Environmental Impact and Risk Assessment

Stage 1 Kittyhawk Estate

Land Development Corporation

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RELIANCE, USES and LIMITATIONS

TABLE OF CONTENTS

Appendices

Tables

Figures

1 INTRODUCTION

The Northern Territory Government's primary industrial land developer, Land Development Corporation (LDC), propose developing Stage 1 Kittyhawk Estate (Stage 1), part of the Middle Arm Industrial Precinct south-east of Darwin. The Kittyhawk Estate (Kittyhawk) is approximately 335 hectares (ha) on the Middle Arm Peninsula and incorporates Section 1902 Hundred of Ayers, Channel Island Road (Figure 1), Stage 1 incorporates approx. 50 ha of Kittyhawk.

The proposal requires Development approval (DA) under the *Planning Act* (NT). This report is a supplement to the application for a development permit and aims to assess the potential environmental impact and risks in a format that fulfils the requirements of the Northern Territory's Environment Protection Authority (NT EPA's) *Guideline for the Preparation of a Notice of Intent* and uses the NT EPA's *Environmental Factors and Objectives* to organise information.

The DA is seeking approval to subdivide Kittyhawk Estate (Section 1902) to create five new lots and two new road reserves with associated road, stormwater and utility infrastructure to service the proposed development. The lots (see Figure 2) are:

- Lot 1 –10m products corridor bounding the Road 1 Reserve
- Lot 2 – 15 ha allotment for future development
- Lot 3 - 1ha allotment for future development
- Lot 4 – 27 ha allotment for future development
- Lot 5 – the balance of Section 1902 reserved for future subdivision.

During the subdivision stage, 5.1 ha of vegetation will be cleared being for:

- Road 1 and products corridor (2.9 ha)
- Drainage (1.2 ha[1])
- Creation of a 1ha allotment for future development (referred to as Lot 3).

Road 2 will also be established as part of the subdivision; however, the corridor is already cleared and so does not require land-clearing approvals.

Lot 2, 4 and 5 will remain uncleared for the subdivision other than that which may be required to establish interim drainage controls. If these lots are sold the owner will be required to lodget a Development Application.

This report outlines the approach and analysis results of the assessment of potential environmental impacts and risks associated with developing Stage 1.

The risk assessment presents mitigation strategies to reduce potential impacts. These are operationalised through the *Construction Environmental Management Plan Framework* (CEMPF). The CEMPF is attached to this document as Appendix A will be updated with the development's approval conditions to create the project's Construction Environmental Management Plan.

1.1 Stage 1 extent and future development

Earlier designs of Stage 1 included a much larger area and a different lot layout. The discovery of threatened species led to significant changes in extent and design. Soon after the detection of threatened species on the site, LDC met with the NT Department of Environment and Natural Resources (DENR) to understand requirements for protection of threatened species. This led to the Stage 1 design being

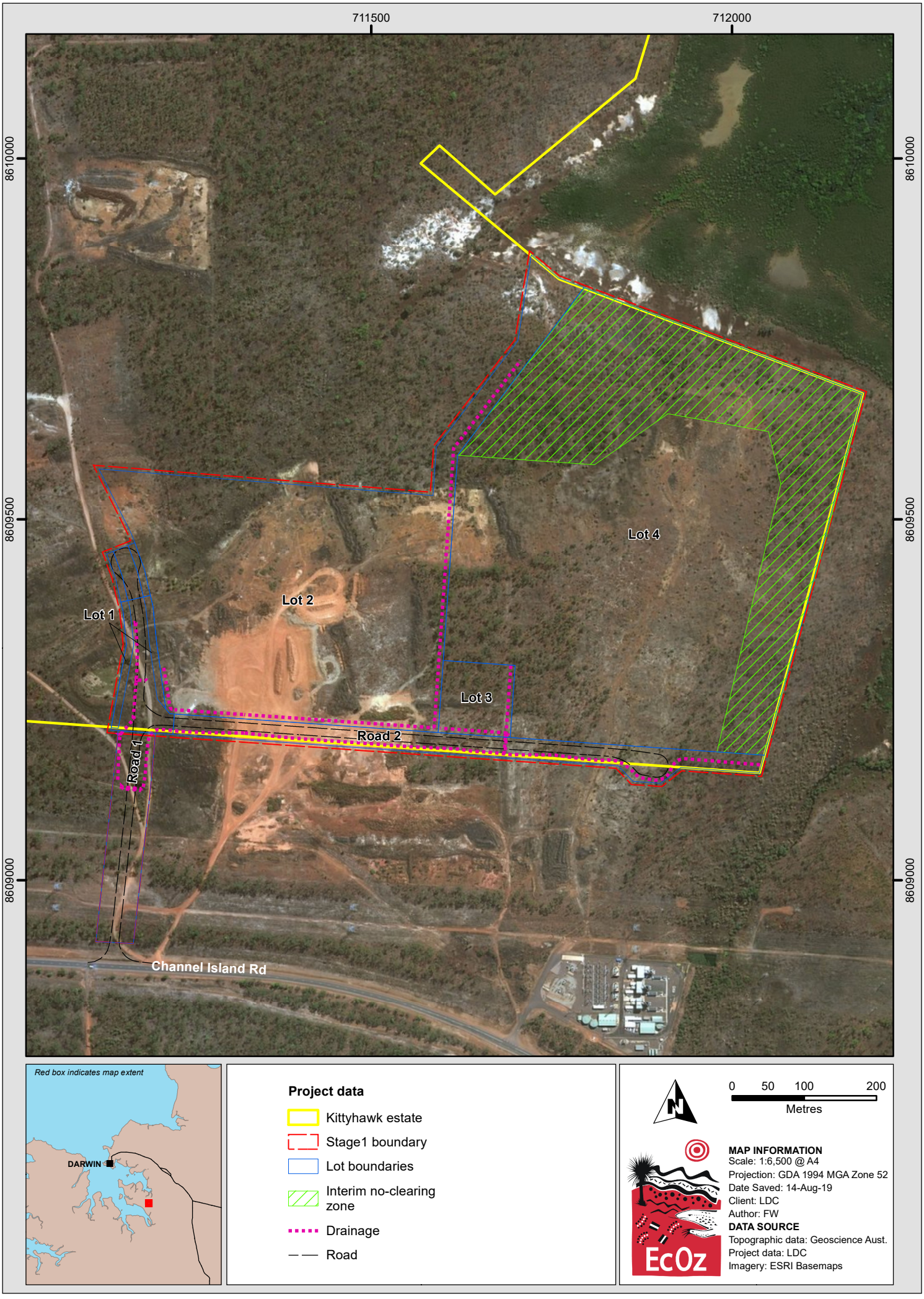
[1] This is an upper estimate

amended to predominantly contain land that was previously disturbed by extractive mining. Subsequent iterations of the final lot layout occurred to ensure that lot size and configuration was suitable for potential land-users, and these changes were discussed with DENR prior to finalising the Stage 1 extant and layout as presented in this report.

Stage 1 now allows for a wildlife corridor (called the Interim no-clearing zone in Figure 2) to the east of Lot 4 to allow passage of the Black-footed Tree-rat. DENR is currently undertaking ecological studies across Middle-Arm as part of a strategic assessment of the region. The outcomes of that study due early in 2020 will guide future development of the area including the fate of the Interim no-clearing zone.

Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ18223 - Kittyhawk Estate Environmental Approvals\01 Project Files\Aug2019\Figure 1. Map showing Stage 1 Kittyhawk Estate and surrounds.mxd

Figure 1. Map showing Stage 1 Kittyhawk Estate and surrounds



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ18223 - Kittyhawk Estate Environmental Approvals\01 Project Files\Aug2019\Figure 2. Map showing Stage 1 Lot layout.mxd

Figure 2. Map showing Stage 1 Lot layout

2 IMPACT AND RISK ASSESSMENT APPROACH

2.1 Environmental factors

The NT EPA has outlined 13 environmental factors as a means of providing a systematic approach to the organisation of environmental information for the assessment of environmental impacts. These factors are the components of the environment that may be impacted by any aspect of a proposal. Associated objectives for each factor are used by the NT EPA to judge whether the impact of a proposal may be significant. These factors, and a preliminary assessment of the potential for impact by the proposal, are presented in Table 1. Those factors which may be impacted by this project (ie. have a Yes in the potentially impacted column) are further explored in subsequent sections

Table 1. Environmental factors and potential impacts

Theme	Factor	Potentially impacted?	Potential impacts
LAND	Terrestrial flora & fauna	Yes	Land clearing, noise, dust, weeds, pest and fire
	Terrestrial environmental quality	Yes	Erosion, chemical spills/contamination
	Landforms	No	Activities will not change the character of existing landforms within the region
WATER	Hydrological processes	Yes	Altered flows to surface and ground water, potential for groundwater draw down
	Inland water environmental quality	Yes	Disturbance to watercourses onsite
	Aquatic ecosystems	No	There are no aquatic ecosystems within the project footprint
SEA	Marine environmental quality	No	Expected that approval conditional upon no change in water quality/quantity coming off site.
	Coastal processes	No	Nature of project will not affect coastal processes
	Benthic habitat & communities	No	Expected that approval conditional upon no change in water quality/quantity coming off site.
	Marine flora & fauna	No	Expected that approval conditional upon no change in water quality/quantity coming off site.
AIR	Air quality & greenhouse gases	Yes	Minor dust expected and no nearby sensitive receptors; greenhouse gases from vehicles used in the development and from land clearing will not be a significant component of

Theme	Factor	Potentially impacted?	Potential impacts
			NT emissions.
PEOPLE & COMMUNITIES	Social, economic & cultural surroundings	Yes	Disturbance to sacred sites, damage to archaeological or heritage sites, dust and increased traffic
	Human health	No	The project does not involve any activities that pose a significant risk to human health and safety. There are no major sources of contaminants that could move off-site and impact the public. Workforce health and safety will be regulated in accordance with national requirements. Impacts associated with road traffic are assessed under the Social, Economic and Cultural Surroundings.

2.2 Risk assessment

Of the 13 factors, five (labelled with a red 'Yes' in Table 1) are considered as potentially likely to be impacted by the proposal. A risk assessment of these potential impacts was undertaken based on *AS/NZS 31000:2009 Risk Management – Principles and Guidelines* was undertaken. An activity-based approach was undertaken, based on the following steps:

1. Identify all project components (and associated incidents/events) that could be a sources of environmental impact that are associated with the preparation of Stage 1
2. Identify the receiving environment the values potentially impacted upon
3. Assign an inherent risk based on the likelihood and consequence of each impact
4. Identify mitigation and management measures that could be applied to avoid or reduce impacts
5. Predict the residual risk (i.e. the worst-possible consequence to the NT EPA's environmental objectives) based on the likelihood and consequence of each impact after mitigation measures are applied
6. Acknowledge any assumptions made during the assessment and note any information gaps/uncertainties that prevent a reliable determination of risk.

The likelihood and consequence categories adopted in the risk assessment are provided in Table 2 and Table 3. The likelihood and consequence ratings were combined to derive an overall risk rating using the matrix in Table 4.

The risk assessment for Stage 1 is included as Table 5. Subsequent chapters of this report describe the outcomes of above the process for each of the five environmental factors potentially impacted by Stage 1. The receiving environment is described, potential impacts are listed together with proposed mitigation measures, and any assumptions made are also noted.

Table 2. Likelihood categories adopted in risk assessment

Categories	Score	Description
Rare	A	Highly unlikely; will only occur in exception circumstances; has never occurred in association with an industrial development in the region
Unlikely	B	Could occur at some time, but unlikely; has only occasionally occurred in association with an industrial development in the region
Moderate	C	Might occur at some stage; has previously occurred in similar industrial developments
Likely	D	Known to occur or will probably occur; has occurred several times in association with recent industrial developments
Almost certain	E	Common or repeating occurrence; is expected to occur several times over the duration of an industrial development project in the region

Table 3. Consequence categories adopted in the risk assessment

Consequence	Score	Terrestrial Flora and Fauna	Terrestrial Environmental Quality	Inland Water Environmental Quality	Hydrological processes	Social, Economic and Cultural Surrounds
Severe Permanent - Impact felt during operations and indefinitely afterwards **Regional** = Impact occurs over a large area beyond the project footprint **Irreversible**	5	Widespread impacts to terrestrial flora and fauna that permanently alter biodiversity and/or ecological integrity over a large area beyond the project footprint	Soil disturbance, erosion or contamination that is irreversible and extends over a larger area beyond the project footprint.	Permanent major exceedance of pre-development water quality for beneficial uses on the Middle Arm Peninsula.	Significant reduction in surface water and groundwater flow volumes, levels and/or timing of flows/discharges leading to permanent irreversible impact to ecological health, land-uses and/or amenity downstream of the project footprint.	Permanent impact that is felt by the majority of regional population. Unauthorised destruction of Aboriginal Sacred Site and/or sites of heritage significance. Irreversible damage.
Major Long-term = Impact felt during operations and for some years **Regional** = Impact occurs beyond the project footprint **Reversible** in the medium-long term with significant remedial works	4	Impacts to terrestrial flora and fauna that lead to long-term alteration of biodiversity and/or ecological integrity and/or extend over a large area beyond the project footprint.	Soil disturbance, erosion or contamination that occurs over a long period of time and/or extends over a larger area than the project area. Significant remedial works required to reverse damage.	Long-term and/or major exceedance of pre-development water quality criteria for beneficial uses downstream of the project footprint. Significant remedial works required over an extended period to return to acceptable water quality.	Reduction in surface water and groundwater flow volumes, levels and/or timing of that compromises ecological health, land-uses and/or amenity long term. Significant remedial works required over an extended period to re-instate hydrological regimes.	Long-term impact felt by some of the regional population. Unauthorised damage to Aboriginal Sacred Sites and/or sites of heritage significance that can be remediated.
Moderate Medium to long-term = Impact felt	**3**	Medium-long term impacts to flora and fauna	Localised soil disturbance, erosion or	On-going minor exceedances of pre-development water	Medium to long-term reduction in surface water flow volumes,	• Medium-long term disruption that is felt by a small number of

Consequence	Score	Terrestrial Flora and Fauna	Terrestrial Environmental Quality	Inland Water Environmental Quality	Hydrological processes	Social, Economic and Cultural Surrounds
during operations and for some months to years' **Localised =** Impact to project footprint or immediate surrounds **Reversible** with a moderate level of remedial works		that are confined to the disturbance footprint and immediate surrounds with no measurable impact to biodiversity and/or ecological integrity	contamination that continues for months to years' post-closure. Damage is reversible with a moderate level of remedial works.	quality criteria beneficial uses. Exceedances will cease within months to a few years following site rehabilitation works.	groundwater levels and/or timing of flows/discharges that impacts ecological health, land-uses and/or amenity within the disturbance footprint and immediate surrounds.	people. • Unauthorised damage to Aboriginal Sacred Sites and/or sites of heritage significance that can be remediated.
Minor Short-term = Impact felt during the subdivision works phase only **Localised =** Impact occurs within the project footprint **Reversible** without significant remedial works	**2**	Short-term impact to flora and fauna with no measurable impact to biodiversity and/or ecological integrity outside of the project footprint.	Short-term and/or localised soil disturbance, erosion or contamination that is reversible without significant remedial works.	Minor temporary exceedances of pre-development water quality criteria for beneficial uses.	Short-term reduction in reduction in surface water flow volumes, groundwater levels and/or timing of flows/discharges that impacts ecological health, land-uses and/or amenity only within the disturbance footprint and immediate surrounds. Natural hydrological regimes will return in a short period of time without significant remedial works.	• Short-term detrimental impact to stakeholder and/or community values. • Short-term disruption/ nuisance that is felt by a small number of people. • Minor damage to Aboriginal Sacred Sites and/or heritage sites that does not require remedial works.

Consequence	Score	Terrestrial Flora and Fauna	Terrestrial Environmental Quality	Inland Water Environmental Quality	Hydrological processes	Social, Economic and Cultural Surrounds
Insignificant No measurable impact outside of the immediate disturbance footprint	**1**	No measureable impact to terrestrial flora and fauna outside of the immediate disturbance footprint.	No measurable soil disturbance, erosion or contamination outside of the immediate disturbance footprint.	No measurable exceedance of pre-development water quality conditions attributable to project activities.	No measurable change to hydrological regimes outside of the immediate disturbance footprint.	• No noticeable impact to stakeholder and/or community values • No impact to Aboriginal Sacred Sites and/or heritage sites.

Table 4. Risk matrix adopted in risk assessment

		Consequence				
Likelihood		1	2	3	4	5
	A	1	3	6	10	15
	B	2	5	9	14	19
	C	4	8	13	18	22
	D	7	12	17	21	24
	E	11	16	20	23	25

Red	Extreme risk	Intolerable
Orange	High risk	Intolerable or tolerable
Yellow	Moderate risk	Tolerable or acceptable
Green	Low risk	Acceptable

Table 5. Risk assessment of Stage 1 Kittyhawk Estate

Environmental Factor/Value	Hazard/Aspect	Incident/event	Possible impact	Assumptions/Limitations/Information	L*	C*	IR*	Mitigation measures	L*	C*	RR*
Terrestrial Flora and Fauna	1 Clearing vegetation / ground disturbance	Removal of vegetation	Loss of significant vegetation types	No significant vegetation types within direct disturbance footprint.	**A**	**1**	**Low**	No significant vegetation communities present, no mitigation required.	**A**	**1**	**Low**
Terrestrial Flora and Fauna	1 Clearing vegetation / ground disturbance	Removal of vegetation	Loss or disturbance of threatened species	The Darwin Cycad is present but in low densities. *Typhonium praetermissum* plants present within Stage 1.	**A**	**1**	**Low**	A translocation management plan will be developed and implemented for all *Typhonium praetermissum* within the Stage 1 boundary.	**A**	**1**	**Low**
Terrestrial Flora and Fauna	1 Clearing vegetation / ground disturbance	Removal of vegetation and concomitant direct impacts on fauna.	Reduced biodiversity value due to loss of habitat	Project area is largely Eucalyptus woodland and some minor drainage lines; these communities are common across the broader area.	**A**	**1**	**Low**	No special environmental values within the area, no mitigation required.	**A**	**1**	**Low**
Terrestrial Flora and Fauna	3 Weeds	Weed introduction and spread	Reduced habitat quality on and off-site due to competition with native plant species and through increased frequency and/or intensity of bushfires.	Project area has existing weeds across the site. There is the potential for the introduction of declared and environmental weeds from off site.	**C**	**3**	**High**	All machinery and equipment to be certified weed free by a suitably qualified person prior to arrival at site and, if required, cleaned. There is an existing Weed Management Plan	**C**	**2**	**Moderate**
Terrestrial Flora and Fauna	5 Noise	Noise emissions from machinery and equipment	Reduced habitat quality for fauna due to noise disturbance.	No sensitive habitats in proximity to site (i.e. wetlands, roost sites).	**A**	**1**	**Low**	No sensitive habitats in proximity to site (i.e. wetlands, roost sites), no mitigation required.	**A**	**1**	**Low**
Terrestrial Flora and Fauna	6 Dust	Dust emissions caused by operation of machinery and equipment	Reduced habitat quality due to smothering of plants	No sensitive habitats in proximity to site (i.e. wetlands, roost sites). Small amounts only of dust emitted during early works	**A**	**1**	**Low**	No sensitive habitats in proximity to site (i.e. wetlands, roost sites), no mitigation required.	**A**	**1**	**Low**
Terrestrial Flora and Fauna	7 Bushfire	Uncontrolled bushfire caused by operation of equipment, lighting fires, discarded cigarette.	Change of vegetation community due to changes in fire frequency.		**B**	**2**	**Low**	No fires allowed on site. Hot works such as welding not to be undertaken on days of total fire ban or high winds. Smokers appropriate disposal of cigarettes, vehicles maintained. Cleared material will not be burnt on site, it will be mulched and use for erosion control or removed from site. Water cart on standby during periods of high fire danger.	**B**	**2**	**Low**
Terrestrial Environmental Quality	13 Storage and handling of hazardous materials	Leaks and spills from fuel storage areas entering surface or groundwater	Soil contamination from leaks/spills	Above-ground fuel storage tanks used during construction. Fuel storage and handling in designated areas and accordance with AS1940.	**C**	**2**	**Moderate**	Fuel storage and handling in designated areas and accordance with AS1940 Spill kits located on site in re fuelling areas and areas where hazardous substances are stored. All workers to be trained in use of spill kits.	**A**	**1**	**Low**
Terrestrial Environmental Quality	2 Erosion	Exposed soils after vegetation clearance	Soil erosion due to increased runoff from cleared areas.		**D**	**2**	**Moderate**	Development and implementation of an Erosion and Sediment Control Plan	**B**	**2**	**Low**
Hydrological processes	11 Hydrology	Change in groundwater recharge	Increase in impervious surfaces leading to altered recharge rates for groundwater.	Very little groundwater onsite, few impervious surfaces resulting from Stage 1.	**B**	**2**	**Low**	No mitigation required.	**B**	**2**	**Low**
Hydrological processes	11 Hydrology	Change in surface water hydrology	Increased flows from impervious areas leading to scouring of onsite drainage lines	Few impervious surfaces resulting from works for this project, any changes managed through drainage controls	**B**	**2**	**Low**	A storm water drainage assessment will be a part of the engineering design and will ensure the drainage from the site is managed to protect stream stability, prevent scouring and not impact on downstream infrastructure.	**B**	**2**	**Low**
Hydrological processes	11 Hydrology	Groundwater drawdown due to use of local bores during construction	Changes in groundwater flow directions and water levels in aquifer	No on-site bore water will be used.	**A**	**1**	**Low**	No mitigation required construction water supplied by registered supplier.	**A**	**1**	**Low**

Environmental Factor/Value	Hazard/Aspect	Incident/event	Possible impact	Assumptions/Limitations/Information	L*	C*	IR*	Mitigation measures	L*	C*	RR*
Inland Water Environmental Quality	13 Storage and handling of hazardous materials	Leaks and spills from fuel storage areas entering surface or groundwater	Hydrocarbon contamination of downstream waterways or groundwater.	Above-ground fuel storage tanks are used during construction fuel storage and handling in designated areas and accordance with AS1940.	**C**	**2**	**Moderate**	Fuel storage and handling in designated areas and accordance with AS1940 Spill kits located on site in re fuelling areas and areas where hazardous substances are stored. All workers to be trained in use of spill kits.	**A**	**1**	**Low**
Inland Water Environmental Quality	15 Waste	Increased nutrients in surface water and groundwater from septic systems	Decreased quality of surface water and groundwater from contaminated water (e.g. bacteria)	Construction phases will use porta-loos. The owner of Lot 1 (and all subsequent lots) will be required to apply for approval through the NT Department of Health for their waste-water management system.	**B**	**2**	**Low**	As lots are developed sewage treatment will have to be approved by DoH.	**A**	**2**	**Low**
Inland Water Environmental Quality	2 Erosion	Erosion of site due to disturbance and exposure of ground surface	Increased turbidity in ephemeral watercourses	Minor ephemeral drainage lines are the receiving waters. Discharge occurs to Darwin Harbour.	**C**	**2**	**Moderate**	Development and implementation of an Erosion and Sediment Control Plan	**B**	**2**	**Low**
Air quality and GHG	6 Dust/GHG	Dust emissions from cleared/disturbed ground and movement of vehicles and material	Increase in air particulates exceeding guidelines values for nuisance and/or protection of human health	Small scale of project, no neighbours nearby	**C**	**2**	**Moderate**	Dust suppression using water carts where necessary.	**B**	**2**	**Low**
Air quality and GHG	6 Dust/GHG	GHG emissions from land clearing	Increase in GHG	Small scale of project / land clearing	**B**	**2**	**Low**	Greenhouse gas emission from that activity will be on par with any small, short-term construction project. No mitigation is required.	**B**	**2**	**Low**
Social, Economic and Cultural Surroundings	1 Clearing vegetation / ground disturbance	Disturbance of ground	Damage or destruction of archaeological or heritage sites	There are no sites listed in the NT Heritage Register within, or proximate to, the project area. There are also no sites listed in the National Heritage List or the Commonwealth Heritage List within, or proximate to, the project area.	**A**	**3**	**Low**	A stop works will be implemented if artefacts are located during activities on site. The project manager will be notified immediately, who will then liaise with the NT Heritage Branch, for further instructions.	**A**	**3**	**Low**
Social, Economic and Cultural Surroundings	1 Clearing vegetation / ground disturbance	Disturbance of ground	Damage, desecration or destruction of Aboriginal sacred sites	An AAPA Authority Certificate has been obtained for this project no restricted works areas were located on-site.	**A**	**3**	**Low**	None required	**A**	**3**	**Low**
Social, Economic and Cultural Surroundings	6 Dust	Dust emissions result in exceedance of air quality (particulates) guidelines	Dust from cleared land or construction activities affecting people off site	No public access to site area; the nearest residential receptor is located approximately 7km away, and commercial receptors located approximately 3km (north/north east) (Ichthys project).	**C**	**2**	**Moderate**	Dust suppression using water carts where necessary.	**B**	**2**	**Low**
Social, Economic and Cultural Surroundings	9 Traffic	Increased traffic movements to and from the project area	Traffic incidents and/or congestion project area traffic	A traffic study has been conducted noting that the traffic from this development will be much less than that during Ichthys LNG peak construction period. The intersection off Channel Island Road has allowed for road train passing and turning lanes passing lanes. DIPL will have approve the intersection design and construction.	**B**	2	**Low**	None required	B	2	**Low**

3 TERRESTRIAL FLORA AND FAUNA

This factor refers to vegetation communities, plants and animals that occur on the land. The NT EPA objective for this environmental factor is to *"protect the NT's flora and fauna so that biological diversity and ecological integrity are maintained."*

This section discusses the potential impacts to flora and fauna within Stage 1 and surrounding areas that may be potentially impacted noise and dust. The potential impact on mangroves due to changes in hydrology is discussed in section 5. The entire Kittyhawk Estate was surveyed for threatened species.

3.1 Existing environment and values

3.1.1 Matters of National Environmental Significance

Matters of National Environmental Significance (MNES) are those nine matters protected by the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Table 6 show the relationship between Kittyhawk and each of these matters and, where relevant, the section in this document that the matter is discussed.

Table 6. MNES on Kittyhawk

EPBC Matter	Comments in relation to Kittyhawk Development	Relevant section in this document
World heritage properties	None on Kittyhawk	
National heritage places	None on Kittyhawk	
Wetlands of international importance (listed under the Ramsar Convention)	There are no aquatic ecosystems on Kittyhawk	Section 5.1.1
Listed threatened species and ecological communities	Listed threatened species: present; ecological communities: none present	Threatened species: Section 3.1.4 Ecological communities: Section 3.1.3
Migratory species protected under international agreements	None present on Kittyhawk or impacted offsite by this development	
Commonwealth marine areas	N/A	
The Great Barrier Reef Marine Park	N/A	
Nuclear actions (including uranium mines)	N/A	
A water resource, in relation to coal seam gas development and large coal mining development	N/A	

3.1.2 Vegetation communities

EcOz Environmental Consultants (EcOz) mapped the vegetation of the Kittyhawk in April 2018 as part of the environmental constraints analysis (Appendix B). The area of Stage 1 is dominated by mixed *Eucalyptus* woodland, with a large proportion (49%) classified as disturbed land, with no remnant vegetation present; see Table 7 and mapping in Figure 3.

The vegetation communities identified within Stage 1 across common across the Greater Darwin region,

Table 7. Vegetation communities of Stage 1 Kittyhawk Estate

Vegetation community	Stage 1 total area (ha)	Stage 1 Clearing (ha)
Mid woodland of *Eucalyptus miniata, Eucalyptus tetrodonta, Corymbia bleeseri* over *Livistona humilis, Cycas armstrongii, Erythrophleum chlorostachys* over tussock grassland of *Heteropogon triticeus, Sorghum intrans, Chrysopogon fallax*	14	**1.7** (0.5 – drainage 0.5 – Lot 3 0.7 – Road 1)
Mid open woodland of *Melaleuca leucadendra, Corymbia polysciada, Melaleuca viridiflora* over *Melaleuca viridiflora, Pandanus spiralis, Planchonia careya* over closed tussock grassland of *Germania grandiflora, Themeda triandra, Dapsilanthus sp.*	6	-
Disturbed	30	**3.4** (0.7 – drainage 0.5 – Lot 3 2.2 – Road 1/Products corridors)
TOTAL	**49.8**	**5.1 ha**

3.1.3 High value ecological/vegetation communities

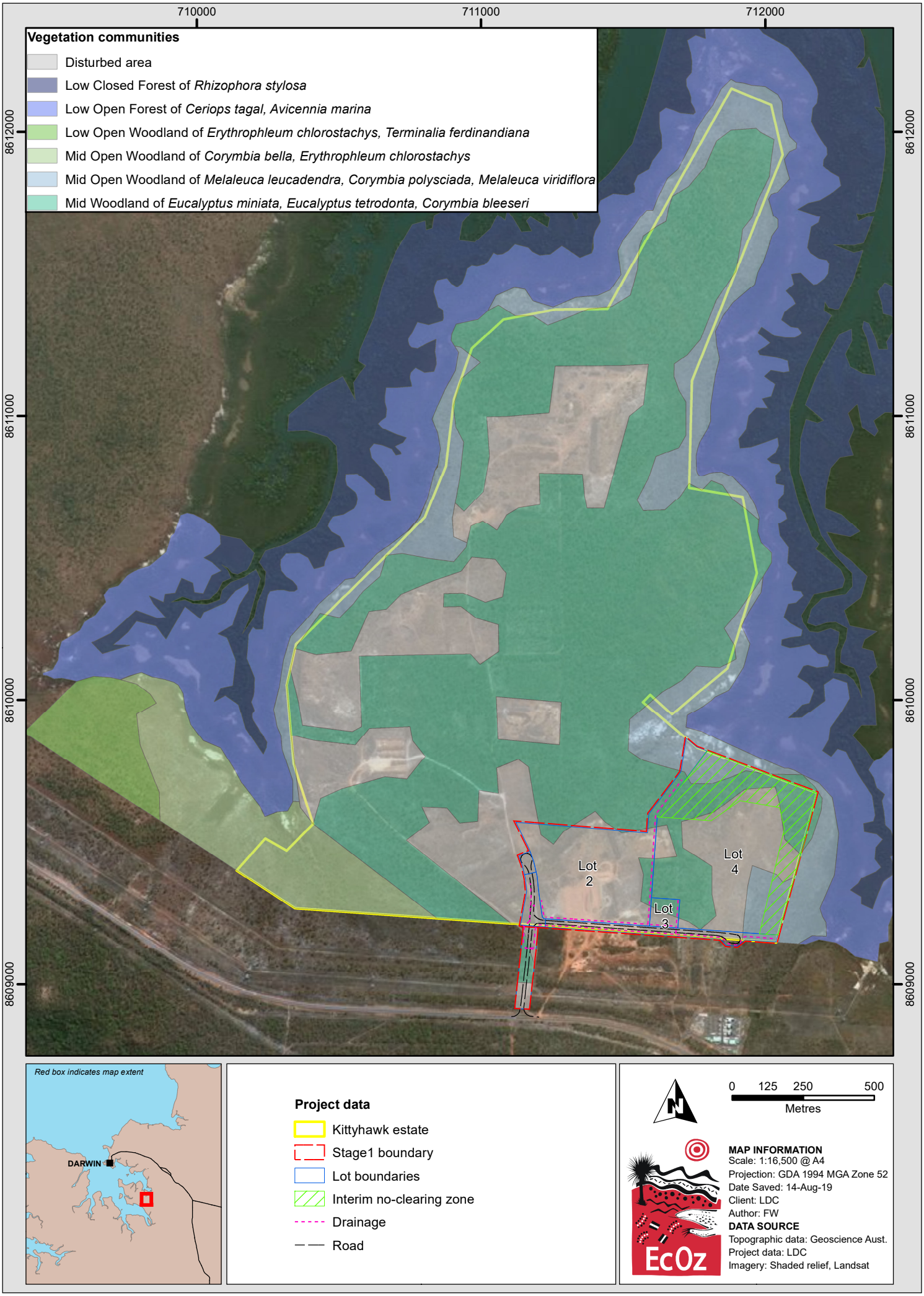
Threatened ecological communities are those ecological communities defined under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). None are present on Kittyhawk.

In the NT, sensitive vegetation are those ecosystems easily impacted by neighbouring or adjacent land uses or management. Significant vegetation includes spatially restricted habitat types that are important to a relatively large number of wildlife species including rainforest, monsoon vine forest or vine thicket; sandsheet heath; riparian vegetation; mangroves; and vegetation containing large trees with hollows suitable for fauna (DENR 2019).

There are no significant vegetation types within the Stage 1 development. Abutting Kittyhawk are mangroves (Figure 3).

3.1.4 Threatened species

To identify the threatened species that may occur on Kittyhawk, data from the NT and Commonwealth governments was collated and analysed. The analysis approach is outlined in the *Ecological Constraints Report* (Appendix B). After that report was completed, the NT listed plant *Typhonium praetermissum*, was added to the list of threatened species that may occur on Kittyhawk. In total there are seven threatened species - five animals and two plants – that are known to occur, or may occur, on Kittyhawk (Table 8).



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ18223 - Kittyhawk Estate Environmental Approvals\01 Project Files\Aug2019\Figure 3. Map showing vegetation communities of Kittyhawk estate.mxd

Figure 3. Map showing vegetation communities of Kittyhawk estate

Table 8. Threatened fauna likelihood of occurrence summary

Name	Group	Status		Desktop likelihood of occurrence
		Cth	NT	
Darwin Cycad *Cycas armstrongii*	Plants	-	VU	Known
Typhonium praetermissum	Plants	-	VU	Known
Black-footed Tree-rat (Kimberley & mainland NT subspecies) *Mesembriomys gouldii gouldii*	Mammals	EN	VU	High
Fawn Antechinus *Antechinus bellus*	Mammals	VU	EN	Medium
Pale Field Rat *Rattus tunneyi*	Mammals	-	VU	Medium
Bare-rumped Sheathtail Bat *Saccolaimus saccolaimus (nudicluniatus)*	Mammals	VU	-	Medium
Floodplain Monitor *Varanus panoptes*	Reptiles	-	VU	Medium

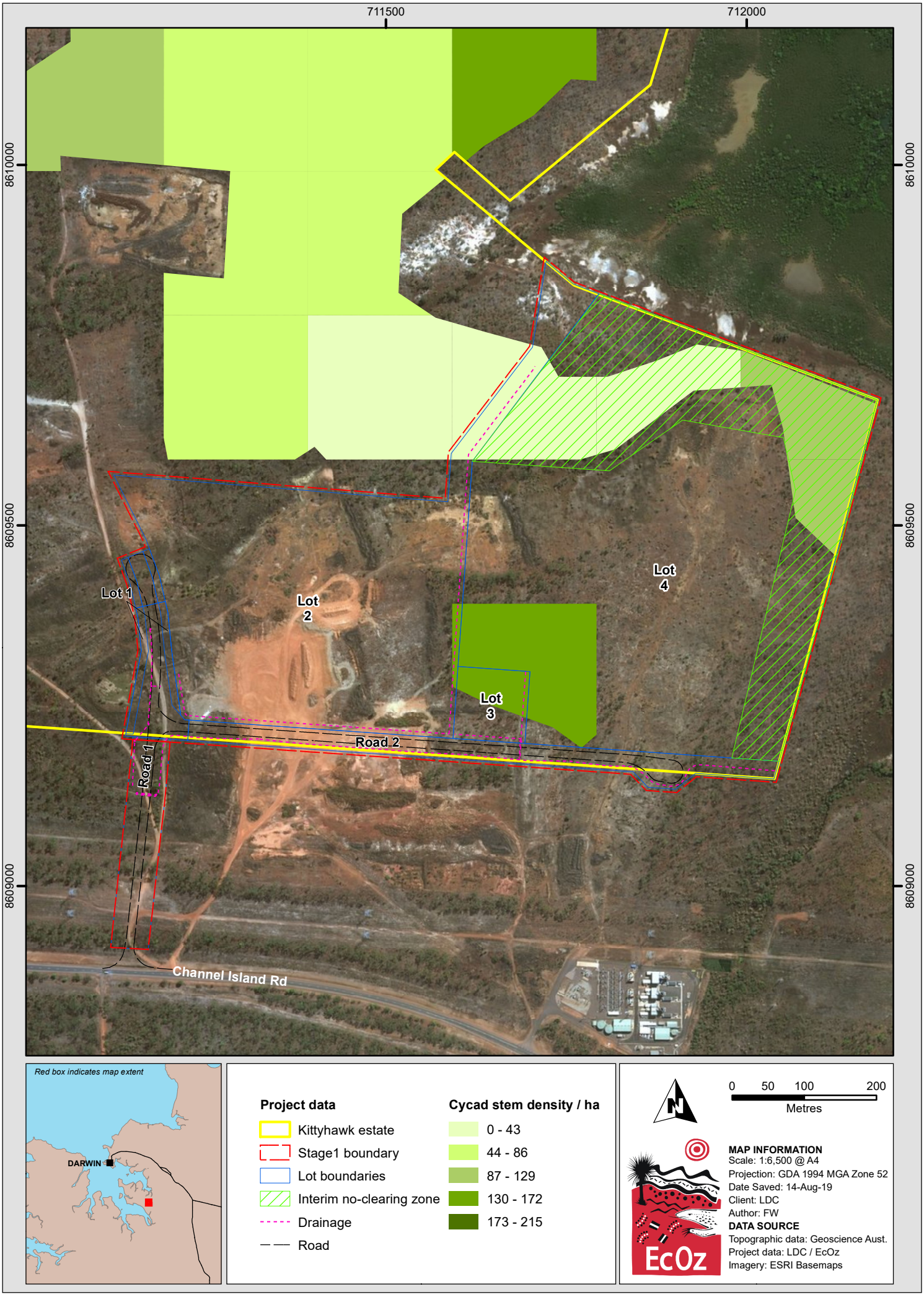
Key: Cth – Commonwealth; NT – Northern Territory. VU – Vulnerable, EN – Endangered (a dash indicates the species is not listed under that jurisdiction

These species were targeted by an ecological survey, the results of which presented as Appendix C. The ecological survey only recorded three threatened species. The survey results and the potential impact to each of these species by this project is discussed below.

The Black-footed Tree-rat was found across Kittyhawk and abutting parts of Middle-Arm (Appendix C). Within Stage 1 there are few opportunities for the presence of the species. Of the 50 ha area of Stage 1, 30 ha is already disturbed and only 5.1 ha will be cleared for this development (Figure 3 and Table 7), clearing of any the remaining vegetation will have to go through another approval process when an owner is found for each lot.

