitative discharge limit complied with	Refer above	Refer above	Compliant
	• cause algal blooms;	Chlorophyll-a persistently elevated with respect to default guidelines indicative of high phytoplankton biomass. At times this biomass may	Notified NTEPA of ongoing non-compliance – D2013/551045	18/10/2013 Ongoing	Non-compliant

Condition	Action	How	Evidence	When (Date)	Status
		be visible as a 'red tide' bloom that is more commonly identified as the dinoflagellate *Kryptoperidinium foliaceum*	Specific observations of 'red tides' in September 2014 reported to NTEPA Email notification to NTEPA D2014/453219 and follow up summary report provided via email D2014/464139 Additionally advised of continued observations on 17/9/2014 via email D2014/476608 Follow up report provided D2014/536042 22/10/2014	4/9/2014 – 22/10/2014	
	• cause visible change in the behaviour of fish or other aquatic organisms;	Qualitative discharge limit complied with	Refer above	Refer above	Compliant
	• cause mortality of fish or other aquatic organisms; or	Qualitative discharge limit complied with	Refer above	Refer above	Compliant
	• cause adverse impacts on plants.	Qualitative discharge limit complied with	Refer above	Refer above	Compliant
	MONITORING				
14.	The Licensee must for all terrestrial sampling points required by this Licence:				
	14.1. install, maintain and provide appropriate identification signage so that they are easily identifiable at all times; and	Signage in place and remains in good condition	Email notification – D2012/153355 Confirmed by NTEPA at site inspection	Ongoing 17/3/2014	Compliant
	14.2. maintain safe access and egress, as is	Clear access on site for monitoring	Site layout drawing B11-1008 –	Ongoing	Compliant

Condition	Action	How	Evidence	When (Date)	Status
	reasonably practicable.	point SLe100/SLEBCDP	D2013/223433 Confirmed by NTEPA at site inspection	17/3/2014	
15.	For each sample required to be collected by this Licence the following information must be recorded and retained:	Refer below	Refer below	Refer below	
	• the date(s) on which the sample was taken;	Recorded on Field Sheets/Site Notes and stored in TRIM	F2011/6237	Ongoing	Compliant
	• the time(s) at which the sample was collected;	Recorded on Field Sheet at each site and stored in TRIM	F2011/6237	Ongoing	Compliant
	• the point(s) at which the sample was taken;	Recorded on Field Sheet at each site and stored in TRIM	F2011/6237	Ongoing	Compliant
	• the name of the person who collected the sample;	Recorded on Site Notes for each trip	F2011/6237	Ongoing	Compliant
	• the chain of custody forms relating to the sample(s);	COC forms submitted with each sample batch and confirmation returned via email and stored in TRIM	F2011/6237	Ongoing	Compliant
	• the field measurements and/or analytical results for the sample; and	Field measurements recorded on Field Sheet for each site and stored in TRIM; Analytical results stored in TRIM by laboratory/matrix type	Field sheets - F2011/6237 Analytical results – example for AWQC (water) by year - F2013/3962 and F2014/4225 example for Eurofins (sediment) F2014/2968	Ongoing	Compliant

Condition	Action	How	Evidence	When (Date)	Status
	• laboratory QA/QC documentation (where laboratory analysis required).	Refer above for analytical result reports; this includes the results for blind QA/QC sampling undertaken by PWC; Location of blind duplicates recorded on site notes and field measurements for QA/QC samples on field sheets	Refer above	Ongoing	Compliant
16.	Discharge water monitoring must be conducted in accordance with Appendix 1.	All discharge water monitoring compliant with Appendix 1	WDL 147 Summary Data and Plots Spreadsheet – D2014/437516 No reports of missed sampling in Field Sheets or Site Notes in F2011/6237 in this period	Ongoing	Compliant

Condition	Action	How	Evidence	When (Date)	Status
17.	Surface water monitoring must be conducted in accordance with Appendix 2.	All surface water monitoring compliant with Appendix 2 except when access not physically possible or access not safe due to rough weather. SLEBC01 and SLEBC03 not accessible by boat on 27/11/2013 due to fallen trees. SLEBC01 not accessible on 11/12/2013 due to fallen trees. SLESB02 not accessible on 6/2/2014 due to rough weather. Samples taken from closest accessible point on 11/12 and 6/2.	NTEPA advised of these unavoidable non-compliances - D2013/630374 D2013/657033 D2014/65647	28/11/2013 12/12/2013 7/2/2014	Non-compliant
18.	The Licensee must, for *Enterococci spp.* at Monitoring Point SLEBC06, meet the National Health and Medical Research Council (NHMRC) Guidelines for secondary recreational contact.	Enterococci exceeded this SSTV twice and only in the wet season when other factors beyond the control of PWC also apply including catchment sources	WDL 147 Summary Data and Plots D2014/437516 November 2013 SSTV Exceedance Report D2014/89001 February 2014 SSTV Exceedance Report D2014/127173	27/11/2013 6/2/2014	Non-compliant

Condition	Action	How	Evidence	When (Date)	Status
19.	The Licensee must, for stressors including nutrients and physiochemical parameters at Monitoring Point SLEBC08, apply the 90th percentile for each respective parameter determined by using the most recent 24 month rolling average from data collected at SLESB02.	Monitoring data processed and SSTVs applied in dedicated spreadsheet	WDL 147 SSTV Mastersheet D2014/227497	Ongoing	Compliant
20.	The Licensee must submit a *Sediment Monitoring Plan* by 30 April 2013. The plan must: 20.1. be approved by the NT EPA noting that the NT EPA may require the Licensee to revise, amend and/or resubmit the proposed plan; and	NTEPA accepted plan to proceed with expert review and submit a revised SMP for approval by 1 October 2013.	NT EPA acknowledgement email - D2013/311007	17/6/2013	NA (last AACR period)
		Expert review of BCISMP provided to NTEPA.	AIMS expert review by Dr Dan Alongi – D2013/434139 Email submission of review to NTEPA – D2013/455654	30/8/2013	
		PWC requested revision of due date for revised BCSMP from 1 October to 18 October 2013	Email to NT EPA requesting extension - D2013/513809	30/9/2013	
		NTEPA acknowledged revised due date	Email from NT EPA - D2013/520789	3/10/2013	
		PWC submitted revised BCSMP	Proposed BCSMP - D2013/534016;and Email submission of BCSMP - D2013/545470	16/10/2013	

Condition	Action	How	Evidence	When (Date)	Status
		PWC revised and resubmitted BCSMP in response to NTEPA comments	Email submission to NTEPA – D2013/651568 Acknowledgment of receipt and that approval letter should follow –D2013/651942	10/12/2013 10/12/2013	Compliant
	20.2. be implemented within 10 Business Days of receiving written approval of the plan from the NT EPA.	Written approval received from NTEPA via email 21/1/2014 (your ref: EN2011/0021~0160)	D2014/35179	21/1/2014	
		PWC notified NTEPA of evidence of implementation dating back to November 2013 with sampling commencing in May (dry season)	D2014/245812	12/5/2014	Compliant
	RECORDING AND REPORTING				
21.	All records required to be kept by this Licence must be in a legible format.	PWC stores all records in dedicated containers in a record management system - TRIM	Refer to links throughout this AACR	Ongoing	Compliant
22.	The Licensee must keep records of all non-compliances with this Licence.	PWC maintains a Compliance Matrix Tracking	Compliance Matrix Tracking Sheet – D2012/66732	Ongoing	Compliant