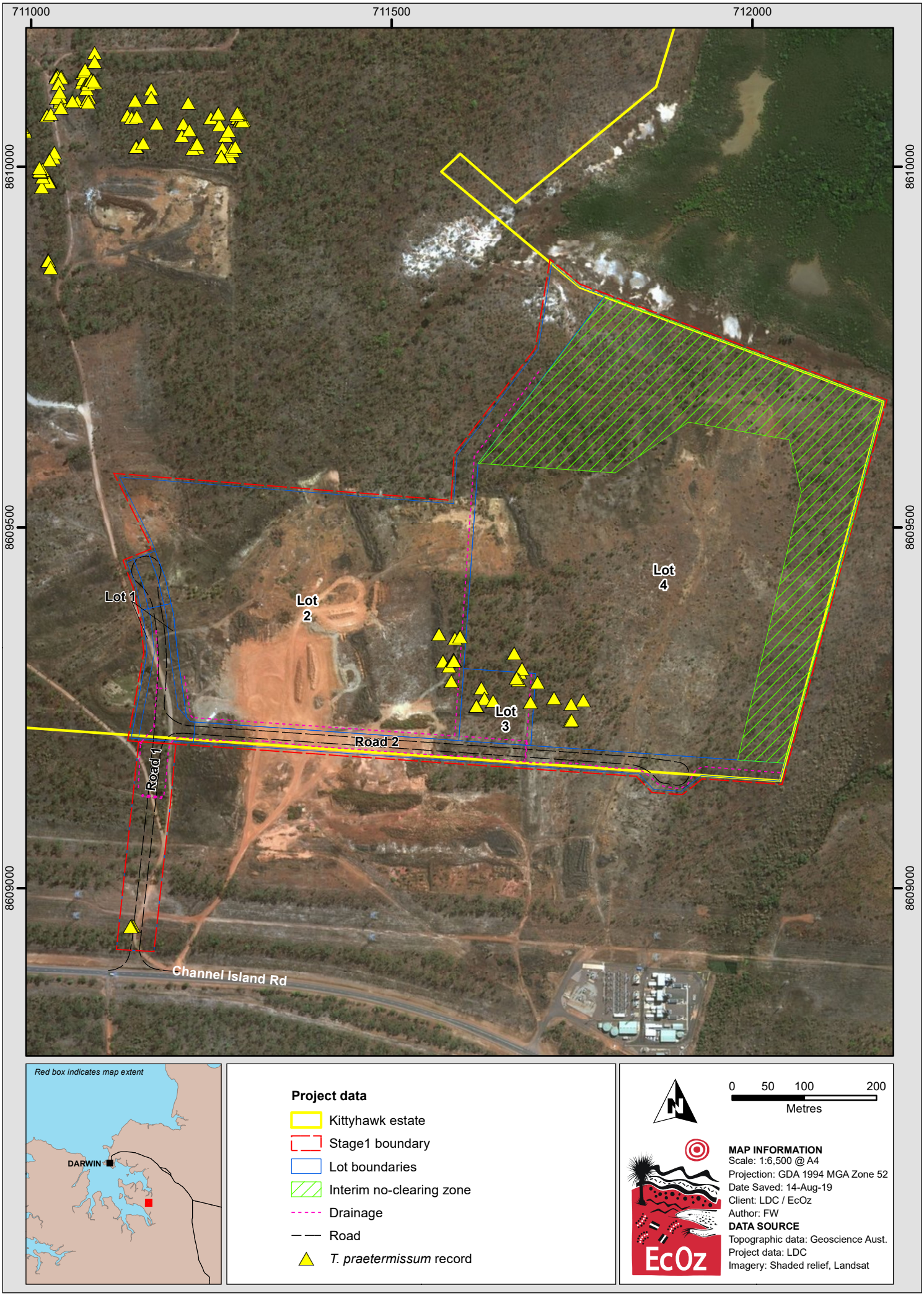
The Darwin Cycad *(Cycas armstrongii)*, listed as vulnerable in the NT, is known to occur on Kittyhawk. To assess the potential impact to the species a density survey was undertaken across Kittyhawk (Appendix C). The results of surveys in the area of Stage 1 are shown in Figure 4. Approximately 0.5 ha of Lot 3 (which will be cleared for this development) contains an area where cycads occur in relatively high-density (130 to 172 cycad stems / ha).

A total of 798 *T. praetermissum* plants were found across Kittyhawk (Appendix C). Of these, 37 are in Stage 1, 15 of which are located in vegetation to be cleared (Figure 5). Ten plants are located within Lot 1, one in the drainage corridor (within Lot 2, north of Lot 3) and four within road corridor (just north of Channel Island Road).



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ18223 - Kittyhawk Estate Environmental Approvals\01 Project Files\Aug2019\Figure 4. Map showing cycad density results within Stage 1.mxd

Figure 4. Map showing cycad density results within Stage 1



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ18223 - Kittyhawk Estate Environmental Approvals\01 Project Files\Aug2019\Figure 5. Map showing Stage 1 development and T praetermissum records.mxd

Figure 5. Map showing Stage 1 development and T praetermissum records

3.1.5 Introduced and invasive species

Thirty-five species of introduced plants may occur on Kittyhawk (Appendix B); of these, two were located during field survey. Gamba Grass (*Andropogon gayanus*) was common, widespread and dense on previously cleared areas and Perennial Mission Grass (*Cenchrus polystachios*) was observed occasionally.

Only one species of introduced animal, the feral pug *Sus scrofa*, was observed during fieldwork.

3.2 Potential impacts and proposed mitigation

The impact and risk assessment process identified the following potential impacts to flora and fauna:

3.2.1 Direct loss of fauna/flora habitat associated with land clearing

The area of vegetation to be cleared for Stage 1 is 5.1 ha. The type of vegetation being cleared is largely Eucalyptus woodland, which are well represented across the Greater Darwin region. The direct loss of this amount and that type of vegetation will not have an impact on the regional species assemblage.

3.2.2 Reduction in habitat quality in surrounding areas due to noise and dust emissions

The noise emissions from developing Stage 1 will be noise from machinery and plant. These are not expected to substantially reduce the habitat quality for fauna. The level of noise associated with construction activities may cause fauna to avoid utilising the immediate area during construction; however, there is ample habitat available for fauna to utilise in surroundings areas.

There will be some deposition of dust on vegetation nearby to Stage 1 during subdivision works. Given the small scale of operations, this is not expected to be at levels that will alter species composition or abundance.

Noise and dust are not expected to significantly impact flora or fauna of Stage 1 or the surrounding area.

3.2.3 Loss of threatened species habitat

Ecological survey found three threatened species resident on Kittyhawk.

A design criteria for the Stage 1 development was to ensure that the Black-footed Tree-rat would not be impacted by vegetation clearing. The extent and layout of Stage 1 was designed in consultation with DENR to ensure that this criteria was optimised. The final layout involves clearing only a small amount of vegetation and retaining a wildlife corridor down the eastern edge of the block.

Some cycads (estimated between 65 and 86) will be destroyed during the Stage 1 development. This species is widely dispersed across the Darwin peri-urban area with many occurrences on Kittyhawk (Appendix C) and Middle-Arm. The impact to the species is considered minor and no mitigation is proposed.

There will be a loss of fifteen *T. praetermissum* individuals for this development. This was discussed with DENR during project design, they thought a suitable offset would be developing a research program aimed at understanding the success of translocation of the species. LDC commits to translocating these plants prior to development. A Translocation Management Plan will be developed in collaboration with DENR with the plan to be approved by DENR prior to being implemented.

3.2.4 Introduction and spread of weeds

The area of Stage 1 has existing weed infestations, mainly the two highly invasive species Gamba Grass and Mission Grass, across areas that were previously disturbed. Gamba Grass is also common in nearby

areas. There is an existing Weed Management Plan for the site (Appendix D) which will manage weeds across Kittyhawk and in Stage 1. There is the potential for the introduction of declared and environmental weeds from off-site that could affect the surrounding areas. To address this issue:

- All machinery and equipment will be certified weed-free by a suitably qualified person prior to arrival at site.
- Control of declared weeds onsite will be undertaken as per Weed and Fire Management Plan (Appendix D).

3.2.5 Changes in fire regime due to accidental fires

Uncontrolled bushfire caused by operation of equipment, lightning fires and discarded cigarettes, has the potential to change vegetation communities due to changes in fire frequency. The following measures will be implemented to mitigate the risk of this impact occurring:

- No fires will be permitted on site.
- Cleared material will not be burnt on site; it will be mulched and used for erosion control or removed from site.
- Water cart on standby during periods of high fire danger.
- Hot works such as welding not to be undertaken on days of total fire ban or high winds.
- Smokers will dispose of cigarettes appropriately.
- Vehicles are to be maintained.

3.3 Conclusion

The proposal is unlikely to have a significant impact on terrestrial flora and fauna because:

- There is no substantial disturbance to vegetation that supports the Black-footed tree-rat.
- Only a relatively small number of Darwin Cycads will be impacted.
- Most of the resident *Typhonium praetermissum* are retained and those that will be disturbed will be translocated under an approved translocation management plan.
- No significant vegetation communities or EPBC Act listed Threatened Ecological Communities will be impacted.
- No new weed species will be introduced if weed hygiene procedures are enacted.

4 TERRESTRIAL ENVIRONMENTAL QUALITY

This factor refers to the chemical, physical, biological and aesthetic characteristics of land and soils. The NT EPA objective for this environmental factor is to *"maintain the quality of land and soils so that environmental values are protected."* This section looks at the potential impacts to this factor from spills and erosion/sedimentation, within the project footprint, and on surrounding vegetation.

4.1 Existing environment and values

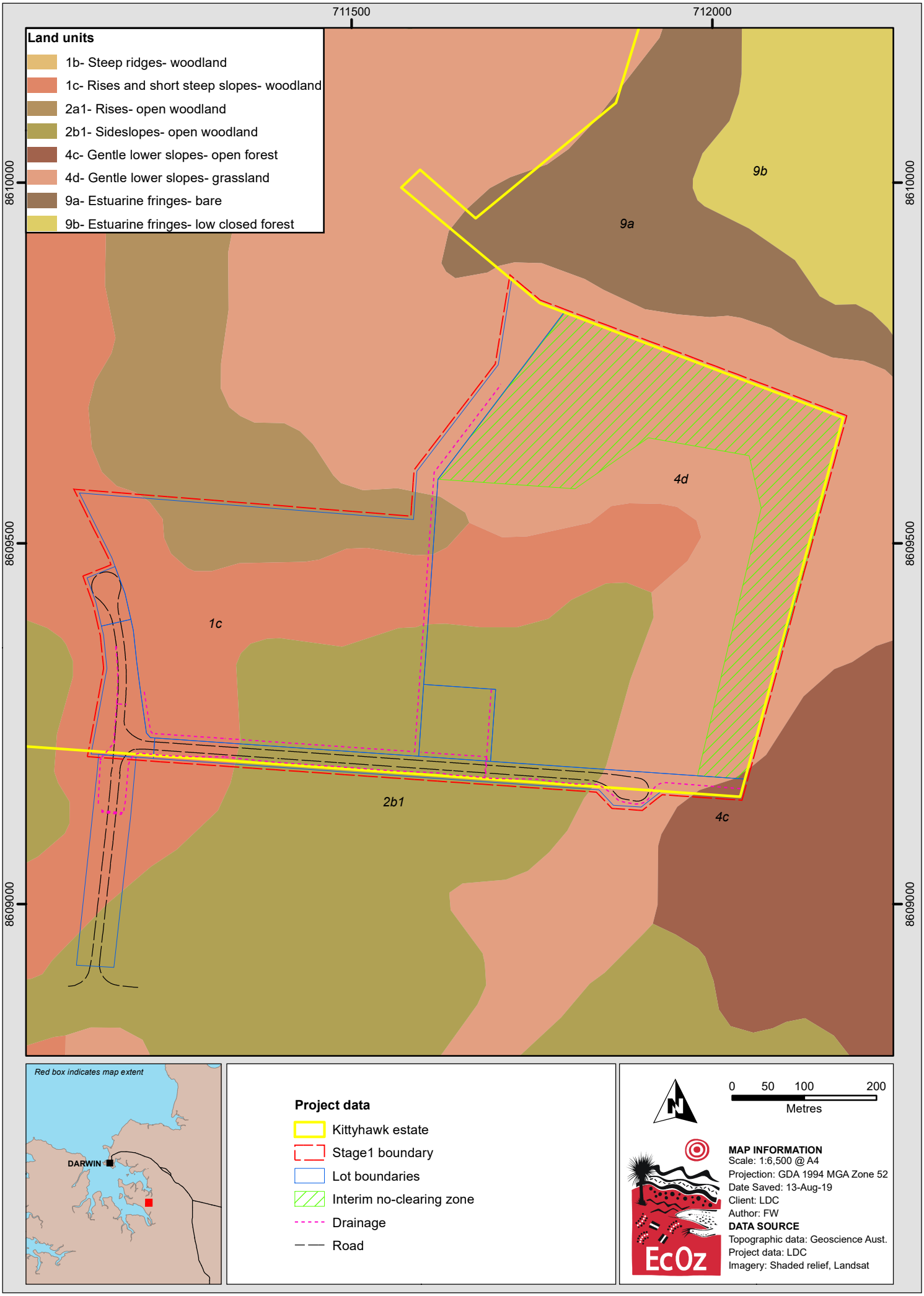
Land unit mapping available from NR Maps NT (Fogarty et al 1979) indicates four distinct land units dominating Stage 1, with very small portions of a fifth land unit associated with mangroves at the site boundaries. Characteristics of these land units are described in Table 9 and their distribution is shown on Figure 6.

Table 9. Land units of Stage 1 Kittyhawk Estate

Land unit	Landscape position	Soil type	Drainage	Stage 1 Area (ha)	Stage 1 clearing (ha)
1c	Low scarps and short steep slopes (5-15% slope)	Shallow gravelly lithosols with extensive outcrops	Very rapid	13.5	2.8
2a1	Low rounded hills (<4% slope)	Gravelly lithosols with extensive gravel	Rapid	3.2	0.1
2b1	Gentle side-slopes (2-5% slope)	Shallow yellow earths with extensive gravel	Rapid	11.6	2
4d	Gentle lower slopes fringing estuarine areas (0.5–1%)	Shallow gravelly lithosols and shallow hardsetting apedal mottled yellow duplex soils.	Imperfectly drained	20	0.2
4c	Gentle lower slopes (0.5-1%)	Deep mottled yellow massive earths	Slow, wet season waterlogging	0.2	

A preliminary geotechnical study concluded that acid sulfate soils are unlikely to be present on the site, other than in the small areas near the site boundaries delineated as land unit 9a (Douglas Partners 2018); these will not be disturbed by this development.

Illegal dumping of construction waste has occurred on Section 1902 (CDM Smith 2017a), resulting in isolated areas of contamination; i.e. soil stockpiles, the majority with a low to moderate contamination risk. Typical contaminant sources include hydrocarbon spills and construction waste. These sites were remediated in late 2017 and mid-2019 as per the Remediation Action Plan (CDM Smith 2017b).



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ18223 - Kittyhawk Estate Environmental Approvals\01 Project Files\Aug2019\Figure 6. Map showing land units of Stage 1.mxd

Figure 6. Map showing land units of Stage 1

4.2 Potential impacts and proposed mitigation

The project will require earthworks to provide flat ground for development. This will expose soil to erosion particularly during the wet season, which if not controlled could result in off-site movement of sediments into watercourses that flow into West Arm of Darwin Harbour. Sediments may deposit on mangroves inundating their pneumatophores leading to their deaths. There have been records of mangrove deaths due to sedimentation in Australia including deaths of Avicennia marina by sedimentation of between 12 to 50 cm and Rhizophora sp. for depths between 50 cm to 70 cm.

The impact and risk assessment process identified the following potential impacts to terrestrial environmental quality:

4.2.1 Soil contamination from leaks/spill from fuel storage areas

Soil contamination could occur if onsite fuel storage areas leak or spills occur. The following mitigation measures will be implemented to minimise the likelihood of contamination occurring:

- Fuel storage and handling in above-ground storage tanks will be in accordance with AS *1940 – The Storage and Handling of Flammable and Combustible Liquids* (AS 1940) standard.
- Spill kits will be located onsite in any re-fuelling areas or where hazardous substances are stored, and all workers will be trained in the use of spill kits.
- Any contaminated soil will be removed from site and disposed of at a licenced facility.

4.2.2 Soil erosion due to increased runoff from cleared areas

To mitigate potential impacts of erosion, a primary erosion and sediment control plan (ESCP) has been developed by a Certified Professional in Erosion and Sediment Control (CPESC) according to the *International Erosion and Sediment Control Guidelines 2008*; see Appendix E. Site-specific ESCP's will be developed prior to any clearing of vegetation to mitigate this impact.

4.3 Conclusion

The proposal is unlikely to have a significant impact on terrestrial environmental quality because:

- Storage and handling of fuels and hazardous materials according to appropriate standards will limit the likelihood of any residual soil contamination.
- The area of disturbance is relatively small and erosion and sediment controls will be put in place according to primary and site-specific ESCP's.

5 HYDROLOGICAL PROCESSES

This factor refers to the occurrence, distribution, connectivity, movement and quantity of surface water and groundwater. The NT EPA objective for this environmental factor is to *"maintain the hydrological regimes so that environmental values are protected."*

This section describes the hydrological regimes across Kittyhawk including surface and groundwater and the values that rely on these systems. It examines the potential impact to this factor from changes in land surface and gives measures to mitigate any impacts.

5.1 Existing environment and values

5.1.1 Surface water

Kittyhawk is located on a south to north peninsula bounded by tidal two estuaries of the East Arm / Elizabeth River; relief is gently sloping from south to north. There are two ephemeral streams in the southern sections, both of which flow during the wet season but remain dry throughout the rest of the year. There are no permanent wetlands on Kittyhawk; however, there are a number of pits formed by past mining activities that retain water through the early dry season.

The project area lies within the Darwin Harbour Region declaration of surface water beneficial uses under the *NT Water Act* (NT Government Gazette No. G27, 7 July 2010), which aims to protect cultural (aesthetic, recreational and cultural), agriculture and rural stock and domestic to be the beneficial uses of water that apply to all natural waterways in the Darwin Harbour catchment.

A desktop surface water assessment was undertaken as part of the Environmental Constraints Report (Appendix B). This assessment included development of a hydrological model to determine total current discharge volumes for Kittyhawk Estate. The model indicates that 15,300 ML will report to at the Kittyhawk Estate catchment outlet (Figure 7) in an average rainfall year.

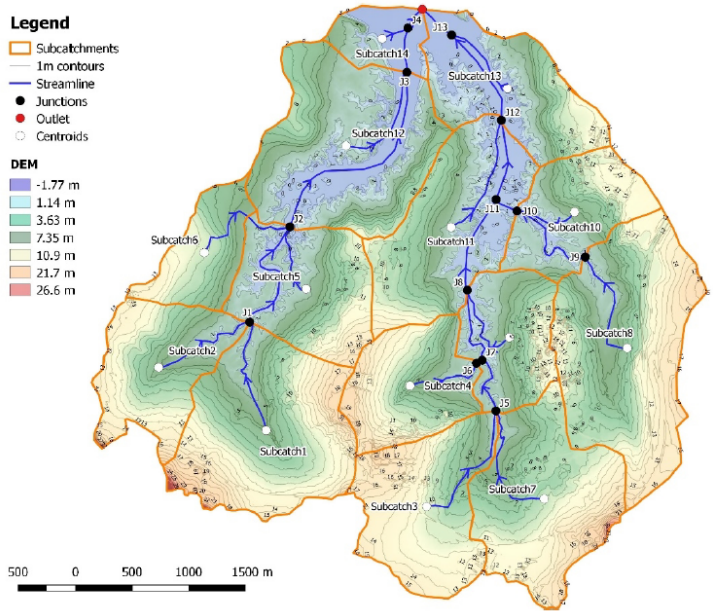


Figure 7. Map showing catchments and catchment outlets from the hydrological model

5.1.2 Groundwater

An assessment of the groundwater potential of Kittyhawk is attached as Appendix F. The Burrell Creek Formation forms the primary aquifer beneath Kittyhawk Estate. It is categorised on the Cox Peninsula Groundwater Hydrogeology Map (NRETA, 2008) as comprising fractured and weathered rocks with minor groundwater resources and typical bore yields of less than 0.5 L/s – this category has the lowest groundwater resource potential in the Greater Darwin region.

Bore drilling for Stage 1 did not locate any water of extractable amounts (ie all < 1l/s).

5.2 Potential impacts and proposed mitigation

The current application is focused on the subdivision only, which limits clearing to the establishment of new roads, temporary drainage lines, and Lot 3 (1 ha). The remaining Lots will remain uncleared until such time that future land owners undertake their developments. Under the current land use zoning, DV (Development), this will require separate Development Approval prior to commencement of works including land clearing. The total vegetation clearing during the Stage 1 subdivision is 5.1 ha, representing <2% of the Kittyhawk Estate. Potential impacts from these works, with respect to hydrological processes were identified by the impact and risk assessment process as follows:

5.2.1 Responsibilities for management of drainage

Changes to hydrological processes can have a deleterious impact to a suit of environmental variables. Responsibilities for the management of drainage ae discussed here. The current application considers subdivision of Sec 1902 and Sec 1905 as follows:

- Subdivision of Sec 1902 to establish two new road reserves (Road 1 and Road 2), to be developed by LDC and handed over to Litchfield Council.
- Subdivision of Sec 1902 to form a new Products Corridor (Lot 1), bordering the Road 1 Reserve, to be developed and owned by LDC.
- Subdivision of Sec 1902 to consolidate a small portion (0.30ha) with Sec 1905 for a drainage outlet from Road 2, to be owned by LDC with an easement in favour of Litchfield Council to allow for lawful discharge of stormwater into Sec 1817 (Crown Land). It is intended that the Road 2 stormwater is discharged via a level spreader prior to this easement to mitigate the need for construction and ongoing maintenance of infrastructure within the easement.
- Subdivision of Sec 1902 to form three new serviced industrial allotments (Lots 2, 3, 4) and one balance lot for future stages (Lot 5).
    - Lot 2 (in part) drains to Kittyhawk Creek and Lot 3 each drain towards Road 2 and a lawful point of discharge into the Road 2 stormwater network will be developed by LDC for handover to Litchfield Council.
    - All other allotment drainage falls away from the roads and towards Wirraway Creek; Lot 2 (in part) and road 1 flows into Kittyhawk Creek (to the west). LDC will be responsible for installing cut-off drains, where necessary to prevent inter-allotment flows post-subdivision/pre-development. Future land owner(s) will then be responsible for containing all post-development stormwater onsite and conveying it to a lawful point of discharge, including seeking approval with Litchfield Council to connect into the Road 2 stormwater network. Under the current land use zone, DV (Development), each purchaser of the subdivided allotments will need to seek Development Approval prior to commencing works within their allotment.

5.2.2 Increased flows from impervious areas leading to scouring of onsite drainage lines

The change in impervious areas resulting from the Stage 1 subdivision works is limited. These works are focused predominantly on construction of road reserves and drainage corridors, in which formalised drainage infrastructure is being established in accordance with industry guidelines to control stormwater flows and mitigate erosion/scour potential. Where these drainage lines outlet into the natural environment, appropriate engineering controls will be installed and implemented prior to the wet season. As Stage 1 further develops, stormwater drainage infrastructure for lots in catchments where flows are directed to the harbour, will be the responsibility of the lot owner and need to approved and managed through their individual development applications. Stormwater entering the harbour from these lots shall be discharged in an approved and controlled manner to the satisfaction of the Relevant Authority(s).

5.2.3 Increase in impervious surfaces leading to altered recharge rates for groundwater

Conversion of the natural soil surfaces to impervious surfaces, such as concrete and bitumen, will affect groundwater recharge. However, there is currently limited groundwater on Kittyhawk Estate and the change in impervious areas resulting from the Stage 1 subdivision works is limited.

5.2.4 Changes in groundwater flow directions and water levels in aquifer due to use of local bores during construction

There is insufficient groundwater below Stage 1 for this it to be used as a water supply during construction; consequently no onsite bore water will be used and no mitigation measures are required. Construction water will be sourced and supplied by the construction contractor and will need to be sourced from an uncontaminated source, for which all the required authority licences and permits will be obtained.

5.2.5 Changes in offsite flows affecting Darwin harbour values

The impact of the proposed subdivision on stormwater flows exiting the site has been assessed and is detailed in Byrne Consultants Stormwater Management Plan (Ref. 18096_SK100), which is submitted as part of the DA. The assessment is focused on Stage 1 and a comparison of pre vs. post-subdivision flows only (i.e. does not consider ultimate development). Under the current land use zoning, DV (Development), each allotment will require separate Development Approval prior to commencement of works.

Catchment areas were developed using available topographic data, and two locations for hydrological impact assessment were chosen adopting natural creek lines within Kittyhawk Creek (Figure 8). The green polygon represents the catchment currently discharging to Point A, whilst the yellow polygon represents the catchment currently discharging to Point B. The white-dash outlined polygon illustrates the area diverted to Point A post-subdivision, resulting in an increase in total catchment contributing to Point A and a reduction at Point B.

Catchment areas, weighted average runoff coefficients, and calculated peak flows for the Major Storm Event (Q100) are provided in Table 10 below for pre and post-subdivision stages. Discharge Point A will experience an increase in flows of 0.624m3/s (or 8.36%) due to an increase in catchment area reporting to this point from Lot 2.

Discharge Point B will experience an increase in peak flows of 0.007m3/s (or 0.05%) due to an increase in runoff coefficient from construction of proposed road reserves and clearing of Lot 3, noting this impact is offset in part by a reduction in catchment area from Lot 2.

No stormwater detention is proposed for the Subdivision stage because the hydrological impact is limited, and each allotment will require its own development approval prior to industrial development.

Table 10. Summary of Pre and Post-Subdivision Peak Flows (Q100)

Discharge Location	Development Stage	Catchment Area (ha)	Weighted Average Runoff Coefficient, C_{100}	Time of Concentration (min)	Rainfall Intensity, I_{100} (mm/hr)	Peak Flow Rate, Q_{100} (m^3/s)
Point A	Pre-Subdivision	40.80	0.52	39	126.66	7.468
	Post-Subdivision	44.20	0.52	39	126.66	8.092
	Difference	+3.40	N/A	0	0	+0.624
Point B	Pre-Subdivision	97.10	0.552	54	104.17	15.517
	Post-Subdivision	94.90	0.565	54	104.17	15.524
	Difference	-2.20	+0.013	0	0	+0.007

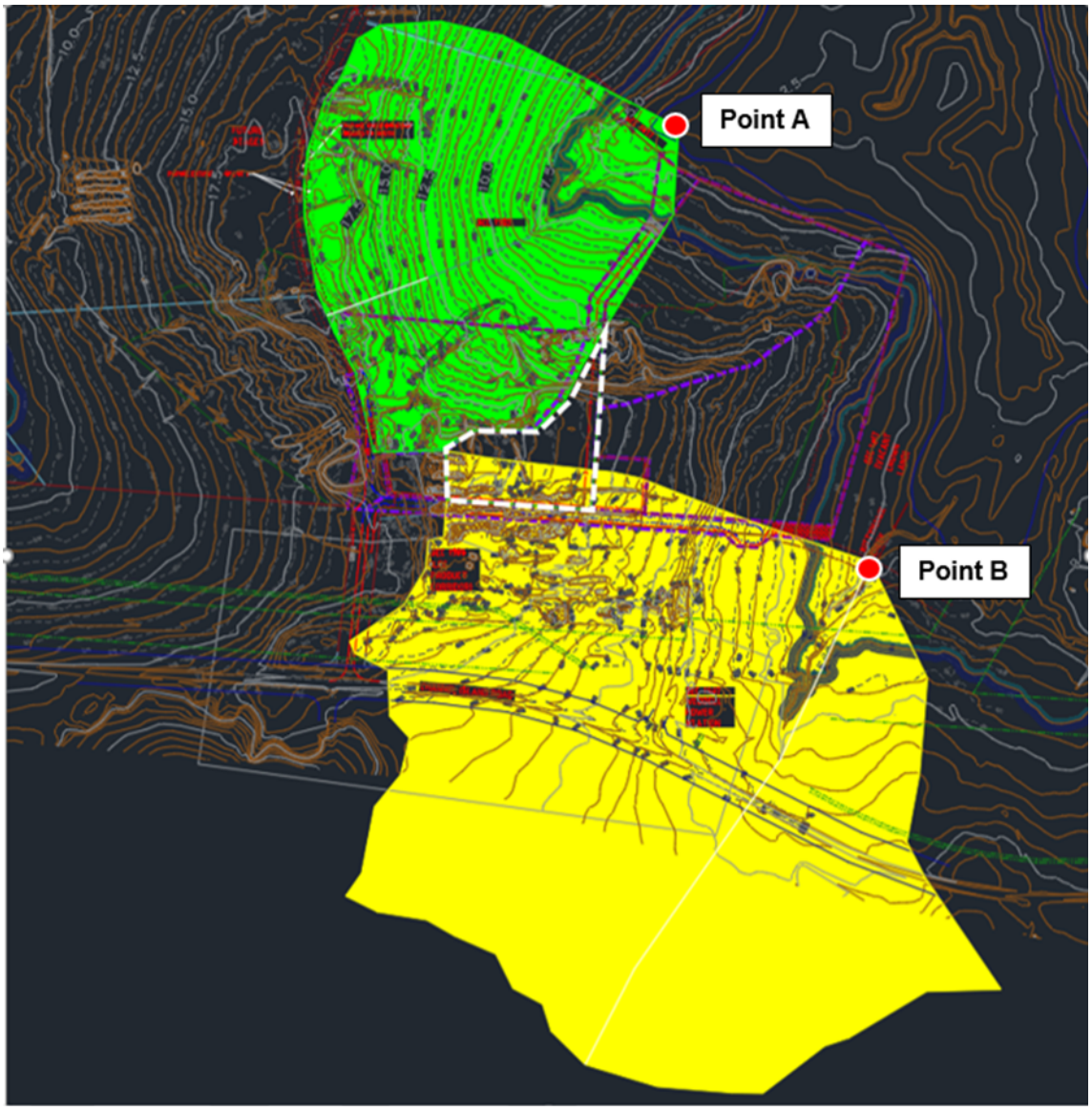


Figure 8. Subdivision Catchment Plan for Hydrological Impact Assessment

5.2.6 Changes to hydrology affecting mangrove communities

The NT Land Clearing Guidelines (DENR 2019) identify mangroves as significant vegetation community and recommend a Riparian Native Vegetation Buffer of 200m to mangroves. Development within this buffer requires developers to demonstrate how potential adverse impacts are mitigated.

In the context of the Stage 1 Subdivision, the allotments fringing the mangrove communities will remain predominantly uncleared. When these allotments are sold and developed in the future, developers will be required to submit their own development application and apply appropriate controls to protect the health of these mangrove communities.

As it currently stands, there is an 'interim no-clearing zone' identified around the perimeter of Lot 4, which allows for a minimum separation of 140m from the mangroves and developable area.

Mangrove environments contain a range of mangrove species, which each have different levels of resilience to salinity and dependencies on freshwater. It could therefore be expected that the fringing mangrove communities around Kittyhawk Estate may experience ecological change because of the development, leading to more luxuriant growth of some species and dieback in others. Mangroves exist in dynamic environments where these types of changes occur naturally as the landscape changes over time; however, it is noted that development of the site may lead to more rapid change.

Another important issue affecting the mangrove communities is erosion and sediment deposition, which can lead to changes in topography and access to tidal inundation, resulting in changes to mangrove communities as noted above. These impacts will be minimised by appropriate erosion and sediment controls being applied throughout the development during construction, as well as management of outfall velocities to mitigate downstream erosion within the mangrove flats.

5.3 Conclusion

The proposal is unlikely to have a significant impact to hydrological processes because:

- Few impervious surfaces will be created by the works leading to little decrease in groundwater recharge.
- Implementation of a stormwater drainage assessment and appropriate design.
- Use of supplied water from a registered supplier rather than onsite bore water.
- While changes to the mangrove species composition could occur, the altered flow regimes are not of a magnitude that would be expected to result in the loss of the mangrove community.

6 INLAND WATER ENVIRONMENTAL QUALITY

Inland waters environmental quality refers to the chemical, physical, biological and aesthetic characteristics of surface water and groundwater. The NT EPA objective for this environmental factor is to *"maintain the quality of groundwater and surface water so that environmental values including ecological health, land uses, and the welfare and amenity of people are protected."*

6.1 Existing environment and values

A baseline assessment of ground and surface water quality is presented in Appendix G. In summary, exceedances of ground and surface water quality above NEPM guidelines are likely to be associated with the geology of the area and nutrients from natural processes such as plant and animal decomposition, given the site and surrounding environment.

6.2 Potential impacts and proposed mitigation

The following potential impacts to inland water environmental quality were identified by the impact and risk assessment process as a result of Stage 1 subdivision works:

6.2.1 Hydrocarbon contamination of groundwater arising from leaks/spills from fuel storages

Leaks or spills from fuel stored onsite could result in hydrocarbon contamination of groundwater. Measures to mitigate the risk of this occurring involve storage of fuel in above-ground storage AS 1940-compliant tanks located in designated areas. Spill kits will be located in designated re-fuelling areas, with all workers trained in their use.

6.2.2 Decreased quality of surface water and groundwater from contaminated water (e.g. bacteria) from septic systems

During Stage 1 development, construction workers will be using portable toilets sourced from a licenced contractor. The owner of Lot 1 (and all subsequent lots) will be required to apply for approval through the NT Department of Health for their on-site wastewater management system.

6.2.3 Increased turbidity in ephemeral watercourses due to erosion of the site

Clearing of vegetation will increase the potential for erosion, which would increase turbidity in the ephemeral drainage line onsite. As is standard for any development involving clearing of land, an ESCP aligning with the International Erosion and Sediment Control Guidelines 2008 will be developed by a CPESC or suitably qualified person prior to clearing, and implemented during clearing and construction. The Primary ESCP is attached as Appendix E.

6.3 Conclusion

The proposal is unlikely to have a significant impact on inland water environmental quality because:

- Storage of fuel onsite in above-ground tanks compliant with AS 1940
- Use of portable toilets sourced from a licensed contractor
- Implementation of erosion and sediment controls according to primary and site-specific ESCPs

7 AIR QUALITY AND GREENHOUSE GASES

The NT EPA objective for this environmental factor is to *"maintain air quality and minimise emissions and their impact so that environmental values are protected."*

7.1 Receiving environment

The project area is located within the wet-dry sub tropics and experiences a Dry season (approximately April to September) and a Wet season (approximately October to March). Mean monthly wind speed recorded at Darwin Airport (BoM station 014072) ranges from 16 km/h (March/April) to 20 km/h (August-October). Prevailing winds in the dry season are south- easterly. During the Wet season, monsoonal weather from the north-west is more typical.

The nearest receptors for air quality are:

- Channel Island Road runs parallel to the project's southern boundary (~200 m)
- The Ichthys LNG project on a nearby peninsula to the north-west (~3 km)
- Channel Island power station to the west (~8 km).

The nearest population centre is Palmerston, location ~7 km north over Middle Arm.

7.2 Potential impacts and proposed mitigation

The following potential impacts to air quality and greenhouse gases were identified by the impact and risk assessment process as a result of Stage 1 subdivision works:

7.2.1 Exceedance in air particulate guideline values

Land clearing and construction activities have the potential to create dust, which would have limited consequence given the small scale of the project and the lack of nearby receptors. This potential impact will be minimised through the use of water trucks during construction works.

7.2.2 Increase in GHG arising from land clearing

Preparation of the site and construction of facilities will require the use of diesel-powered vehicles for vegetation clearing. Greenhouse gas emission from this activity will be on par with other relatively small, short-term construction projects; accordingly, no mitigation is required.

7.3 Conclusion

The development of Stage 1 will not result in a significant impact to air quality and greenhouse gases given the following:

- The use of water trucks to control dust from construction works
- The small-scale nature of the project and any vegetation clearing involved

8 SOCIAL, ECONOMIC AND CULTURAL SURROUNDINGS

The NT EPA objective for this environmental factor is to *"protect the rich social, economic, cultural and heritage values of the Northern Territory."*

This section describes the potential social, economic and cultural impacts from the development of Stage 1. It describes the project's location and how that may interact with the human environment, as well as the heritage and archaeological values and describes, where required, the approach to mitigating these impacts.

8.1 Existing environment and values

Kittyhawk Estate forms part of the Middle Arm Industrial Precinct, which was established to accommodate large strategic industries for downstream gas processing and gas related developments. Situated on the Middle Arm Peninsula, surrounded by Darwin Harbour on three sides, Channel Island Road is the only land access route. The bulk of the developable land on the peninsula is zoned for industrial or future development. The Ichthys LNG Plant and the Channel Island Power Station are located further west on the peninsula and there are some extractive industry sites to the east.

8.1.1 Location and traffic

The nearest residential receptor is located approximately 7 km away in Palmerston, with commercial receptors (Ichthys LNG Plant and Channel Island Power Station) located approximately four and eight kilometres respectively to the north/north-east of the site. The Weddell Power Station is less than one kilometre to the south-west of Stage 1 (see Figure 1).

Analysis of average daily traffic data on Channel Island Road for the ten-year period from 2003 to 2014 (undertaken as part of a traffic impact assessment in 2015) showed a long-term average growth rate of 13% per annum, though off a low base. Traffic spiked from 2012 to 2014, coinciding with the nearby Ichthys project, activity for which has now peaked. Traffic volumes are expected to decline to their former levels, and then to resume growing at around 13% per annum (Jacobs 2015).

8.1.2 Heritage and archaeological values

There are no sites listed in the NT Heritage Register within or proximate to the project area.

An archaeological study of the region in 2007 did not locate any archaeological sites within Kittyhawk. Two background scatters were located near the Weddell Power Station to the south east of Kittyhawk; constituting isolated areas of stone artefacts. The artefacts were not in great enough density to constitute a formal archaeological 'site' (Burke & Guse, 2007).

An Aboriginal Areas Protection Authority (AAPA) Certificate (201806700) has been received (Appendix H). There are no Sacred Sites (Registered or Recorded) or Restricted Works Areas within Stage 1.

8.2 Potential impacts and proposed mitigation

The following are potential impacts by project activities to the social, economic and cultural surroundings:

8.2.1 Damage or destruction of archaeological or heritage sites

There are no sites listed in the NT Heritage Register within, or proximate to, the project area. No archaeological sites were located during a targeted survey (Burke & Guse, 2007).

A stop works will be implemented if artefacts are located onsite during project activities. The LDC project manager will be notified immediately, who will then liaise with the NT Heritage Branch.

8.2.2 Damage, desecration or destruction of Aboriginal sacred sites

The AAPA certificate confirms no known sacred sites across Kittyhawk.

8.2.3 Dust from cleared land or construction activities affecting people off site

Dust can be a nuisance to people accessing areas around the development site. The risk of this being a significant impact is considered low given there are no sensitive receptors near the project area; nearest residential receptor is located approximately 7 km away, and commercial receptors located approximately 4 km north/north-east of the site. No public access to site area will be allowed. Dust suppression using water carts will be implemented where necessary during construction.

8.2.4 Traffic incidents and/or congestion project area traffic

There was a considerable spike in traffic volume on Channel Island Road recently due to the construction of the Ichthys project; this is now falling following the end of the construction phase. Traffic associated with the preparation of Stage 1 is not expected to exceed the spikes associated with the Ichthys project.

The proposed intersection development will allow for road train passing and turning lanes that have minimal impact on the current traffic on the Channel Island Road.

DIPL will approve the intersection design and construction.

8.3 Conclusion

Works involved in the preparation of Stage 1 will not result in a significant impact to social, economic and cultural values given the following:

- The site is remote from sensitive receptors.
- There are no listed Heritage or archaeological sites in the project area.
- No sacred sites recorded.
- Traffic from construction and the operation of Stage 1 will be minor compared to the traffic during the Ichthys development.

9 PROPONENT'S STATEMENT OF WHETHER SIGNIFICANT IMPACTS ARE LIKELY

Taking into consideration the proposed development, the location of the development, the existing environmental values and the redesign of the development LDC does not believe that this development will have a significant impact on the environment because:

(i) The area is already highly impacted by previous land use (extractive industry) and only a small area (5.1 ha) of vegetation is being cleared.

(ii) The vegetation types being cleared for this development are common across the Darwin region.

(iii) There were three threatened species potentially affected by Stage 1. The development extent and layout was revised in consultation with DENR to ensure that the threatened Black-footed Tree-rat will not be impacted. Both cycads and the plant *Typhonium praetermissum* will be impacted by this development; however, the small number of plants being removed from the sub-populations is not expected to have a significant impact on these species.

(iv) There is limited groundwater in the area and surface water values are limited to two ephemeral streams that flow into Darwin Harbour during the wet season. Standard mitigation measures used on construction sites (i.e. stormwater design standards and ESCP's) are expected to ensure there is no significant impact to water quality or availability.

(v) There will be no substantial change to air quality during construction of Stage 1 and the nearest residential receptors are 7km away.

(vi) There are no heritage, archaeological or sacred sites within Stage 1.

(vii) Road intersection design will be required to be approved prior to development.

The mitigation measures outlined in this document are captured in the Framework Environmental Management Plan (Appendix A) which, along with any approval conditions, will be incorporated into the Contractor's EMP prior to any on-ground development.

10 REFERENCES

AAPA 2019. AAPA Certificate C2019/029. Aboriginal Areas Protection Authority.

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APPENDIX A FRAMEWORK ENVIRONMENTAL MANAGEMENT PLAN

APPENDIX B ENVIRONMENTAL CONSTRAINTS REPORT

APPENDIX C THREATENED SPECIES SURVEY REPORT

APPENDIX D WEED MANAGEMENT PLAN

APPENDIX E PRIMARY ESCP

APPENDIX F GROUNDWATER ASSESSMENT REPORT

APPENDIX G WATER QUALITY AND MONITORING REPORT

APPENDIX H AAPA CERTIFICATE

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Framework EMP
Stage 1 Kittyhawk Estate

Land Development Corporation

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TABLE OF CONTENTS

Tables

1 INTRODUCTION

1.1 Background

This Framework Environmental Management Plan (FEMP) relates to the subdivision and early works of Section 1902 Hundred of Ayers, Channel Island Road. The project involves subdividing 5 lots and clearing 5.1 ha of vegetation for an allotment, road, products corridor and drainage. This development is generically referred to as Stage 1 Kittyhawk Estate.