Condition	Action	How	Evidence	When (Date)	Status
		Worksheet and a dedicated WDL Compliance and Administration TRIM container.	TRIM Container – F2006/5058		
23.	The Licensee must as soon as practicable and in any case within 24 hours notify the NT EPA of non-compliances with this Licence.	PWC has notified NTEPA asap of each non-compliance	Compliance Matrix Tracking Sheet – D2012/66732 TRIM Container – F2006/5058 Notification emails throughout this AACR	Ongoing	Compliant
24.	The Licensee must immediately and in any case within 24 hours notify the NT EPA of any potential or actual environmental harm or pollution not subject to the conditions of this Licence by contacting the Pollution Hotline on telephone number 1800 064 567 and emailing pollution@nt.gov.au.	PWC notified NTEPA of potential environmental harm due to preliminary identification of *Gymnodinium sp* by TWS staff. Subsequently identified as *Kryptoperidinium foliaceum* (not harmful to human health). Follow up reports were subsequently provided to NTEPA	Notification email – D2014/453219 Follow up reports detailed in Condition 13	4/9/2014	Compliant
25.	The Licensee must for any exceedance of a site specific trigger value at SLEBC08 or NHMRC Guide at SLEBC06: 25.1. notify the NT EPA of the exceedance as soon as practicable and in any case within 24 hours by emailing	SSTV exceedances recorded and reported for each month since November 2013 (data from October	All SSTV reports/notification emails stored in dedicated TRIM Container for WDL 147 – F2013/6185	Ongoing	Compliant

<table>
<tr><th>Condition</th><th>Action</th><th>How</th><th>Evidence</th><th>When (Date)</th><th>Status</th></tr>
<tr><td></td><td>pollution@nt.gov.au; and
25.2. provide a written report within 10 business days of the notification provided in accordance with condition 25.1. The written report must include an assessment of the risk posed by the exceedance and any management actions taken.</td><td>2014 not processed to date due to reporting commitments at this time)</td><td>All monthly reports compiled in dedicated excel file WDL 147 SSTV Mastersheet D2014/227497</td><td></td><td></td></tr>
<tr><td>26.</td><td>The Licensee must comply with the requirements of section 14 of the Waste Management and Pollution Control Act.</td><td>No section 14 Incidents in this reporting period</td><td>Compliance Matrix Tracking Sheet – D2012/66732</td><td>Ongoing</td><td>Compliant</td></tr>
<tr><td>27.</td><td>The Licensee must provide to the NT EPA a Periodic Report.
The Periodic report must:
27.1. include a tabulation of discharge flow data, field results and laboratory analytical results including discharge water, surface water and sediment monitoring parameters required as a condition of this Licence;
27.2. include a trend chart for all parameters at monitoring point SLEBC08, showing a comparison with the SSTV's; and
27.3. be submitted in accordance with the following schedule:
<table>
<tr><th>Reporting Period</th><th>Report Submission at end of:</th></tr>
<tr><td>January, February, March, April, May, June</td><td>July</td></tr>
<tr><td>July, August, September, October, November, December</td><td>January</td></tr>
</table></td><td>January 2014 submission
July 2014 submission</td><td>D2014/54302
D2014/391324</td><td>31/01/2014
31/07/2014</td><td>Compliant</td></tr>
</table>

Condition	Action	How	Evidence	When (Date)	Status
28.	The Licensee must complete the attached Annual Audit and Compliance Report (AACR), Appendix 4 and provide to the NT EPA a minimum of 20 Business Days prior to the anniversary of the commencement date of this Licence, for each year of this Licence noting that the NT EPA may require the Licensee to revise, amend and/or resubmit the AACR.	2013 AACR due 13/12/2013 provided early. NTEPA did not advise that any revision, amendment or resubmission was required	Email submission to NTEPA – D2013/641895	4/12/2013	Compliant
		2014 AACR due 15/12/2014 (this document in prep)	This AACR – D2014/606122	Due outside this AACR period	NA
29.	The Licensee must provide to the NT EPA a minimum of 20 Business Days prior to the expiry date of this Licence a Licence Report.	Licence Report due 12/12/2014 submitted 3/11/2014	Submission to NTEPA – D2014/555780 2014 Licence Report -	3/11/2014	Compliant
30.	The Licence Report must include:				
	30.1. a Monitoring Report prepared in accordance with the requirements for a Monitoring Report identified on pages 12-21 of the document: *Guidelines for Consultants Reporting on Environmental Issues* available from: http://www.nretas.nt.gov.au/__data/assets/pdf_file/0009/14031/consultants_reporting_environmental_issues.pdf; and	The Guideline/page numbers referred to no longer relevant (subsequently revised). NTEPA confirmed that a relevant targeted report was appropriate	Email from responsible NTEPA officer – D2014/499940	30/9/2014	NA
	30.2. a trend analysis and interpretation of all monitoring data required as a condition of this Licence.	Attachment A of report submission and Licence Report itself. Isotope Report provided separately	Refer to Condition 29 above Submission email – D2014/503524	3/11/2014 3/10/2014	Compliant
	PERFORMANCE IMPROVEMENT				

Condition	Action	How	Evidence	When (Date)	Status
31.	The Licensee must conduct a desktop environmental risk assessment for the Licensed Activity.	Draft ERA prepared and undergoing internal review	Draft ERA – D2014/534342	1/12/2014	Compliant
32.	The environmental risk assessment must be:				
	32.1. conducted with reference to the Conceptual Site Model in Appendix 3; and	Refer Condition 31 (Draft includes approved CSM)	Refer above	1/12/2014	Compliant
	32.2. submitted to the NT EPA with the Licence Report developed in accordance with condition 30 of this Licence, noting that the NT EPA may require the Licensee to revise, amend and/or resubmit the proposed assessment.	ERA not due until 12/12/2014 which is outside this AACR period (Licence Report submitted early – Refer condition 29)	NA	NA	NA
33.	The Licensee must implement measures to improve the discharge such that the 80 and 20 percentile of the SLESB02 reference dataset may be defined for selected stressors at Monitoring Site SLEBC08 in the following licensing period.	TDT and Associated Monitoring Program implemented in 2014 Dry season. However it takes 2 years of data under altered conditions to determine new SSTVs (ANZECC and ARMCANZ 2000). At this stage PWC still needs to assess the effect of the TDT before this discharge strategy can be implemented under the performance improvement plan for Leanyer	Data from TDT still incoming and requires significant clean up and compilation into assessable formats – F2014/4236. The data assessment is a large task that will need to be outsourced in 2015. The 2013 AACR advised NTEPA that it was not possible to comply with this condition as written (never feasible due to the timeframes required and prior to an assessment of impacts of the TDT).		Non-compliant

Condition	Action	How	Evidence	When (Date)	Status
		Sanderson.			
END OF CONDITIONS					

2. Summaries

Complaints Recording

Number of complaints recorded by the licensee during the reporting period (as required by condition 10 of the licence	0
Summary of complaints	NA
Summary of outcomes	NA

Notifications of potential or actual environmental harm or pollution

Number of events recorded by the licensee during the reporting period (as required by condition 24 of the licence	1
Summary of events	Potential environmental harm due to preliminary identification of harmful species in visible bloom in Buffalo Creek.
Summary of outcomes	Specific expert identification did not identify harmful species. Follow up monitoring showed rapid bloom dissipation and DO not anoxic. Blooms naturally dissipate with tidal changes and it seems likely these observations are more of a physical phenomenon (aggregation of biomass under lower tidal ranges) in the way that phytoplankton presents on these neap tides at this time of the year.

Signature and Certification

This declaration must only be signed by a person(s) with the legal authority to sign it. The ways in which the application may be signed, and the people who may sign the application, are set out in the categories below.

If the licence holder is:	Tick	The application must be signed and certified by one of the following:
An individual		The individual.
A partnership		A partner.
A company		The common seal being affixed in accordance with the *Corporations Act*, or
		Two directors, or
		A director and a company secretary, or
		If a proprietary company that has a sole director who is also the sole company secretary – by that director.
A public authority	✓	The Chief Executive Officer (CEO) of the public authority, or
		By a person delegated to sign on the public authority's behalf in accordance with its legislation (Please note: a copy of the relevant instrument of delegation must be attached to this application).

I/We hereby declare that the information provided in this Annual Audit and Compliance Report and accompanying documents is to the best of my/our knowledge, true and correct.

Signature	Baskerville	Signature	
Name (printed)	**John Baskerville**	Name (printed)	
Position	**Chief Executive**	Position	
Date	5/12/14	Date	
Seal (if signing under seal):			

APPENDIX U

Waste Discharge Licence 147-08

Northern Territory Government

WASTE DISCHARGE LICENCE

(Pursuant to section 74 of the *Water Act)*

Licence Details

Licence Number:	**WDL147-08**
Registered Business Address:	Level 2, Mitchell Centre 55 – 59 Mitchell Street Darwin NT 0800
ABN:	15 947 352 360
Premises Address:	141 Fitzmaurice Drive LEANYER NT 0812 Lot 06204 and Lot 03388, Location Code 055
Anniversary Date:	14 April
Commencement Date:	15 April 2017
Amendment Date:	
Expiry Date:	14 April 2022
Licensed Activity	The discharge of wastewater from the Leanyer Sanderson Waste Stabilisation Ponds (WSPs) to Buffalo Creek subject to the Licence Conditions.

Contents

INFORMATION ABOUT THIS LICENCE 3
Duration of Licence 3
Amendment, Modification or Revocation of Licence (section 93 of the *Water Act*) 3
Public Register 3
Environmental Interests 3
Cultural Interests 3
RULES FOR INTERPRETING THE CONDITIONS OF THIS LICENCE 3
LICENCE CONDITIONS 5
GENERAL 5
EARLY SURRENDER OF LICENCE 6
OPERATIONAL 6
DISCHARGES 6
MONITORING 6
RECORDING AND REPORTING 7
PERFORMANCE IMPROVEMENT 8
DEFINITIONS 10
Appendix 1: Surface Water and Discharge-Monitoring Plan 12
Appendix 2: Sediment Monitoring Plan 13
Appendix 3: Location Map for Sampling Sites and Authorised Discharge Point 14
Appendix 4: Surface Water Reporting Limits 15
Appendix 5: Baseline Condition Assessment of Water Quality – Protocol for Periodic Reporting 16
Appendix 6: Leanyer Sanderson Wastewater Treatment Plant Site Layout Map 17
Appendix 7: Conceptual Site Model 18

INFORMATION ABOUT THIS LICENCE

Duration of Licence

- This Licence will remain in force until its expiry date, it is surrendered by the Licensee, or until it is suspended or revoked by the Controller of Water Resources.
- The Licensee must notify the Northern Territory Environment Protection Authority (Administrating Agency) within 14 days after ceasing to conduct the activity.
- The Licensee may surrender the Licence to the Administrating Agency.

Amendment, Modification or Revocation of Licence (section 93 of the *Water Act*)

- As set out in section 93 of the Water Act, the Controller of Water Resources may, by notice:
  - amend or modify the terms and conditions of a Licence;
  - revoke a Licence; or
  - suspend a Licence.

Public Register

- A copy of waste discharge Licences and any plans for environmental management, reports, submissions or documents required as a condition of a waste discharge Licence, will be placed on a register.
- A copy of the Annual Return and Monitoring Report will be placed on the register.
- The Administrating Agency makes this register freely available from the Administrating Agency website.

Environmental Interests

- This section highlights the beneficial uses as declared under the *Water Act* and the sensitivity of the surrounding land use and environment associated with the location of the approved activity.
  - Declared beneficial uses and or water quality objectives are:

    Declaration of Beneficial Uses and Objectives, Darwin Harbour Region, Northern Territory Government Gazette No. G27, 7 July 2010.
  - Sites of Conservation Significance
  - Ramsar Wetland

Cultural Interests

- It is the Licensee's responsibility to contact the Aboriginal Areas Protection Authority, appropriate land council or other governing body and ensure that any Authority Certificates required as a result of conducting the Licenced activity are obtained and complied with.

RULES FOR INTERPRETING THE CONDITIONS OF THIS LICENCE

- Where there is a discrepancy between the conditions of this Licence and any plan, standard, guideline or other document referred to in this Licence, the conditions of this Licence prevail to the extent of the inconsistency.

- Any reference to any standard (Australian or international) in this Licence means the relevant parts of the current version of that standard.
- A reference to any guideline or code of practice (or to the relevant parts of any guideline or code of practice) in this Licence means the current version of the guideline or code of practice.
- Under section 76 of the *Water Act*, any contravention of or failure to comply with this Licence by the Licensee may be an offence.
- In this Licence, unless the contrary intention appears, words that are defined in the *Water Act* are intended to have the meaning given to them in that Act.

LICENCE CONDITIONS

GENERAL

1. The Licensee must ensure the contact details recorded with the Administrating Agency for this Licence are correct at all times.
2. The Licensee must at all times have a 24 hour emergency contact.
3. The Licensee must notify the Administrating Agency prior to making any operational change that will cause, or is likely to cause, an increase in the potential for environmental harm.
4. The Licensee must cause clear and legible signage, in English, to be displayed in a prominent location at each public entrance to the premises that includes the following details; within 6 months of the commencement date of this licence:
    - 4.1. waste discharge licence issued under the *Water Act*; and
    - 4.2. 24 hour emergency contact details.
5. The Licensee must cause a copy of this Licence to be available for inspection by any person, in hard copy form, at the registered business address.
6. The Licensee must provide to the Administrating Agency, within 10 business days of a request, a copy of any document, monitoring data or other information in relation to the activity, in the format requested by the Administrating Agency.
7. All notices, reports, documents or other correspondence required to be provided as a condition of this Licence, unless otherwise specified as a condition of this Licence, must be provided in electronic form by emailing waste@nt.gov.au.
8. The Licensee must, for the duration of this Licence, implement, maintain and follow a Consultation and Communication Plan which includes a strategy for communicating with persons who are likely to have a real interest in, or be affected by, the activity.
9. The Licensee must submit to the Administering Agency a Communications Action Plan for WDL147-08 within 2 months from commencement date of this Licence
10. The Licensee must operate and maintain a community feedback number.
11. The Licensee must display the community feedback number:
    - 11.1. where the Licensee has a website, in a prominent location on the Licensees website;
    - 11.2. in the Consultation and Communication Plan; and
    - 11.3. in other publicly available documents relating to the activity.
12. The Licensee must maintain a Complaint Log for all complaints received by the Licensee in relation to the activity.
13. The Licensee must ensure that the Complaint Log includes, for each complaint received by the Licensee, the following information:
    - 13.1. the date and time of the complaint;
    - 13.2. the contact details of the complainant if known;
    - 13.3. the nature of the complaint and events giving rise to the complaint;
    - 13.4. prevailing weather conditions at the time of the complaint;
    - 13.5. the action taken in relation to the complaint;

13.6. any conclusions the Licensee made regarding the cause of the complaint; and

13.7. any preventative measure put in place to prevent reoccurrence.

14. The Licensee must implement, maintain and follow an Emergency Response Plan that addresses procedures for responding to emergencies associated with the activity that may cause environmental harm.

EARLY SURRENDER OF LICENCE

15. Any reports, records or other information required or able to be provided by the Licensee under this Licence must be submitted to the Administrating Agency prior to the Licensee surrendering the Licence. If the date on which a report, record or other information is required falls after the date the Licensee requests to surrender this Licensee, the Licensee must provide the report, record or information as far as possible using data available to the Licensee up to and including the date the request to surrender the Licence is made.

OPERATIONAL

16. The Licensee must, without limiting any other condition of this Licence in conducting the Activity do all things reasonable and practicable to ensure the Activity does not adversely affect the Declared Beneficial Uses and Objectives as declared from time to time, including those applying to:
    - The Darwin Harbour Region.