The area being subdivided is approx. 50 ha, the majority (30 ha) is already cleared or disturbed from previous land use. A risk assessment has been performed for this development with the only risk considered moderate after mitigation is the risk of introducing new weeds to the area.

This FEMP will guide the development of future Contractor's Environmental Management Plans (CEMP) for the various stages of construction. This FEMP captures the project's environmental commitments for the DA and will be updated will any conditions in the DP.

The framework is based on the Department of Infrastructure and Logistics (DIPL) Contractor's Environmental Management Plan.

This document is an appendix to the *Risk and Impact Assessment* submitted with the DA.

1.2 Scope

This CEMP framework identifies the key elements to be included with project CEMPs as follows:

- Objective
- Project description
- Responsibilities
- Background
- Statutory requirements
- Approvals, licences and permits
- Environmental safeguards
- Monitoring and assessment
- Non-conformance and corrective actions
- Emergency response procedures
- Environments audit program
- Soil erosion and sediment control plan
- Waste management plan
- Weed management plan

1.3 Objective

The objective of CEMPs for Stage 1 is to avoid, reduce and mitigate the environmental impacts of the contracted construction activities. This document details the environmental management measures, controls and monitoring that will be implemented by LDC and provides a framework for environmental management to be implemented by all staff and contractors undertaking the works.

2 PROJECT DESCRIPTION

Each CEMP prepared for the Kittyhawk Estate Stage 1 works is to include the following information (or cross-reference additional plans containing such information):

- Brief overview of the project, location, purpose and outcomes
- Proposed construction, activities, staging and limits of disturbance
- Time of year and estimated duration of construction activities/stages
- Reference to, or attachment of relevant plans including:
  - Site layout/stages
  - Final design
  - Technical notes.

3 RESPONSIBILITIES

LDC will be responsible for the overall compliance with the Development Permit conditions, reviewing/approving subcontractor EMP's and monitoring compliance.

The responsibilities for implementing and monitoring compliance for the CEMP are provided in Table 3-1.

Table 3-1. Project personnel and environmental responsibilities

Responsibility	Personnel	Contact details
Develop CEMP	Company Site Manager	NAME – Site Manager T: M: email:
Develop and maintain environmental management procedures		
Implement management measures	Company Site Manager Works crews and contractors	
Assure CEMP compliance and reporting whilst onsite		

4 STATUTORY REQUIREMENTS

The Kittyhawk Stage 1 development will occur in accordance with the conditions of the Development Permit issued under the *Planning Act*. As part of the development application process, LDC engaged EcOz Environmental Consultants to assess the potential for the project to cause any significant impact to the environment. The assessment concluded that the proposal does not require assessment under the *Environmental Assessment Act* or *Environment Protection Biodiversity Conservation Act*.

LDC and all sub-contractors will comply with the requirements of the following legislation:

- *Northern Territory Aboriginal Sacred Sites Act*
- *Dangerous Goods Act*
- *Heritage Act*
- *Territory Parks and Wildlife Conservation Act*
- *Waste Management and Pollution Control Act*
- *Water Act*
- *Weeds Management Act.*

5 APPROVALS, LICENCES AND PERMITS

Each sub-contractor is responsible for identifying and obtaining approvals, licences and permits relevant to their scope of works. All CEMP's must list the requirements in this section.

Sub-contractors will comply with all relevant sections of *DIPL Standard Specification for Road Maintenance 2017* and the *Standard Specification for Environmental Management 2013/2014.*

6 ENVIRONMENTAL SAFEGUARDS

An environmental risk assessment was undertaken for the Kittyhawk Stage 1 works. The risk assessment identified mitigation measures reduce environmental impacts to as low as reasonably practicable. The tables below document the minimum suite of management actions that LDC and sub-contractors when undertaking works on Stage 1 Kittyhawk Estate. The mitigation measures may require review as determined in the Development Permit (DP).

Sub-contractors are responsible for reviewing the risk assessment, any approval conditions of the DP and identifying any additional risks relevant to their scope of works, and including details of these risks and proposed mitigation measures in the CEMP.

6.1 Environmental Induction and Training

Action	Responsibility	Timing	Sign off
All site staff will be made aware of the site CEMP, environmentally sensitive areas and environmental responsibilities	Site manager	Prior to construction	

6.2 Community liaison

Action	Responsibility	Timing	Sign off
Members of the affected community will be notified of the proposed works prior to their commencement where required	Site manager	Prior to construction	
Complaints received will be recorded and attended to promptly. On receiving a complaint, works will be reviewed to determine whether issues relating to the complaint could be avoided or minimised. Feedback will be provided to the complainant explaining what outcomes resulted. All details regarding the response to the complainant will be recorded in the register and provided to the Site Manger.	Site manager	During construction	
Where work is required to be carried out in easements or on land adjacent to the works area for the purpose of connecting services or joining up of roads etc. the Company will ensure that the appropriate licences and approvals are obtained for	Site manager	Prior to construction	

work in those particular areas			

6.3 Vegetation and fauna

Action	Responsibility	Timing	Sign off
• Marking of clearing boundaries to ensure that clearing only occurs in the permitted area. • No clearing of areas with Typhonium until translocation has occurred. • Machinery and equipment will be inspected for pest species such as weeds and ants/cane toads prior to arrival and departure from site.	Site manager	During construction	

6.4 Stockpile sites

Action	Responsibility	Timing	Sign off

• All stockpile sites will be located in previously cleared and disturbed areas within the site boundaries.
• No stockpile site will be established within the following areas without prior consultation with the Site Manager:
  ○ an environmentally sensitive area
  ○ vegetated areas
  ○ within 40 m of a watercourse
  ○ where it will affect a cultural and/or heritage site.
  ○ No stockpiles will be established within proximity of stormwater drainage infrastructure without appropriate erosion controls.
  ○ Stockpiled material heights will not exceed 2.0 m.
  ○ Stockpiles will be maintained to prevent erosion and the growth of weeds.
	Site manager	Pre, during and Post construction	

6.5 Soil erosion and sedimentation management

Action	Responsibility	Timing	Sign off
• Progressive Erosion and Sediment Control Plan (ESCP) will be prepared and implemented. These ESCPs will be based on the Primary ESCP (see appendix in DA). • Temporary control measures will be installed where required to prevent erosion of disturbed areas and stockpiled materials. This will include diversions to minimise water run-on to works areas and sediment controls to prevent run-off from the works area. • Erosion and sediment control measures will be maintained regularly and after rainfall events. • Erosion and sediment control measures will not be	Site manager	Pre, during and Post construction	

removed until disturbed areas have been stabilised. • Appropriately maintain the erosion and sediment control function of roadside drainage structures. • Disturbed areas will be stabilised progressively with vegetation during construction, where necessary, and stabilisation will be undertaken after works are complete			

6.6 Water quality

Action	Responsibility	Timing	Sign off
• Water quality control measures will be implemented to prevent any materials entering drain inlets and waterways. Control measures will include: sediment controls, bunding of chemicals and hazardous goods and the availability of spill kits. • Major maintenance activities and hazardous materials storage will be at the Company's workshop area. • All hazardous materials and dangerous goods will be used, handled, stored and disposed of appropriately and in accordance with the *Dangerous Goods Act* and the *Waste Management and Pollution Control Act.* • The location of any fuel storage areas will not be within 50 m of any areas of concentrated water flow, flood and poorly drained areas, on slopes. Storage areas will not be located adjacent to any areas of native vegetation to be preserved within the works area and/or areas of stormwater drainage. • Storage areas for fuels, oils and chemicals will be surrounded by an impervious bund that could contain 120% of the largest container stored in the bund. • Refuelling plant and equipment will be undertaken within bunded areas and more than 50 m away from waterways. • Cleaning of equipment will be undertaken in appropriate areas and in a manner, which prevents or minimises pollution to waters. • Spill containment equipment kits will be available on the works area and adequately sized to represent the volume of hazardous materials stored within the works areas. • Works in waterways will be postponed during or immediately following heavy rainfall or when waterways are running high. • All water to be used during the project activities is to be sourced from off-site. Testing of water is to be undertaken to ensure no contamination.	Site manager	Pre, during and Post construction	

6.7 Air quality

Action	Responsibility	Timing	Sign off
• Dust generation will be minimised by using a water cart or sprinkler system where required • No burning of vegetation or other materials will be permitted on site • Exhaust emissions from plant and equipment will be minimised through equipment maintenance and pre-state inspections, and minimising running times of equipment • Any vehicle transporting waste or other materials that may produce odours or dust will be covered during transportation	Site manager	During construction	

6.8 Noise and vibration

Action	Responsibility	Timing	Sign off
• All vehicles and machinery will be fitted with noise attenuating reverse alarms • All reasonable practical steps will be undertaken to reduce maintenance activity noise and vibration from site • Records of noise complaints to be kept and investigation actions undertaken after a complaint is made.	Site manager	During construction	

6.9 Heritage

Action	Responsibility	Timing	Sign off
• Should any item be encountered which is suspected to be a relic of heritage value or any relic, artefact or material suspected of being of Aboriginal origin, all construction work that might affect the item will cease and the item protected from damage and disturbance. The site manager and LDC project manager will be notified immediately. • All personnel working on site will receive training regarding their responsibilities regarding cultural heritage and will be made aware of any sites or areas which must be avoided. Such sites or areas will be identified on a site map and made available to all relevant personnel during the works.	Site manager	Pre, during and Post construction	

6.10 Waste management

Action	Responsibility	Timing	Sign off
• Waste materials will be stored in designated areas on site. • Storage areas will be designed and managed to allow for waste segregation and ensure secure storage (i.e. no rain ingress or windblown waste). • Putrescible wastes will be stored in lidded secure storage bins to exclude pest and vermin. A regular waste removal schedule will be in place for putrescible wastes. • Waste suitable for reuse or recycling will be reused or recycled • Materials and products with recycled content will be proposed for the works wherever these are cost and performance competitive and they are environmentally preferable to the non-recycled alternative • Waste oil will be sent to approved recyclers where appropriate • Waste and containers not able to be recycled will be disposed of at a licensed landfill site • No construction material will be left onsite once the construction activities have been completed • The site will be left in a clean and tidy state on completion of the project works.	Site manager	During and post construction	

6.11 Weed management

Action	Responsibility	Timing	Sign off
• All machinery and equipment to be certified weed free by a suitably qualified person prior to arrival on site. • Upon leaving the site, all machinery and equipment must be either washed down at the site wash-down bay (if one is in place), or taken directly to the sub-contractors base for wash-down prior to use at any other location. • Excavated material and cleared vegetation must be certified weed free prior to movement off-site. Any material that contains weed seed will not be taken off-site unless prior approval is obtained for disposal at a licenced facility. • Excavated material and cleared vegetation from areas known to contain listed weeds will not be moved around within the site. • Cleared areas and stockpiles will be inspected for weed outbreaks post-wet season each year and new outbreaks will be controlled.	Site manager	During works	

6.12 Fire management

Action	Responsibility	Timing	Sign off
• All activities undertaken in works areas must take in to consideration and comply with the *Bushfires Act* as well as any relevant Australian Standards (AS). • Firebreaks will be required to be installed and maintained as per relevant legislation. • Smokers are to appropriately dispose of cigarette butts. • Fires which have been started accidently must be immediately extinguished, if it is safe to do so. • The work crews are to have fire extinguishers in the cab of the vehicles and machinery and a first-response fire unit at site if needed. • During high winds, any activities likely to accidently start a fire are ceased until safe to continue. • In case of emergency dial 000.	Site manager	During works	

6.13 Hazardous materials and dangerous goods

Action	Responsibility	Timing	Sign off
• All hazardous materials and dangerous goods will be used, handled, stored and disposed of appropriately and in accordance with the *Dangerous Goods Act* and the *Waste Management and Pollution Control Act.* • Storage areas for fuels, oils and chemicals will be surrounded by an impervious bund that contains 120% of the largest container stored in the Bund. The location of storage areas will not be within 50 m of any areas of concentrated water flow, flood and poorly drained areas, on slopes above 100 or near any areas of native vegetation. • Drums used as markers will not contain chemicals or fuels. • Refuelling plant and equipment will be undertaken within bunded areas and more than 50 m away from waterways. • Spill containment equipment kits will be available in works areas. All personnel on site will be trained how to use these spill kits.	Site manager	During works	

6.14 Traffic management

Action	Responsibility	Timing	Sign off
• A Traffic Management Plan is to be developed and implemented for the duration of works onsite.	Site manager	Prior to / During works	

7 MONITORING AND ASSESSMENT

Monitoring and inspections of the site are to be undertaken to ensure environmental management measures are being implemented and assessments can be made of their effectiveness. The monitoring and assessment requirements to be applied by LDC and sub-contractors are summarised in Table 7-1. A monitoring checklist is to be completed by the Site Management weekly to ensure controls and management measures are in place and requirements of the CEMP are met.

Table 7-1. Monitoring and assessment frequencies for site

Category	Monitoring/Assessment Method	Frequency	Target
Induction and training	Review induction register.	Prior to commencement on-site.	All staff inducted prior to working on site.
Complaints	Review complaints register.	As required.	All complaints followed up and feedback provided to complainant.
Erosion and sediment control	Visually inspect controls (sediment fences, temporary drains, diversion berms etc.) Visually inspect immediately downstream of site for signs of erosion or sediment deposition.	Weekly during works from Oct to April. Immediately following rainfall.	No damage to controls. No significant erosion of stockpiles or work area. No sediment leaving site.
Spills	Visually inspect product storage areas, parking areas and laydown areas for signs of spills. Monitor for leaks during equipment pre-starts.	Weekly for laydown/ storage areas. Daily for equipment pre-starts. Continuously during re-fuelling.	No indication of significant spill. Any spill of stored product contained within bund. No leaks from equipment.
Stockpiles	Visually inspect stockpile areas for weeds and evidence of erosion. Check stockpile heights and sediment controls.	Weekly during works.	No new weeds or erosion at stockpiles.
Dust/air quality & Noise	Visually monitor for signs of dust leaving the works area. Pre-start checks performed daily on equipment, which includes assessments of noise levels.	Ongoing during works.	No significant dust leaving the works areas. No noise or dust complaints received.
Waste	Visually inspect waste storage areas and site.	Daily prior to work commencing.	No inappropriately disposed of waste. No waste laying around site. Waste segregation occurring.
Weeds	Visually monitor site for spread of weeds and any new infestations.	Weekly particularly after the wet season begins.	No new weed infestations on site. Existing infestations controlled in accordance with contract requirements.
Fire	Visually monitor site for any fires that may occur.	Ongoing during works.	No fires onsite.

8 NON-CONFORMANCE AND CORRECTIVE ACTIONS

Any non-conformances will be documented stating the nature of the non-conformance and corrective actions implemented.

LDC must be notified of any non-conformance within 24 hours of the incident occurring. Corrective/preventative action will be taken by LDC and sub-contractors in a timely manner (e.g. within seven days of the event occurring) to ensure that the issue is addressed. If management controls are not being undertaken in the designated manner, additional training will be undertaken by the Site Manager.

The targets stipulated in the monitoring and assessment section above, provide the overarching performance indicators for the site, against which compliance will be assessed. If targets are not being met, or unexpected issues arise, LDC and sub-contractors will be responsible for implementing corrective actions, adapting the management methods and updating CEMP's.

Indicative corrective actions for each monitoring and assessment category are provided in Table 8-1.

Table 8-1. Corrective actions for continual improvement

Category	Target	Corrective Action
Erosion and sediment control	• No damage to controls. • No significant erosion of stockpiles or work area. • No sediment leaving site.	• Maintain controls and remove captured sediment as needed to ensure capacity. • Review of the ESCP and update as necessary
Spills	• No indication of significant spill. • Any spill of stored product contained within bund. • No leaks from equipment.	• Maintain good housekeeping. • Increase bunds as required. • Maintain equipment. • Implement spill response procedure as needed.
Dust/air quality & Noise	• No significant dust creation or air quality issues resulting from works. • No disturbance to stakeholders from dust or noise generated by the project.	• Water down work areas for dust • suppression.
Waste	• Waste being appropriately disposed of • and recycled where possible. • No waste left on site. • Site to be clean and tidy.	• Review recycling and waste disposal processes. • Maintain good housekeeping.
Weeds	• No new weed infestations onsite.	• Review weed management procedures
Fire	• No fires onsite.	• Review site procedures. • Ensure all personnel are aware of fire bans on site.

9 EMERGENCY RESPONSE PROCEDURES

Sub-contractors are responsible for reporting all incidents to LDC within 24 hours. All incidents which cause or have the potential to cause material or serious environmental harm, will be reported to the NT Environment Protection Authority (NT EPA) by LDC within 24 hours as required under Section 14 of the NT Waste Management and Pollution Control Act.

The details of the designated contact persons responsible for on-site environmental management are to be provided in Table 9-1. Also included are emergency contacts for reporting pollution incidents (including non-urgent problems such as dust/noise) and contacts for provision of advice.

In the case of any spills the following procedure is to be implemented:

- Locate the source to identify volume and type of spill and assess risk to workers and environment to ensure appropriate PPE and measures to be implemented.
- Control and contain the spill by isolating or removing source.
- Clean the spill using spill kit and absorbent material or installing bunds.
- Dispose of contaminated spill control material appropriately.
- Report significant spills or spills that have entered stormwater to NT EPA Pollution Hotline (1800 064 567).

Spill containment equipment kits will be available in works areas. All personnel on site will be trained how to use these spill kits.

Table 9-1. Emergency contact details

Contact	Contact details
Site Manager	Name T: M: Email:
LDC Project Manager	Name T: M: Email:
NT EPA Pollution Hotline / Pollution Reporting	GPO Box 3675 Darwin NT 0801 Pollution Hotline: 1800 064 567 pollution@nt.gov.au
Aboriginal Areas Protection Authority (AAPA)	AAPA 08 8999 5511 enquiries.aapa@nt.gov.au
NT Police	131 444

10 ENVIRONMENTAL AUDIT PROGRAM

Compliance with the EMP will be monitored by LDC on an ongoing basis. Environmental audits will be undertaken at the following times:

Insert the dates and information re. audit program that will be undertaken

11 SOIL EROSION & SEDIMENT CONTROL PLAN

An ESCP aligning with the *International Erosion Control Association (IECA) Guidelines* will be developed by a Certified Professional in Erosion and Sediment Control or suitably qualified person, prior to commencement of construction activities. The ESCP will be based on the framework developed by EcOz (see Appendix in DA).

12 WASTE MANAGEMENT PLAN

Identify major waste streams that will be generated during the project including:

- Green waste
- Construction waste, including;
    - spoil
    - demolition waste
    - asphalt or bitumen
    - concrete and metal
    - paint materials
    - office waste
    - kitchen waste
    - sewage effluent
- For each waste stream indicate how and where the waste is to be reused, recycled, stockpiled or disposed of.
- How the waste will be transported between the site and point of reuse, recycling, stockpiling, treating or disposal and who will be responsible.
- Methods for monitoring the Waste Management Plan.

13 WEED MANAGEMENT PLAN

The following items are to be included in the Weed Management Plan:

- Identify weeds and infestation zones within the work site/ investigation date.
- Subcontractors who will treat weed infestations.
- Chemical handlers/ qualifications/ date/ spray type used/ target weed and its identified location by Chainage or Latitude and Longitude.
- Certification requirements of personnel inspecting vehicles & machinery and the inspection date
- Method of cleaning vehicles & machinery/ cleaning date.
- Cleaning bay location/ treatment date.
- Contaminated fill stockpile/ treatment type/ treatment date.
- Methods for monitoring the Weed Management Plan and who is responsible.

14 REFERENCES

Department of Infrastructure, Planning and Logistics (DIPL) (2013). *Standard Specification for Environmental Management 2013/2014*. Darwin: Northern Territory Government.

Department of Infrastructure, Planning and Logistics (DIPL) (2016). *Contractor's Environmental Management Plan Framework 2016*. Darwin: Northern Territory Government.

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Environmental constraints report

Kittyhawk Estate

Turner & Townsend Thinc

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EXECUTIVE SUMMARY

The Northern Territory Government's (NTG's) primary industrial land developer, Land Development Corporation (LDC), is master planning the 'Middle Arm Industrial Precinct' (MAIP) located on the Middle Arm Peninsula, Northern Territory (NT).

Within the MAIP, Kittyhawk Estate is comprised of portions 1900 and 1902. LDC has commissioned this study to undertake environmental assessments and identify environmental constraints to development within the Kittyhawk Estate. The environmental assessments undertaken were detailed in the scope of works provided by LDC and have been informed by previous gap analyses and the environmental factors identified by the Northern Territory Environmental Protection Authority (NT EPA).

The key environmental assessments undertaken were:

- Vegetation mapping
- Weeds and pest assessment
- Marine benthic habitat assessment
- Protected species likelihood of occurrence assessment
- Surface water hydrology assessment.

This environmental constraints report details the results of environmental assessment undertaken, identifies environmental constraints within the study area and highlights further environmental investigations required.

Generally, the area assessed had limited environmental values that would constrain development. The key considerations are summarised below:

- The Kittyhawk Estate abuts mangrove vegetation communities. These communities are considered a sensitive vegetation type and disturbance should be avoided; the NT Vegetation Clearing Guidelines state that development should not occur within 200 m of the edge of the mangroves. Development can occur within 200m metres however there will be an onus on the proponent to show the potential impact to the mangrove community. Consideration also needs to be given to the impact any changes of hydrology on Kittyhawk Estate may have on mangroves.
- There are a number of weeds and pests which may occur within the Kittyhawk Estate. The management of weeds and pests can be achieved through the development and implementation of appropriate management plans prior to construction.
- The marine benthic habitats proximate to the Kittyhawk Estate are unlikely to be impacted from the development provided that appropriate erosion and sediment controls and water management are implemented.
- There is one threatened species known to occur within Kittyhawk Estate (Darwin Cycad) and five threatened species (Black-footed Tree-rat, Fawn Antechinus, Pale Field-rat, Bare-rumped Sheathtail Bat and Floodplain monitor) with a high or medium likelihood of occurring within Kittyhawk Estate and should be considered further. The environmental assessment process will require an assessment of the potential impact to these species. DENR should be engaged to confirm which species require further assessment.
- The surface hydrology assessment determined the peak flow and total discharge for the four main sub-catchments of Kittyhawk Estate. These values provide a basis for stormwater design. The assessment also determined the area of Kittyhawk Estate which would be inundated during storm events and tidal surges. Development should be located outside these areas.

Recommendations for further work to be undertaken are outlined below.

Environmental factor	Recommendations	Timeframe
Terrestrial flora and fauna	A density assessment of Darwin Cycad within the stage 1 area is completed.	Prior to DA being submitted
	Confirmation of survey requirements for threatened species with DENR.	Determine prior to field survey program
	Surveys for presence of threatened species within the Kittyhawk Estate are undertaken.	Prior to DA being submitted
	A weed management plan is developed for the construction activities associated with the development of stage 1.	Prior to construction
Inland water environmental quality	Surface water quality assessment during first flush event prior to construction.	2018-2019 wet season
	Development and implementation of an erosion and sediment control plan.	Prior to construction
Land capability	To ensure that the soils for the area are suitable for wastewater disposal a land capability assessment for the stage 1 area be completed.	Prior to DA being submitted

TABLE OF CONTENTS

Appendices

Tables

Figures

ACRONYMS

LDC	Land Development Corporation
NTG	Northern Territory Government
MAIP	Middle Arm Industrial Precinct
T&TT	Turner and Townsend Thinc
ha	Hectares
PMST	Protected matters Search Tool
WoNS	Weed of National Significance
NT	Northern Territory
EPBC Act	Environment Protection and Biodiversity Conservation Act
TPWC Act	Territory Parks and Wildlife Conservation Act
BOM	Bureau of Meteorology
ML	Mega-litres
km^2	Square kilometres
hr	Hour
m^3s^{-1}	Cubic metres per second
m	Metres
HAT	Highest Astronomical Tide
AHD	Australian Height Datum

1 INTRODUCTION

The Northern Territory Government's (NTG's) primary industrial land developer, Land Development Corporation (LDC), is master planning the 'Middle Arm Industrial Precinct' (MAIP) located on the Middle Arm Peninsula, Northern Territory (NT).

LDC is currently focussing upon the development of Kittyhawk Estate, an envisaged 335 ha industrial estate on Sections 1900 and 1902 Hundred of Ayers, Channel Island Road within the MAIP. Within Kittyhawk Estate, it is proposed to initially develop a 100 ha area (referred to as Stage 1) which will involve subdivision and provision of network and corridors for the transmission of utilities, gas, feedstock and products, additional infrastructure and associated developments required to support industrial growth at the Middle Arm Peninsula. Access to Sections 1900 and 1902 may traverse Section 1905 a section parallel and abutting Channel Island Road.

LDC has committed significant investment to previous reviews of available information, gap analysis and baseline studies within the MAIP. In 2018, LDC contracted Turner & Townsend Thinc (T&TT) to complete a multi-criteria pre-feasibility analysis and develop three concept layouts across the Kittyhawk Estate. Part of this multi-criteria pre-feasibility analysis is undertaking preliminary planning, engineering and technical studies including environmental investigations. This environmental constraints report identifies environmental values within Kittyhawk Estate to help in determining the location of Stage 1.

1.1 Purpose

The purpose of this report is to:

- Detail the environmental investigations which are part of the preliminary planning, engineering and technical studies. The environmental investigations included in this report are:
    - Mapping of vegetation communities within Kittyhawk Estate, and assessment of mangrove assemblages abutting the Kittyhawk Estate
    - Survey of weeds and pests within the Kittyhawk Estate
    - Analysis of marine benthic habitats in the marine waters proximate to the Kittyhawk Estate
    - A protected species likelihood of occurrence analysis for terrestrial and marine protected species
    - A surface water hydrological investigation for the Kittyhawk estate.
- Identify any environmental constraints within the study area
- Highlight further environmental investigations that would be required for an environmental assessment process.

2 VEGETATION MAPPING

2.1 Background and scope

Vegetation mapping was undertaken to determine the vegetation communities present within Kittyhawk Estate. Vegetation communities provide context to understand the likelihood of threatened species occurring within Kittyhawk Estate and those with higher environmental significance (sensitive vegetation) require special protection.

Thus vegetation mapping aimed to:

- Produce a map of, and provide descriptions for, vegetation communities within Kittyhawk Estate
- Identify areas of sensitive vegetation within the Kittyhawk Estate.

Field studies were conducted to map vegetation within the Kittyhawk Estate.

2.2 Methods

Vegetation mapping was undertaken across Kittyhawk Estate and the adjacent area.

A base map of vegetation communities was created using the *Land Units of the Greater Darwin Region 1:25,000* and available satellite imagery. The *Land Units of the Greater Darwin Region 1:25,000* datasets were used as a basis to select sites for vegetation assessment. Land units are areas of comparatively similar landform, soils and vegetation; and are a useful base for mapping vegetation communities and for identifying sensitive vegetation types. At least one vegetation assessment site was selected within each mapped land unit. In total 13 sites were assessed within the survey area.

Field vegetation survey was undertaken on 28 – 29 April by EcOz Senior Botanist David Van den Hoek and EcOz Environmental Consultant Nicole Clark.

Vegetation survey sites were undertaken (within a 20 x 20 m quadrat) which provides a comprehensive assessment and includes a detailed description of the vegetation and soil. The information collected was: soil type (surface examination only), vegetation description and dominant flora species within each stratum (including height range, average height and percent cover). This information was used to describe the vegetation community at each site and extrapolate to each area of that community.

Data collected at survey sites was based on methods used by Brocklehurst et al. (2007).

All mapping and editing was performed using GIS software (ArcGIS 10.2) in ESRI shape file format. The area of each vegetation community within the survey area and Kittyhawk Estate was calculated using ArcGIS10.2.

2.3 Vegetation communities

There were six vegetation communities mapped within the survey area. Brief descriptions and areas of each of these communities are documented in Table 2-1, along with the corresponding land units from the *Land Units of the Greater Darwin Region 1:25,000* dataset. Mapped vegetation communities are shown in Figure 2-1.

Vegetation within Kittyhawk Estate was predominately *Eucalyptus miniata, E. tetrodonta* and *Corymbia bleeseri* mid woodland, with a sparse shrubland mid-storey over tussock grassland (184.4 ha or 55.1% of the Kittyhawk Estate).

Representative photos of each vegetation community are shown in Appendix A.

Table 2-1. Vegetation communities within the survey area and Kittyhawk Estate

Vegetation description	Corresponding land unit	Drainage	Soil	Area in survey (ha)	Area within Kittyhawk Estate (ha)
Rises					
Mid woodland of *Eucalyptus miniata, Eucalyptus tetrodonta, Corymbia bleeseri* over *Livistona humilis, Cycas armstrongii, Erythrophleum chlorostachys* over Tussock Grassland of *Heteropogon triticeus, Sorghum intrans, Chrysopogon fallax*.	2a1	Rapid drainage. Nil to low level of seasonal waterlogging.	Leptic rudosols	188.5	184.4
Plains					
Low Open Woodland of *Erythrophleum chlorostachys, Terminalia ferdinandiana* over *Lophostemon lactifluus, Corymbia polysciada, Pandanus spiralis* over Tussock Grassland of *Themeda triandra, Chrysopogon fallax*	4d	Slow drainage. Occasional seasonal waterlogging.	Leptic rudosols	12.6	12.3
Mid Open Woodland of *Corymbia bella, Erythrophleum chlorostachys* over *Planchonia careya, Pandanus spiralis, Vitex glabrata* over Closed Tussock Grassland of *Heteropogon triticeus, Germainia grandiflora, Themeda triandra*				28.7	24.0
Mid Open Woodland of *Melaleuca leucadendra, Corymbia polysciada, Melaleuca viridiflora* over *Melaleuca viridiflora, Pandanus spiralis, Planchonia careya* over Closed Tussock Grassland of *Germainia grandiflora, Themeda triandra, Dapsilanthus sp.*				57.1	27.5
Marine					
Low Closed Forest of *Rhizophora stylosa* over low open forest of *Rhizophora stylosa, Ceriops tagal*	9b	Tidal inundation.	Intertidal Hydrosols	130.2	0
Low Open Forest of *Ceriops tagal, Avicennia marina* over Low Open Forest of *Ceriops tagal, Rhizophora stylosa*				142.8	0
Disturbed areas					
Disturbed areas (no remnant native vegetation present)	-	-	-	87.3	87.3

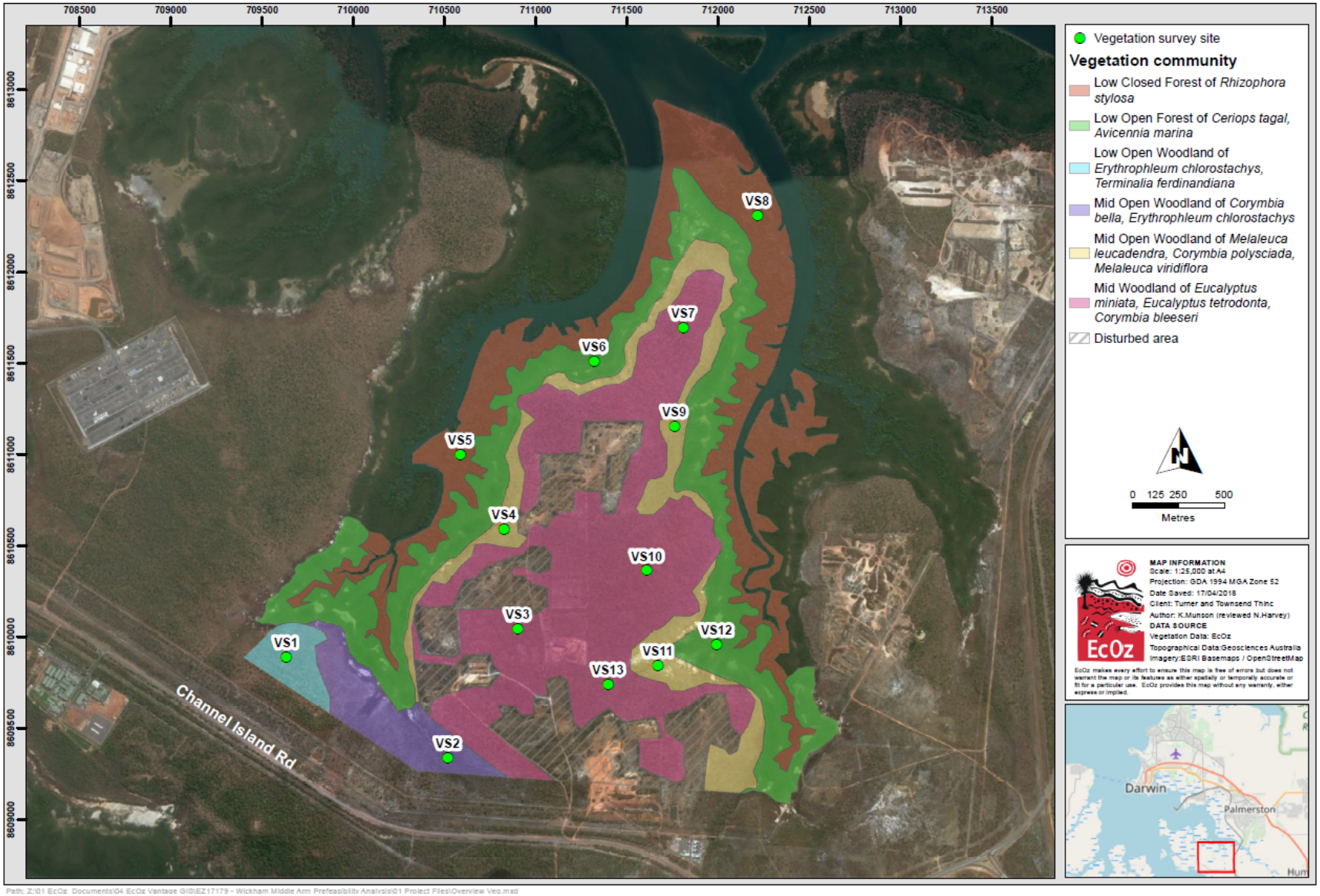

Figure 2-1. Map showing vegetation communities across Kittyhawk Estate.

2.3.1 Sensitive vegetation

Sensitive vegetation is defined under clause 10.3 of the Northern Territory Planning Scheme to include rainforest, vine thicket, closed forest or riparian vegetation. The definition has been expanded under the land clearing guidelines to include mangroves, monsoon vine forest, sand sheet heath and vegetation containing large trees with hollows suitable for fauna. The land clearing guidelines identifies the Northern Territory Goals in Native Vegetation Management which include avoiding impacts on environmentally significant or sensitive vegetation.

There are two mangrove community types within the survey area - vegetation communities five and six (Figure 2-1 and Appendix A). Vegetation community five is taller, denser mangroves and is described as *Rhizophora stylosa* Low Closed Forest over *Rhizophora stylosa, Ceriops tagal* low open forest. Vegetation community six has shorter and more open mangroves and is described as *Ceriops tagal, Avicennia marina* Low Open Forest over *Ceriops tagal, Rhizophora stylosa* Low Open Forest. Both mangrove communities are considered sensitive vegetation, and lie just outside the boundary of Kittyhawk Estate.

2.3.2 Darwin Cycad

Whilst vegetation surveys were undertaken, the presence of the Darwin Cycad (*Cycas armstrongii*) was noted and a count undertaken. Approximately 85 Darwin Cycads were found across four sites (VS3, VS7, VS10 and VS13). The Darwin Cycad is listed as vulnerable in the NT. This species is found in open grassy woodlands where adequate drainage appears to be a limiting factor (Kerrigan et al. 2006). Prime habitat was deep loamy soil (Liddle 2009).

2.4 Conclusions

The vegetation mapping identified the vegetation communities present within Kittyhawk Estate. There was no sensitive vegetation present within Kittyhawk Estate, however, Kittyhawk Estate is abutted by mangrove communities – a sensitive vegetation type. These communities are considered a sensitive vegetation type and disturbance should be avoided; the NT Vegetation Clearing Guidelines state that development should not occur within 200 m of the edge of the mangroves. If development is to occur within this buffer zone, there will be an onus on the proponent to show the potential impact to the mangrove community. Consideration also needs to be given to the impact any changes of hydrology on Kittyhawk Estate may have on mangroves.

The presence of cycads is discussed in Section 6.

3 WEEDS AND FERAL ANIMALS

3.1 Background and scope

The *Weeds Management Act* declares undesirable species of plants as weeds, and requires these species to be controlled, eradicated or prevented from entering the NT depending on their classification. Weeds are classified into one of three classes:

- Class A declared plant: to be eradicated
- Class B declared plant: growth and spread to be controlled
- Class C declared plant: not to be introduced into the NT

The Act stipulates general duties for the owner or occupier of land to take all reasonable measures to prevent land being infested with a declared weed, to prevent a declared weed spreading to other land, and to report to a Weed Management Officer, within 14 days of first becoming aware, when a declared weed that has not been previously known in an area is identified.

Where weeds are present within an area of development, such a development has the potential to spread or increase abundance of weed species within the site through project activities such as soil and truck movement. Project activities could also transport new weed species to site. Prevention of weed spread and invasion can be managed through appropriate development and application of a weed management plan, however, to develop that weed management plan an understanding of the weed and pest presence and abundance on site needs to be understood.

Animal species can be declared feral animals under the *Territory Parks and Wildlife Act*. These species can have a negative effect on native wildlife. Project activities can alter the environment such that conditions for feral species are improved and the abundance of feral species increases. Increases in feral animal abundance can be managed through appropriate controls – however, these would only be required if project activities were to increase feral animals such that they posed a threat to native wildlife. To determine if such controls are required, an understanding of the feral animals within Kittyhawk Estate needs to be developed.

In order to develop this understanding, an assessment of weeds within stage 1 was undertaken. The scope of this assessment is:

- Undertake a desktop assessment of stage 1 and the surrounding area using available datasets
- Complete field surveys to identify any weeds or pests within the Kittyhawk Estate.

3.2 Methods

3.2.1 Desktop assessment

Two data sets were used in the desktop assessment of weeds and within stage 1 and the surrounding area:

- Use the Protected Matters Search Tool to determine weed and pest species listed within a buffer of 20 km.
- Search NT Infonet (www.infonet.org.au) to generate a list of weed and pest species which have been recorded within across Middle Arm.

These two lists were amalgamated to form a list of weed and pest species which could occur within stage 1. The list of weeds was cross referenced with the classification of the weed species under both NT (Class A, B, C) and Commonwealth legislation (Weed of National Significance – WoNS or ALERT). Only listed weed species were included in the list – introduced plants with no listing (under either Territory or Commonwealth legislation) were excluded. Invasive bird species were excluded as they are not considered to be threats to any threatened species within stage 1.

3.2.2 Survey methods

Presence of weeds and pests in and around stage 1 were recorded during vegetation mapping field surveys.

3.3 Results

Table 3-1 shows NT listed weeds and Weeds of National Significance (WoNS) which may be present within stage 1. Table 3-2 shows the pest animals which may occur within stage 1.

The most notable result from the field surveys was that Gamba Grass was common within disturbed areas across Kittyhawk Estate.