DISCHARGES

17. This Licence authorises discharge to water from the authorised discharge point(s) as identified in Table 1 and Appendix 3, and as otherwise allowed in accordance with the conditions of this Licence.

Table 1

Authorised Discharge Point	Description	Location
Buffalo Creek Outfall SLEEOP	End of pipe for combined outlets from Leanyer Maturation Pond 5 and Sanderson Maturation Pond 5 to Buffalo Creek.	Longitude: 130.91060 Latitude: -12.35890

18. The Licensee must ensure that all discharges from the Authorised Discharge Point in Table 1 must not:

18.1. contain any visible matter, floating oil and grease or petroleum hydrocarbon sheen or scum, or litter or other objectionable matter;

18.2. cause or generate odours which would adversely affect the use of surrounding waters;

18.3. cause visible change in the behaviour of fish or other aquatic organisms;

18.4. cause mortality of fish or other aquatic organisms; or

18.5. cause adverse impacts on plants.

MONITORING

19. The licensee must conduct surface water and discharge water monitoring in accordance

with Appendix 1.

20. The licensee must conduct sediment monitoring in accordance with Appendix 2.

21. The Licensee must for all terrestrial sampling points required by this Licence:

    21.1. install, maintain and provide appropriate identification signage so that they are easily identifiable at all times; and

    21.2. maintain safe access and egress, as is reasonably practicable.

22. The licensee must ensure that all samples and field environmental data are representative of the conditions at the time of sampling.

23. The licensee must ensure that all samples and field environmental data are collected in accordance with recognised Australian Standards and guidelines (such as AS/NZS 5667, ANZECC/ARMCANZ).

24. The licensee must ensure that all monitoring samples are analysed at a laboratory with current NATA accreditation or equivalent, for the parameters to be measured.

25. The Licensee must ensure that, for each sample collected in accordance with the activity the following information must be recorded and retained:

    25.1. the date(s) on which the sample was collected;

    25.2. the time(s) at which the sample was collected;

    25.3. the point(s) at which the sample was collected;

    25.4. the name of the person who collected the sample;

    25.5. the chain of custody forms relating to the sample(s);

    25.6. any field measurements and analytical results relating to the sample; and

    25.7. laboratory quality assurance and quality control documentation (where laboratory analysis is required).

RECORDING AND REPORTING

26. The Licensee must keep records of all non-compliances with this licence. These records must be adequate to enable the licensee to comply with the non-compliance notification conditions of this licence.

27. The Licensee must notify the Administrating Agency of any non-compliance with this licence by emailing waste@nt.gov.au, as soon as practicable after (and in any case within 5 Business days after) first becoming aware of the non-compliance.

28. The Licensee must include in the notification of non-compliance the following information:

    28.1. when the non-compliance was detected and by whom;

    28.2. the date and time of the non-compliance;

    28.3. the actual and potential causes and contributing factors to the non-compliance;

    28.4. the risk of environmental harm arising from the non-compliance;

    28.5. the action(s) that have or will be undertaken to mitigate any environmental harm arising from the non-compliance;

    28.6. corrective actions that have or will be undertaken to ensure the non-compliance does not reoccur

    28.7. if no action was taken, why no action was taken; and

28.8. If further investigation is necessary, the date the Licensee will submit an investigation report to the Administrating Agency.

29. The Licensee must comply with the requirements of section 14 of the *Waste Management and Pollution Control Act.*

30. The Licensee must as soon as practicable and in any case within 5 Business days notify the Administering Agency of any exceedances of the surface water reporting limits specified in Appendix 4.

31. The Licensee must provide to the Administering Agency an assessment of water quality in a Periodic Report. The Periodic Reports must:

31.1. assess water quality in accordance with Appendix 5 for that seasonal reporting period;

31.2. include a tabulation of data and trend analysis for the indicators in Appendix 5 for both surface water and discharge monitoring locations; and

31.3. be submitted in accordance with the following schedule:

Seasonal Reporting Period	Report Submission at end of:
October to April (Wet season)	June
May to September (Dry season)	November

32. The Licensee must provide to the Administering Agency a Monitoring Report:

32.1. within 10 Business Days prior to the 1 September 2019; and

32.2. 30 Business Days prior to the expiry date of this Licence.

33. The Licensee must ensure that each Monitoring Report:

33.1. is prepared in accordance with the requirements of the NT EPA 'Guideline for Reporting on Environmental Monitoring';

33.2. includes a tabulation of all monitoring data required as a condition of this licence;

33.3. includes long term trend analysis of monitoring data to demonstrate any environmental impact associated with the activity over a minimum period of six years (where the data is available); and

33.4. reports on progress relating to the Leanyer Sanderson WDL 147 Improvement Plan 2017 dated March 2017 and the Darwin Region Sewerage Strategy.

34. The Administrating Agency may require the Licensee to revise or amend and resubmit any Monitoring Report. Where the Administrating Agency requires the Monitoring Report to be resubmitted, the Licensee must submit it to the Administrating Agency by the date specified by the Administrating Agency.

35. The Licensee must submit an updated Environmental Risk Assessment for the activity:

35.1. within 10 Business Days prior to the 1 September 2019; and

35.2. 30 Business Days prior to the expiry date of this Licence.

36. The Licensee must submit a completed Annual Return within 10 business days prior to each anniversary date of this licence and within 30 Business days prior to the Licence expiry date.

PERFORMANCE IMPROVEMENT

37. The Licensee must progress the actions identified in the Leanyer Sanderson WDL 147 Improvement Plan 2017 dated March 2017.

38. Within 1 year from the commencement date of this Licence, the Licensee must develop and implement a plan to conduct further investigations to characterise the risks to human health relating to algal toxins in aquatic fauna harvested from Buffalo Creek for human consumption.

END OF LICENCE CONDITIONS

This Licence is not valid unless signed below:

Jo Townsend

Controller of Water Resources

Dated the 13. April 2017

END NOTES

This Licence supersedes WDL 147-07 which was issued 15 April 2015

WDL 147-06 was issued on 15 January 2015

WDL 147-05 was issued on 2 August 2013.

WDL 147-04 was issued on 22 March 2013.

WDL 147-03 was issued on 15 January 2013.

WDL 147-02 was issued on 11 May 2012.

WDL 147-01 was issued on 15 January 2011.

WDL 147 was issued on 13 October 2006.

DEFINITIONS

In this licence, unless a contrary intention appears:

Term	Definition
24 hour emergency contact	the phone number of a person who can be contacted at any time and be capable of responding to and providing information about any incident associated with the activity.
Activity	the Licenced activity as described on the covering page of this licence.
Annual Return	A prescribed format for demonstrating and reporting compliance with the conditions of this licence.
ANZECC/ARMCANZ	Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000: National Water Quality Management Strategy: *Australian Guidelines for Water Quality Monitoring and Reporting*.
Business days	a day not Saturday, Sunday or a public holiday, in the Northern Territory.
Community feedback number	a telephone number enabling members of the public to contact, at any time, a person or voice mail system that can accept, on behalf of the licensee, enquiries or complaints about the activity, and to which the licensee must respond.
Complaint Log	a register of complaints to be maintained by the Licensee that records the details of each complaint received in relation to the activity.
Consultation and Communication Plan	a written plan documenting proposed consultation and communications for the activity before, during and after the activity which includes a strategy for communicating with members of the public who are likely to have a real interest in, or be affected by, the activity.
Contact details	includes the 24 hour emergency contact, and name, position title and phone number of a representative of the licensee who can be contacted about the licence and activity.
Discharges	allow a liquid, gas or other substance to flow out from where it has been confined.
Emergency Response Plan	a written plan documenting the licensee's procedures for responding to emergencies caused by, resulting from or associated with the activity and that may cause environmental harm.
Environmental harm	any harm to or adverse effect on, or potential harm to or potential adverse effect on, the environment
incident	includes: (a) an accident, emergency or malfunction; and (b) a deliberate action, whether or not that action was taken by the person conducting the activity in the course of which the incident occurred.
Maintain	kept in a manner that it does not present or cause a risk of environmental harm or a hazard to persons or property or, for the purposes of documents including plans, a process of reviewing and amending documentation to ensure it is relevant.
NATA	National Association of Testing Authorities, Australia.
Non-compliance	failure or refusal to comply, whether by act or omission, with obligations or requirements and includes any exceedance of a licence limit.
Non-compliance notification	a prescribed format for notifying the Administrating Agency of a non-compliance.
Plant and equipment	all material items used in association with the activity, including (but not

Term	Definition
	limited to) storage vessels and containers, pipe work and hosing, vehicles (including vessels), tools, and measuring equipment.
Pollute	in relation to water, means directly or indirectly to alter the physical, thermal, chemical, biological or radioactive properties of the water so as to render it less fit for a prescribed beneficial use for which it is or may reasonably be used, or to cause a condition which is hazardous or potentially hazardous to: (a) public health, safety or welfare; (b) animals, birds, fish or aquatic life or other organisms; or (c) plants.
Premises	the premises identified in this licence which includes equipment, plant and structures, whether stationary or portable, and the land on which premises are situated.
Public entrance	access to the premises that is utilised by the public.
Qualified sampler	a person who has training and experience in obtaining samples from the relevant environmental medium.
Waste	Includes matter or a thing, whether wholly or partly in a solid, liquid or gaseous state, which, if added to water, may pollute the water.
Wastewater	water that contains a contaminant or waste.
Water	means water, whether or not it contains impurities.
WMPC Act	the Northern Territory *Waste Management and Pollution Control Act*.

Appendix 1: Surface Water and Discharge-Monitoring Plan

		Sampling Locations[a]					
	Classification	Discharge	Upper zone		Transition zone	Outer zone	
	Site Code	SLEBCDP (SLe100)	SLEBC01	SLEBC03	SLEBC06	SLEBC08	SLESB02
	Latitude	-12.36033	-12.35148	-12.35246	-12.33833	-12.34260	-12.33546
	Longitude	130.90943	130.91045	130.90735	130.90816	130.92511	130.93008
Indicator		**Monitoring Frequencies**					
Physico-chemical							
Flow		D	NR	NR	NR	NR	NR
pH		F	M				
Electrical conductivity							
Dissolved oxygen							
Temperature							
Turbidity							
Total suspended solids		M					
Biological							
Biochemical oxygen demand		M					
Chlorophyll-a							
Nutrients							
Ammonia (total as N)		M					
Total nitrogen							
Oxidised nitrogen (NO_X as N)							
Total phosphorous							
Filterable reactive phosphorous							
Metals							
Copper (filtered)		M					
Zinc (filtered)							
Pathogen indicators							
Escherichia coli		F	M				
Enterococci							
Phytoplankton							
Total phytoplankton identification and enumeration		M					
Biovolume (cyanobacteria)		M					

a As identified in Appendix 3 (Location Map)

Where: **NR** = Not required; **D** = daily (if flow monitoring equipment is impaired data may be based on reasonable estimates for the period that the data is affected); **F** = fortnightly, **M** = monthly

Appendix 2: Sediment Monitoring Plan

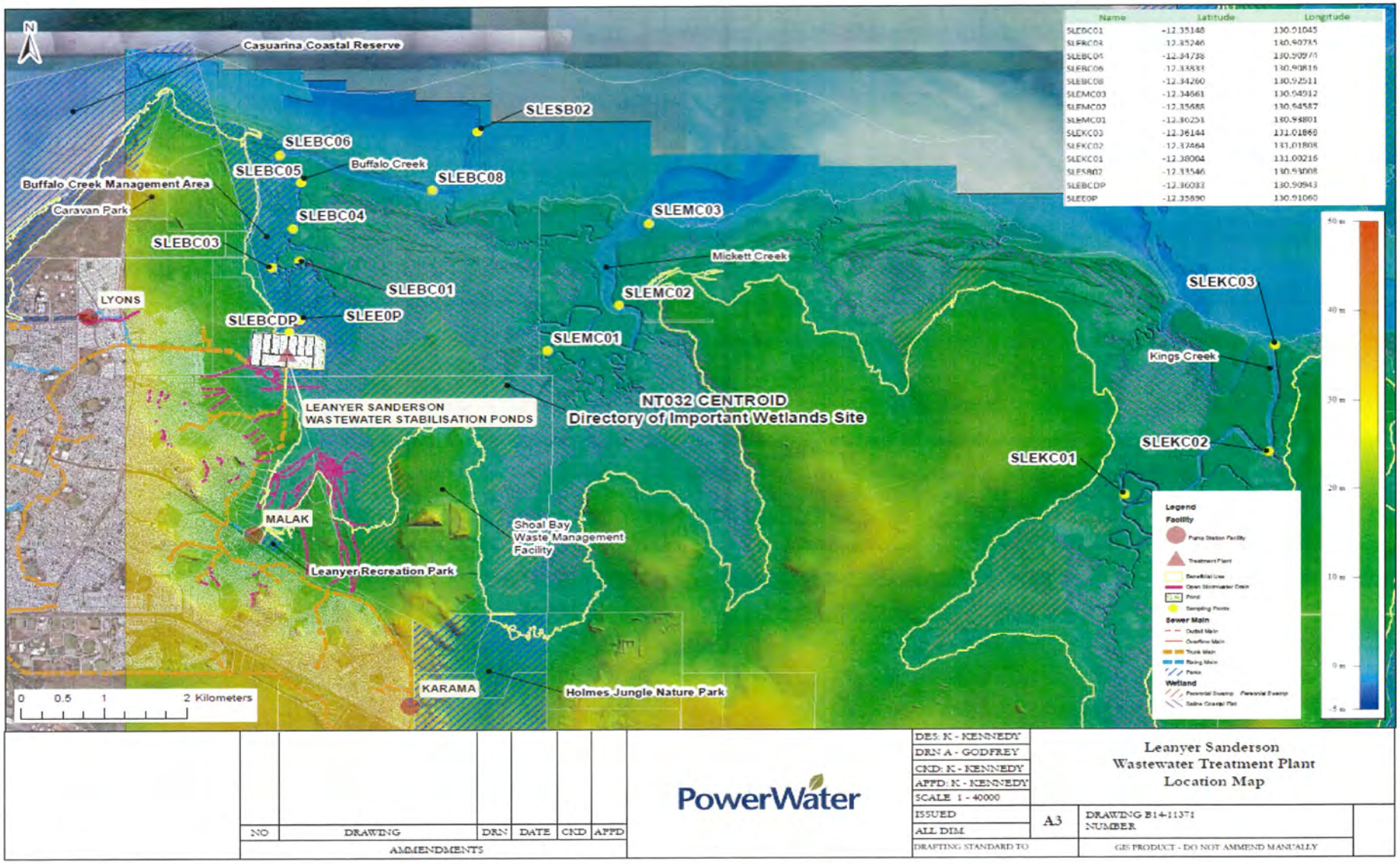
			Classification	Test Estuary – Buffalo Creek[a]						Reference – Mickett Creek[a]			Reference – Kings Creek[a]		
			Site Code	SLEBC01	SLEBC03	SLEBC04	SLEBC05	SLEBC06	SLEBC08	SLEMC01	SLEMC02	SLEMC03	SLEKC01	SLEKC02	SLEKC03
			Latitude	-12.35148	-12.35246	-12.34738	-12.34259	-12.33833	-12.34260	-12.36251	-12.35688	-12.34661	-12.38004	-12.37464	-12.36144
			Longitude	130.91045	130.90735	130.90974	130.91037	130.90816	130.92511	130.93801	130.94587	130.94912	131.00216	131.01808	131.01868
Indicators	**Matrix**		**Assessment Protocol**	**Monitoring Frequency**											
	Sediment	**Pore waters**													
Interpretive															
Total organic carbon	✓	×	C:N ratios	Dry season											
Aluminium	✓	×	Al normalisation of total sediment metals												
pH	×	✓	pH adjustment of ANZECC and ARMCANZ SMD TV												
Biological															
Chlorophyll-a	✓	×	1. Compare to 2 x 80th perdentile of reference data; 2. Determine photosynthetic activity using ratios to pheophytin-a	Dry season											
Nutrients															
Total nitrogen	✓	✓	1. Compare to 2 x 80th percentile of reference data	Dry season											
Ammonia (Total as N)	×	✓	1. Compare to pH adjusted ANZECC and ARMCANZ SMD TV[b] 2. Compare to 2 x 80th percentile of reference data												
Total phosphorous	✓	✓	1. Compare to 2 x 80th percentile of reference site data												
Filterable reactive phosphorous	×	✓	1. Compare to 2 x 80th percentile of reference site data												
Metals															
Copper	✓ T,B	✓ F	1. Compare to ANZECC and ARMCANZ ISQG Low[c] in sediment and SMD TV[d] in porewater 2. Compare to 2 x 80th percentile of reference data in sediment and porewaters 3. Compare Al normalised data in sediment to 2 x 80th percentile of reference data in that season and assess for significant differences	Dry season											
Zinc	✓T,B	✓ F													