Table 3-1. Weeds and pest which may occur within stage 1

Species	Observed during survey	NT status	National Status
Starburr - *Acanthospermum hispidum*	-	B/C	-
Gamba Grass - *Andropogon gayanus*	Y (disturbed areas)	A/C	WoNS
Barleria - *Barleria prionitis*	-	A/C	ALERT
Mossman River Grass - *Cenchrus echinatus*	-	B/C	-
Mission Grass (perennial) - *Cenchrus polystachios*	Y (VS4)	B/C	-
Madagascan Rubber Vine - *Cryptostegia madagascariensis*	-	A/C	-
Fierce Thornapple - *Datura ferox*	-	A/C	-
Olive Hymenachne - *Hymenachne amplexicaulis*	-	A/C	WoNS
Hyptis - *Hyptis suaveolens*	-	B/C	
Physic Nut - *Jatropha curcas*	-	A/C	
Bellyache Bush - *Jatropha gossypiifolia*	-	A/C	WoNS
Lantana - *Lantana camara*	-	B/C	WoNS
Mimosa - *Mimosa pigra*	-	B/C	WoNS
Common Sensitive Plant - *Mimosa pudica*	-	C	
Cow Itch - *Mucuna pruriens* var. *utilis*	-	-	ALERT
Parkinsonia - *Parkinsonia aculeata*	-	B/C	WoNS
Salvinia - *Salvinia molesta*	-	B/C	WoNS
Candle Bush - *Senna alata*	-	B/C	-
Sicklepod - *Senna obtusifolia*	-	B/C	-
Spiny-head Sida - *Sida acuta*	-	B/C	-
Flannel Weed - *Sida cordifolia*	-	B/C	-
Paddy's Lucerne - *Sida rhombifolia*	-	B/C	-
Branched Porterweed - *Stachytarpheta australis*	-	B/C	-
Cayenne Snakeweed - *Stachytarpheta cayennensis*	-	B/C	-
Jamaican Snakeweed - *Stachytarpheta jamaicensis*	-	B/C	-
Grader Grass - *Themeda quadrivalvis*	-	B/C	-
Beach Caltrop - *Tribulus cistoides*	-	B/C	-
Caltrop - *Tribulus terrestris*	-	B/C	-
Cat's Claw Vine – *Dolichandra unguis-cati*	-	A/C	WoNS

Water Hyacinth – *Eichhornia crassipes*	-	A/C	WoNS
Cabomba – *Cabomba caroliniana*	-	A/C	WoNS
Pond Apple – *Annona glabra*	-	A/C	WoNS

Y – Yes; a dash indicates the species was not observed; A/C – class A and class C weed in the NT; B/C – class B and class C weed in the NT; WoNS – Weed of National Significance, ALERT – alert weed, VS4 – vegetation survey site 4 (refer to Figure 2-1).

Table 3-2. Pests which may occur within stage 1

Species	Observed during survey
Cane Toad – *Rhinella marina*	-
Domestic Cattle – *Bos Taurus*	-
Water Buffalo – *Bubalus bubalis*	-
Domestic Dog – *Canis lupus familiaris*	-
Horse – *Equus caballus*	-
Cat – *Felis catus*	-
House Mouse – *Mus musculus*	-
Black rat – *Rattus rattus*	-
Pig – *Sus scrofa*	Y (VS6)
Asian House Gecko – *Hemidactylus frenatus*	-
Flower-pot Blind Snake – *Indotyphlops braminus*	-
Rabbit – *Oryctolagus cuniculus*	-

Y – Yes; a dash indicates the species was not observed; VS6 – Vegetation survey site 6 (refer to Figure 2-1)

3.4 Conclusions

There are a number of weeds and pests which may occur within the Kittyhawk Estate these could have potential negative environmental impacts if project activities cause increases in their abundance. It is not expected that project activities will create additional habitat for the feral animal species which could occur within the project area. As such further work relating to feral animals is not recommended. The management of weeds can be achieved through the development and implementation of an appropriate management plan prior to construction. It is recommended that a weed management plan be developed prior to construction commencing but following finalisation of planning for the Stage 1 area. The weed management plan should be reviewed by the weed management branch of DENR.

4 FIRE HISTORY

4.1 Background and scope

An analysis of fire history was not included in the scope of works provided by LDC, however, fire is an important consideration. Generally, fire frequency has increased in the NT in recent times. This increase in fire frequency can have negative effects on environmental values within an area. For instance, native vegetation community structure can change as those species better adapted to frequent fire become established at the expense of more fire intolerant species. This change in vegetation structure can have associated impacts on native species – particular small mammals; the vegetation change changes habitat availability for these species.

It is important to understand the fire history of a site as it will help make informed assessments of the values at that site. If a site experiences a high fire frequency, then the likelihood of fire intolerant species, or species that prefer long unburnt areas, occurring on site is diminished.

To assess the potential impact of fire within the Kittyhawk Estate, a desktop analysis of fire history at the site was undertaken.

4.2 Methods

Fire history within Kittyhawk Estate was obtain from the Northern Australia Fire Information website (http://www.firenorth.org.au/nafi3/). The data shows how many years an area has been burnt between 2000 and 2017 (17 years). The data is available in 250 m x 250 m grid cells.

Fire frequency was divided into categories (intervals) of years burnt between 2000 and 2017. Fire frequency within the surrounding area (4775 hectares) was used to determine the length of these intervals. Count of grid cells with a particular fire frequency within this surrounding area showed three intervals each containing a peak of fire frequency occurrence. Intervals were divided by fire frequencies with fewer occurrences (Figure 4-1). Intervals were: 0-4 times, 5-8 times and 9-17 times.

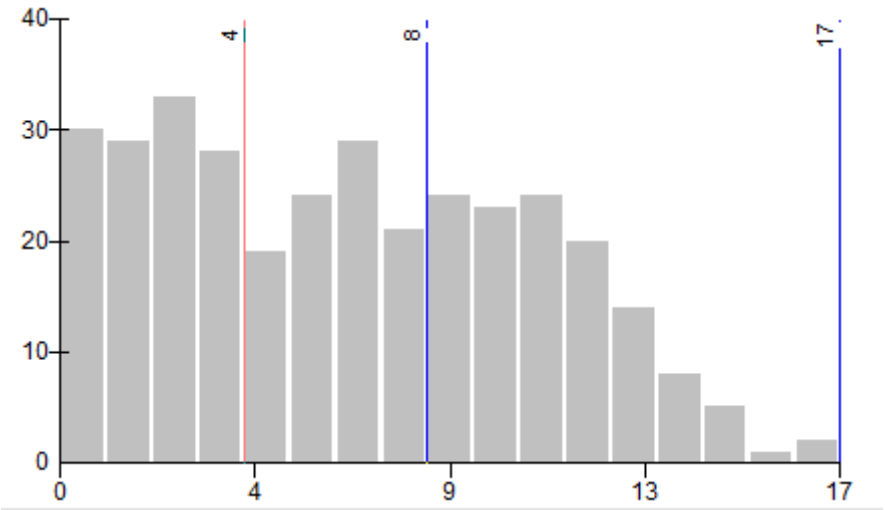

Figure 4-1. Graph showing interval breaks of fire frequency classification

These intervals were used to display the fire frequency within the Kittyhawk Estate (there were no areas of Kittyhawk Estate burnt less than twice between 2000 and 2017, hence the first interval is 2-4 years).

4.3 Results

Kittyhawk Estate has experienced regular fire between 2000 and 2017. Fire is more frequent in the southern areas of Kittyhawk Estate.

The southern and mid areas of Kittyhawk Estate burnt greater than nine times in the 17-year period to 2017. Areas in the north of Kittyhawk Estate burnt less frequently, but most areas burnt at least 5-8 times between 2000 and 2017. Small areas on the edge of the Kittyhawk Estate boundary burnt less than 4 times between 2000 and 2017.

In the broader area fires occur less frequently further along Middle Arm (to the west) and more frequently to the south east.

Fire frequency in Kittyhawk Estate is shown in Figure 4-2. The areas of Kittyhawk Estate which relate to each of the fire frequency intervals is shown in Table 4-1

Table 4-1. Fire frequency experienced in Kittyhawk Estate

Fire frequency between 2000 and 2017	Area (ha)
0-4 times	13
5-8 times	94
9-17 times	228

4.4 Conclusions

The high frequency of fire within the Kittyhawk Estate should be taken into account when assessing the likelihood of threatened species occurring within the site. The high frequency is likely to reduce the likelihood that fire intolerant species, or species that prefer long unburnt areas, occurring within the Kittyhawk Estate. Given the less frequent occurrence of fire in the northern areas of the Estate (towards the *Melaleuca* mangrove vegetation communities), threatened species which may use vegetation in these areas as habitat would likely be less affected.

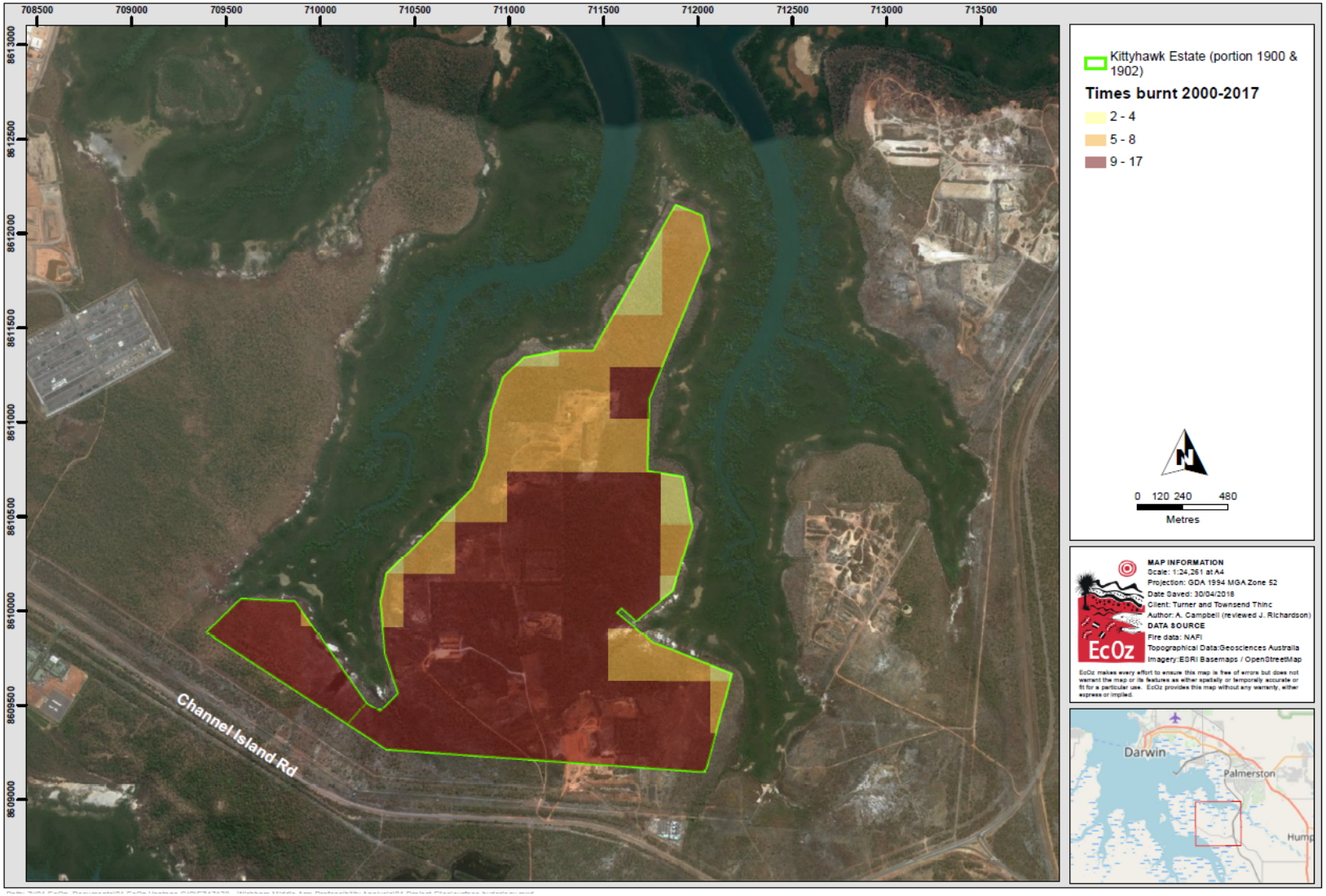

Figure 4-2. Map showing fire frequency in Kittyhawk Estate

5 MARINE BENTHIC HABITATS

5.1 Background and scope

Marine benthic habitats are important providers of ecosystem function and habitat for other marine species. Such habitats include seagrass beds, corals, macro algae and filter feeder communities. Seagrass communities are particularly important to marine mammals and turtles which utilise these environments for feeding. Darwin Harbour is known to support a variety of marine habitats, however, the distribution of these habitats within the Harbour is not uniform.

The location of benthic marine habitats within the harbour will affect the likelihood of occurrence of protected marine species (Section 6.3.2). To inform the likelihood of occurrence analysis, this section provides a desktop analysis of the marine benthic habitats within close proximity to the Kittyhawk Estate of MAIP. Marine benthic habitats within close proximity to stage 1 are those which may be impacted by development of stage 1. This impact can occur through two means:

- Offsite discharges of chemically or sediment laden water into the marine environment
- Direct impact to marine benthic habitats through on-water development.

5.2 Methods

The marine benthic habitats within close proximity to stage 1 (proximate area) include the Darwin Harbour end of the Elizabeth River, the Blackmore River and the majority of Darwin Harbour. It excludes the west side of Darwin Harbour as water currents transporting water from near stage 1 are not expected to deposit material here, but rather transport it out the mouth of the harbour. The proximate area is shown on Figure 5-1 and Figure 5-2.

This assessment of marine benthic habitat was completed using available desktop data. The following data sets, obtained from the Department of Environment and Natural Resources (DENR), were used in the desktop analysis:

- Marine benthic fauna compiled 2017 – A compilation of existing marine benthic habitat data for the NT. Shows the presence of each marine benthic habitat taxa group per 250 m grid cell. Does not show where surveys recorded an absences of benthic taxa (dataset 1).
- Seagrass – a compilation of existing seagrass layers for the NT up until 20 January 2017. Shows the presence/absence of each marine benthic habitat taxa group per 250 m grid cell. Includes areas where surveys have been conducted but no seagrass was recorded (dataset 2).

This assessment describes the benthic marine habitats within the proximate area where that information is contained within the datasets. Where data is lacking on the composition of the marine benthic habitat within the proximate area, this is noted.

5.3 Analysis of data

Given the important role seagrass plays in supporting other marine species, and the availability of extra data relating to these species, seagrass was analysed separately from other benthic habitats.

5.3.1 Seagrass

With the proximate area, there are 207 grid cells where the presence or absence of seagrass has been recorded. Of these grid cells, 15 contained seagrass and 192 had no records of seagrass being present. Of the grid cells where seagrass has been recorded, two are within the East Arm of the Darwin Harbour and two

are within Middle Arm (Figure 5-1). The remaining 11 records of seagrass came from Darwin Harbour (i.e. outside the estuarine arms).

There have been few surveys within the upper reaches of Middle Arm; 8 survey records (seagrass either present or absent).

5.3.2 Other benthic habitats

Filter feeders and Octo-corals were the two most common taxa within the East Arm section of Darwin Harbour. There were 25 grid cells where filter feeders were present within the East Arm Section of the Darwin Harbour, and 161 grid cells within the proximate area. There were 16 grid cells where Octo-corals were present within the East Arm section of Darwin Harbour and 81 grid cells within the proximate area.

There are fewer records of stony corals from the proximate area (40) and no records from the East Arm section of the harbour. There are four records of macro algae from the East Arm section of Darwin Harbour and 38 records from the proximate area. See Figure 5-2 for records of benthic habitats other than seagrass.

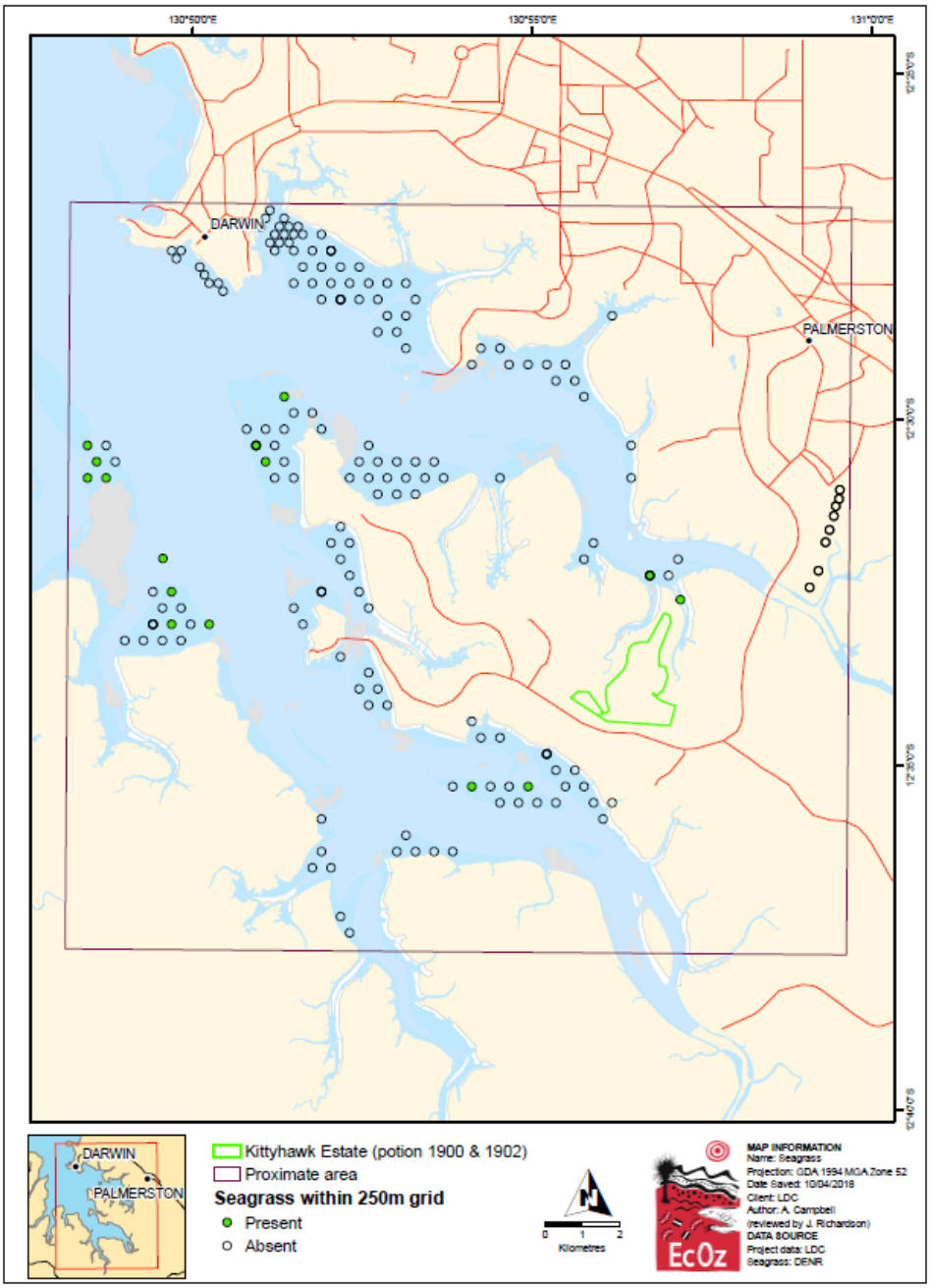

Figure 5-1. Seagrass records from the proximate area

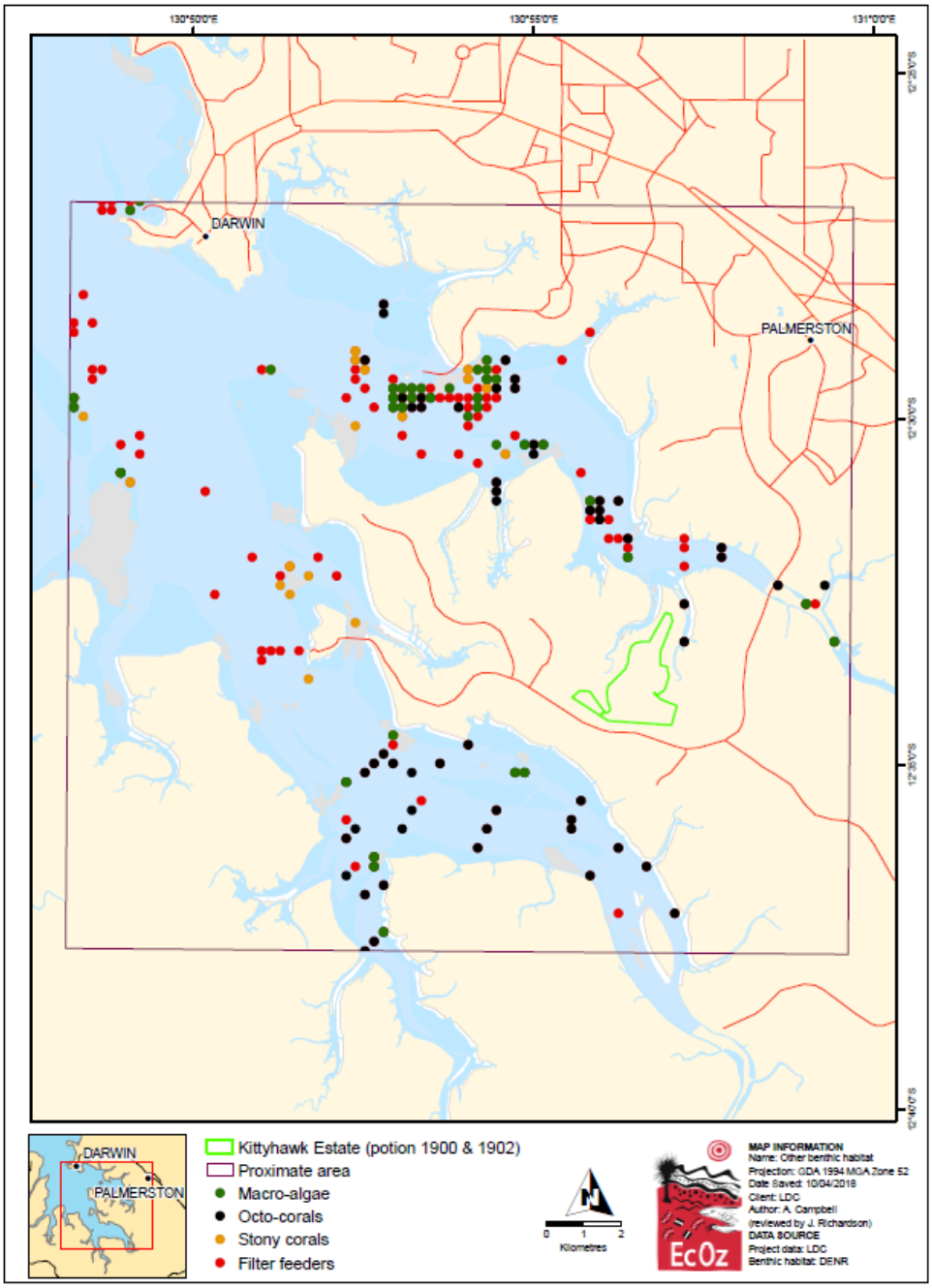

Figure 5-2. Other benthic habitats within the proximate area

5.4 Conclusions

There are limited records of seagrass within the East Arm section of Darwin harbour and few within the proximate area. The data shows seagrass patches predominately occurring at the mouth and outside the harbour. The main taxa shown in the data within the East Arm section of Darwin Harbour and the proximate area are filter feeders and Octo-corals.

It should be noted that the data is not comprehensive for the proximate area – there are areas which have not been surveyed and different survey methods have been used across the area which biases the data – so caution should be applied during interpretation. If future work proposes discharge of low quality surface water, or direct impact to marine benthic habitats, further analysis and possibly survey of these habitats may be required.

That being said, the data demonstrates that there is potential of benthic habitats within the proximate area, however, the quality of the data is unable to demonstrate the exact nature of these environmental values. Although there are more records of benthic habitat in the proximate area from closer to the Harbour mouth, this is due to survey effort/locations rather than a true representation of habitat presence.

Despite the presence of benthic habitat within the proximate area, the likely impact to these habitats is low provided that appropriate controls are implemented for erosion and sediment management and freshwater discharge from the site. Management of discharges should take into consideration the Darwin Harbour Water Quality Protection Plan.

6 THREATENED AND MIGRATORY SPECIES

6.1 Background and scope

The International Union for the Conservation of Nature nominates a set of criteria used to identify species at risk of extinction. These criteria are used by the Northern Territory Government to determine which threatened species are listed under the *Territory Parks and Wildlife Conservation Act (NT)* (TPWC Act), and by the Commonwealth Government to determine which threatened species are listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Additionally, species which migrate to Australia or through Australian waters are listed as migratory under the *EPBC Act*. All migratory species listed in the *EPBC Act* are protected to the same degree as threatened species.

The potential impact to threatened and migratory species will be considered during the environmental assessment of a project. To complete this assessment, a determination of which species are likely to occur within the project area or areas impacted by the project needs to be made. This is termed a likelihood of occurrence assessment. The aim of the likelihood of occurrence assessment is to determine which species need to be considered further in the environmental assessment process through targeted survey work or impact assessment.

6.1.1 Scope

This report details the likelihood of occurrence assessment for:

- Threatened and migratory terrestrial species which may occur within the Kittyhawk Estate area and
- Threatened and migratory marine species which occur in marine waters proximate to Kittyhawk Estate.

It does not include a potential impact assessment for threatened and migratory species assessed as likely to occur within the relevant areas.

The likelihood of occurrence assessment is primarily a desktop exercise but has incorporated the results of vegetation surveys (see Section 2). There have not been any targeted surveys for particular protected species.

6.2 Methods

To determine which terrestrial protected species have potential to occur within Kittyhawk Estate, analysis of regional flora and fauna records – informed by the results of the Commonwealth and NT threatened species search tools (described below) – was undertaken. For each of these species, the likelihood that the species occurs within the Kittyhawk Estate was then assessed based on habitat requirements, distribution, and the number and dates of proximate records. The purpose of such an assessment was to identify those species that required further consideration (including, possibly, field surveys), and those that can be reasonably excluded from further assessment because they are unlikely to occur.

The following procedure was used to undertake the likelihood of occurrence assessment for each relevant protected species:

1) Identify which bioregions are intersected by the Kittyhawk Estate.
2) Collate threatened flora and fauna records within the bioregion/s using the latest NT Flora and Fauna Atlas database (last updated in December 2016).
3) Use the Protected Matters Search Tool to determine species listed as threatened or migratory under the *EPBC Act 1999* (undertaken March 2018). A buffer of 20 km around the centre of Kittyhawk Estate was used. This covers the Middle Arm Peninsula and surrounding terrestrial environment.

4) Combine the results of steps 2 and 3 to generate the following two lists:
    a. Terrestrial threatened or migratory species that may occur within the Kittyhawk Estate.
    b. Marine threatened or migratory species that may occur within the waters proximate to the Kittyhawk Estate.
5) Filter lists to remove groups of species for which there is no habitat within the Kittyhawk Estate (i.e. shorebirds and migratory wetland species).
6) Collate the following details for each of those species – conservation status (NT and Commonwealth), habitat requirements, distribution, and number of records within the search area (from the NT Fauna and Flora Atlas dataset).
7) Correlate the information from step 6 with the results of the vegetation mapping for terrestrial species and the results of the benthic habitat assessment for the marine species.
8) Analyse the likelihood that each species occurs within the Kittyhawk Estate or proximate marine waters by applying the following likelihood classifications:
    a. HIGH – it is expected that this species lives within the Kittyhawk Estate or proximate marine waters because of the presence of suitable habitat, and/or there are recent proximate records.
    b. MEDIUM – this species may live within the Kittyhawk Estate or proximate marine waters; however, there is evidence that lowers its likelihood of occurrence (i.e. lack of core habitat, no recent records with the database search area, species is naturally-rare or occurs at a low density etc.).
    c. LOW – apart from the occasional transient, it is not expected that this species occurs within the Kittyhawk Estate or proximate marine waters, as there is no suitable habitat and/or there has been a known range contraction of the species in the region.
    d. NONE – there is strong evidence (the species is considered likely to be regionally extinct or the species has a restricted range outside the Kittyhawk Estate or proximate marine waters) that this species will not occur within the Kittyhawk Estate or proximate marine waters.

The EPBC protected matters search report is provided as Appendix B; terrestrial and marine protected species likelihood of occurrence analysis are shown in Appendix C and Appendix D respectively; the results are summarised in Section 6.3.

6.3 Likelihood of occurrence summary

The results of the 'likelihood of occurrence' assessment are presented in Table 6-1 and Table 6-2 and can be summarised as follows:

- Darwin Cycad was identified during vegetation surveys and is thus known from the Kittyhawk Estate.
- Six terrestrial threatened species were ranked as known to occur, or as having a high or medium likelihood of occurring within the Kittyhawk Estate (Table 6-1).
- One terrestrial migratory species (Oriental Cuckoo – *Cuculus optatus*) was ranked as having a medium chance of occurring within the Kittyhawk Estate. However, the Kittyhawk Estate is not considered core habitat for the species and it is not recommended that further survey work be undertaken for the species.
- Seven marine threatened species were ranked as having a medium likelihood of occurring within marine water proximate to the Kittyhawk Estate. No marine threatened species were ranked as having a high likelihood of occurrence within marine water proximate to the Kittyhawk Estate.

- Eight marine migratory species were ranked as having a high or medium chance of occurring within marine water proximate to the Kittyhawk Estate or above the Kittyhawk Estate (bird species).

The full results of the likelihood of occurrence analysis are presented in Appendix C and Appendix D.

6.3.1 Terrestrial species

Threatened species

Table 6-1 shows the terrestrial threatened species with a known, high or medium chance of occurring within the Kittyhawk Estate.

Table 6-1. Terrestrial threatened species likelihood of occurrence summary

Name	Group	Status		Desktop likelihood
		Cth	NT	
Darwin Cycad *Cycas armstrongii*	Plants	-	VU	**Known**
Black-footed Tree-rat (Kimberley and mainland NT subspecies) *Mesembriomys gouldii gouldii*	Mammals	EN	VU	**High**
Fawn Antechinus *Antechinus bellus*	Mammals	VU	EN	**Medium**
Pale Field Rat *Rattus tunneyi*	Mammals	-	VU	**Medium**
Bare-rumped Sheathtail Bat *Saccolaimus saccolaimus (nudicluniatus)*	Mammals	VU	-	**Medium**
Floodplain Monitor *Varanus panoptes*	Reptiles	-	VU	**Medium**

Key: VU – Vulnerable, EN – Endangered, a dash indicates the species is not listed under that jurisdiction. Cth – Commonwealth, NT – Northern Territory.

Migratory species

One terrestrial migratory species (Oriental Cuckoo – *Cuculus optatus*) was ranked as having a medium chance of occurring within the Kittyhawk Estate. However, the Kittyhawk Estate is not considered core habitat for the species and it is not recommended that further survey work be undertaken for the species

6.3.2 Marine species

Threatened species

Table 6-2 shows the marine threatened species with a high or medium chance of occurring within the marine waters proximate to the Kittyhawk Estate.

Table 6-2. Marine threatened species likelihood of occurrence summary

Name	Group	Status		Desktop likelihood
		Cth	NT	
Green Turtle *Chelonia mydas*	Reptiles	VU	-	**Medium**
Hawksbill Turtle *Eretmochelys imbricata*	Reptiles	VU	VU	**Medium**
Olive Ridley Turtle *Lepidochelys olivacea*	Reptiles	EN	VU	**Medium**
Flatback Turtle *Natator depressus*	Reptiles	VU	-	**Medium**
Dwarf Sawfish *Pristis clavata*	Fish	VU	VU	**Medium**
Freshwater or Largetooth Sawfish *Pristis pristis*	Fish	VU	VU	**Medium**
Green Sawfish *Pristis zijsron*	Fish	VU	VU	**Medium**

Key: VU – Vulnerable, EN – Endangered, a dash indicates the species is not listed under that jurisdiction. Cth – Commonwealth, NT – Northern Territory.

Migratory species

Table 6-3 shows the marine threatened species with a high or medium chance of occurring within the marine waters proximate to the Kittyhawk Estate.

Table 6-3. Marine migratory species likelihood of occurrence summary

Name	Group	Desktop likelihood
Indo-Pacific Humpback Dolphin *Sousa chinensis/sahulensis*	Mammals	**High**
Saltwater Crocodile *Crocodylus porosus*	Reptiles	**High**
Fork-tailed Swift *Apus pacificus*	Birds	**Medium**
Little Tern *Sternula albifrons*	Birds	**Medium**
Dugong *Dugong dugong*	Mammals	**Medium**
Irrawaddy Dolphin *Orcaella brevirostris/heinsohni*	Mammals	**Medium**
Spotted Bottlenose Dolphin *Tursiops aduncus*	Mammals	**Medium**
Olive Ridley Turtle *Lepidochelys olivacea*	Reptiles	**Medium**

6.4 Conclusions

There are six protected species that are likely to occur within Kittyhawk Estate and should be considered further. The approvals process for the development of Stage 1 will need to assess the potential impact to these species and potentially others, as deemed necessary by DENR.

Surveys will likely be required for the terrestrial threatened species which have been assessed as having a known, high or medium chance of occurring within the Kittyhawk Estate. However, we recommend that DENR be engaged to confirm those species requiring further assessment. It is not recommended that survey work be undertaken for the marine threatened or migratory species.

7 SURFACE HYDROLOGY

7.1 Background and scope

A surface water assessment was completed by EnviroConsult for the Kittyhawk Estate (Appendix E). The results of the assessment are summarised below. The aim of the surface water assessment was to determine:

- the volume of water discharged from the Kittyhawk Estate during an average rainfall year;
- the peak and total discharge of water from each of the four major outlet catchments within Kittyhawk Estate during a 1 in 100-year rainfall event;
- the area of the Kittyhawk Estate which may be inundated during a 1 in 100-year flood event with 1 in 100-year primary tidal surge based on 2018 and 2100 mean sea levels; and
- the area of the Kittyhawk Estate which may be inundated during a 1 in 1000-year flood event with a 1 in 1000-year secondary storm surge based on 2018 and 2100 mean sea levels.

7.2 Methods

As the surface water assessment was a desktop based task, and Kittyhawk Estate is un-gauged, a model was developed to determine discharge and inundation. Although there are existing datasets of inundation level, the development of a site specific model is more accurate due to additional input variables and provides information on a finer spatial scale.

The following generalised method was used to complete the surface water assessment (see Appendix E for full methodology):

Water discharge

- A digital elevation model of the site was developed.
- The four major outlet catchments of Kittyhawk Estate, which drain the majority of surface water, were defined.
- A RORBwin hydrology model used Monte Carlo simulations to determine the probable peak flows at the outlet of the four outlet catchments for a 1 in 100-year and 1 in 1000-year storm event based on Bureau of Meteorology (BOM) data.
- Data from an average rainfall year was used to determine total discharge from the Kittyhawk Estate (total area including four outlet catchments and other areas).

Inundation

- Inundation of Kittyhawk Estate during a 1 in 100-year storm event with primary storm surge and 1 in 1000-year storm event with secondary storm surge was modelled using a HEC-RAS 5.03 two dimensional model.
- The model used available topographic and bathymetric data and ran four simulations for each storm event for 2018 and 2100 mean sea levels.
- Inundation form the model was compared to broad modelling including those involving sea level rise.

7.3 Results

7.3.1 Discharge

The total discharge volume at the Kittyhawk Estate catchment outlet (Figure 7-2) for an average rainfall year is 15300 ML.

Within Kittyhawk Estate there are four sub-catchments which drain the majority of the surface water (Figure 7-1). The peak discharge (which occurs approximately 20 minutes after the start of the 1 in 110-year rainfall event) and total discharge (there is no more flow from site following the end of the 1 in 100-year rainfall event) from each of these four outlet catchments is shown in Table 7-1. This is not the total volume of water discharged from the entirety of Kittyhawk Estate or the Stage 1 area, however, they represent the majority of surface water discharge from the Kittyhawk Estate.

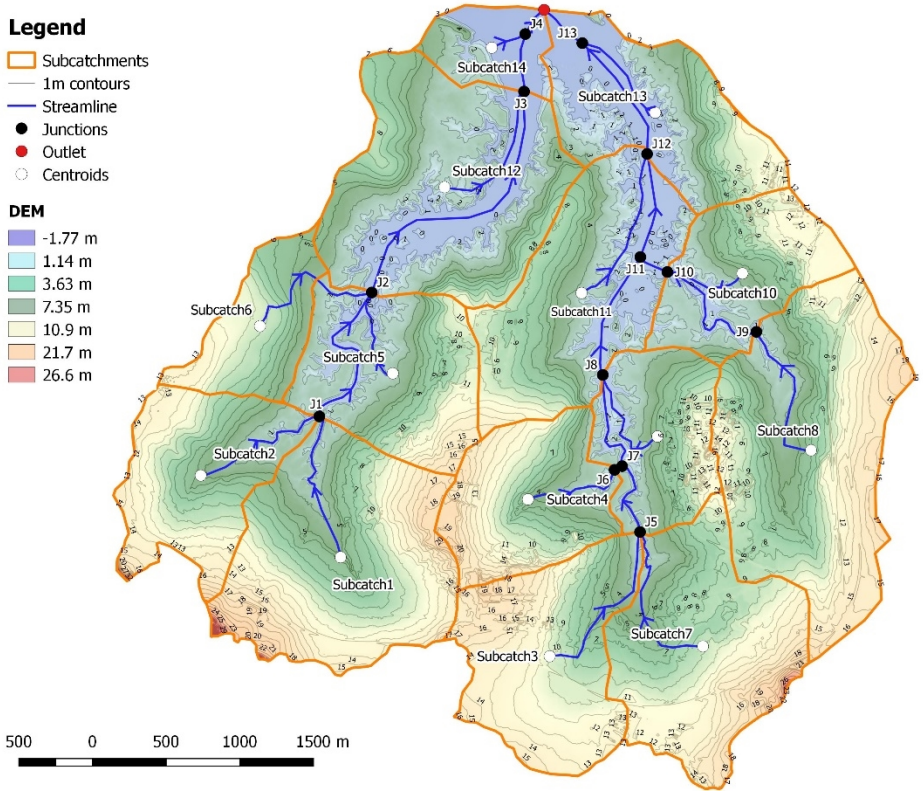

Figure 7-1. Map showing Kittyhawk Estate catchments and catchment outlet

Table 7-1. Volume of surface water discharge from Kittyhawk Estate's four major outlet catchments[1]

Sub-catchment	Area (km^2)	Peak discharge (m^3s^{-1})	Total discharge following 1hr rainfall event (ML)
1	0.37	17.7	33.5
2	0.29	15.0	28.3
3	0.04	1.9	3.5
4	0.62	32.0	60.5
Total	**3.28**		**125.8**

[1] See Figure 7-2 for location of outlet catchments.

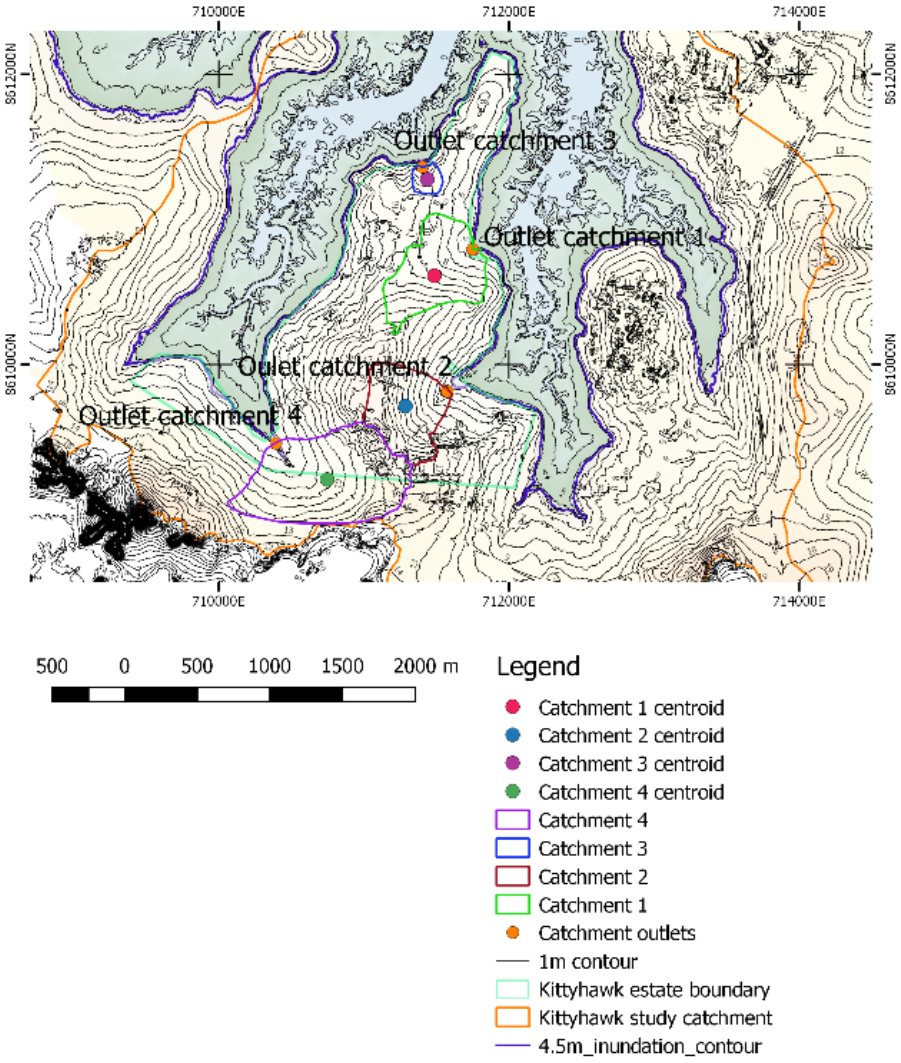

Figure 7-2. Map showing Kittyhawk Estate four major sub-catchments

7.3.2 Inundation

The maximum water level at the main catchment outlet (Figure 7-2) during a 1 in 100-year flood event using 2018 water levels is 5.7 m AHD, this is 1.2 m higher than the NT government's predicted highest astronomical tide (HAT) (including considerations of 1 in 100-year inundation level) for 2010. The maximum water level at the catchment outlet (Figure 7-2) during a 1 in 100-year flood event using 2100 water levels is 6.4 m AHD, this is 0.7 m higher than the 2018 scenario.

The maximum water level at the catchment outlet (Figure 7-2) during a 1 in 1000-year flood event using 2018 water levels is 6.2 m AHD, this is 1.1 m higher than the NT government's predicted HAT (including considerations of 1 in 100-year inundation level) for 2010. The maximum water level at the catchment outlet (Figure 7-2) during a 1 in 1000-year flood event using 2100 water levels is 6.8 m AHD, this is 0.6 m higher than 2018 scenarios.

The inundation extent from these modelling results area shown on Figure 7-3.

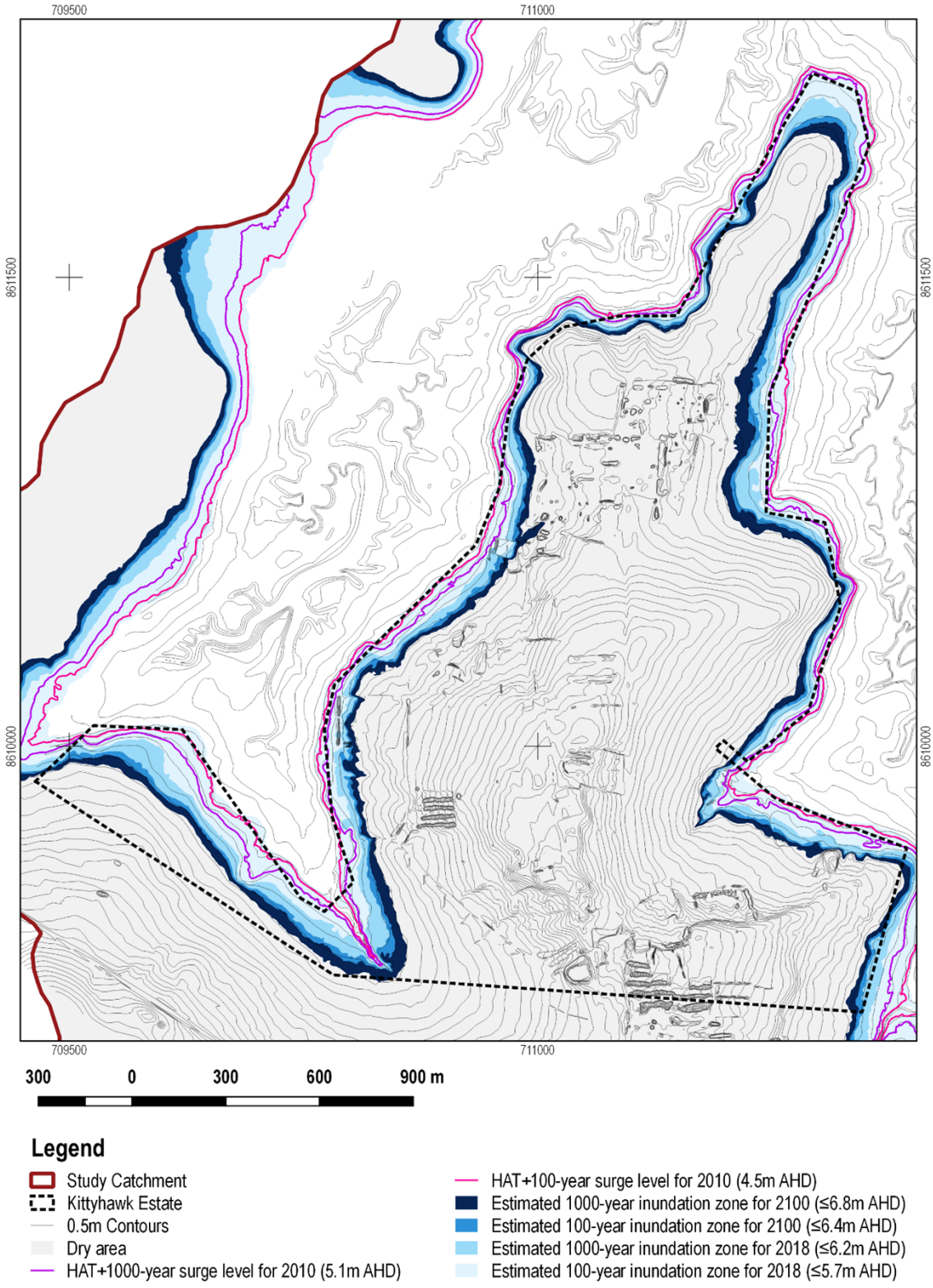

Figure 7-3. Map showing inundation levels for Kittyhawk Estate for each of the modelling scenarios

7.4 Conclusions

The hydrological assessment determined the peak flow rates from the four major sub-catchments within Kittyhawk Estate during a 1 in 100-year rainfall event. This information can help inform designs for storm water management.

The maximum water level at the catchment outlet during a 1 in 1000-year flood event using 2100 water levels is 6.8 m AHD. The inundation levels shown on Figure 7-3 should be taken into account when locating development within Kittyhawk Estate and for determining surface levels and drainage design.

8 CONCLUSION AND RECOMMENDATIONS

This environmental constraints report details the results of studies assessing vegetation, weeds and pests, marine benthic habitats, protected species and surface hydrology within and around Kittyhawk Estate within the Middle Arm Industrial Precinct. The assessment aimed to identify environmental constraints which need to be considered during the planning and approvals process for stage 1.

Generally, the area assessed had limited environmental values that would constrain development. The key considerations are summarised below:

- The Kittyhawk Estate is bordered by areas of mangrove vegetation communities. These communities are considered sensitive vegetation in the NT. The NT Vegetation Clearing Guidelines state that development should not occur within 200 m of the edge of the mangroves. Development can occur within 200 m however there will be an onus on the proponent to show how the development will not affect the mangroves. Consideration also needs to be given to the impact any changes of hydrology on Kittyhawk Estate may have on mangroves.
- There are a number of weeds and pests which may occur within the Kittyhawk Estate, and thus the stage 1 area. The management of weeds and pests can be achieved through the development and implementation of appropriate management plans prior to construction.
- The marine benthic habitats proximate to the Kittyhawk Estate are unlikely to be impacted from the development provided that appropriate erosion and sediment controls and water management are implemented.
- There are six protected species that have a known, high or medium likelihood of occurring within Kittyhawk Estate and should be considered further. The approvals process for the development of Stage 1 will need to assess the potential impact to these species and potentially others, as deemed necessary by DENR.
- The surface hydrology assessment determined the peak flow and total discharge for the four main sub-catchments of Kittyhawk Estate. These values provide a basis for stormwater design. The assessment also determined the area of Kittyhawk Estate which would be inundated during storm events and tidal surges. Development should be located outside these areas.

8.1 Further work required

Table 8-1 identifies the studies which should be undertaken to progress the environmental assessment.

Table 8-1. Recommendations for further work

Environmental factor	Recommendations	Timeframe
Terrestrial flora and fauna	A density assessment of Darwin Cycad within the stage 1 area is completed.	Prior to DA being submitted
	Confirmation of survey requirements for threatened species with DENR.	Determine prior to field survey program
	Surveys for presence of the identified threatened species within the Kittyhawk Estate are undertaken.	Prior to DA being submitted
	A weed management plan is developed for the construction activities associated with the development of stage 1.	Prior to construction
Inland water environmental quality	Surface water quality assessment during first flush event prior to construction	2018-2019 wet season

Environmental factor	Recommendations	Timeframe
	Development and implementation of an erosion and sediment control plan	Prior to construction
Land capability	To ensure that the soils for the area are suitable for wastewater disposal a land capability assessment for the stage 1 area be completed.	Prior to DA being submitted

9 REFERENCES

Brocklehurst, P., Lewis, D., Napier, D. & Lynch, D. (2007). *Northern Territory Guidelines and Field Methodology for Vegetation Survey and Mapping.* Department of Natural Resources, Environment and the Arts, Palmerston, Northern Territory. Available at: http://www.territorystories.nt.gov.au/jspui/bitstream/10070/237908/1/NT_Guidelines_and_Field_Methodology_for_Vegetation_Survey_and_Mapping.pdf

Kerrigan, R., Cowie, I. and Liddle, D. (2006). *Threatened Species of the Northern Territory - Cycas armstrongii*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0017/208430/cycas-armstrongii.pdf [Accessed 10 April 2018].

Liddle, D.T. (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. [online] Available at: http://www.territorystories.nt.gov.au/jspui/bitstream/10070/265358/1/Management%20program%20for%20cycads%20in%20the%20Northern%20Territory%20of%20Australia%202009%20to%202014.pdf [Accessed 10 April 2018].

APPENDIX A VEGETATION COMMUNITY DESCRIPTIONS

Community 1 – *Erythrophleum chlorostachys, Terminalia ferdinandiana* Low Open Woodland over *Lophostemon lactifluus, Corymbia polysciada, Pandanus spiralis* Sparse Shrubland over *Themeda triandra, Chrysopogon fallax* Tussock Grassland			
Vegetation Description: *Erythrophleum chlorostachys, Terminalia ferdinandiana* Low Open Woodland over *Lophostemon lactifluus, Corymbia polysciada, Pandanus spiralis* Sparse Shrubland over *Themeda triandra, Chrysopogon fallax* Tussock Grassland			
Upper 1: Low open woodland dominated by *Erythrophleum chlorostachys* (fq 100.0%) and *Terminalia ferdinandiana* (fq 100.0%)			
Mid 1: Sparse shrubland dominated by *Lophostemon lactifluus* (fq 100.0%), *Corymbia polysciada* (fq 100.0%) and *Pandanus spiralis* (fq 100.0%)			
Ground 1: Tussock grassland dominated by *Themeda triandra* (fq 100.0%) and *Chrysopogon fallax* (fq 100.0%)			
			
No. of sites: 1			
Land units – Greater Darwin 25K: 4d – Gentle lower slopes fringing estuarine areas.			
Soils: Leptic Rudosols			
Total area of survey area: 12.6 ha (2.3%)		**Total area of project area:** 0 ha (0%)	
Community 1 structural summary:			

Strata	Modal growth form	Mean cover %	Mean height (m)
Upper U1	Tree	20	10
Mid M1	Shrub	10	8
Ground G1	Tussock grass	80	1

Community 2 – *Corymbia bella, Erythrophleum chlorostachys* Mid Open Woodland over *Planchonia careya, Pandanus spiralis, Vitex glabrata* Sparse Shrubland over *Heteropogon triticeus, Germainia grandiflora, Themeda triandra* Closed Tussock Grassland	
Vegetation Description: *Corymbia bella, Erythrophleum chlorostachys* Mid Open Woodland over *Planchonia careya, Pandanus spiralis, Vitex glabrata* Sparse Shrubland over *Heteropogon triticeus, Germainia grandiflora, Themeda triandra* Closed Tussock Grassland	
Upper 1: Mid open woodland dominated by *Corymbia bella* (fq 100.0%) and *Erythrophleum chlorostachys* (fq 100.0%)	
Mid 1: Sparse shrubland dominated by *Planchonia careya* (fq 100.0%), *Corymbia polysciada* (fq 100.0%), *Pandanus spiralis* (fq 100.0%) and *Vitex glabrata* (fq 100.0%)	
Ground 1: Closed Tussock grassland dominated by *Heteropogon triticeus* (fq 100.0%), *Germainia grandiflora* (fq 100.0%), *Themeda triandra* (fq 100.0%) and *Panicum sp.* (fq 100.0%)	
	
No. of sites: 1	
Land units – Greater Darwin 25K: 4d – Gentle lower slopes fringing estuarine areas.	
Soils: Leptic Rudosols	
Total area of survey area: 28.7 ha (5.1%)	**Total area of project area:** 11.1 ha (3.3%)
Community 2 structural summary:	

Strata	Modal growth form	Mean cover %	Mean height (m)
Upper U1	Tree	20	11
Mid M1	Shrub	15	8
Ground G1	Tussock grass	95	1.5

Community 3 – *Eucalyptus miniata, Eucalyptus tetrodonta, Corymbia bleeseri* Mid Woodland over *Livistona humilis, Cycas armstrongii, Erythrophleum chlorostachys* Sparse Shrubland over *Heteropogon triticeus, Sorghum intrans, Chrysopogon fallax* Tussock Grassland
Vegetation Description: *Eucalyptus miniata, Eucalyptus tetrodonta, Corymbia bleeseri* Mid Woodland over *Livistona humilis, Cycas armstrongii, Erythrophleum chlorostachys* Sparse Shrubland over *Heteropogon triticeus, Sorghum intrans, Chrysopogon fallax* Tussock Grassland
Upper 1: Mid woodland dominated by *Eucalyptus miniata* (fq 100.0%), *Eucalyptus tetrodonta* (fq 75.0%), *Corymbia bleeseri* (fq 75.0%), *Corymbia confertiflora* (fq 25.0%) and *Grevillea dunlopii* (fq 25.0%)
Mid 1: Sparse shrubland dominated by Livistona humilis (fq 100.0%), *Cycas armstrongii* (fq 50.0%), *Erythrophleum chlorostachys* (fq 50.0%), *Cochlospermum fraseri* (fq 25.0%) and *Terminalia ferdinandiana* (fq 25.0%)
Ground 1: Tussock grassland dominated by *Heteropogon triticeus* (fq 100.0%), *Sorghum intrans* (fq 50.0%), *Chrysopogon fallax* (fq 50.0%) and *Mnesithea rottboellioides* (fq 25.0%)

No. of sites: 4	
Land units – Greater Darwin 25K: 2a1 – Low rounded hills and associated upper slopes	
Soils: Leptic Rudosols	
Total area of survey area: 188.5 ha (33.7%)	**Total area of project area:** 184.4 ha (55.1%)

Community 3 structural summary:

Strata	Modal growth form	Mean cover %	Mean height (m)
Upper U1	Tree	28.8 (20 – 35)	16.8 (12 – 24)
Mid M1	Shrub	12.5 (10 – 15)	7.3 (4 – 14)
Ground G1	Tussock grass	57.5 (50 – 70)	1.1 (1 – 1.5)

Community 4 – *Melaleuca leucadendra, Corymbia polysciada, Melaleuca viridiflora* Mid Open Woodland over *Melaleuca viridiflora, Pandanus spiralis, Planchonia careya* Sparse Shrubland over *Germainia grandiflora , Themeda triandra, Dapsilanthus sp.* Closed Tussock Grassland

Vegetation Description: *Melaleuca leucadendra, Corymbia polysciada, Melaleuca viridiflora* Mid Open Woodland over *Melaleuca viridiflora, Pandanus spiralis, Planchonia careya* Sparse Shrubland over *Germainia grandiflora , Themeda triandra, Dapsilanthus sp.* Closed Tussock Grassland

Upper 1: Mid open woodland dominated by *Melaleuca leucadendra* (fq 33.3%), *Corymbia polysciada* (fq 33.3%), *Melaleuca viridiflora* (fq 33.3%), *Corymbia polycarpa* (fq 33.3%) and *Pandanus spiralis* (fq 33.3%)

Mid 1: Sparse shrubland dominated by *Melaleuca viridiflora* (fq 100.0%), *Pandanus spiralis* (fq 66.7%), *Planchonia careya* (fq 33.3%), *Melaleuca nervosa* (fq 33.3%) and *Grevillea pteridifolia* (fq 33.3%)

Ground 1: Closed Tussock grassland dominated by *Germainia grandiflora* (fq 33.3%), *Themeda triandra* (fq 33.3%), *Dapsilanthus sp.* (fq 33.3%), *Heteropogon triticeus* (fq 33.3%), *Panicum sp. (annual)* (fq 33.3%) and *Aristida sp.* (fq 33.3%)

No. of sites: 3

Land units – Greater Darwin 25K: 4d – Gentle lower slopes fringing estuarine areas.

Soils: Leptic Rudosols

Total area of survey area: 57.1 ha (10.2%)	**Total area of project area:** 27.5 ha (8.2%)

Community 4 structural summary:

Strata	Modal growth form	Mean cover %	Mean height (m)
Upper U1	Tree	20 (15 – 25)	10.3 (7 – 12)
Mid M1	Shrub	10 (5 – 20)	5.7 (4 – 8)
Ground G1	Tussock grass	81.7 (60 – 95)	1 (1 – 1)

Community 5 – *Rhizophora stylosa* Low Closed Forest over *Rhizophora stylosa, Ceriops tagal* low open forest			
Vegetation Description: *Rhizophora stylosa* Low Closed Forest over *Rhizophora stylosa, Ceriops tagal* low open forest			
Upper 1: Low closed forest dominated by *Rhizophora stylosa* (fq 50.0%)			
Mid 1: Low open forest dominated by *Rhizophora stylosa* (fq 50.0%) and *Ceriops tagal* (fq 50.0%)			
Ground 1: -			
			
No. of sites: 2			
Land units – Greater Darwin 25K: 9b – Estuarine fringe.			
Soils: Intertidal Hydrosols			
Total area of survey area: 130.2 ha (23.3%)		**Total area of project area:** 0 ha (0%)	
Community 5 structural summary:			

Strata	Modal growth form	Mean cover %	Mean height (m)
Upper U1	Tree	80	6
Mid M1	Tree	70	6
Ground G1	-	-	-

Community 6 – *Ceriops tagal, Avicennia marina* Low Open Forest over *Ceriops tagal, Rhizophora stylosa* Low Open Forest			
Vegetation Description: *Ceriops tagal, Avicennia marina* Low Open Forest over *Ceriops tagal, Rhizophora stylosa* Low Open Forest			
Upper 1: Low open forest dominated by *Ceriops tagal* (fq 50.0%) and *Avicennia marina* (fq 50.0%)			
Mid 1: Low open forest dominated by *Ceriops tagal* (fq 50.0%) and *Rhizophora stylosa* (fq 50.0%)			
Ground 1: -			
			
No. of sites: 2			
Land units – Greater Darwin 25K: 9b – Estuarine fringe.			
Soils: Intertidal Hydrosols			
Total area of survey area: 142.8 ha (25.5%)		**Total area of project area:** 0 ha (0%)	
Community 6 structural summary:			

Strata	Modal growth form	Mean cover %	Mean height (m)
Upper U1	Tree	42.5 (5 – 80)	9 (8 – 10)
Mid M1	Tree	60	6
Ground G1	-	-	-

APPENDIX B EPBC PROTECTED MATTERS SEARCH REPORT

Australian Government
Department of the Environment and Energy

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

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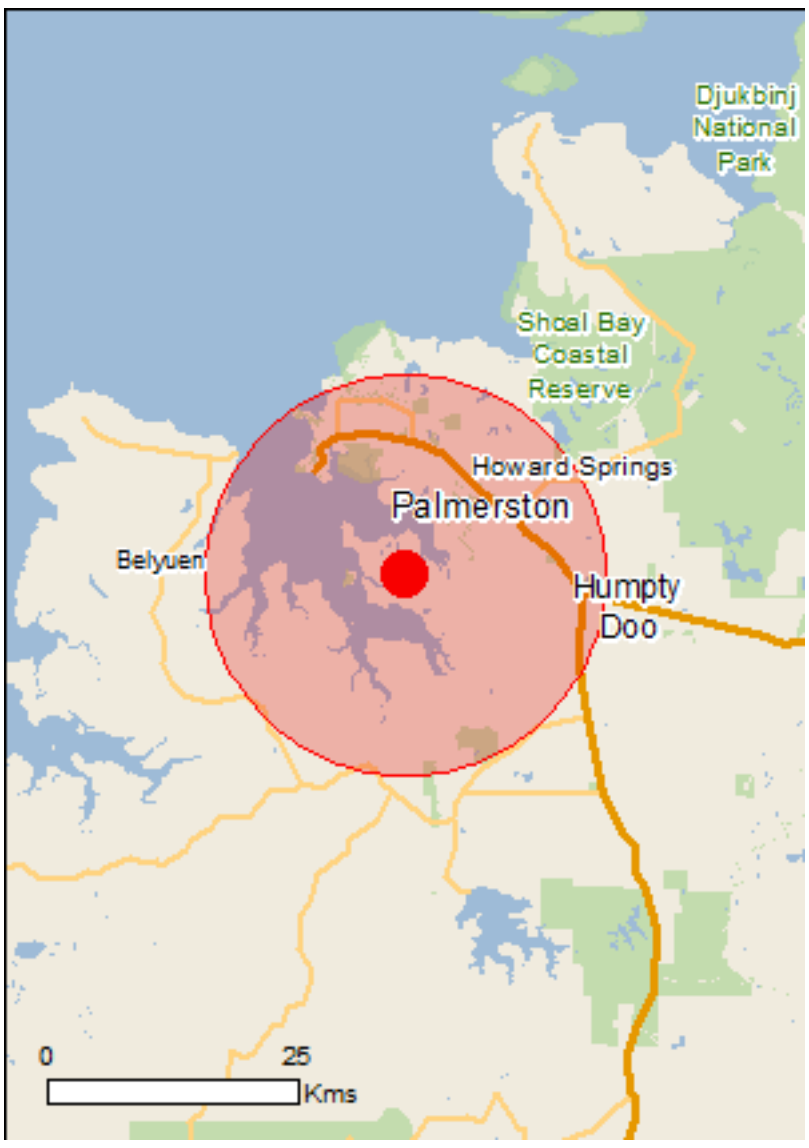

This map may contain data which are ©Commonwealth of Australia (Geoscience Australia), ©PSMA 2010

Coordinates

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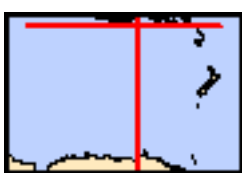

Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	41
Listed Migratory Species:	69

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	27
Commonwealth Heritage Places:	7
Listed Marine Species:	111
Whales and Other Cetaceans:	12
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Commonwealth Reserves Marine:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	11
Regional Forest Agreements:	None
Invasive Species:	31
Nationally Important Wetlands:	2
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

Listed Threatened Species		[Resource Information]
Name	Status	Type of Presence
Birds		
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Roosting known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Epthianura crocea tunneyi Alligator Rivers Yellow Chat, Yellow Chat (Alligator Rivers) [67089]	Endangered	Species or species habitat may occur within area
Erythrotriorchis radiatus Red Goshawk [942]	Vulnerable	Species or species habitat known to occur within area
Erythrura gouldiae Gouldian Finch [413]	Endangered	Species or species habitat known to occur within area
Geophaps smithii smithii Partridge Pigeon (eastern) [64441]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica baueri Bar-tailed Godwit (baueri), Western Alaskan Bar-tailed Godwit [86380]	Vulnerable	Species or species habitat may occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Bar-tailed Godwit (menzbieri) [86432]	Critically Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area

Name	Status	Type of Presence
Tyto novaehollandiae kimberli Masked Owl (northern) [26048]	Vulnerable	Species or species habitat likely to occur within area
Mammals		
Antechinus bellus Fawn Antechinus [344]	Vulnerable	Species or species habitat known to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat may occur within area
Conilurus penicillatus Brush-tailed Rabbit-rat, Brush-tailed Tree-rat, Pakooma [132]	Vulnerable	Species or species habitat may occur within area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat known to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat may occur within area
Mesembriomys gouldii gouldii Black-footed Tree-rat (Kimberley and mainland Northern Territory), Djintamoonga, Manbul [87618]	Endangered	Species or species habitat known to occur within area
Petrogale concinna canescens Nabarlek (Top End) [87606]	Endangered	Species or species habitat likely to occur within area
Phascogale pirata Northern Brush-tailed Phascogale [82954]	Vulnerable	Species or species habitat likely to occur within area
Saccolaimus saccolaimus nudicluniatus Bare-rumped Sheath-tailed Bat, Bare-rumped Sheathtail Bat [66889]	Vulnerable	Species or species habitat known to occur within area
Xeromys myoides Water Mouse, False Water Rat, Yirrkoo [66]	Vulnerable	Species or species habitat likely to occur within area
Plants		
Atalaya brevialata [86125]	Critically Endangered	Species or species habitat known to occur within area
Stylidium ensatum a triggerplant [86366]	Endangered	Species or species habitat known to occur within area
Typhonium taylori a herb [65904]	Endangered	Species or species habitat likely to occur within area
Reptiles		
Acanthophis hawkei Plains Death Adder [83821]	Vulnerable	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur

Name	Status	Type of Presence
		within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Breeding known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Sharks		
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Glyphis garricki Northern River Shark, New Guinea River Shark [82454]	Endangered	Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area

Listed Migratory Species		[Resource Information]
* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.		
Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat known to occur within area
Sternula albifrons Little Tern [82849]		Species or species habitat may occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat known to occur

Name	Threatened	Type of Presence within area
[Balaenoptera edeni](#) Bryde's Whale [35]		Species or species habitat may occur within area
[Balaenoptera musculus](#) Blue Whale [36]	Endangered	Species or species habitat may occur within area
[Carcharodon carcharias](#) White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
[Caretta caretta](#) Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
[Chelonia mydas](#) Green Turtle [1765]	Vulnerable	Breeding known to occur within area
[Crocodylus porosus](#) Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
[Dermochelys coriacea](#) Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
[Dugong dugon](#) Dugong [28]		Species or species habitat known to occur within area
[Eretmochelys imbricata](#) Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
[Lepidochelys olivacea](#) Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Breeding known to occur within area
[Manta alfredi](#) Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat may occur within area
[Manta birostris](#) Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat may occur within area
[Megaptera novaeangliae](#) Humpback Whale [38]	Vulnerable	Species or species habitat may occur within area
[Natator depressus](#) Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
[Orcaella brevirostris](#) Irrawaddy Dolphin [45]		Species or species habitat known to occur within area
[Orcinus orca](#) Killer Whale, Orca [46]		Species or species habitat may occur within area
[Pristis clavata](#) Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
[Pristis pristis](#) Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
[Pristis zijsron](#) Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area

Name	Threatened	Type of Presence
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Breeding known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Migratory Terrestrial Species		
Cecropis daurica Red-rumped Swallow [80610]		Species or species habitat known to occur within area
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat known to occur within area
Migratory Wetlands Species		
Acrocephalus orientalis Oriental Reed-Warbler [59570]		Species or species habitat may occur within area
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area
Calidris subminuta Long-toed Stint [861]		Roosting known to occur within area

Name	Threatened	Type of Presence
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius dubius Little Ringed Plover [896]		Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Roosting known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Roosting known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting known to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Roosting known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Roosting known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting known to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Tringa brevipes Grey-tailed Tattler [851]		Roosting known to occur within area
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area
Tringa incana Wandering Tattler [831]		Roosting known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area

Name	Threatened	Type of Presence
Xenus cinereus		
Terek Sandpiper [59300]		Roosting known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Land [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Name
Commonwealth Land -
Commonwealth Land - Australian Customs Service
Commonwealth Land - Australian Government Solicitor
Commonwealth Land - Department of Administrative Services
Commonwealth Land - Department of Community Services & Health
Commonwealth Land - Department of Immigration Local Government & Ethnic Affairs
Commonwealth Land - Department of Transport & Regional Development
Commonwealth Land - Deputy Crown Solicitor
Commonwealth Land - Director of Property Services Defence Estate
Defence - AUSTRALIAN ARMY BAND - DARWIN
Defence - BERRIMAH ONE
Defence - DARWIN - TRANSMITTING STATION '11 MILE'
Defence - DARWIN RELOCATIONS CENTRE
Defence - DEFENCE FORCE CAREERS REFERENCE CENTRE
Defence - Esanda Builidng
Defence - HMAS COONAWARRA (Berrimah)
Defence - KOWANDI NORTH COMMUNICATION STATION
Defence - KOWANDI SOUTH REPEATING STATION
Defence - LARRAKEYAH BARRACKS
Defence - LEANYER BOMBING RANGE
Defence - Patrol Boat Base (DARWIN NAVAL BASE)
Defence - RAAF BASE DARWIN
Defence - ROBERTSON BARRACKS (Waler Barracks)
Defence - SHOAL BAY RECEIVING STATION
Defence - STOKES HILL OIL FUEL INSTALLATION
Defence - WINNELLIE ONE
Defence - WINNELLIE TWO

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Historic		
Larrakeyah Barracks Headquarters Building	NT	Listed place
Larrakeyah Barracks Precinct	NT	Listed place
Larrakeyah Barracks Sergeants Mess	NT	Listed place
RAAF Base Commanding Officers Residence	NT	Listed place
RAAF Base Precinct	NT	Listed place
RAAF Base Tropical Housing Type 2	NT	Listed place
RAAF Base Tropical Housing Type 3	NT	Listed place

Listed Marine Species		[Resource Information]
* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.		
Name	Threatened	Type of Presence
Birds		
Acrocephalus orientalis Oriental Reed-Warbler [59570]		Species or species habitat may occur within area
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Anseranas semipalmata Magpie Goose [978]		Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat known to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area
Calidris subminuta Long-toed Stint [861]		Roosting known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Charadrius dubius Little Ringed Plover [896]		Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Roosting known to occur within area

Name	Threatened	Type of Presence
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius ruficapillus Red-capped Plover [881]		Roosting known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Roosting known to occur within area
Cuculus saturatus Oriental Cuckoo, Himalayan Cuckoo [710]		Species or species habitat known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting known to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Roosting known to occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Heteroscelus brevipes Grey-tailed Tattler [59311]		Roosting known to occur within area
Heteroscelus incanus Wandering Tattler [59547]		Roosting known to occur within area
Himantopus himantopus Black-winged Stilt [870]		Roosting known to occur within area
Hirundo daurica Red-rumped Swallow [59480]		Species or species habitat known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Roosting known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to occur within area

Name	Threatened	Type of Presence
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting known to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat known to occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat may occur within area
Sterna albifrons Little Tern [813]		Species or species habitat may occur within area
Stiltia isabella Australian Pratincole [818]		Roosting known to occur within area
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area
Fish		
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Corythoichthys haematopterus Reef-top Pipefish [66201]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Festucalex cinctus Girdled Pipefish [66214]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys cyanospilos Blue-speckled Pipefish, Blue-spotted Pipefish [66228]		Species or species habitat may occur within area
Hippichthys parvicarinatus Short-keel Pipefish, Short-keeled Pipefish [66230]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Solenostomus paegnius Rough-snout Ghost Pipefish [68425]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammals		
Dugong dugon Dugong [28]		Species or species habitat known to occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Crocodylus johnstoni Freshwater Crocodile, Johnston's Crocodile, Johnston's River Crocodile [1773]		Species or species habitat may occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Enhydrina schistosa Beaked Seasnake [1126]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis atriceps Black-headed Seasnake [1101]		Species or species habitat may occur within area
Hydrophis coggeri Slender-necked Seasnake [25925]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis inornatus Plain Seasnake [1107]		Species or species habitat may occur within area
Hydrophis mcdowelli null [25926]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area
Hydrophis pacificus Large-headed Seasnake, Pacific Seasnake [1112]		Species or species habitat may occur within area
Lapemis hardwickii Spine-bellied Seasnake [1113]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Breeding known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Parahydrophis mertoni Northern Mangrove Seasnake [1090]		Species or species habitat may occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans		[Resource Information]
Name	Status	Type of Presence
Mammals		
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat may occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within

Name	Status	Type of Presence
		area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat may occur within area
Orcaella brevirostris Irrawaddy Dolphin [45]		Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Breeding known to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area

Extra Information

State and Territory Reserves	[Resource Information]
Name	State
Blackmore River	NT
Casuarina	NT
Channel Island	NT
Charles Darwin	NT
George Brown Darwin	NT
Holmes Jungle	NT
Howard Springs	NT
Knuckey Lagoons	NT
Shoal Bay	NT
Territory Wildlife Park / Berry Springs Nature Park	NT

Invasive Species	[Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		

Name	Status	Type of Presence
Acridotheres tristis Common Myna, Indian Myna [387]		Species or species habitat likely to occur within area
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Passer domesticus House Sparrow [405]		Species or species habitat likely to occur within area
Passer montanus Eurasian Tree Sparrow [406]		Species or species habitat likely to occur within area
Sturnus vulgaris Common Starling [389]		Species or species habitat likely to occur within area
Frogs		
Rhinella marina Cane Toad [83218]		Species or species habitat likely to occur within area
Mammals		
Bos taurus Domestic Cattle [16]		Species or species habitat likely to occur within area
Bubalus bubalis Water Buffalo, Swamp Buffalo [1]		Species or species habitat likely to occur within area
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Equus caballus Horse [5]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Sus scrofa Pig [6]		Species or species habitat likely to occur within area
Plants		
Andropogon gayanus Gamba Grass [66895]		Species or species habitat likely to occur within area
Annona glabra Pond Apple, Pond-apple Tree, Alligator Apple, Bullock's Heart, Cherimoya, Monkey Apple, Bobwood, Corkwood [6311]		Species or species habitat may occur within area
Brachiaria mutica Para Grass [5879]		Species or species habitat likely to occur within area
Cabomba caroliniana Cabomba, Fanwort, Carolina Watershield, Fish		Species or species

Name	Status	Type of Presence
Grass, Washington Grass, Watershield, Carolina Fanwort, Common Cabomba [5171]		habitat likely to occur within area
Cenchrus ciliaris		
Buffel-grass, Black Buffel-grass [20213]		Species or species habitat may occur within area
Dolichandra unguis-cati		
Cat's Claw Vine, Yellow Trumpet Vine, Cat's Claw Creeper, Funnel Creeper [85119]		Species or species habitat likely to occur within area
Eichhornia crassipes		
Water Hyacinth, Water Orchid, Nile Lily [13466]		Species or species habitat likely to occur within area
Hymenachne amplexicaulis		
Hymenachne, Olive Hymenachne, Water Stargrass, West Indian Grass, West Indian Marsh Grass [31754]		Species or species habitat likely to occur within area
Jatropha gossypifolia		
Cotton-leaved Physic-Nut, Bellyache Bush, Cotton-leaf Physic Nut, Cotton-leaf Jatropha, Black Physic Nut [7507]		Species or species habitat likely to occur within area
Lantana camara		
Lantana, Common Lantana, Kamara Lantana, Large-leaf Lantana, Pink Flowered Lantana, Red Flowered Lantana, Red-Flowered Sage, White Sage, Wild Sage [10892]		Species or species habitat likely to occur within area
Mimosa pigra		
Mimosa, Giant Mimosa, Giant Sensitive Plant, ThornySensitive Plant, Black Mimosa, Catclaw Mimosa, Bashful Plant [11223]		Species or species habitat likely to occur within area
Parkinsonia aculeata		
Parkinsonia, Jerusalem Thorn, Jelly Bean Tree, Horse Bean [12301]		Species or species habitat likely to occur within area
Pennisetum polystachyon		
Mission Grass, Perennial Mission Grass, Missiongrass, Feathery Pennisetum, Feather Pennisetum, Thin Napier Grass, West Indian Pennisetum, Blue Buffel Grass [21194]		Species or species habitat likely to occur within area
Salvinia molesta		
Salvinia, Giant Salvinia, Aquarium Watermoss, Kariba Weed [13665]		Species or species habitat likely to occur within area
Reptiles		
Hemidactylus frenatus		
Asian House Gecko [1708]		Species or species habitat likely to occur within area
Lepidodactylus lugubris		
Mourning Gecko [1712]		Species or species habitat likely to occur within area
Ramphotyphlops braminus		
Flowerpot Blind Snake, Brahminy Blind Snake, Cacing Besi [1258]		Species or species habitat likely to occur within area

Nationally Important Wetlands	[Resource Information]
Name	State
Adelaide River Floodplain System	NT
Port Darwin	NT

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-12.54941 130.91664

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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APPENDIX C TERRESTRIAL PROTECTED SPECIES LIKELIHOOD OF OCCURRENCE ANALYSIS

Terrestrial protected species likelihood of occurrence assessment

To determine which terrestrial protected species have potential to occur within the Kittyhawk Estate area, analysis of regional flora and fauna records – informed by the results of the Commonwealth and NT threatened species search tools (described below) – was undertaken. For each of these species, the likelihood that the species occurs within the Stage 1 area was then assessed based on habitat requirements, distribution, and the number and dates of proximate records. The purpose of such an assessment was to identify those species that required further consideration (including, possibly, field surveys), and those that can be reasonably excluded from further assessment because they are unlikely to occur within the Kittyhawk Estate.

The following procedure was used to undertake the likelihood of occurrence assessment for each relevant protected species:

1) Identify which bioregions are intersected by the Kittyhawk Estate.
2) Correlate threatened flora and fauna records with the bioregion using the latest NT Flora and Fauna Atlas database (last updated in December 2016).
3) Use the Protected Matters Search Tool to determine species listed as threatened or migratory under the EPBC Act 1999 (undertaken March 2018). A buffer of 20 km around the Kittyhawk Estate was used. This covers the Middle Arm Peninsula and surrounding terrestrial environment.
4) Combine the results of steps 2 and 3 to generate a list of threatened or migratory species that may occur within the Kittyhawk Estate.
5) Filter the list to remove groups of species for which there is no habitat within the Kittyhawk Estate (i.e. shorebirds and migratory wetland species) or are marine species (addressed elsewhere).
6) Collate the following details for each of those species – conservation status (NT and Commonwealth), habitat requirements, distribution, and number of records within the search area (from the NT Fauna and Flora Atlas dataset).
7) Correlate the information from step 6 with the results of the vegetation mapping.
8) Analyse the likelihood that each species will occur in the Kittyhawk Estate by applying the following likelihood classifications (this assessment uses the existing environment information described in the main report to determine habitat suitability within Kittyhawk Estate):
    a. HIGH – it is expected that this species lives within the Kittyhawk Estate because of the presence of suitable habitat, and/or there are recent proximate records.
    b. MEDIUM – this species may live within the Kittyhawk Estate; however, there is evidence that lowers its likelihood of occurrence (i.e. lack of core habitat, no recent records with the search area, species is naturally-rare or occurs at a low density etc.).
    c. LOW – apart from the occasional transient, it is not expected that this species occurs within the Kittyhawk Estate, as there is no suitable habitat and/or there has been a known range contraction of the species in the region.
    d. NONE – there is strong evidence (the species is considered likely to be regionally-extinct or the species has a restricted range outside the Kittyhawk Estate) that this species will not occur within the Kittyhawk Estate.

The results of this analysis are presented in two tables; Table 1details analysis of threatened species and Table 2 details analysis of migratory terrestrial species. Marine species (threatened, migratory or marine) are assessed in Appendix D.