a As identified in Appendix 3 (Location Map)

b Table 8.3.7 Volume 2; cTable 3.5.1 Volume 1; d Table 3.4.1 Volume 1

Where – **T** = Total; **B** = bioavailable estimated by dilute 1 M HCL extraction; **F** = filtered; **ANZECC and ARMCANZ** = Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2000); **SMD** = slightly to moderately disturbed; **ISQG** = interim sediment quality guidelines; **TV** = trigger value

Appendix 3: Location Map for Sampling Sites and Authorised Discharge Point



Appendix 4: Surface Water Reporting Limits

	Sampling Locations[a]			
Classification	Upper zone	Transition zone	Outer zone	
Site Code	SLEBC03	SLEBC06	SLEBC08	SLESB02
Latitude	-12.35246	-12.33833	-12.34260	-12.33546
Longitude	130.90735	130.90816	130.92511	130.93008
Indicator	**Unit**	**Reporting Limits**		
pH	pH Units	<6 and > 8.5		
Dissolved oxygen	% Saturation	<30 %	<50	<75	<75
Enterococci	Enterococci/ 100 mL	-	>200	>50 DRY and >200 WET	
Ammonia (total as N)	µg/L	-	>1700[b]	>910[c]	>20
Copper (filtered)	µg/L	-	>3[d]	>1.3[c]	>1.3[c]

a As identified in Appendix 3 (Location Map)

b 80 % Level of Protection, Table 3.4.1 ANZECC and ARMCANZ (2000)

c 95 % Level of Protection, Table 3.4.1 ANZECC and ARMCANZ (2000)

d 90 % Level of Protection, Table 3.4.1 ANZECC and ARMCANZ (2000)

Where, **DRY** = reporting limit for data collected in the dry season between May and September and **WET** = reporting limit for data collected in the wet season between October and April

Appendix 5: Assessment of Water Quality – Protocol for Periodic Reporting

		Sampling Locations[a]					
	Classification	Upper zone		Transition zone	Outer zone		
	Site Code	SLEBC01	SLEBC03	SLEBC06	SLEBC08	SLESB02	
	Latitude	-12.35148	-12.35246	-12.33833	-12.34260	-12.33546	
	Longitude	130.91045	130.90735	130.90816	130.92511	130.93008	
Indicator	**Unit**	**Assessment Criteria**					**Assessment Statistic**
Dissolved oxygen	% saturation	<75 and > 100[b]					median
Total suspended solids	mg/L	10[b]				6[b]	median
Chlorophyll-a*	µg/L	4[b]				2[b]	median
Ammonia (Total as N)	µg/L	20[b]					median
		2490[c]		1100[c]			95th percentile
Total nitrogen	µg/L	300[b]				270[b]	median
Oxidised nitrogen (NOx as N)	µg/L	20[b]				17[b]	median
Total phosphorous	µg/L	30[b]				20[b]	median
Filterable reactive phosphorous	µg/L	9[b]				5[b]	median
Copper (filtered)	µg/L	1.3[d]					95th percentile
Zinc (filtered)	µg/L	15[d]					95th percentile
Enterococci	Enterococci/100 mL	50[b,]					maximum
		A, B,C,D[e]					Long term 95th percentile (Hazen Method)

a As identified in Appendix 3 (Location Map)

b Water Quality Objectives for the Darwin Harbour Region – Background Document (Department of Natural Resources, Environment, The Arts and Sport, 2010)

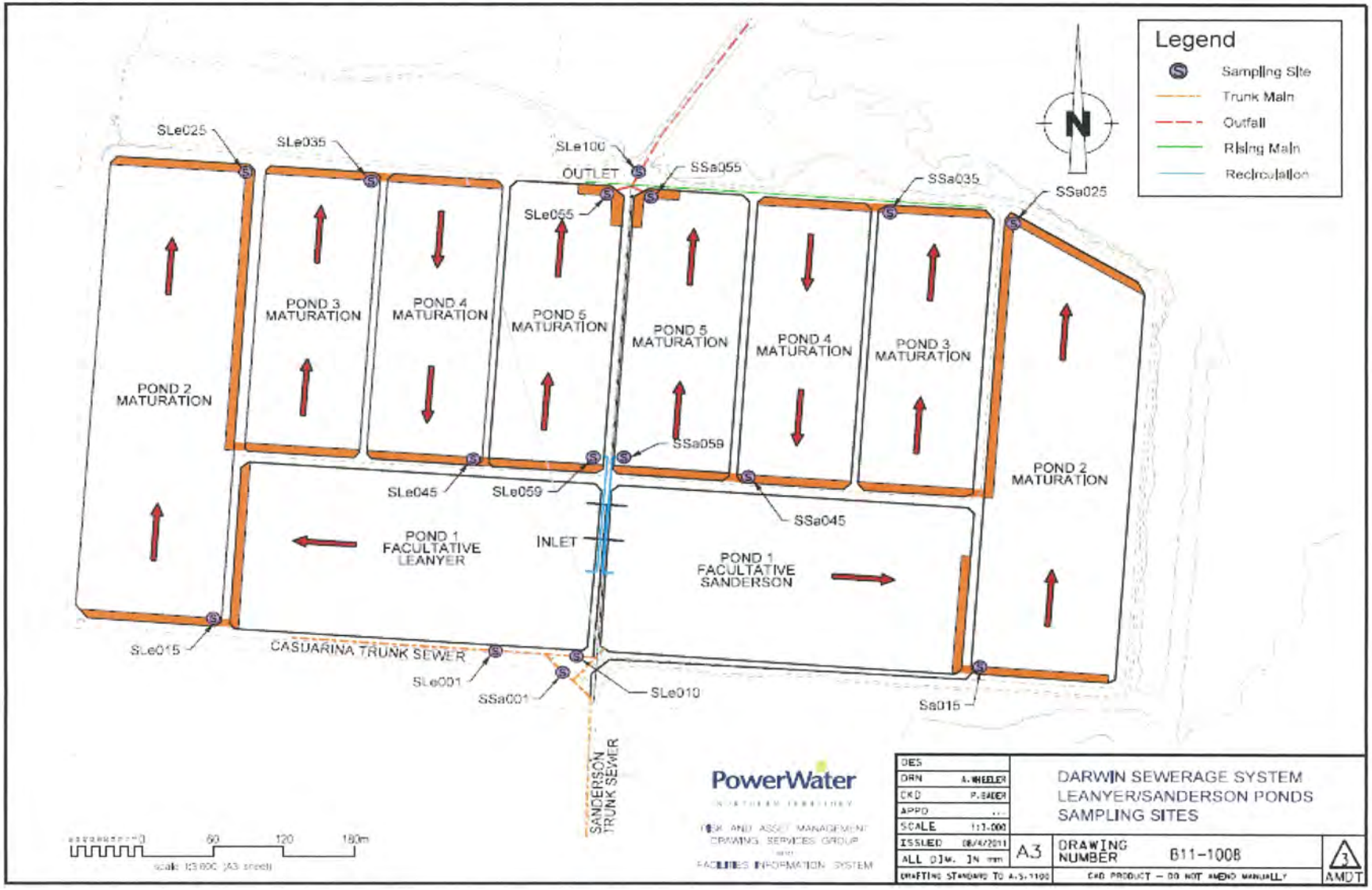
c Table 8.3.7 Volume 2 of ANZECC and ARMCANZ (2000) - pH adjusted SMD Trigger Value based on long-term average pH for sites in these zones