Table 1. Likelihood of occurrence analysis for threatened terrestrial species

Name	Status		Summary	Likelihood of occurrence
	Cth	NT		
BIRDS				
Yellow Chat (Alligator River subspecies) *Epthianura crocea tunneyi*	EN	EN	**Habitat:** Floodplain depressions and channels, concentrating around wetter areas at the end of the dry season (Armstrong 2004). **Distribution:** Top End of the NT, where restricted to a small number of sites in the floodplains from the Adelaide River to the East Alligator River (Woinarski & Armstrong 2006).	**NONE** • No suitable habitat • Outside distribution and range
	Armstrong, M. (2004). *The yellow chat Epthianura crocea tunneyi in Kakadu National Park*. Report to Parks Australia (North), NT Department of Infrastructure Planning and Environment, Darwin. Woinarski, J. and Armstrong, M. (2006). *Threatened Species of the Northern Territory - Yellow Chat (Alligator River subspecies) - Epthianura crocea tunneyi*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0019/206344/yellow-chat.PDF [Accessed 30 May 2017].			
Red Goshawk *Erythrotriorchis radiatus*	VU	VU	**Habitat:** Prefers tall, open Eucalypt forest and riparian areas. Nests in large trees, frequently the tallest and most massive in a tall stand, nest trees are invariably within 1 km of permanent water (Debus & Czechura 1988; Aumann & Baker-Gabb 1991). **Distribution:** Sparsely distributed across much of the northern Australia, from the Kimberley in WA to south-eastern Qld. Within this range, generally occurs in taller forests characteristic of higher rainfall areas, but there are some isolated records from central Australia (Woinarski 2006).	**LOW** • No suitable habitat • Outside core distribution and range • Few vagrant records for the greater Darwin region
	Aumann, T. & Baker-Gabb, D. (1991). *A Management Plan for the Red Goshawk*. RAOU Report 75, Royal Australasian Ornithologists Union, Melbourne. Debus, S. & Czechura, G. (1988). Field identification of the Red Goshawk Erythrotriorchis radiates*. Australian Bird Watcher*, Vol. 12, pp. 154-159. Woinarski, J. (2006). *Threatened Species of the Northern Territory - Red Goshawk - Erythrotriorchis radiates*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0018/206352/red-goshawk.pdf [Accessed 30 May 2017].			
Gouldian Finch *Erythrura gouldiae*	EN	VU	**Habitat:** 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. tintinnans, E. brevifolia* and *E. leucophloia*) (Tidemann 1996; O'Malley 2006). **Distribution:** Sparsely across northern Australia from the Kimberley to north-central Qld (Dostine 1998; Franklin et al. 1999; Barrett et al. 2003; Franklin et al. 2005). In the NT, most known breeding populations occur in the Top End. Non-breeding birds disperse widely (Garnett et al. 2011), greatly increasing the possible range of this species.	**LOW** • No suitable habitat • Outside core distribution and range • Few vagrant records for the greater Darwin region
	Barrett, G., Silcocks, A., Barry, S., Cunningham, R. & Poulter, R. (2003). *The New Atlas of Australian Birds*. Royal Australian Ornithologists Union, Melbourne, Victoria. Dostine, P. (1998). *Gouldian Finch Recovery Plan Erythrura gouldiae*. Gouldian Finch Recovery Team and Parks & Wildlife Commission NT, Darwin. Franklin, D.C., Burbidge, A.H. & Dostine, P.L. (1999). The harvest of wild birds for aviculture: an historical perspective on finch trapping in the Kimberley with special emphasis on the Gouldian Finch. *Australian Zoologist,* Vol. 31, pp. 92-109. Franklin, D.C., Whitehead, P.J., Pardon, G., Matthews, J., McMahon, P. & McIntyre, D. (2005). Geographic patterns and correlates of the decline of granivorous birds in northern Australia. *Wildlife Research*, Vol. 32, pp. 399-408. Garnett, S.T., Szabo, J.K. and Dutson, G. (2011). *The Action Plan for Australian Birds 2010.* CSIRO Publishing. Collingwood, Australia. O'Malley, C. (2006). *National Recovery Plan for the Gouldian Finch (Erythrura gouldiae*). WWF-Australia, Sydney and Parks and Wildlife NT, Department of Natural Resources, Environment and the Arts, NT Government, Palmerston.			

	Tidemann, S.C. (1996). Causes of the decline of the Gouldian Finch *Erythrura gouldiae*. *Biological Conservation International*, Vol. 6, pp. 49-61.			
Grey Falcon *Falco hypoleucos*	-	VU	**Habitat:** Occurs in areas of lightly-timbered lowland plains, typically on inland drainage systems, where the average annual rainfall is less than 500 mm (Ward 2012). **Distribution:** Sparsely distributed through much of the arid and semi-arid areas of Australia but is recorded in all Australian mainland states and territories. In the NT, the majority of records are from the southern half, but there are records all the way up to Darwin (Ward 2012).	**LOW** • Marginally-suitable habitat • Outside core distribution and range • Few vagrant records for the greater Darwin region
	Ward, S. (2012). *Threatened Species of the Northern Territory - Grey Falcon - Falco hypoleucos*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0020/206354/grey-falcon.pdf [Accessed 30 May 2017].			
Partridge Pigeon (eastern subspecies) *Geophaps smithii smithii*	VU	VU	**Habitat:** Occurs in open forests and woodlands with an understorey of grasses (Woinarski 2006). Prefers woodland dominated by *Eucalyptus tetrodonta* and *E. miniata* (Braithwaite 1985; Garnett et al. 2011; Higgins & Davies 1996). **Distribution:** Historically, across the Top End (from Kununurra in WA to Borroloola in the NT). Since early 20th century a severe range contraction from the western, eastern and southern parts of the former distribution (Higgins & Davies 1996; Woinarski et al. 2007). Currently, distribution is limited to sub-coastal NT from Yinberrie Hill in the south, Litchfield NP in the west and (western) Arnhem Land in the east (Garnett et al. 2011).	**LOW** • Marginally-suitable habitat • Outside current distribution and range • Nearest records 17 km to the south around the Berry Springs region
	Braithwaite, R.W. (1985). *The Kakadu fauna survey: an ecological survey of Kakadu National Park*. Australian National Parks & Wildlife Service, Canberra. Garnett, S.T., Szabo, J.K. and Dutson, G. (2011). *The Action Plan for Australian Birds 2010*. Birds Australia, CSIRO Publishing, Melbourne. Higgins, P.J. and Davies S.J.J.F. (eds) (1996). *Handbook of Australian, New Zealand and Antarctic Birds. Volume Three: Snipe to Pigeons*. Oxford University Press. Melbourne, Victoria. Woinarski, J.C.Z. (2006). *Threatened Species of the Northern Territory - Partridge Pigeon (eastern subspecies) - Geophaps smithii*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0003/206355/partridge-pigeon.pdf [Accessed 30 May 2017]. Woinarski, J., Pavey, C., Kerrigan, R., Cowie, I. and Ward, S. (Eds) (2007). *Lost from Our Landscape: Threatened Species of the Northern Territory*. Northern Territory Government, Darwin.			
Masked Owl (northern subspecies) *Tyto novaehollandiae kimberli*	VU	VU	**Habitat:** Mainly in *Eucalyptus* tall open forests (especially those dominated by *Eucalyptus miniata* and *E. tetrodonta*), but also roosts in monsoon rainforests and forages in more open vegetation types, including grasslands (Woinarski & Ward 2012). **Distribution:** Poorly known, with few records from across a broad range in northern Australia. In the NT, records from the Top End, Kakadu, Coburg Peninsula (majority of records) and south-west Gulf country (Woinarski & Ward 2012).	**LOW** • No suitable roosting habitat; small areas of foraging habitat • Nearest recent record 45 km east in the Fogg Dam area
	Woinarski, J.C.Z. and Ward, S. (2012). *Threatened Species of the Northern Territory - Masked Owl (north Australian mainland subspecies) - Tyto novaehollandiae kimberli.* Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/word_doc/0008/373553/masked-owl-mainland-top-end.docx [Accessed 30 May 2017].			
Australian Painted Snipe *Rostratula (benghalensis) australis*	EN	VU	**Habitat:** Fringes of permanent and temporary freshwater wetlands, swamps and inundated grasslands (Taylor et al. 2013). **Distribution:** Nomadic and scattered across Australia with no predictable occurrence (Rogers 2001), but could occur at any wetland or inundated grassland across its distribution, including nearly all of the NT and Qld (Garnett et al. 2011).	**NONE** • No suitable habitat • Vagrant to the region
	Garnett, S.T., Szabo, J.K. and Dutson, G. (2011). *The Action Plan for Australian Birds 2010*. CSIRO Publishing. Collingwood, Australia. Rogers, D. (2001). Painted Snipe. *Wingspan*, Vol. 11 (No. 4), pp. 6-7. Taylor, R., Chatto, R. and Woinarski, J.C.Z. (2013). *Threatened Species of the Northern Territory - Australian pained snipe - Rostratula australis*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0018/206361/australian-painted-snipe.pdf [Accessed 30 May 2017].			

MAMMALS (TERRESTRIAL)				
Fawn Antechinus *Antechinus bellus*	VU	EN	**Habitat:** Mostly in open forests and woodlands dominated by *Eucalyptus miniata* and/or *E. tetrodonta*, particularly where these forests have a relatively dense shrubby understorey (Friend 1985; Friend & Taylor 1985). Declines in areas with frequent intense fires (Corbett et al. 2003) but not necessarily common in areas where fire has been excluded for long periods (>20 years) (Woinarski et al. 2004). **Distribution:** Restricted to the Top End of the NT (Watson & Calaby 2008), with one record from Melville Island. No records during a small mammal survey undertaken across Darwin in 2014 (Stokeld and Gillespie 2015)	**MEDIUM** • Relatively recent (2001) record located within the Kittyhawk Estate • Woodland habitat present but high fire frequency limits suitability • Not recorded in most recent survey of the area
	Corbett L. K., Andersen, A.N. and Muller, W.J. (2003). Terrestrial vertebrates. In: Andersen, A.N., Cook, G.D. and Williams, R.J. (eds.). *Fire in tropical savannas: the Kapalga experiment.* Springer-Verlag, New York: pp. 126–152. 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,* Vol. 10, pp. 173–185. Friend, G.R. (1985). Ecological studies of a population of *Antechinus bellus* (Marsupalia: Dasyuridae) in tropical Australia. *Australian Wildlife Research*, Vol. 12 (No. 2), pp. 151-162. Stokeld, D. & Gillespie, G. (2015). Assessment of small mammal fauna of the Darwin area, final report February 2015. Flora and Fauna Division Land Resource Management and NERP Northern Australia Hub. Northern Territory Government. Watson, M.L. and Calaby, J.H. (2008). Fawn Antechinus: *Antechinus bellus*. In: Van Dyck, S. and Strahan, R. (eds.). *The Mammals of Australia: 3rd Edition.* Reed New Holland, Sydney. Woinarski, J.C.Z., Risler, J. and Kean, L. (2004). The response of vegetation and vertebrate fauna to 23 years of fire exclusion in a tropical Eucalyptus open forest, Northern Territory, Australia. *Austral Ecology,* Vol. 29, pp. 156–176.			
Brush-tailed Rabbit-Rat *Conilurus penicillatus*	VU	EN	**Habitat:** Largely restricted to mixed *Eucalypt* open forest and woodland, or on dunes with *Casuarina* – seeming to prefer habitats that are not burnt annually, that have an understorey of predominantly perennial grasses and a sparse-to-moderate middle storey (Firth et al. 2006; Firth 2007; Kemper & Firth 2008). **Distribution:** Formerly widespread across northern Australia, but has declined extensively from Qld and lower rainfall areas of the Kimberley in WA and the Top End in the NT. No recent records from much of the historically-recorded NT range between near the mouth of Victoria River (in the west) and Sir Edward Pellew island group (in east). Most recently known from Cobourg Peninsula, Tiwi Islands, Groote Eylandt and a small area within Kakadu National Park (Woinarski & Hill 2012).	**LOW** • Marginally-suitable habitat • No recent records from the search area
	Firth, R.S.C. (2007). *Ecology and conservation status of the brush-tailed rabbit-rat Conilurus penicillatus*. PhD thesis, Charles Darwin University, Darwin, Northern Territory. Firth, R.S.C., Woinarski, J.C.Z. and Noske, R.A. (2006). Home range and den characteristics of the brush-tailed rabbit-rat *Conilurus penicillatus* in the monsoonal tropics of the Northern Territory, Australia. *Wildlife Research*, Vol. 33, pp. 397-408. Kemper, C.M. and Firth, R.S.C. (2008). Brush-tailed Rabbit-rat. In: Van Dyck, S. and Strahan, R. (eds). *The Mammals of Australia*. Reed New Holland, Chatswood, NSW. Woinarski, J.C.Z. and Hill, B. (2012). *Threatened Species of the Northern Territory - Brush-tailed rabbit-rat, Brush-tailed tree-rat - Conilurus penicillatus*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0016/205504/brush-tailed-rabbit-rat.pdf [Accessed 30 May 2017].			
Northern Quoll *Dasyurus hallucatus*	EN	CR	**Habitat:** Wide range of habitats – especially coastal *Eucalypt* tall open forests – but since Cane Toads the most suitable habitats are rocky areas (Van Dam et al. 2002). Prime habitat in the NT consists of rocky sandstone escarpments (Braithwaite & Griffiths 1994). **Distribution:** Historically occurred from Borroloola in the south-east as far west as the NT/WA border (Woinarski et al. 2007). Dramatic range contraction associated with Cane Toad invasion. Now occurs across northern Australia in five regional populations – including the Top End in the NT.	**LOW** • No refuge habitat • Numerous records from surrounding regions of Darwin up to 2001 • Drastic decline in the region

				since arrival of Cane Toads
	Braithwaite, R.W. and Griffiths, A.D. (1994). Demographic variation and range contraction in the Northern Quoll, *Dasyurus hallucatus* (Marsupialia: Dasyuridae). *Wildlife Research,* Vol. 21, pp. 203-218. Van Dam, R.A., Walden, D.J. and Begg, G.W. (2002). *A preliminary risk assessment of cane toads in Kakadu National Park.* Supervising Scientist Report 164, Darwin, Northern Territory. Woinarski, J.C.Z., Rankmore, B.R., Fisher, A. and Milne, D. (2007). *The natural occurrence of northern quolls Dasyurus hallucatus on islands of the Northern Territory: assessment of refuges from the threat posed by cane toads Bufo marinus.* Report to Natural Heritage Trust.			
Ghost Bat *Macroderma gigas*	VU	-	**Habitat:** Ranging from the arid Pilbara (WA) to tropical savannah woodlands and north Qld rainforests (TSSC 2016). Permanent roost sites are generally deep natural caves or disused mines (TSSC 2016). **Distribution:** Geographically-disjunct colonies occur in the Pilbara and Kimberley in WA, NT north of approximately 17º latitude (including Elcho Island and Groote Eylandt), the Gulf of Carpentaria, eastern Qld from Cape York to near Rockhampton, and western Qld (including Riversleigh and Camooweal districts) (TSSC 2016). Distribution likely influenced by the availability of suitable caves and mines for roost sites (Ward & Milne 2016). Only 14 breeding sites known (Worthington Wilmer 2012). In arid Australia, including southern NT until the early 1960's (Ward & Milne 2016).	**LOW** • No proximate permanent roost sites • Outside core distribution and range
	Milne, D. and Ward, S. (2016). *Threatened Species of the Northern Territory – Ghost Bat - Macroderma gigas*. Northern Territory Department of Environment and Natural Resource. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0010/376138/ghost-bat.pdf [Accessed 30 May 2017]. Threatened Species Scientific Committee (2016). *Approved Conservation Advice for Macroderma gigas (ghost bat).* Canberra: Department of the Environment. Available at:http://www.environment.gov.au/biodiversity/threatened/species/pubs/174-conservation-advice-05052016.pdf [Accessed 30 May 2017]. Worthington Wilmer, J. (2012). Ghost Bat Macroderma gigas. In: Curtis et al. (eds.). *Queensland's Threatened Animals*. CSIRO, Canberra: pp. 382-383.			
Black-footed Tree-rat (Kimberley and mainland NT subspecies) *Mesembriomys gouldii gouldii*	EN	VU	**Habitat:** In the NT, found in tropical woodlands and open forests in coastal areas. Shelters in tree hollows and Pandanus stands during the day (Hill 2012). **Distribution:** Occurs in the Top End of the NT, the Kimberley in WA and Cape York Peninsula south to Townsville in Qld (Hill 2012). Has remained relatively abundant in the Darwin rural area (Price et al. 2005). Recorded on Middle Arm Peninsula in 2014 (Stokeld and Gillespie 2015).	**HIGH** • Suitable habitat within and near to Kittyhawk area • Recorded near to Kittyhawk area in 2014
	Hill, B. (2012). *Threatened Species of the Northern Territory- Black-footed Tree-rat - Mesembriomys gouldii*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0018/205515/black-footet-tree-rat.pdf [Accessed 30 May 2017]. Price, O., Rankmore, B., Milne, D.J., 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. Stokeld, D. & Gillespie, G. (2015). Assessment of small mammal fauna of the Darwin area, final report February 2015. Flora and Fauna Division Land Resource Management and NERP Northern Australia Hub. Northern Territory Government.			
Nabarlek (Top End subspecies) *Petrogale concinna canescens*	EN	VU	**Habitat:** Isolated and rocky areas consisting of both sandstone and granite escarpments (Churchill 1997; Telfer et al. 2008). Shelters in caves and crevices during the day (Churchill 1997) and may move from these to forage in adjacent flat areas (Sanson et al. 1985). **Distribution:** Restricted to the Top End of the NT in scattered populations from sandstone cliffs bordering the Arafura Swamp (Arnhem Land) in the east, to the Daly River catchment in the west (Ward & Woinarski 2012).	**NONE** • No suitable habitat • Nearest records 55 km south from the 1950's
	Churchill, S. (1997). Habitat use, distribution and conservation status of the Nabarlek, *Petrogale concinna*, and sympatric rock-dwelling mammals, in the Northern Territory. *Australian Mammalogy*, Vol. 19, pp. 297-308. Sanson, G.D., Nelson, J. and Fell, P. (1985). Ecology of *Peradorcas concinna* in Arnhem Land in a wet and a dry season. *Proceedings of the Ecological Society of Australia*, Vol. 13, pp. 65-72. Telfer, W.R., Griffiths, A.D. and Bowman, D.M.J.S. (2008). The habitat requirements of four sympatric rock-dwelling macropods of the Australian monsoon tropics. *Austral Ecology,* Vol. 33, pp. 1033-1044. Ward, S. and Woinarski, J. (2012). *Threatened Species of the Northern Territory - Nabarlek - Petrogale concinna*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0017/205523/nabarlek.pdf [Accessed 30 May 2017].			

Northern Brush-tailed Phascogale *Phascogale pirata*	VU	EN	**Habitat:** Most records are from tall open forests dominated by *Eucalyptus miniata* and *E. tetrodonta* (Woinarski et al. 2014). **Distribution:** Very few records exist, reported in West Island, east Arnhem Land, Coburg Peninsula, Kakadu, Litchfield and the Tiwi Islands. Only recorded once in Kakadu, Coburg Peninsula and the Tiwi Islands throughout the last 10 years (Woinarski et al. 2014).	**LOW** • Marginally-suitable habitat • Nearest records 60 km south from 1995 • Drastic decline in the region
	Woinarski, J., Burbidge, A. and Harrison, P. (2014). *The Action Plan for Australian Mammals 2012*. CSIRO Publishing: pp. 125-127.			
Pale Field-rat *Rattus tunneyi*	-	VU	**Habitat:** Historically occurred in a wide range of habitats, but now primarily in dense vegetation along creeks (Aplin et al. 2008). **Distribution:** Higher rainfall areas of northern Australia, extending from Kimberley in WA to south-eastern Qld, including the Top End of the NT (Braithwaite & Griffiths 1996). Not recorded on Middle Arm Peninsula during 2014 survey. Recorded during surveys between 2001 and 2008.	**MEDIUM** • Marginally suitable habitat - no dense vegetation along creeks. • Not recorded on Middle Arm in 2014 survey • There are nearby records from Middle Arm in similar habitat
	Aplin, K., Braithwaite, R. and Baverstock, P. (2008). Pale Field-rat: *Rattus tunneyi*. In: Van Dyck, S. and Strahan, R. (eds.). *The Mammals of Australia (3rd Edition*). Reed New Holland, Sydney, NSW. Braithwaite, R. and Griffiths, A. (1996). The paradox of *Rattus tunneyi*: endangerment of a native pest. *Wildlife Research,* Vol. 23, pp. 1-21. Stokeld, D. & Gillespie, G. (2015). Assessment of small mammal fauna of the Darwin area, final report February 2015. Flora and Fauna Division Land Resource Management and NERP Northern Australia Hub. Northern Territory Government.			
Bare-rumped Sheathtail Bat *Saccolaimus saccolaimus (nudicluniatus)*	VU	-	**Habitat:** In the NT, specimens have been collected from Pandanus woodland fringing the sedgelands of the South Alligator River and Eucalypt tall open forests (Friend & Braithwaite 1986; Churchill 1998). Predominantly found throughout the monsoonal tropics. Most records occur within near-coastal habitats with one recent exception (Jasper Gorge) 150 km inland (Woinarski et al. 2014). **Distribution:** Widely distributes from India through south-eastern Asia to the Solomon Islands including north-eastern Qld and the NT. The north-eastern Australian population is described as the subspecies *S. s. nudicluniatus*, although it is not clear whether this should be applied to the NT (Milne & Woinarski 2006).	**MEDIUM** • Suitable habitat • Nearest record 20 km east from 2006 • Likely a naturally rare species in the NT
	Churchill, S. (1998). *Australian Bats*. Reed New Holland, Sydney. Friend, G.R. and Braithwaite, R.W. (1986). Bat fauna of Kakadu National Park, Northern Territory. *Australian Mammalogy*, Vol. 9, pp. 43-52. Milne, D. and Woinarski, J. (2006). *Threatened Species of the Northern Territory - Bare-rumped Sheathtail Bat - Saccolaimus saccolaimus*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/ data/assets/pdf file/0007/376117/bare-rumped-sheathtail-bat.pdf [Accessed 30 May 2017]. Woinarski, J., Burbidge, A. and Harrison, P. (2014). *The Action Plan for Australian Mammals 2012*. CSIRO Publishing: pp. 511-514.			
False Water Rat *Xeromys myoides*	VU	-	**Habitat:** Utilises both intertidal and freshwater habitats, with most records from mangrove forests, saltmarsh, sedgelands, clay pans and freshwater melaleuca wetlands (DoE 2017). **Distribution:** In the NT, known only from coastal Top End with ten records at six sites – South Alligator River in 1903, Daly River floodplain in 1972, two sites on the Tomkinson River in 1975, Melville Island in 1975 and Glyde River floodplain in 1998 and 1999 (Woinarski 2006).	**LOW** • No core habitat within Kittyhawk Estate • No recent proximate records • Likely a naturally rare species in the NT
	Department of the Environment (2017). *Xeromys myoides - Water Mouse, False Water Rat, Yirrkoo*. Species Profile and Threats Database, Department of the Environment, Canberra. Available at: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=66 [Accessed 30 May 2017].			

	Woinarski, J.C.Z. (2006). *Threatened Species of the Northern Territory - False water-rat, Water mouse - Xeromys myoides*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0008/376136/false-water-rat.pdf [Accessed 30 May 2017].			
REPTILES (TERRESTRIAL)				
Plains Death Adder *Acanthophis hawkei*	VU	VU	**Habitat:** Floodplains and cracking soil plains (Webb et al. 2002). **Distribution**: Habitat mapping suggests the potential geographic range extends from western Qld, across the north of the NT to north-eastern WA. Fragmented populations occur in the Mitchell Grass Downs of western Qld, the Barkly Tablelands on the NT/Qld border and east of Darwin in the NT (TSSC 2012).	**NONE** • No suitable habitat • No proximate records
	Webb, J.K., Christian, K.A. & Fisher, P. (2002). Fast growth and early maturation in a viviparous sit-and-wait predator, the northern death adder (*Acanthophis praelongus*) from tropical Australia. *Journal of Herpetology*, Vol. 36, no. 3, pp. 505-509. Threatened Species Scientific Committee (2015). *Approved Conservation Advice – Acanthophis hawkei – Plains Death Adder.* Canberra: Department of the Environment. [online] Available at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/83821-conservation-advice.pdf [Accessed 30 May 2017].			
Mertens' Water Monitor *Varanus mertensi*	-	VU	**Habitat:** Semi-aquatic, occupying edges of freshwater watercourses and lagoons, but seldom seen far from water (Christian 2004). **Distribution:** Across far northern Australia from the western Cape York Peninsula in Qld to the Kimberley in WA (Christian 2004). Widespread in the NT, occupying all of the Top End river systems (Ward et al. 2006).	**LOW** • No suitable freshwater habitat within Kittyhawk Estate • Marginal habitat adjacent to Kittyhawk Estate • Closest record is 7 km south
	Christian, K. (2004). Varanus mertensi. In: Pianka et al. (eds.). *Varanoid lizards of the world*. Indiana University Press, Bloomington, Indianapolis. Ward, S., Woinarski, J., Griffiths, T. and McKay, L. (2006). *Threatened Species of the Northern Territory - Mertens Water Monitor - Varanus mertensi*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0018/206460/mertens-water-monitor.pdf [Accessed 30 May 2017].			
Mitchell's Water Monitor *Varanus mitchelli*	-	VU	**Habitat:** Semi-aquatic and arboreal, inhabiting margins of freshwater watercourses, swamps and lagoons (Ward 2012). **Distribution:** Top End of the NT and Kimberley in WA (Schultz & Doody 2004). In the NT, recorded in most catchments flowing into the Timor Sea, Arafura Sea and the Gulf of Carpentaria (Ward 2012).	**LOW** • No suitable freshwater habitat • No records from the Middle Arm Peninsula
	Doody, J.S., 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. Schultz, T. and Doody, S. (2004). Varanus mitchelli. In: Pianka et al. (eds.). *Varanoid lizards of the world*. Indiana University Press, Bloomington, Indianapolis. Ward, S. (2012). *Threatened Species of the Northern Territory - Mitchell's Water Monitor - Varanus mitchelli*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0019/206461/mitchells-water-monitor.pdf [Accessed 30 May 2017].			
Floodplain Monitor *Varanus panoptes*	-	VU	**Habitat:** Broad range of habitats from coastal beaches to savannah woodlands (Christian 2004). Also common throughout floodplains grasslands and a variety of native woodlands (Ward et al. 2012). **Distribution:** Across northern Australia from the Kimberley in WA to Cape York Peninsula, and southwards through most of Qld. In the NT, recorded across most of the Top End and the Gulf Region (Christian 2004). Experienced significant declines due to cane toad poisoning (Doody et al. 2009).	**MEDIUM** • Suitable habitat • Recent records for greater Darwin region • Drastic decline in the region since arrival of Cane Toads – persistence is generally in coastal areas
	Christian, K. (2004). Varanus panoptes. In: Pianka et al. (eds). *Varanoid lizards of the world*. Indiana University Press, Bloomington, Indianapolis.			

	Doody, J.S., 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. Ward, S., Woinarski, J., Griffiths, T. & McKay, L. (2012). *Threatened Species of the Northern Territory - Yellow Spotted Monitor, Northern Sand Goanna, Floodplain Monitor - Varanus panoptes.* Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0006/206466/floodplain-monitor.pdf [Accessed 30 May 2017].			
AMPHIBIANS				
Howard Springs Toadlet *Uperoleia daviesae*	-	VU	**Habitat**: Very little is known; however, appears to be confined to sandsheet heathland. Suitable habitat consists of short vegetation and sandy substrates which become inundated during the wet season (Ward et al. 2012). **Distribution**: Endemic to the NT. Confined to sandsheet heathlands in the Howard and Elizabeth River catchments and Scrubby Creek (Ward et al. 2012).	**NONE** • No suitable habitat • Nearest records 10 km to the east in the Weddell area from 2012
	Ward, S., Young, S. and Hill, B. (2012). *Threatened Species of the Northern Territory - Howard River Toadlet – Uperoleia daviesae.* Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0003/205527/howard-river-toadlet.PDF [Accessed 30 May 2017].			
FLORA				
a shrub *Atalaya brevialata*	CR	-	**Habitat:** Restricted to foot-slope sites with more open vegetation on deeper, coarser sandy soils, mostly along a specific, distinct geological boundary (Cowie 2014). **Distribution:** Endemic to the NT; found south of Darwin, near Elizabeth River at Virginia, and its tributary – Amy's Creek (Cowie 2014). Few targeted survey and there is uncertainty as to the taxonomic distinctness of the species. Extent of occurrence is 7.6 km^2, with a high degree of confidence as it occurs within one of the most heavily-surveyed areas in the NT (Cowie 2014).	**NONE** • No suitable habitat • Nearest records 13 km east at Amy's Creek • According to PMST, species or species habitat 'known' to occur within 100 km search area
	Cowie, I. (2014). *Threatened Species of the Northern Territory - Atalaya brevialata.* Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0008/376262/atalaya-brevialata.pdf [Accessed 11 May 2017].			
a herb *Cleome insolata*	-	VU	**Habitat:** Inundated sedge land growing on silty loam with coverage of laterite gravels in close proximity to a river catchment (Short 2010). **Distribution:** Endemic to the NT, known from a population located near Humpty Doo and three populations in Lloyd Creek in the Darwin rural area (Westaway & Cowie 2012; EcOz records). A species-specific survey has not been carried out (Westaway & Cowie 2012).	**NONE** • No suitable habitat • No proximate records
	Short, P.S. (2010). New species of *Cleome* L. (Cleomaceae) from the Northern Territory, Australia. *The Beagle*, Records of the Museum and Art Galleries of the Northern Territory, 2010, Vol. 26, pp. 1–12. [online] Available at: https://dtc.nt.gov.au/__data/assets/pdf_file/0011/254954/Short.pdf [Accessed 28 April 2017]. Westaway, J. and Cowie, I. (2012). Threatened Species of the Northern Territory - *Cleome insolata.* Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0006/208428/cleome-insolata.pdf [Accessed 28 April 2017].			
an orchid *Crepidium marsupichila*	-	VU	**Habitat:** Prefers protected shady areas and moist soils rich in leaf litter along the margins of monsoon rainforest and littoral rainforest (Kerrigan & Cowie 2006). **Distribution:** An Australian endemic with known populations from north-eastern Qld and the NT. In the NT, only known from one locality, Gunn Point (Kerrigan & Cowie 2006). Limited amount of recent survey in the area, though extensive surveys in the 1980's of rainforest areas failed to find the species (Kerrigan & Cowie 2006).	**NONE** • No suitable habitat • Outside restricted range
	Kerrigan, R. and Cowie, I. (2006). *Threatened Species of the Northern Territory - Malaxis marsupichila.* Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0007/208690/malaxis-marsupichila.pdf [Accessed 28 April 2017].			

Darwin Cycad *Cycas armstrongii*	-	VU	**Habitat:** Open grassy woodland where adequate drainage appears to be a limiting factor (Kerrigan et al. 2006). Prime habitat has deep loamy soil (Liddle 2009). **Distribution:** Restricted to the Top End of the NT – from Gunn Point to Hayes Creek, west to within 50km of the coastline and east to the Wildman River catchment (Kerrigan et al. 2006). Also on the Tiwi Islands and Cobourg Peninsula.	**HIGH** • Suitable habitat • Observed during field surveys within Kittyhawk Estate
	Kerrigan, R., Cowie, I. and Liddle, D. (2006). *Threatened Species of the Northern Territory - Cycas armstrongii*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0017/208430/cycas-armstrongii.pdf [Accessed 28 April 2017]. Liddle, D.T. (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. [online] Available at: http://www.territorystories.nt.gov.au/jspui/bitstream/10070/265358/1/Management%20program%20for%20cycads%20in%20the%20Northern%20Territory%20of%20Australia%202009%20to%202014.pdf [Accessed 28 April 2017].			
a ground orchid *Dienia montana*	-	VU	**Habitat:** Wet (spring-fed) rainforest (Kerrigan et al. 2013). **Distribution:** Northern Qld, and one population in the NT, near Munmarlary in Kakadu National Park. A targeted search in 2003 failed to record any plants at this locality (Kerrigan et al. 2013).	**NONE** • No suitable habitat • No proximate records
	Kerrigan, R., Cowie, I. and Ward S. (2013). *Threatened Species of the Northern Territory - Dienia montana*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0007/208474/dienia-montana-malaxis-latifolia.pdf [Accessed 28 April 2017].			
Native Walnut *Endiandra limnophila*	-	VU	**Habitat:** Well-developed spring-fed rainforests on swampy or very wet substrates along creek margins (Kerrigan & Cowie 2006). **Distribution:** Endemic to Australia – far north of Cape York Peninsula in Qld, and the Tiwi Islands and Channel point in the NT (Kerrigan & Cowie 2006). In the NT, recorded at approximately 22 locations with no more than 6 individuals at any one locality (Liddle et al. 1994). Extensive survey of the Tiwi Islands in 2000-02 yielded no further populations (Woinarski et al. 2003).	**NONE** • No suitable habitat • No proximate records
	Kerrigan, R. and Cowie, I. (2006). *Threatened Species of the Northern Territory - Endiandra limnophila*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0003/208434/endiandra-limnophila.pdf [Accessed 28 April 2017]. Liddle, D.T., Russell-Smith, J., Brock, J., Leach, G.J. and Connors, G.T. (1994). *Atlas of the vascular rainforest plants of the Northern Territory*. Flora of Australia Supplementary Series No. 3, Australian Biological Resources Study, Canberra. Woinarski, J., Brennan, K., Cowie, I., Kerrigan, R., and Hempel, C. (2003). *Biodiversity conservation on the Tiwi islands, Northern Territory. Part 1. Plants and environments*. Department of Infrastructure Planning and Environment, Darwin.			
Narrow-leaf Climbing Pandan *Freycinetia excelsa*	-	VU	**Habitat:** Wet lowland rainforest and spring-fed rainforests in sandstone gullies (Kerrigan & Cowie 2006). **Distribution:** Known from Papua New Guinea, coastal Qld, and in the NT from seven locations between Bathurst Island and the Arafura Swamp (Kerrigan & Cowie 2006).	**NONE** • No suitable habitat • No proximate records
	Kerrigan, R. and Cowie, I. (2006). *Threatened Species of the Northern Territory - Freycinetia excelsa*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0018/208440/freycinetia-excelsa.pdf [Accessed 28 April 2017].			
a herb *Goodenia quadrifida*	VU	-	**Habitat:** Ecology not well known, however, one population was recorded growing in grassland, whilst another grows on the upper parts of estuarine floodplains on poorly drained soils (Cowie & Kerrigan 2006). **Distribution:** Endemic to the Top End of the NT. Known from the Marrakai Crossing area on the Adelaide River and Hardies Creek (Cowie & Kerrigan 2006).	**NONE** • Possibly-suitable habitat • No proximate records • Well outside distribution
	Cowie, I. and Kerrigan, R. (2006). *Threatened Species of the Northern Territory - Goodenia quadrifida*. Northern Territory Department of Environment and Natural Resources. [online] Available at:			

	https://nt.gov.au/__data/assets/pdf_file/0006/376269/goodenia-quadrifida.pdf [Accessed 28 April 2017].			
a ground orchid *Habenaria rumphii*	-	EN	**Habitat:** In the NT, collected on sand-plains adjacent to spring-fed rainforests (Kerrigan & Cowie 2006). **Distribution:** In the NT, only known from a single locality, the Howard River sand-plain (upper Howard River catchment) (Kerrigan & Cowie 2006) despite considerable survey effort in potentially-suitable habitat.	**NONE** • No suitable habitat • No proximate records
	Kerrigan, R. and Cowie, I. (2006). *Threatened species of the Northern Territory - Habenaria rumphii*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0004/208444/habenaria-rumphii.pdf [Accessed 28 April 2017].			
a shrub *Helicteres macrothrix*	EN	EN	**Habitat:** Woodland dominated by *Eucalyptus tectifica, E. tetrodonta* and *E. miniata* on sandy loam and rocky siltstone slopes or granitic rocks (Cowie et al. 2012). Absent from the laterite country predominant in the region (DoE 2017). **Distribution:** Restricted to the Top End of the NT where only three populations known – Mt Bundey, Batchelor/Glenluckie Creek and Lake Bennett (DoE 2017). While it is possible that extensive targeted searches may uncover additional subpopulations, there is a high degree of confidence in the broader distributional data (Cowie et al. 2012).	**NONE** • No suitable habitat • No proximate records
	Cowie, I., Kerrigan, R. and Stuckey, B. (2012). *Threatened species of the Northern Territory - Helicteres Sp. Glenluckie Creek*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0005/208445/helicteres-macrothrix.pdf [Accessed 28 April 2017]. Department of the Environment (2017). *Helicteres macrothrix*. Species Profile and Threats Database, Department of the Environment, Australian Government, Canberra. [online] Available at: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=86586 [Accessed 28 April 2017).			
Luisia Orchid *Luisia corrugata*	-	VU	**Habitat:** An epiphyte that commonly grows on trees with scaly bark and prefers the areas of bright light (non-shaded area). Within the NT, collected from the margins of monsoon rainforests (Kerrigan & Cowie 2012). **Distribution:** Appears to be endemic to the NT with known populations from Melville Island and the mainland (Bankers Jungle and Crocodile Creek in Black Jungle Conservation Reserve) (Kerrigan & Cowie 2012). It is likely that that the existing collections accurately reflect the abundance and distribution of this species (Kerrigan & Cowie 2012).	**NONE** • No suitable habitat • No proximate records • Known population extent – outside Kittyhawk Estate
	Kerrigan, R. and Cowie, I. (2012). *Threatened Species of the Northern Territory - Luisia corrugata.* Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0005/208472/luisia-corrugata.pdf [Accessed 28 April 2017].			
Arrowleaf Monochoria *Monochoria hastata*	-	VU	**Habitat:** Grows in floating mat vegetation in permanent to near-permanent back-swamps, drainage channels and billabongs (Kerrigan & Cowie 2006). **Distribution:** New Guinea, India, Sri Lanka, South-East Asia. In Australia, only found in the NT on the floodplains of the Finniss, Reynolds and Wildman Rivers (Kerrigan & Cowie 2006). There is a negative collection bias associated with the swampy habitat in which this species occurs. However, extensive coverage of floodplains in the Kakadu region detected this species at only one location in that region (Wildman River). Furthermore, it is considered that the extensive surveys of the Top End floodplain communities (Wilson et al. 1991) during the 1990s would have detected this species more often had it been more common or widespread (Kerrigan & Cowie 2006).	**NONE** • No suitable habitat • No proximate records • Known population extent – outside Kittyhawk Estate
	Kerrigan, R. and Cowie, I. (2006). *Threatened Species of the Northern Territory - Monochoria hastate*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0003/208479/monochoria-hastata.pdf [Accessed 1 May 2017]. Wilson, B.A., Brocklehurst, P.S. and Whitehead, P.J. (1991). *Classification, distribution and environmental relationships of coastal floodplain vegetation, Northern Territory, Australia*. Technical Report 91/2. Conservation Commission of the Northern Territory, Darwin.			