d Table 3.4.1 ANZECC and ARMCANZ (2000) – SMD Trigger Value

e Determine the Microbial Water Quality Assessment Category for the assessment statistic (A, B,C,D), Table 5.7 in order to apply these categories within Table 5.17 Classification Matrix for Faecal Pollution of Recreational Water Environments of the Guidelines for Managing Risks in Recreational Waters (National Health and Medical Research Council 2008)

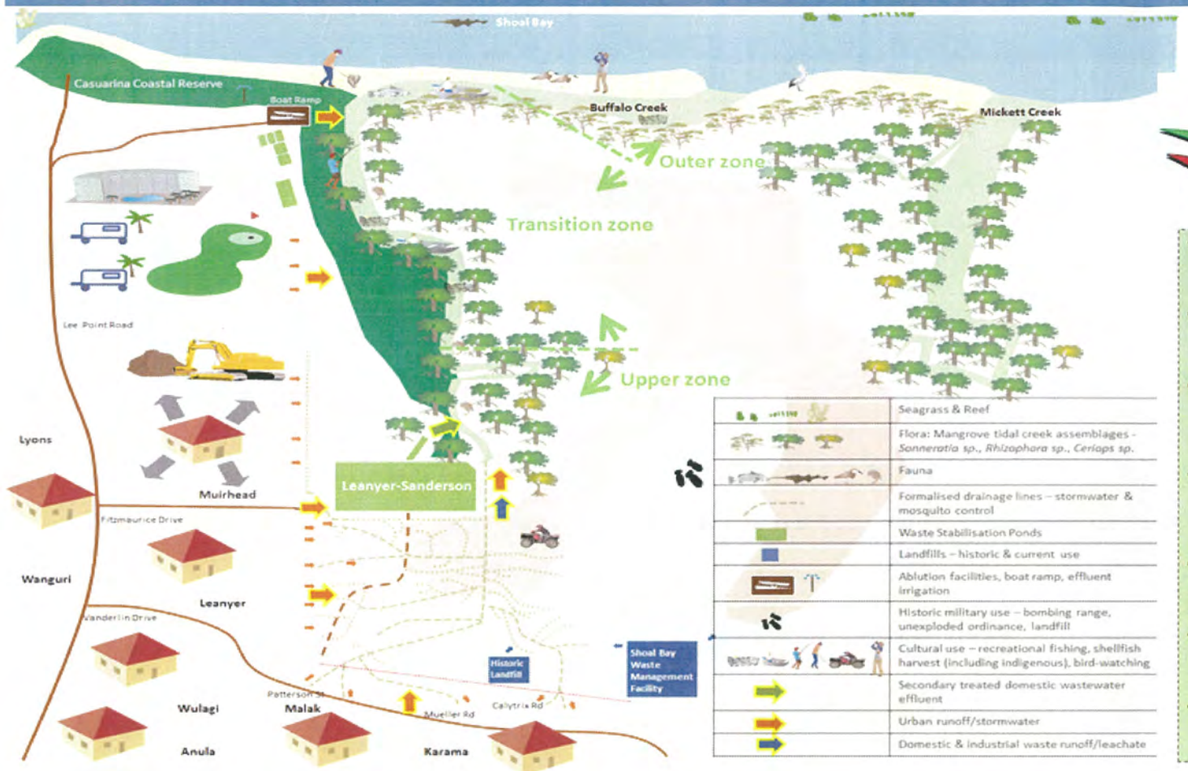
Where, 'Long term' means all monitoring data collected to date pooled. Hazen based assessments require more data points to be reasonably accurate in terms of the true 95th percentile (i.e. N > 21)

Appendix 6: Leanyer Sanderson Wastewater Treatment Plant Site Layout Map



Appendix 7: Conceptual Site Model

CONCEPTUAL SITE MODEL – LEANYER SANDERSON DISCHARGE



KEY STRESSORS & ZONES IN BUFFALO CREEK

Upper zone

- Narrow, convoluted channel with shading of water column by mangrove canopy reducing light penetration;
- Multiple barriers to tidal exchange and greater distance from direct marine influence;
- Lower recreational use with difficult boat access and terrestrial access restricted due to defence safety and mosquito control activities;
- Relatively small catchment area but higher proportion urbanised compared to larger Mickett Creek and Howard River catchment areas;
- Upper zone has been artificially drained for development/mosquito control (including high value wetland areas);
- Inputs from other sources including stormwater and landfills poorly characterised;
- Water colour heavily influenced by freshwater phytoplankton in discharge

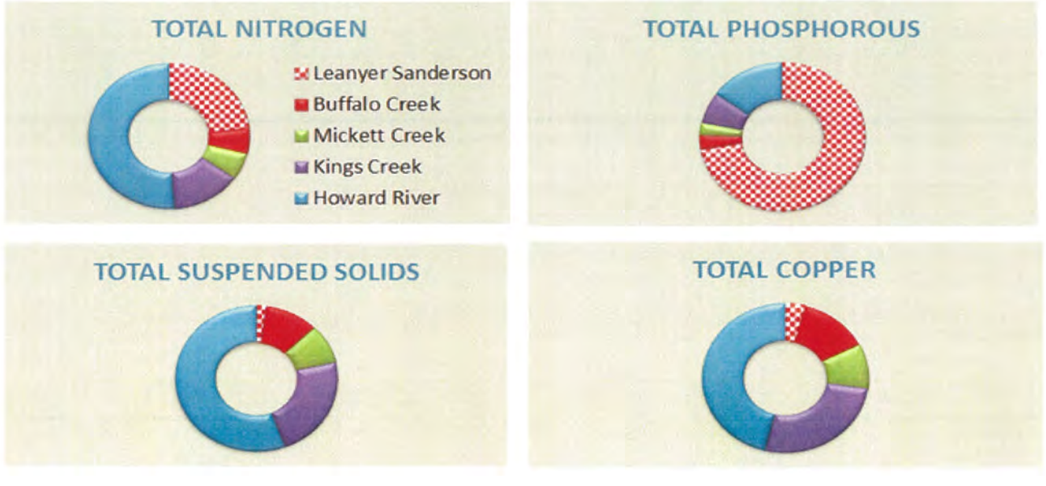
Transition zone

- Wider and less convoluted channel with improved potential light penetration to water column;
- Multiple barriers to tidal exchange still but improved mixing with more proximal marine waters;
- Higher recreational use primarily via boat access to upper reaches but also a very high level of terrestrial access via the boat ramp area near the mouth. Very popular fishing and shellfish harvesting area in it's own right but also used to launch boats to access other tidal creeks in Shoal Bay that are not serviced by boat ramps (Mickett and Kings Creek).
- Inputs from other sources including stormwater from increasing urban footprint extending towards Lee Point, effluent irrigation from ablution facilities and additional waste stabilisation ponds poorly characterised
- Water colour commonly influenced by in-situ phytoplankton biomass stimulation that can be described as 'red-tide' like appearance

Outer zone

- Change in water type from high retention upper estuary within the creek itself to mid-estuary water type in Shoal Bay;
- Barrier-sand bar across the mouth with the entrance to the creek shifting along the sand bar at times, out-side of which the highest level of mixing with marine waters occurs;
- High level of recreational use with terrestrial access at low tide possible along the sand-bar across the mouth of the creek;
- More sensitive receptors including reef areas (Lee Point) and sea-grass beds (seasonally) can be present in these more pristine marine areas;
- Water colour not typically impacted by discharge
- Marine waters influenced seasonally by catchment inputs from Howard River in particular

DISCHARGE VS. CATCHMENT LOADS

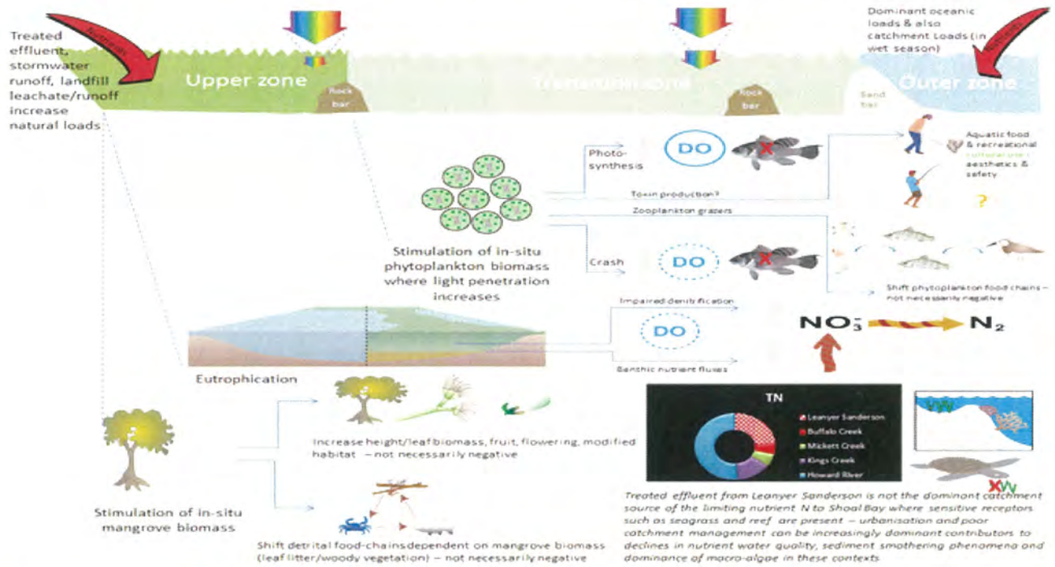


TREATMENT LOAD REDUCTION

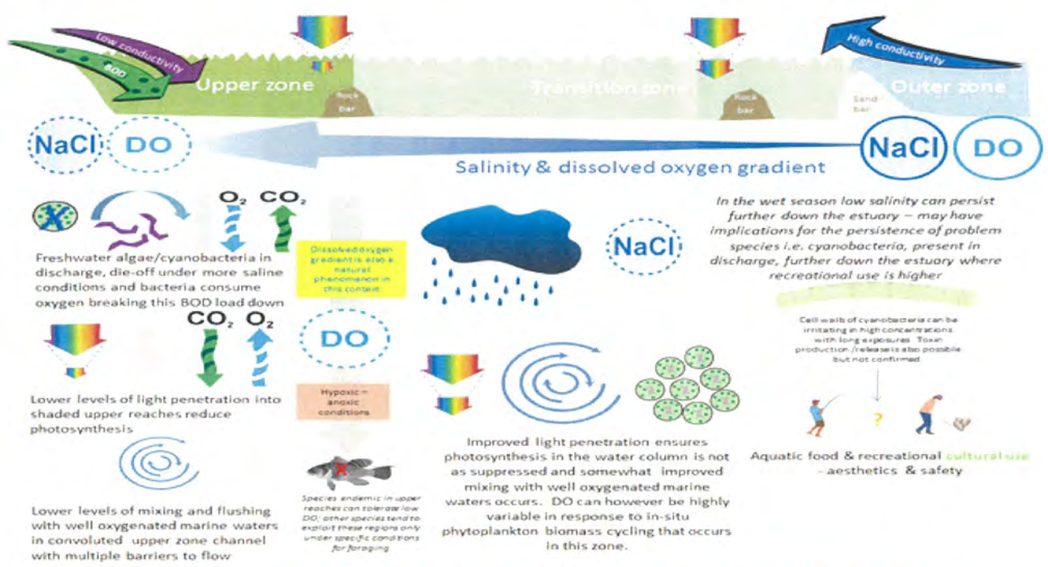
INDICATOR	TREATMENT
Nitrogen	↓ Load by 57 %
Phosphorous	↓ Load by 34 %
Ammonia	↓ Load by 75 %
BOD	↓ Load by 67 %
Copper	↓ Load by 94 %
E.coli	↓ Load by 4 orders of magnitude

CONCEPTUAL SITE MODELS FOR KEY PROCESSES THAT MAY IMPACT BENEFICIAL USES IN BUFFALO CREEK

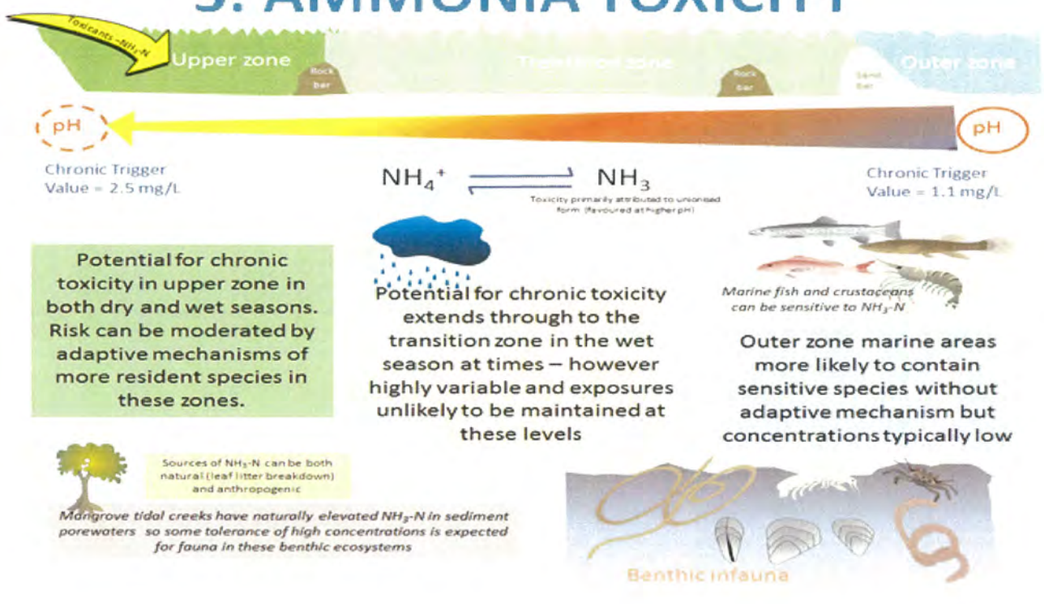
1. NUTRIENT ENRICHMENT



2. BOD & DISSOLVED OXYGEN



3. AMMONIA TOXICITY



4. PATHOGEN INDICATORS