Darwin Palm *Ptychosperma macarthurii*	-	EN	**Habitat:** Dense rainforests fed from lowland springs at the edges of tropical riverine floodplains. Common in deep organic loamy clay substrates without humus development (Liddle et al. 2006). **Distribution:** Known from the NT, Cape York Peninsula and Papua New Guinea. Within the NT, known from eight locations on the western margin of the Adelaide River Floodplain (Liddle et al. 2006). Survey effort is not documented.	**NONE** • DENR mapping identifies there is no potentially-suitable habitat within Kittyhawk Estate • No proximate records • Not observed during vegetation mapping
	Liddle, D.T., Brook, B., Matthews, J., Taylor, S.M. and Caley, P. (2006). Threat and response: A decade of decline in a regionally endangered rainforest palm affected by fire and introduced animals. *Biological Conservation*, Vol. 132, pp. 362-375.			
Trigger plant *Stylidium ensatum*	EN	EN	**Habitat:** Margins of drainage areas in damp heavy clay or peaty soil (Cowie & Westaway 2012). **Distribution**: Known from three localities in Darwin – Shoal Bay, Girraween Rd, Hayes Creek. Other historical collections recorded; however, the exact locality for these collections is unknown. Not collected since 1974 (Cowie & Westaway 2012). No additional subpopulations have been located despite several flora and biodiversity surveys in the Darwin region over the last ten years (but no systematic survey of potentially suitable habitat at an appropriate time of year). Substantial areas of potentially-suitable habitat south from Darwin towards Hayes Creek that are relatively poorly surveyed and it is likely that additional subpopulations exist (Cowie & Westaway 2012).	**NONE** • No suitable habitat • No proximate records • Herbarium surveys within Kittyhawk Estate did not detect species
	Cowie, I. and Westaway, J. (2012). *Threatened species of the Northern Territory - Stylidium ensatum*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0009/208494/stylidium-ensatum.pdf [Accessed 2 May 2017].			
a herb *Typhonium praetermissum*	-	VU	**Habitat***:* Open woodland including relatively unshaded areas in red brown clay and shallow or gravelly lateritic soil (Cowie & Westaway 2012). **Distribution:** Endemic to the NT. Previous recorded at six locations in the Darwin/Litchfield area – Virginia, Karama, the Palmerston escarpment, Mandorah and Humpty Doo (Cowie & Westaway 2012). Two new sub-populations recorded in Lloyd Creek (EcOz records). Low number of fertile collections thought to be due to the species seasonality rather than its abundance. Targeted survey of potential habitat in the Darwin region is a priority for this species (Cowie & Westaway 2012).	**LOW** • DENR mapping identifies small area of potentially-suitable habitat but mapping also confirmed absence during DENR surveys • No proximate records
	Cowie, I. and Westaway, J. (2012). *Threatened species of the Northern Territory - Typhonium praetermissum.* Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0017/208502/typhonium-praetermissum.pdf [Accessed 2 May 2017].			
a herb *Typhonium taylori*	EN	EN	**Habitat:** Seasonally-saturated sandy substrate in nutrient-deficient grass/sedge land (Kerrigan & Cowie 2006). **Distribution:** Endemic to the NT, with the only known population from the edge of the Howard River floodplain (Kerrigan & Cowie 2006). Targeted survey for this species in the Howard River Floodplain as part of a biodiversity assessment survey (Cowie 2002) did not relocate or uncover any additional populations of this species. Considered adequately surveyed, based on the strong survey effort in the area and the high profile of this genus amongst collectors. While more populations may exist, the paucity of collections of this species is considered to accurately reflect its very restricted distribution and abundance (Kerrigan & Cowie 2006).	**NONE** • No suitable habitat • No proximate records
	Cowie, I. D. (2002). *Preliminary report on a survey of Utricularia (Lentibulariaceae) in the Howard River – Shoal Bay area*. NT Department of Infrastructure Planning and Environment, Darwin. Kerrigan, R. and Cowie, I. (2006). *Threatened species of the Northern Territory - Typhonium taylori.* Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0019/208504/typhonium-taylori.pdf [Accessed 2 May 2017].			

a bladderwort *Utricularia dunstaniae*	-	VU	**Habitat***:* Wet sand, often in shallow water, in paperbark (*Melaleuca nervosa*) woodland or Feather-flower (*Verticordia*) shrub land. Occurs in slightly wetter micro-habitats than other sympatric *Utricularia* species, frequently where water is percolating from the ground (Kerrigan & Cowie 2012). **Distribution:** Endemic to Australia, known from WA and the NT – where known from nine locations. Locations near Darwin are Noonamah, Howard Springs and the Howard River floodplain. Other sub-populations on the Cobourg Peninsula, near Murgenella and near Finniss River (Kerrigan & Cowie 2012). As apparently suitable habitat within the extent of occurrence remains unsurveyed, it is likely that additional, undiscovered subpopulations exist (Kerrigan & Cowie 2012).	**NONE** • No suitable habitat • No proximate records
	Kerrigan, R. and Cowie, I. (2012). *Threatened Species of the Northern Territory - Utricularia dunstaniae*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0020/208505/utricularia-dunstaniae.pdf [Accessed 2 May 2017].			
a bladderwort *Utricularia singeriana*	-	VU	**Habitat:** Margins of wet sandy flats and swamps with short grasses and sedges (Kerrigan & Cowie 2012). **Distribution**: Endemic to the NT with known populations from five locations between Darwin and Katherine – the nearest Darwin being Finn Rd in Weddell. Other sites are the Edith River area, near the Finniss River, and the Marrawal Plateau east of Pine Creek. Port Darwin population (early 1900's record) no longer in existence (Kerrigan & Cowie 2012). As much apparently suitable habitat within the extent of occurrence remains unsurveyed, it is likely that additional undiscovered sub-populations exist (Kerrigan & Cowie 2012).	**NONE** • No suitable habitat • No proximate records
	Kerrigan, R. and Cowie, I. (2012). *Threatened Species of the Northern Territory - Utricularia singeriana.* Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0003/208506/utricularia-singeriana.pdf [Accessed 2 May 2017].			
a ground orchid *Zeuxine oblonga*	-	VU	**Habitat:** Grows in clusters in dark and moist situations on the rainforests floor or in wet peaty areas near streams (Jones 1988). **Distribution:** Qld, NSW and in the NT, where known from five widely-spaced locations south and south-west of Darwin, from Keep River near the WA border to south-west of Adelaide River (Liddle et al. 1994). Not collected since 1992, despite efforts to relocate the Keep River population in 2000 and 2001 (Kerrigan & Cowie 2006). There is a negative collection bias associated with this species due to its ephemeral nature.	**NONE** • No suitable habitat • No proximate records
	Jones, D.L. (1988). *Native Orchids of Australia*. Reed, Sydney. Kerrigan, R. and Cowie, I. (2006). *Threatened Species of the Northern Territory – Zeuxine oblonga*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0008/208691/zeuxine-oblonga.pdf [Accessed 2 May 2017]. Liddle, D.T., Russell-Smith, J., Brock, J., Leach, G.J. and Connors, G.T. (1994). Atlas of the vascular rainforest plants of the Northern Territory. *Flora of Australia Supplementary Series No. 3*, Australian Biological Resources Study, Canberra.			

Table 2. Likelihood of occurrence analysis for migratory terrestrial species

Name	Summary	Likelihood of occurrence
BIRDS		
Red-rumped Swallow *Cecropis daurica*	**Habitat:** Predominately forages over wetlands or open areas such as golf courses. Perches on bare branches or wires (DoE 2017). **Distribution:** Vagrant to Australia; may be found between December and February in around the Top End (DoE 201).	**LOW** • Habitat of low suitability • Records from Darwin Region • Vagrant.
	Department of Environment (DoE) 2017, *Cecropis daurica* in Species Profile and Threats Database, Department of the Environment, Canberra, viewed September 2017, http://www.environment.gov.au/.	
Oriental Cuckoo *Cuculus optatus*	**Habitat:** Uses a range of vegetated habitats such as monsoon rainforest, wet sclerophyll forest, open woodlands and appears quite often along edges of forests, or ecotones between forest types (DoE 2017). **Distribution:** Widespread in Top End from Darwin, north to Melville and South Goulburn Islands, east to Gove Peninsula, Groote Eylandt and Sir Edward Pellew Group and south to Roper River (DoE 2017).	**MEDIUM** • Records from Darwin Region and Middle Arm • Suitable habitat present
	Department of Environment (DoE) 2017, *Cuculus optatus* in Species Profile and Threats Database, Department of the Environment, Canberra, viewed September 2017, http://www.environment.gov.au/.	
Barn Swallow *Hirundo rustica*	**Habitat:** Found above open vegetated areas including farmland, sports grounds, native grasslands and airstrips as well as over open water such as billabongs, lagoons, creeks and sewage treatment plants. Perch on bare branches or wires, and gather in flocks to during the day, and roost at night perched in vegetation, usually tall wetland grasses (DoE 2017). **Distribution:** Found between December and February in around the Top End including Darwin (DoE 2017).	**LOW** • Habitat of low suitability • Records from Darwin Region
	Department of Environment (DoE) 2017, *Hirundo rustica* in Species Profile and Threats Database, Department of the Environment, Canberra, viewed September 2017, http://www.environment.gov.au/.	
Grey Wagtail *Motacilla cinerea*	**Habitat:** Has a strong association with water with all confirmed Australian records being associated with water; especially creeks, rivers and waterfalls (DoE 2017). **Distribution:** Scarce but regular visitor to northern Australia, including the Top End of the Northern Territory around the greater Darwin region (DoE 2017).	**LOW** • Habitat of low suitability • Few vagrant records for the greater Darwin region
	Department of Environment (DoE) 2017, *Motacilla cinerea* in Species Profile and Threats Database, Department of the Environment, Canberra, viewed September 2017, http://www.environment.gov.au/.	
Yellow Wagtail *Motacilla flava*	**Habitat:** Typically inhabit open grassy flats near water, including open areas with low vegetation such as grasslands, airstrips, pastures, sports fields; damp open areas such as muddy or grassy edges of wetlands, rivers, irrigated farmland, dams, waterholes; sewage farms, sometimes utilise tidal mudflats and edges of mangroves (DEE, 2015). **Distribution:** Regular summer visitor to Northern Australia including the greater Darwin area (DEE, 2015).	**LOW** • Marginally-suitable habitat • Vagrant to Australia
	Department of Environment (DoE) 2017, *Motacilla flava* in Species Profile and Threats Database, Department of the Environment, Canberra, viewed September 2017, http://www.environment.gov.au/.	
Rufous Fantail *Rhipidura rufifrons*	**Habitat:** In north and north-east Australia, they often occur in tropical rainforest and monsoon rainforests, including semi-evergreen mesophyll vine forests, semi-deciduous vine thickets or thickets of Paperbarks (*Melaleuca* spp.) (DOE 2018). **Distribution:** Occurs in coastal and near coastal districts of northern and eastern Australia (DOE 2018)	**LOW** • Potentially suitable habitat • No proximate records
	Department of Environment (DoE) 2018, *Rhipidura rufifrons* in Species Profile and Threats Database, Department of the Environment, Canberra, viewed September 2017, http://www.environment.gov.au/.	

APPENDIX D MARINE PROTECTED SPECIES LIKELIHOOD OF OCCURRENCE ANALYSIS

Marine protected species likelihood of occurrence assessment

For the purposes of this assessment marine protected species means those that are listed as threatened, migratory marine birds or migratory marine species under the *Environment Protection and Biodiversity Conservation (EPBC Act) 1999*. As the project is not located in or near Commonwealth waters, species listed as marine have not been considered.

To determine which marine protected species have potential to occur within the marine waters proximate to the Stage 1 area, analysis of species returned through a protected matters search was undertaken. For each of these species, the likelihood that the species occurs within the marine waters proximate to the Stage 1 area was assessed based on habitat requirements, distribution, and the number and dates of proximate records. The purpose of such an assessment was to identify those species that required further consideration (including, possibly, field surveys), and those that can be reasonably excluded from further assessment because they are unlikely to occur within the marine waters proximate to the Stage 1 area.

The following procedure was used to undertake the likelihood of occurrence assessment for each relevant protected species:

1) Use the Protected Matters Search Tool to generate a list of species listed as threatened or migratory under the EPBC Act 1999 (undertaken March 2018) that may occur near the Stage 1 area. A buffer of 20 km around the stage 1 area was used. This covers the Middle Arm Peninsula and surrounding marine environment.
2) Collate the following details for each of those species – conservation status (NT and Commonwealth), habitat requirements and distribution.
3) Correlate the information from step 2 with the results of the benthic habitats assessment.
4) Determine the nearest records using the NT flora and fauna atlas and/or Atlas of Living Australia.
5) Analyse the likelihood that each species will occur in the marine waters proximate to the Stage 1 area by applying the following likelihood classifications (this assessment uses the existing environment information described in the main report to determine habitat suitability within marine waters proximate to the Stage 1 area):
    a. HIGH – it is expected that this species lives within the marine waters proximate to the Stage 1 area because of the presence of suitable habitat, and/or there are recent proximate records.
    b. MEDIUM – this species may live within the marine waters proximate to the Stage 1 area; however, there is evidence that lowers its likelihood of occurrence (i.e. lack of core habitat, no recent records with the search area, species is naturally-rare or occurs at a low density etc.).
    c. LOW – apart from the occasional transient, it is not expected that this species occurs within the marine waters proximate to the Stage 1 area, as there is no suitable habitat and/or there has been a known range contraction of the species in the region.
    d. NONE – there is strong evidence (the species is considered likely to be regionally-extinct or the species has a restricted range outside the marine waters proximate to the Stage 1 area) that this species will not occur within the marine waters proximate to the Stage 1 area.

Name	Status		Summary	Likelihood of occurrence
	Cth	NT		
THREATENED MARINE MAMMALS				
Blue Whale *Balaenoptera musculus*	EN	-	**Habitat:** Polar to tropical regions in coastal, continental shelf and oceanic waters (DoE 2017). **Distribution:** Global. Annual migration from Antarctic feeding areas, through Australian waters, to tropical breeding areas (DoE 2017). Most Australian waters have no particular significance to the whales and are used only for migration and opportunistic feeding (DoE 2017). The only known areas of significance in Australia are feeding areas around the southern continental shelf near southern WA, SA and Victoria (DEH 2005). In the NT, known only from two beach-washed specimens at Cape Hotham near Darwin in 1980 and Port Essington on Cobourg Peninsula in 2003 (Woinarski & Chatto 2006).	**NONE** • Darwin Harbour represents marginal habitat; generally oceanic • Few NT records; none from Darwin Harbour
	Department of the Environment (2017). *Balaenoptera musculus – Blue Whale*. Species Profile and Threats Database, Department of the Environment, Canberra. Available at: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=36 [Accessed 21 April 2017]. Woinarski, J.C.Z. and Chatto, R. (2006). *Threatened Species of the Northern Territory - Blue Whale - Balaenoptera musculus.* Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0008/376127/blue-whale.pdf [Accessed 21 April 2017].			
Humpback Whale *Megaptera novaeangliae*	VU	-	**Habitat:** All major oceans, mostly in coastal and continental shelf waters (Reeves et al. 2002). **Distribution:** Global. Annual migration from Antarctic feeding areas, through Australian waters to tropical breeding areas off the Kimberley coast in WA, and central Qld coast (DoE 2017). In the NT, only known from one beach-washed specimen on the Napier Peninsula (east Arnhem Land) in 1881 and a pair sighted west of Darwin in 2002 (Woinarski et al. 2012).	**NONE** • Darwin Harbour represents marginal habitat; generally oceanic • Few NT records
	Department of Environment (2017) *Megaptera novaeangliae - Humpback Whale*. Species Profile and Threats Database, Commonwealth Department of the Environment, Canberra. Available at: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=38 [Accessed 21 April 2017]. Reeves, R.R., Stewart, B.S., Clapham, P.J. and Powell, J.A. (2002). *Sea mammals of the world.* A & C Black, London. Woinarski, J.C.Z., Chatto, R. and Ward, S. (2012). *Threatened Species of the Northern Territory - Humpback Whale - Megaptera novaeangliae.* Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0006/376152/humpback-whale.pdf [Accessed 21 April 2017].			
THREATENED MARINE REPTILES				
Loggerhead Turtle *Caretta caretta*	EN	VU	**Habitat:** Pelagic in tropical, sub-tropical and temperate waters. Nests mainly on sub-tropical sandy beaches (Marquez 1990). **Distribution:** Global, including the Australian coast (DoE 2017) where nesting is concentrated in southern Qld and from Shark Bay to the North West Cape in WA (DoE 2017). No breeding known to occur in the NT, but records in NT waters (Taylor et al. 2006).	**LOW** • Darwin Harbour provides marginal foraging habitat, and limited nesting habitat • Middle Arm does not provide nesting habitat • Nearest record 175 km north-east from Cobourg Peninsula
	Department of Environment (2017). *Caretta caretta - Loggerhead Turtle*. Species Profile and Threats Database, Department of the Environment, Australian Government, Canberra. [online] Available at: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=1763 [Accessed 30 May 2017]. Marquez, R. (1990). FAO Species Catalogue: Sea Turtles of the World. An annotated and illustrated catalogue of the sea turtle species known to date. Rome: Food and Agriculture Organisation of United Nations. *FAO Fisheries Synopsis*, Vol. 125 (No. 11), pp. 81.			

	Taylor, R., Chatto, R. and Woinarski, J. (2006). *Threatened Species of the Northern Territory - Loggerhead Turtle - Caretta caretta*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0019/206452/loggerhead-turtle-vu.pdf [Accessed 30 May 2017].			
Green Turtle *Chelonia mydas*	VU	-	**Habitat:** Pelagic in tropical and subtropical waters, although individuals may also stray into temperate waters (Cogger et al. 1993). In the NT, nesting mainly on wide beaches backed by large dune systems (Chatto 1998). **Distribution:** Global. Nests, forages and migrates across tropical northern Australia, with main breeding sites being the Great Barrier Reef of Qld, the north-west shelf of WA, Wellesley Island group in the southern Gulf of Carpentaria and the Top End coast (DoE 2017). Many nesting sites in the NT, mostly from the western end of Melville Island to near NT/Qld border (Chatto 1998).	**MEDIUM** • Darwin Harbour provides foraging habitat, but limited nesting habitat • Middle Arm does not provide nesting habitat • One record for Darwin Harbour, remainder are more than 30 km away
	Chatto, R. (1998). A preliminary overview of the locations of marine turtle nesting in the Northern Territory. In: Kennett et al. 9eds.). *Marine turtle conservation and management in northern Australia*. Northern Territory University, Darwin: pp. 33-40. Cogger, H.G., Cameron, E.E., Sadlier, R.A. and Eggler, P. (1993). *The Action Plan for Australian Reptiles*. Australian Nature Conservation Agency. Canberra, ACT. Department of Environment (2017). *Chelonia mydas - Green Turtle*. Species Profile and Threats Database, Commonwealth Department Environment, Canberra. [online] Available at: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=1765 [Accessed 30 May 2017].			
Leatherback Turtle *Dermochelys coriacea*	EN	CR	**Habitat:** Pelagic in tropical, subtropical and temperate waters (DoE 2017). **Distribution:** Global, including the northern and eastern seaboards of Australia (DoE 2017). No major nesting recorded in Australia. In the NT, only a few records in the waters off northern Arnhem Land and the Gulf of Carpentaria (Taylor et al. 2013).	**LOW** • Darwin Harbour provides marginal foraging habitat, and limited nesting habitat • Middle Arm does not provide nesting habitat • Nearest record 175 km north-east from Cobourg Peninsula
	Department of Environment (2017). *Dermochelys coriacea - Leatherback Turtle, Leathery Turtle, Luth*. Species Profile and Threats Database, Commonwealth Department of the Environment, Canberra. [online] Available at: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=1768 [Accessed 30 May 2017]. Taylor, R., Chatto, R., Whiting, S. and Ward, S. (2013). *Threatened Species of the Northern Territory - Leatherback Turtle - Dermochelys coriacea*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0010/206398/leatherback-turtle.pdf [Accessed 30 May 2017].			
Hawksbill Turtle *Eretmochelys imbricata*	VU	VU	**Habitat:** Tropical, sub-tropical and temperate waters (DoE 2017). In the NT, most nesting occurs on islands rather than mainland beaches (Taylor et al. 2012). **Distribution:** Global. In the NT, principal nesting sites are concentrated around north-eastern Arnhem Land and Groote Eylandt (Chatto 1998).	**MEDIUM** • Darwin Harbour provides foraging habitat, but limited nesting habitat • Middle Arm does not provide nesting habitat • Nearest record from Fannie Bay Beach, remainder of records more than 40 km away
	Chatto, R. (1998). A preliminary overview of the locations of marine turtle nesting in the Northern Territory. In: Kennett et al. (eds.). *Marine turtle conservation and management in northern Australia*. Northern Territory University, Darwin: pp. 33-40 Department of the Environment (2017). *Eretmochelys imbricate – Hawksbill Turtle.* Species Profile and Threats Database, Department of the Environment, Canberra. [online] Available at: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=1766 [Accessed 30 May 2017]. Taylor, R., Chatto, R., Woinarski, J., Whiting, S. and Ward, S. (2012). *Threatened Species of the Northern Territory – Hawksbill Turtle - Eretmochelys imbricata*. Northern Territory Department of			

	Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0003/206454/hawksbill-turtle.pdf [Accessed 30 May 2017].			
Olive Ridley Turtle *Lepidochelys olivacea*	EN	VU	**Habitat:** Tropical and subtropical waters, preferring shallow protected waters (DoE 2017). In the NT, breeds at a wide range of sites on island and, less commonly, mainland beaches (Chatto 1998). **Distribution:** Global. In the NT, second most widespread nesting species (after Flatbacks) (Chatto & Baker 2008). Vast majority of the nesting population recorded from Melville Island to Groote Eylandt (Chatto 1998).	**MEDIUM** • Darwin Harbour provides foraging habitat, but limited nesting habitat • Middle Arm does not provide nesting habitat • No records from within Darwin Harbour
	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. Chatto, R. (1998). A preliminary overview of the locations of marine turtle nesting in the Northern Territory. In Kennett et al. (eds.). *Marine turtle conservation and management in northern Australia*. Northern Territory University, Darwin: pp. 33-40. Department of the Environment (2017). *Lepidochelys olivacea - Olive Ridley Turtle, Pacific Ridley Turtle*. Species Profile and Threats Database. Department of the Environment, Canberra. [online] Available at: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=1767 [Accessed 30 May 2017].			
Flatback Turtle *Natator depressus*	VU	-	**Habitat:** Prefers shallow, soft-bottomed seabed habitats away from reefs (DoE 2017). In the NT, nests on a wide variety of beach types around the entire coastline (Chatto & Baker 2008) **Distribution:** Northern Australia and New Guinea, with all known breeding sites occurring only in Australia (DoE 2017). In the NT, the most widely spread marine turtle species, nesting around the entire coastline (Chatto & Baker 2008).	**MEDIUM** • Darwin Harbour provides foraging habitat, but limited nesting habitat • Records within Darwin Harbour near Middle Arm
	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. [online] Available at:https://dtc.nt.gov.au/__data/assets/pdf_file/0006/279915/marine_turtle_nesting.pdf [Accessed 30 May 2017]. Department of the Environment (2017). *Natator depressus - Flatback Turtle. Species Profile and Threats Database*. Commonwealth Department of the Environment, Canberra. [online] Available at: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=59257 [Accessed 30 May 2017]. Taylor, R., Chatto, R. and Woinarski, J. (2006). *Threatened Species of the Northern Territory - Flatback Turtle - Natator depressus*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0008/376172/flatback-turtle.pdf [Accessed 30 May 2017].			
THREATENED FISH				
Great White Shark *Carcharodon carcharias*	VU	-	**Habitat:** Marine, anywhere between close inshore habitats (such as shallow coastal bays or reefs) and the outer continental shelf and slope areas (DoE 2017). **Distribution:** Globally in all seas in both hemispheres. In Australia, from central Qld on the south coast to north-west WA (DoE 2017). There have been no verified sightings in the NT (DoE 2017).	**LOW** • Darwin Harbour represents marginal habitat • Few NT records
	Department of the Environment (2017). *Carcharodon carcharias – White Shark, Great White Shark*. Species Profile and Threats Database, Department of the Environment, Canberra. [online] Available at: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=64470 [Accessed 21 April 2017].			
Northern River Shark *Glyphis garricki*	EN	EN	**Habitat:** Little is known of the ecology, probably restricted to shallow, brackish reaches of large rivers (Ward & Larson 2012). **Distribution:** In Australia, there are few records, including in the NT from the Adelaide, East and South Alligator River systems. Also known from the Kimberley coast and King Sound in WA (Thorburn & Morgan 2004; Compagno et al. 2008).	**LOW** • River systems unlikely to be large enough to provide suitable habitat • No records from within

				catchment
	Compagno, L.J.V., White, W.T. and Last, P.R. (2008). Glyphis garricki sp. nov., a new species of river shark (Carcharhiniformes: Carcharhinidae) from northern Australia and Papua New Guinea, with a redescription of Glyphis glyphis (Müller & Henle, 1839). In: Last et al. (eds.). *Descriptions of New Australian Chondrichthyans*. CSIRO Marine and Atmospheric Research Paper, 022: pp. 203-226. Thorburn, D.C. and Morgan, D.L. (2004). The northern river shark, Glyphis sp. C (Carcharhinae) discovered in Western Australia. *Zootaxa,* Vol. 685, pp. 1-8. Ward, S. and Larson, H. (2012). *Threatened Species of the Northern Territory – Northern River Shark - Glyphis garricki*. Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0005/206384/northernr-river-shark.pdf [Accessed 21 April 2017].			
Dwarf Sawfish *Pristis clavata*	VU	VU	**Habitat:** Tropical 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). **Distribution:** Indonesia, South-East Asia and northern Australia (Cavanagh et al. 2003). In the NT, known to occur around Darwin (including Buffalo Creek and Rapid Creek), in Kakadu National Park (Alligator River), Keep River and Victoria River (Thorburn et al. 2003).	**MEDIUM** • Suitable habitat • Known from nearby estuarine systems • Likely a naturally-rare species
	Cavanagh, R., Kyne, P., Fowler, S., Musick, J. and Bennett, M. (eds.) (2003). *The Conservation Status of Australian Chondrichthyans*. Report of the IUCN Shark Specialist Group Australia and Oceania Red List Workshop. The University of Queensland, School of Biomedical Sciences, Brisbane, Australia. Peverell, S.C. (2005). Distribution of sawfishes (Pristidae) in the Queensland Gulf of Carpentaria, Australia, with notes on their ecology. *Environmental Biology of Fishes,* Vol. 73, pp. 391-402. Thorburn, D.C., Peverell, S., Stevens, S., Last, J.D. and Rowland, A.J. (2003). *Status of freshwater and estuarine elasmobranchs in Northern Australia*. Report to Natural Heritage Trust, Canberra.			
Freshwater or Largetooth Sawfish *Pristis pristis*	VU	VU	**Habitat:** Tropical 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). **Distribution:** Circumtropical, with distinct populations in the eastern Atlantic, western Atlantic, eastern Pacific and Indo-West Pacific – including northern Australia (TSSC 2014). In the NT, reported in Adelaide, Victoria, Daly, East and South Alligator, Goomadeer, Roper, McArthur, Wearyan and Robinson Rivers (TSSC 2014).	**MEDIUM** • Suitable habitat • No records from catchment • Likely a naturally-rare species
	Peverell, S.C. (2005). Distribution of sawfishes (Pristidae) in the Queensland Gulf of Carpentaria, Australia, with notes on their ecology. *Environmental Biology of Fishes,* Vol. 73, pp. 391-402. Threatened Species Scientific Committee (2014). *Approved Conservation Advice - Pristis pristis (largetooth sawfish).* Canberra: Department of the Environment. In effect under the EPBC Act from 11-April-2014. [online] Available at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/60756-conservation-advice.pdf [Accessed 26 April 2017].			
Green Sawfish *Pristis zijsron*	VU	VU	**Habitat:** Tropical waters including marine inshore waters, estuaries, lagoons and freshwater. However, the majority of records are from marine or estuarine waters (Thorburn 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). **Distribution:** Northern Australia, South-East Asia and the Indian Ocean (Cavenagh et al. 2003). Most frequently encountered of the sawfish species in Australian waters (Last & Stevens 1994). Most commonly known from the Gulf of Carpentaria (Stevens et al. 2005). In the NT specimens have only been collected from Buffalo Creek in Darwin (Stirrat et al. 2006).	**MEDIUM** • Suitable habitat • No records from catchment but, records from nearby estuarine systems (Buffalo Creek) • Likely a naturally-rare species
	Cavanagh, R., Kyne, P., Fowler, S., Musick, J. and Bennett, M. (eds.) (2003). *The Conservation Status of Australian Chondrichthyans*. Report of the IUCN Shark Specialist Group Australia and Oceania Red List Workshop. The University of Queensland, School of Biomedical Sciences, Brisbane, Australia. Last, P.R. and Stevens, J.D. (1994). *Sharks and Rays of Australia*. CSIRO, Melbourne. Peverell, S.C. (2005). Distribution of sawfishes (Pristidae) in the Queensland Gulf of Carpentaria, Australia, with notes on their ecology. *Environmental Biology of Fishes,* Vol. 73, pp. 391-402 Stirrat, S., Larson, H. and Woinarski, J. (2006). *Threatened Species of the Northern Territory - Green Sawfish - Pristis zijsron.* Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0006/206394/green-sawfish.pdf [Accessed 26 April 2017]. Thorburn, D.C., Peverell, S., Stevens, S., Last, J.D. and Rowland, A.J. (2003). *Status of freshwater and estuarine elasmobranchs in Northern Australia*. Report to Natural Heritage Trust, Canberra.			
Whale Shark			**Habitat:** Pelagic, in both oceanic and coastal areas in tropical to warm-temperate waters. Most	**LOW**

Rhincodon typus	VU	-	common in offshore open waters; however, often seen close to shore, and known to enter lagoons and atolls (DoE 2017). **Distribution:** Records from NSW, Qld, NT and WA, occasionally sighted in Victoria and SA. Most common off the north-western WA coast (Ningaloo Reef) (DoE 2017). Status and distribution within the NT is not well known, with only a few unconfirmed sightings (Woinarski & Larson 2006).	• Darwin Harbour represents marginal habitat; an oceanic species • No proximate records; few NT records
	Department of the Environment (2017). *Rhincodon typus – Whale Shark*. Species Profile and Threats Database, Department of the Environment, Australian Government, Canberra. [online] Available at: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=66680 [Accessed 26 April 2017]. Woinarski, J. and Larson, H. (2006). *Threatened Species of the Northern Territory - Whale Shark - Rhincodon typus.* Northern Territory Department of Environment and Natural Resources. [online] Available at: https://nt.gov.au/__data/assets/pdf_file/0003/376275/whale-shark.pdf [Accessed 26 April 2017].			
MIGRATORY MARINE BIRDS				
Common Noddy *Anous stolidus*	**Habitat:** During the breeding season, the Common Noddy usually occurs on or near islands, on rocky islets and stacks with precipitous cliffs, or on shoals or cays of coral or sand. When not at the nest, individuals will remain close to the nest, foraging in the surrounding waters. Birds may nest in bushes, saltbush, or other low vegetation. **Distribution:** The species is rarely encountered off the coast of the Northern Territory; only one breeding location is known from an offshore island in north east Arnhem Land (Chatto 2001).			**LOW** • No suitable habitat • No nearby records • May occasionally pass through area.
	Chatto, R. (2001). The distribution and status of colonial breeding seabirds in the Northern Territory. Parks & Wildlife Commission of the NT Technical Report. 70. Department of Environment (DoE) 2018, *Anous stolidus* in Species Profile and Threats Database, Department of the Environment, Canberra, viewed March 2018, http://www.environment.gov.au/.			
Fork-tailed Swift *Apus pacificus*	**Habitat:** Almost exclusively aerial. Mostly occurs over dry or open habitats, including riparian woodland and tea-tree swamps, low scrub, heathland or saltmarsh. Catches insects on the wing (DoE 2018). **Distribution:** A non-breeding visitor to all states and territories of Australia. Breeds in Siberia and migrates southward during the northern winter (DoE 2018).			**MEDIUM** (above the project area) • Given the broad distribution and wide ranging nature of *Apus pacificus* it is likely to be present at some time. • The project area is within the species' distribution.
	Department of Environment (DoE) 2018, Apus pacificus in Species Profile and Threats Database, Department of the Environment, Canberra, viewed March 2018, http://www.environment.gov.au/.			
Streaked Shearwater *Calonectris leucomelas*	**Habitat:** Pelagic species found also in near shore waters, and nests on offshore islands of Japan and Korea. **Distribution:** Breeds in Northern Hemisphere; migrates south tropical areas including northern Australian waters during non-breeding season.			**LOW** • Habitat of low suitability • No records from Darwin Harbour • Non breeding migrant to Australian waters.
	BirdLife International. 2017. *Calonectris leucomelas* (amended version of 2016 assessment). The IUCN Red List of Threatened Species 2017. viewed March 2018, http://dx.doi.org/10.2305/IUCN.UK.2017-1.RLTS.T22698172A110671395.en.			
Lesser Frigatebird *Fregata ariel*	**Habitat:** The Lesser Frigatebird breeds on small, remote tropical and sub-tropical islands, in mangroves or bushes, and even on bare ground. **Distribution:** Major breeding populations of the Lesser Frigatebird are found in tropical waters of the Indian and Pacific Ocean (excluding the east Pacific)			**LOW** • Potentially suitable feeding habitat in Darwin Harbour, but not adjacent to Stage 1 area • Rare occurrences near Darwin

		• No breeding habitat
	BirdLife International. 2017. *Fregata ariel* (amended version of 2016 assessment). The IUCN Red List of Threatened Species 2017, viewed March 2018, http://dx.doi.org/10.2305/IUCN.UK.2017-1.RLTS.T22697738A110668304.en.	
Great Frigatebird *Fregata minor*	**Habitat:** The Great Frigatebird breeds on small, remote tropical and sub-tropical islands, in mangroves or bushes and occasionally on bare ground, and feeds on fish, squid and chicks of other bird species. **Distribution:** Major breeding populations of the Great Frigatebird are found in tropical waters of the Pacific and Indian Ocean, as well as one population in the South Atlantic	**LOW** • Potentially suitable feeding habitat in Darwin Harbour, but not adjacent to Stage 1 area • No records from Darwin Harbour • No breeding habitat
	BirdLife International. 2017. *Fregata minor* (amended version of 2016 assessment). The IUCN Red List of Threatened Species 2017: viewed March 2018, http://dx.doi.org/10.2305/IUCN.UK.2017-1.RLTS.T22697733A110667065.en	
Little Tern *Sternula albifrons*	**Habitat:** The species breeds on barren or sparsely vegetated beaches, islands and spits. It feeds on small fish, crustaceans and insects, usually in very shallow water often over the advancing tideline. **Distribution:** Breeding populations of this species can be found through much of Europe, scattered along the coast and inland in parts of Africa, in much of western, central and the extreme east and south of Asia, and in northern parts of Australasia.	**MEDIUM** • Potentially suitable feeding habitat adjacent to Stage 1 area • Records from Darwin Harbour • No breeding habitat
	BirdLife International. 2017. *Sternula albifrons* (amended version of 2016 assessment). The IUCN Red List of Threatened Species 2017: viewed March 2018, http://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22694656A86737634.en	
MIGRATORY MARINE SPECIES[1]		
Narrow Sawfish *Anoxypristis cuspidata*	**Habitat:** The Narrow Sawfish is a bentho-pelagic species that inhabits estuarine, inshore and offshore waters to at least 40 m depth. Inshore and estuarine waters are critical habitats for juveniles and pupping females, whilst adults predominantly occur offshore. **Distribution:** In Australia, distribution extends from Exmouth Gulf in WA to Rockhampton in Qld including NT waters. This range contains the most viable, ecologically functional populations that remain worldwide	**MEDIUM** • Potentially suitable habitat • No records from Darwin Harbour • Rare/scarcity of records.
	D'Anastasi, B., Simpfendorfer, C. & van Herwerden, L. 2013. Anoxypristis cuspidata. The IUCN Red List of Threatened Species 2013. Viewed march 2018, http://dx.doi.org/10.2305/IUCN.UK.2013-1.RLTS.T39389A18620409.en	
Bryde's Whale *Balaenoptera edeni*	**Habitat:** Bryde's Whales are found year-round in waters between 40° S and 40° N, primarily in temperatures exceeding 16.3 °C. Insufficient information exists as to how Australian Bryde's Whales use their habitat, as no specific feeding or breeding grounds have been discovered off Australia. The inshore form appears to be resident in waters containing suitable prey stocks of pelagic shoaling fishes, while the offshore form appears to undergo extensive migrations between subtropical and tropical waters during the winter months (DEE 2018). **Distribution:** Bryde's Whales occur in temperate to tropical waters, both oceanic and inshore, bounded by latitudes 40° N and 40° S, or the 20 °C isotherm (DEE 2018).	**LOW** • No records from Darwin Harbour • Darwin Harbour not considered core habitat
	Department of Environment (DoE) 2018, *Balaenoptera edeni* in Species Profile and Threats Database, Department of the Environment, Canberra, viewed march 2018 http://www.environment.gov.au/.	
Saltwater	**Habitat:** Saltwater Crocodile mostly occurs in tidal rivers, coastal floodplains and channels, billabongs and swamps	**HIGH**

[1] Migratory marine species which are also threatened have been considered above.

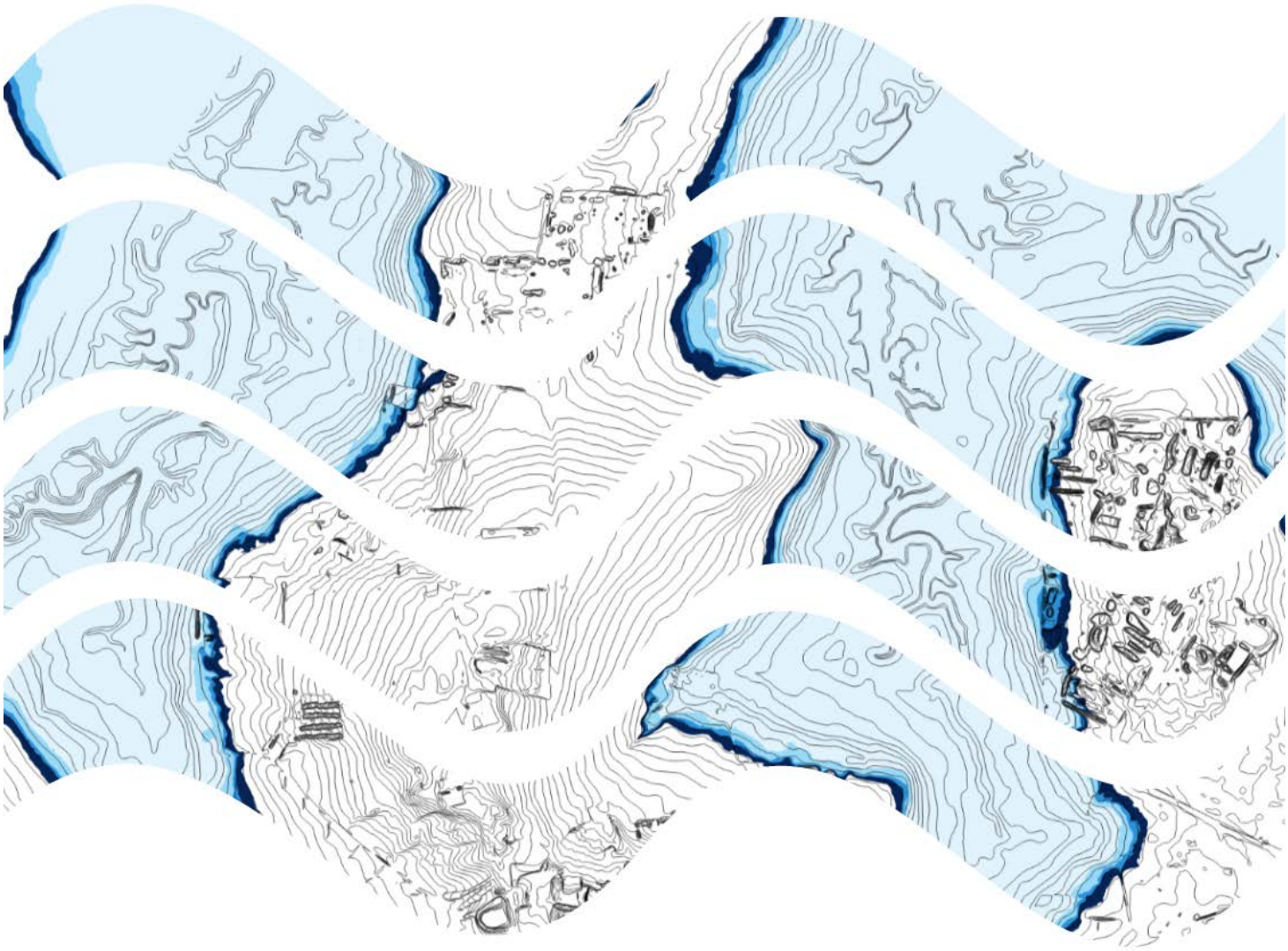
Crocodile *Crocodylus porosus*	up to 150 km inland from the coast (DoE 2017). **Distribution:** Widely distributed in Top End Rivers (DEE 2018) and have been regularly recorded in Darwin Harbour.	• Suitable habitat adjacent to Stage 1 area • Records from Darwin Harbour including Middle Arm
	Department of Environment (DoE) 2017 *Crocodylus porosus* in Species Profile and Threats Database, Department of the Environment, Canberra, viewed March 2018, http://www.environment.gov.au/	
Dugong *Dugong dugong*	**Habitat:** Dugongs are seagrass community specialists and the range of the dugong is broadly coincident with the distribution of seagrasses in the tropical and sub-tropical waters in their Australian range. Dugong feeding aggregations tend to occur in large seagrass meadows within wide, shallow protected bays; wide, shallow mangrove channels; and in the lee of large inshore islands. In turbid areas where most seagrass is intertidal, temporary or permanent destruction of intertidal seagrass may mean that dugong cannot feed on enough seagrass in the time available for feeding to maintain their body weight (DEE 2018). **Distribution:** Dugongs occur in coastal and island waters from Shark Bay in Western Australia (25° S) across the northern coastline to Moreton Bay in Queensland including Darwin Harbour (DoE 2018).	**MEDIUM** • Seagrass present adjacent to Stage 1 area but is small meadows in high tidal area. • Multiple records from Darwin Harbour but mostly from harbour mouth.
	Department of Environment (DoE) 2018, *Dugong dugong* in Species Profile and Threats Database, Department of the Environment, Canberra, viewed March 2018, http://www.environment.gov.au/.	
Reef Manta Ray *Manta alfredi*	**Habitat:** Commonly sighted inshore, but also found around offshore coral reefs, rocky reefs and seamounts. **Distribution:** Information is lacking on distribution but is known to include tropical water and down both east and west coast of Australia.	**LOW** • Low suitability of habitat (no reef habitat, high tidal influence) adjacent to Stage 1 area • No confirmed records from Darwin harbour
	Marshall, A., Kashiwagi, T., Bennett, M.B., Deakos, M., Stevens, G., McGregor, F., Clark, T., Ishihara, H. & Sato, K. 2011. Manta alfredi. The IUCN Red List of Threatened Species 2011. Viewed march 2018, http://dx.doi.org/10.2305/IUCN.UK.2011-2.RLTS.T195459A8969079.en	
Giant Manta Ray *Manta birostris*	**Habitat:** Commonly sighted along productive coastlines with regular upwelling, oceanic island groups and particularly offshore pinnacles and seamounts. The Giant Manta Ray is commonly encountered on shallow reefs while being cleaned or is sighted feeding at the surface inshore and offshore. It is also occasionally observed in sandy bottom areas and seagrass beds. **Distribution:** Circumglobal in tropical and temperate waters, this species has a widespread distribution.	**LOW** • Area adjacent to Stage 1 area is not core habitat • No proximate records
	Marshall, A., Bennett, M.B., Kodja, G., Hinojosa-Alvarez, S., Galvan-Magana, F., Harding, M., Stevens, G. & Kashiwagi, T. 2011. Manta birostris. The IUCN Red List of Threatened Species 2011, viewed march 2018, http://dx.doi.org/10.2305/IUCN.UK.2011-2.RLTS.T198921A9108067.en	
Irrawaddy Dolphin *Orcaella brevirostris/ heinsohni*	**Habitat:** Have been recorded almost exclusively in coastal and estuarine waters close to seagrass beds. It is doubtful that they venture very far upstream in river systems, although occasional vagrants may venture upstream (DEE 2018). **Distribution:** Occur only in waters off the northern half of Australia, from approximately Broome (17° 57´ S) on the west coast to the Brisbane River (27° 32´ S) (DEE 2018).	**MEDIUM** • Potentially suitable seagrass habitat near Stage 1 area • Proximate records from within Darwin Harbour • Stage 1 area may be too far up estuarine system
	Department of Environment (DoE) 2018, *Orcaella heinsohni* in Species Profile and Threats Database, Department of the Environment, Canberra, viewed March 2018, http://www.environment.gov.au/.	
Orca	**Habitat:** The preferred habitat of Killer Whales includes oceanic, pelagic and neritic (relatively shallow waters over	**LOW**

Orcinus orca	the continental shelf) regions, in both warm and cold waters. They may be more common in cold, deep waters, but off Australia, Killer Whales are most often seen along the continental slope and on the shelf, particularly near seal colonies (DEE 2018). **Distribution:** In Australia, Killer Whales are recorded from all states, with concentrations reported around Tasmania. A sighting at Yirrkala in April 1999 provides evidence that they also occur in Northern Territory waters (DEE 2018).	• Darwin Harbour is not preferred habitat • No proximate records
	Department of Environment (DoE) 2018, *Orcinus orca* in Species Profile and Threats Database, Department of the Environment, Canberra, viewed March 2018, http://www.environment.gov.au/.	
Indo-Pacific Humpback Dolphin *Sousa chinensis/ sahulensis*	**Habitat:** Within their geographical range, Australian humpback dolphins are found primarily in coastal waters (however, the use of offshore waters is not fully understood), and re more likely to be found in relatively shallow and protected coastal habitats such as inlets, estuaries, major tidal rivers, shallow bays, inshore reefs and coastal archipelagos, rather than in open stretches of coastline (DEE 2018) **Distribution:** In Australia, humpback dolphins are thought to be widely distributed along the northern Australian coastline from approximately the Queensland–New South Wales border to western Shark Bay, Western Australia. A recent helicopter survey along the eastern half of the Northern Territory found Australian humpback dolphins were sparsely distributed across this region (DEE 2018).	**HIGH** • Suitable habitat adjacent to Stage 1 area • Numerous records from within Darwin Harbour, East Arm and Middle Arm.
	Department of Environment (DoE) 2018, *Sousa sahulensis* in Species Profile and Threats Database, Department of the Environment, Canberra, viewed March 2018, http://www.environment.gov.au/.	
Spotted Bottlenose Dolphin *Tursiops aduncus*	**Habitat:** In Australia, the Spotted Bottlenose Dolphin is restricted to inshore areas such as bays and estuaries, nearshore waters, open coast environments, and shallow offshore waters including coastal areas around oceanic islands (DEE 2018) **Distribution:** Spotted Bottlenose Dolphins are known to occur in four main regions around Australia: eastern Indian Ocean, Tasman Sea, Coral Sea, and Arafura/Timor Seas (DEE 2018).	**MEDIUM** • Suitable habitat within Darwin Harbour. • Numerous records from within Darwin Harbour. • No records as far upstream as Stage 1 area.
	Department of Environment (DoE) 2018, *Tursiops aduncus* in Species Profile and Threats Database, Department of the Environment, Canberra, viewed March 2018, http://www.environment.gov.au/.	

APPENDIX E SURFACE WATER HYDROLOGY REPORT

Kittyhawk Estate Surface water Study

Report ECA-HA-0002-01



Kittyhawk Estate Surface water Study

Prepared for EcOz Environmental Consultants

Report ECA-HA-0002-01

May 2018

RELIANCE, USES and LIMITATIONS

This study, report and analyses have been based on the information available to EnviroConsult Australia at the time of preparation. EnviroConsult Australia accepts responsibility for the report and its conclusions to the extent that the information was sufficient and accurate at the time of preparation. EnviroConsult Australia does not take responsibility for errors and omissions due to incorrect information or information not available to at the time of preparation of the study, report or analyses. No chemical analysis, groundwater hydrology, water quality or contaminant export studies of any kind were conducted. Any comment made in the report with respect to the above are speculative based on the surface hydrology analysis and should not be relied upon as fact.

EnviroConsult Australia Pty Ltd

Executive Summary

This report supports the prefeasibility analysis of the proposed Kittyhawk Estate development by supplying:

1. A desktop review of surface water hydrology,
2. Analysis of stormwater quantity discharge from four specific sub-catchments at the outlet of the sub-catchment where it meets the estuary shore line, and
3. An assessment of the effect of a Q100 and Q1000 rainfall event on local inundation occurring at the same time as a 2100 primary storm surge and a 2100 secondary storm.

The Kittyhawk Estate has gently sloping relief from south to north and is located on a south to north peninsular bounded by to two estuaries.

For the desktop review of the surface water hydrology, we defined 14 sub-catchments across the two estuarine inlet catchments (one to the east and one to the west of the estate) covering both onshore and offshore areas. Hydrological modelling indicated that at the confluence of the two estuaries with the Elizabeth River, the Q100 and the Q1000 events gave peak discharges of $398m^3s^{-1}$ and $763m^3s^{-1}$ respectively and total discharge volumes of 1460ML and 2180ML respectively. For an average annual rainfall year (Channel Island gauge, 1940, 1617mm), the simulated total discharge volume at the confluence was 15300ML.

The four specific sub-catchments of interest, total discharge at their outlets for the Q100 storm were 33.5, 28.3, 3.5 and 60.5ML for sub-catchments 1 to 4 respectfully with a total discharge of 125.8ML. For the average rainfall year, 1940, the total discharge volume from the catchments was 555, 407, 58, and 988ML for catchments 1 to 4 respectively with a total discharge volume of 2082ML.

Inundation modelling indicated that local inundation may occur should a Q100 and a Q1000 rainfall event occur at the same time as a peak primary tidal surge and peak secondary tidal surge. Simulations estimated that for 2018, the Q100 event caused a local inundation high water level (HWL) with the local storm effect of 5.7m AHD compared with predicted highest astronomical tide (HAT) + Q100 tidal surge level of 4.5 m AHD without the local storm effect. For 2018, the Q1000 storm, local inundation HWL with the local storm effect is 6.2m AHD compared with predicted the HAT + Q1000 tidal surge level of 5.2m AHD without the local storm effect. When 2100 sea level rise predictions are considered the Q100 and Q1000 maximum simulated HWLs with the local storm event, are 6.4m AHD and 6.8 m AHD respectively. Water could extend inland on the site area by up to 307 m.

Recommendations include but are not limited to studies to calibrate the models to local data, bathymetric studies of the catchments, Monte Carlo simulations of flood events in the Elizabeth River, and the effects of very rare rainfall events (up to 1 in 2000y).

Contents

Figures

Tables

1. Introduction

The proposed Kittyhawk Estate is part of the Middle Arm Industrial Precinct with the former undergoing a prefeasibility analysis.

EcOz Environmental Consultants commissioned, EnviroConsult Australia Pty Ltd to deliver an understanding of the surface water hydrology of Kittyhawk Estate. The objectives of this study were:

1. A desktop review of surface water hydrology.
2. Analysis of stormwater quantity and in 4 specific sub-catchments draining 38% of water from the land surface of Kittyhawk Estate site, and
3. A desktop review of local inundation zones for a Q100[1] and Q1000 rainfall event occurring at the same time as Q100 Primary storm surge and Q1000 Secondary storm surge based on 2018 and 2100 mean sea levels.

To achieve the objective, the following tasks were completed:

a) Prepare a digital elevation model (DEM) for the project area,
b) Determine the hydrology of the Kittyhawk Estate catchment and sub-catchments for Q100 rainfall event and the Q1000 rainfall event,
c) Simulation of total discharge volumes at the outlets of the 4 specific sub-catchments i.e. where the outlets meet the estuary shoreline, and
d) Determine the effect of local inundation on the Estate should a Q100 rainfall event and a Q1000 rainfall event occur in the Kittyhawk Estate catchments at the same time as the Q100 primary storm surge and the Q1000 secondary surge respectively.

1.1 Study Site

Kittyhawk Estate is located on a peninsula created by 2 north-south trending left-bank tidal estuaries of the East Arm/Elizabeth River (***Figure 1***). The site is to the south east of Ichthys Onshore Processing facility and is zoned as “gas related industry and downstream processing”.

The intertidal zones of the estuaries are dominated by mangroves and the estate area, above high water, is dominated by annual grasses and aerial photography indicates numerous areas of anthropogenic disturbance.

The relief ranges from approximately 20m AHD from the southern end of the peninsula to about 5 m AHD at the northern tip of the peninsula over about 3.9km.

[1] Engineers Australia is changing the terminology for return intervals of events. A 1 in 100y events is referred to a s 1%AEP and 1 in 1000y event is referred to as 0.1%AEP. For the continuity with earlier studies this report uses the term Q100 and Q1000 for a 1 in 100y and 1 in 1000y event respectively.

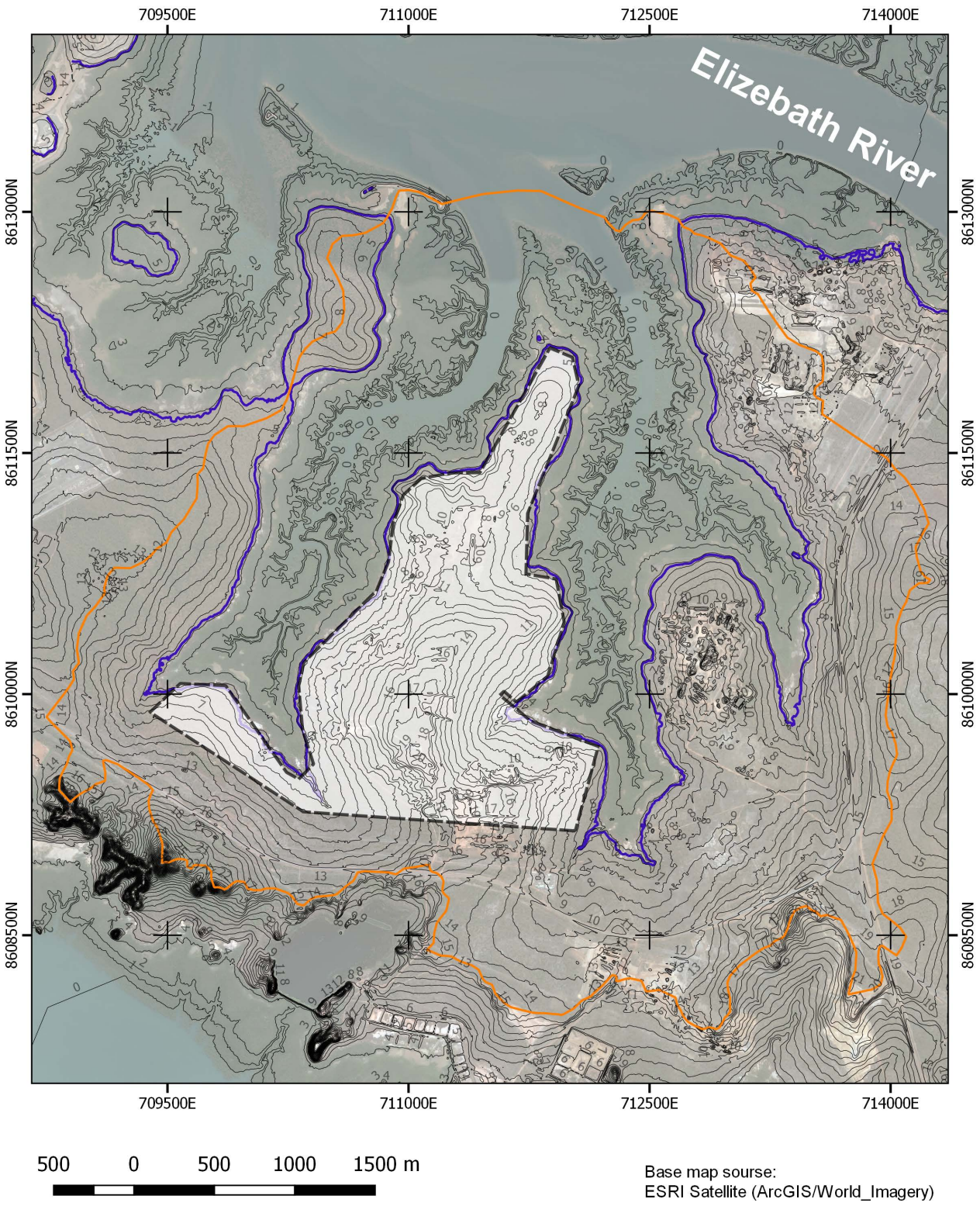


Figure 1. Map of Kittyhawk Estate the study catchment and the 4.5m tidal inundation line.

2. Methods

2.1 Digital Elevation Model preparation

A digital elevation model (DEM) is a numeric 3-dimensional representation of a land surface. The DEM is the basis of hydrological modelling used in this study.

A 5 m DEM for the required area was downloaded from GeoScience Australia and resampled to produce a 1 m DEM. We consider that the resampled 1 m DEM is of sufficient accuracy for this initial study.

2.2 Study catchment hydrology

Catchment hydrology was determined using modelling.

No rainfall or runoff data are available for the study area and it is good practice to calibrate a model to measured data. Therefore, two models were used as, for ungauged catchments, it is good practice to use 2 models and calibrate one against the other. In this study RORBwin was calibrated against and Regional Flood Frequency Estimation (RFFE) methods.

RORBwin

The RORBwin hydrology model uses Monte Carlo simulation to determine the features of the Q100 and Q1000 rainfall events and the resulting probable peak flows for those events applied to a catchment.

The Kittyhawk Estate study site is situated on a peninsula created by two estuaries as described above. The two estuaries and their catchment areas were combined as 1 catchment debouching to the Elizabeth River. This catchment was divided into 14 sub-catchments, covering both onshore and offshore areas, (*Figure 2*) for the use in the RORBwin model. The co-ordinates of sub-catchment centroids and junctions, and sub-catchment areas are given in *Table 1*.

Four specific sub-catchments of interest (*Figure 3*), representing the sub-catchments producing ≈38% of the total runoff from the land surface area of the development site, were further analysed to assess surface water runoff characteristics for the Q100 and Q1000 events. These sub-catchments are not the same as those delineated for the large Kittyhawk Estate catchment that debouches to the Elizabeth River/East Arm. These specific catchments have their outlet at the shoreline of the estuaries and volumes of surface flow at this point is assessed.

Annual discharge volumes for an average rainfall year was also simulated. Data from the nearby BOM Channel Island weather station was used. The average annual rainfall recorded at that site was 1631mm. There were daily rainfall data going back to 1932. The year 1940 had 1617mm which was the year closest to the average annual rainfall, so those data were used in RORBwin to determine annual discharge volume.

Regional Flood Frequency Estimation (RFFE) and RORBwin calibration

Peak surface water flows (i.e. Q100) for the large catchment (***Figure 2***) and the four specific sub-catchments (***Figure 3***) was estimated using the using RFFE. RFFE is an online method developed by Engineers Australia and Western Sydney University for estimation of the probability distribution of peak discharges of various return interval flood events. Inputs for the RFFE method are co-ordinates of the catchment outlet and the catchment centroid, and the catchment area.

As stated above, for ungauged catchments it is good practice to use 2 models and calibrate one against the other; this is achieved through analysis of the two methods, RFFE and RORBwin. To check that RORBwin outputs are reasonably accurate, the parameter values in RORBwin were adjusted until the peak discharge for the chosen event was similar for the peak discharge determined using RFFE. However, this method does not allow calibration to continuous flow as RFFE can only produce peak discharges.

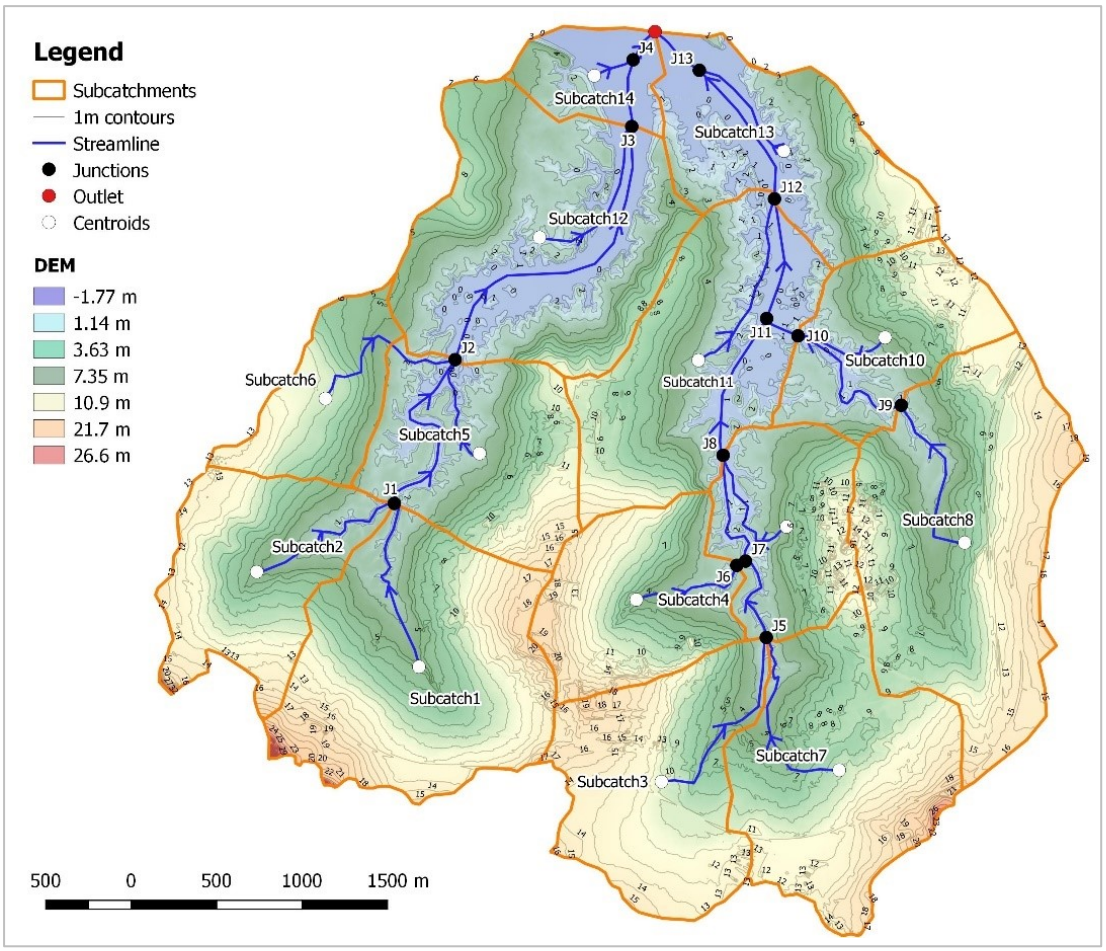


Figure 2. Sub-catchments used in RORBwin Monte Carlo simulation

Table 1. RORBwin sub-catchment areas, centroid co-ordinates and junction co-ordinates.

Sub-catchment	Area (Km^2)	Centroid Coordinates	
		Latitude	Longitude
Subcatch1	2.014	-12.571	130.936
Subcatch2	1.146	-12.566	130.927
Subcatch3	1.414	-12.577	130.949
Subcatch4	1.075	-12.567	130.947
Subcatch5	1.25	-12.56	130.939
Subcatch6	0.683	-12.557	130.93
Subcatch7	1.665	-12.576	130.958
Subcatch8	2.287	-12.564	130.965
Subcatch9	0.897	-12.563	130.955
Subcatch10	0.956	-12.553	130.961
Subcatch11	1.644	-12.554	130.951
Subcatch12	2.146	-12.548	130.942
Subcatch13	1.317	-12.543	130.955
Subcatch14	0.439	-12.539	130.945

Junctions	Coordinates	
	Latitude	Longitude
J1	-12.56272	130.9348
J2	-12.55505	130.9381
J3	-12.54269	130.9474
J4	-12.53917	130.9476
J5	-12.56971	130.9549
J6	-12.56586	130.9531
J7	-12.56557	130.9537
J8	-12.56008	130.9524
J9	-12.55739	130.9620
J10	-12.55365	130.9565
J11	-12.55280	130.9548
J12	-12.54648	130.9551
J13	-12.53972	130.9511
Outlet	-12.53768	130.9486

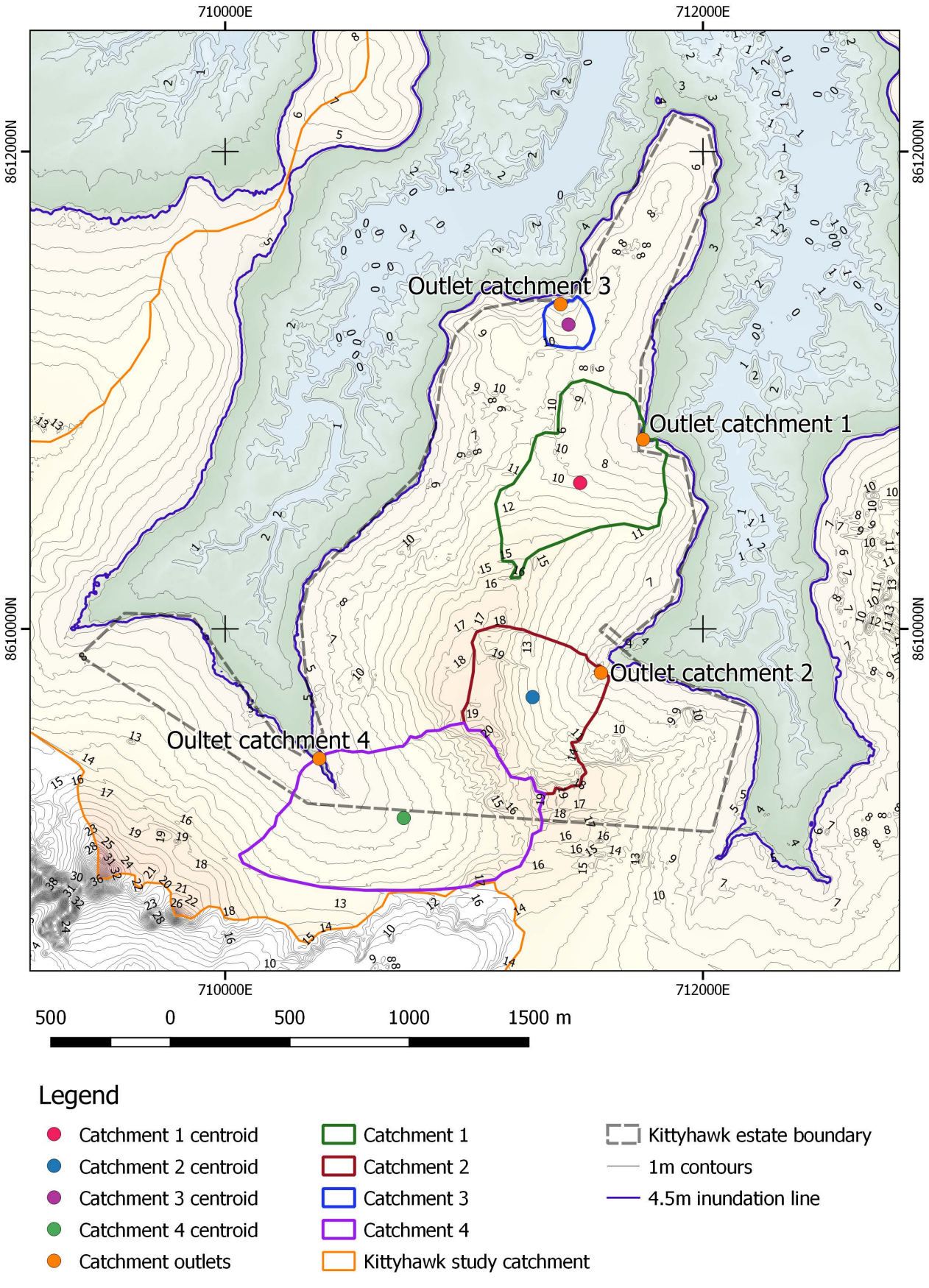


Figure 3. The four specific sub-catchments used for detailed surface water hydrology analysis

2.3 Inundation modelling

Local inundation zones caused by the Q100 and Q1000 rainfall events in the catchments occurring at the same time as the Q100 primary storm surge and the Q1000 secondary storm surge were modelled using a HEC-RAS 5.03 two-dimensional model.

The model mesh was constructed from available topographic and bathymetric data. 4 simulations were conducted with inputs at 3 locations (***Figure 4***). The inputs at those locations for each simulation are described below:

1%AEP Flood/Storm Primary Surge simulations for 2018 and 2100 mean sea levels

- TDBC: 2018 and 2100 Q100 tidal graphs derived from the measured data at Stokes Hill Wharf tidal gauge (G8150029) and 2018 and 2100 mean sea levels.
- USBC: Q100 hydrograph of the inflow from the upstream of Elizabeth River derived from Regional Flood Frequency Estimation (RFFE) results.
- RORB1 and RORB2: Q100 hydrographs at the outlet of each of the catchments of two estuaries generated from RORBwin Monte Carlo simulations (simulated hydrographs at the outlets of sub-catchments 14 and sub-catchment 13 (***Figure 2***) are inputs at RORB1 and RORB2 respectively

Q1000 Flood/Storm Secondary Surge simulations for 2018 and 2100 mean sea levels

- TDBC: 2018 and 2100 Q1000 tidal graphs derived from the measured data at Stokes Hill Wharf tidal gauge (G8150029) and 2018 and 2100 mean sea levels.
- USBC: Q100 hydrograph of the inflow from the upstream of Elizabeth River derived from Regional Flood Frequency Estimation (RFFE) results (Q1000 data is not available in RFFE website, the impact of Q1000 upstream flow needs further investigation).
- RORB1 and RORB2: Q1000 hydrographs at the outlet of each of the catchments of two estuaries generated from RORBwin Monte Carlo simulations (simulated hydrographs at the outlets of sub-catchments 14 and sub-catchment 13 (***Figure 2***) are inputs at RORB1 and RORB2 respectively.)

The effects of the Elizabeth River discharge were assessed by derivation of peak discharges for the Q100 event for the river catchment using RFFE. These discharges were input as boundary condition in the inundation model (USBC, ***Figure 4***) and considered to be constant throughout the time period of the simulated storm. This may have the effect of over-estimating the inundation levels.

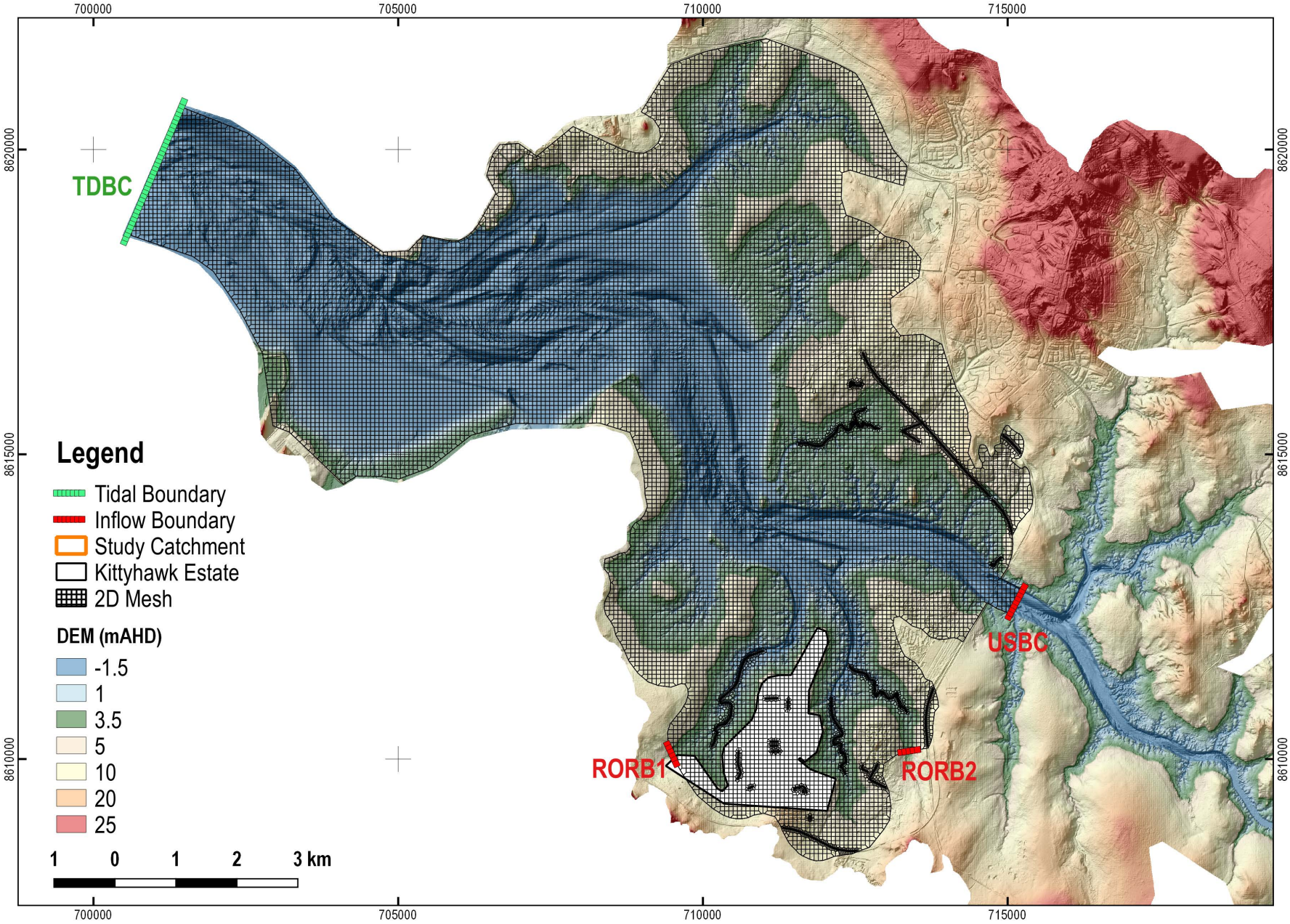


Figure 4. HEC-RAS 2D model mesh and locations of model inputs

3. Results and discussion

3.1 Desktop review of surface water hydrology

The peak discharge and total discharge for the Kittyhawk Estate RORBwin sub-catchments (*Figure 1*) are given in *Table 2*.

Table 2. RORBwin catchment total discharge and peak discharge for the Kittyhawk Estate catchments for the Q100 and Q1000. Total discharge volume using 1940 rainfall is also shown.

Catchment	Area (Km^2)	Discharge (m^3s^{-1})			Total Discharge (ML)		
		Q100	Q1000	1940	Q100	Q1000	1940
Sub-catchment 1	2.014	53.29	91.9	1.8	164	245	1600
Sub-catchment 2	1.146	29.83	51.85	1	93.4	140	912
Sub-catchment 3	1.414	34.35	61.7	1.2	115	172	1368
Sub-catchment 4	1.075	0.039	0.065	0.9	87.6	131	855
Sub-catchment 5	1.25	111.9	209.2	1.1	102	152	995
Sub-catchment 6	0.683	16.78	29.99	0.6	55.6	83.2	553
Sub-catchment 7	1.665	42.37	74.5	1.4	136	203	1350
Sub-catchment 8	2.287	50.89	105	2.0	186	279	1820
Sub-catchment 9	0.897	84.6	152.2	0.8	73.1	109	714
Sub-catchment 10	0.956	73.76	136.2	0.8	77.9	117	761
Sub-catchment 11	1.644	193.7	363.4	1.4	134	363.4	1310
Sub-catchment 12	2.146	167.6	309.9	1.9	175	262	1730
Sub-catchment 13	1.317	223	437	1.1	107	161	1050
Sub-catchment 14	0.439	179.9	326.2	0.4	35.8	53.5	349
East	11.153	223	437	7.6	831	1240	9080
West	7.678	179.9	326.2	6.2	626	936	6220
Catchment outlet	18.831	398.6	763.1	15.4	1460	2180	15300

The Monte Carlo simulations gave the critical duration of 1h for the Q100 and Q1000. RFFE indicated peak discharge of $344m^3s^{-1}$ at the outlet of the combined estuary catchment for the Q100 event (*Table 3*). This compares well with the RORBwin simulated peak discharge of $398m^3s^{-1}$ (*Figure 5*). Initial loss for the simulations for the Q100 was $42mmh^{-1}$, continuing loss $4.3mmh^{-1}$, time to peak discharge is approximately 30min, and cease to flow from end of rain is approximately 5h. Total discharge at the outlet of the Kittyhawk catchments of the Q100 event is 1460ML.

For the Q1000 the simulation gave a peak discharge of 763m^3s^{-1} (***Figure 6***) for the large catchment. RFFE cannot be used for the Q1000 event. Initial loss for the simulations for the Q100 was 42mmh^{-1}, continuing loss 4.3mmh^{-1}, time to peak discharge is approximately 50min, and cease to flow from end of rain is >5h with a lengthy recessional tail to the hydrograph. Total discharge at the outlet of the Kittyhawk estuary catchments combined of the Q1000 event is 2180ML.

The total discharge volume for an average rainfall year (1940) is 15300ML.

The simulated rainfall graph and its resulting hydrograph for the Q100 event with peak discharge are shown in ***Figure 5***. In ***Figure 5*** and ***Figure 6*** the upper hyetograph (rainfall) is the depth per 5-min interval and the continuous hydrograph as estimated by RORBwin Monte Carlo simulations for the probable peak discharge shown in the lower hydrograph.

These hydrographs are used as input to the inundation model to assess local inundation as a result of both the storm event occurring in the Kittyhawk Estate catchments and the surges occurring at the same time.

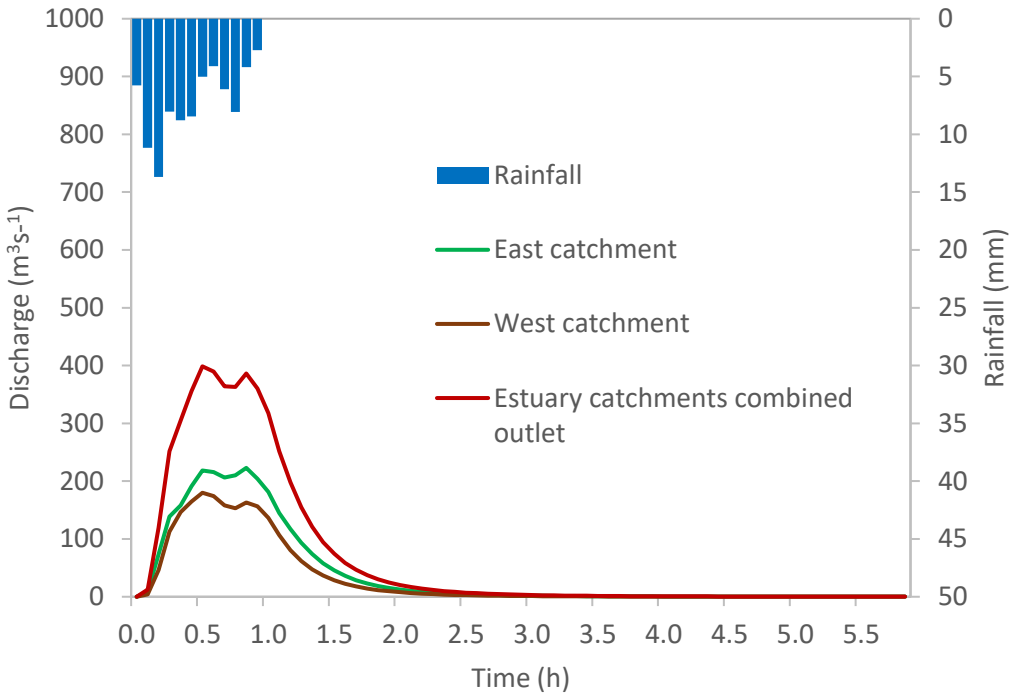


Figure 5. Rainfall graph and probable peak flow rate at the mouth of the catchments the Q100 flood

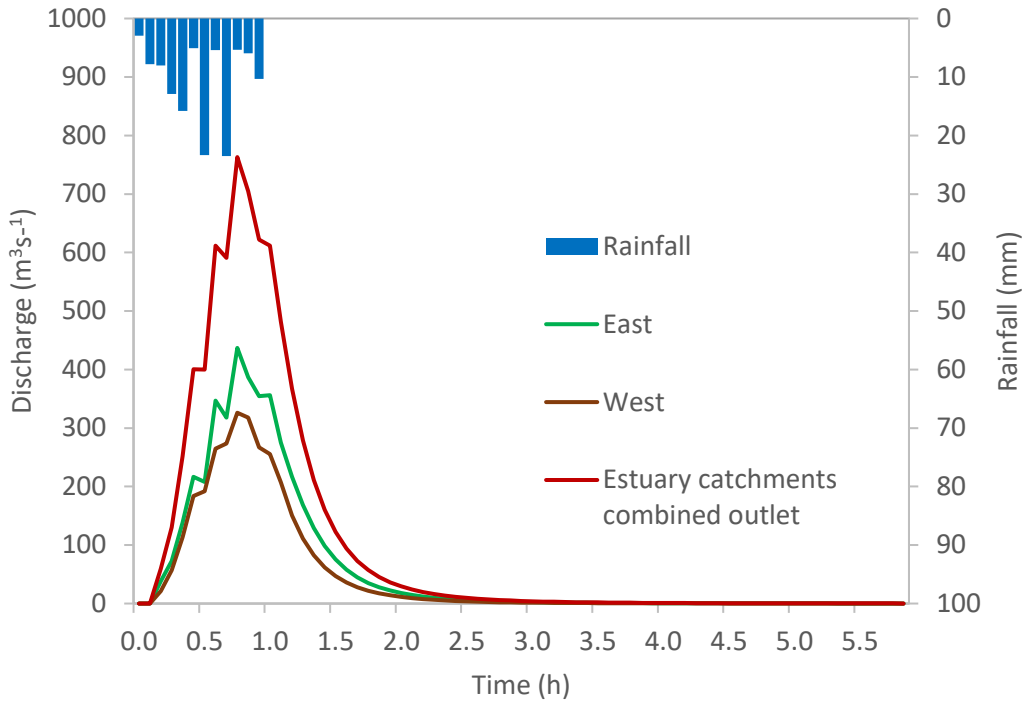


Figure 6. Rainfall graph and probable peak flow rate at the mouth of the catchments for the Q1000 flood.

3.2 Hydrology of 4 specific sub-catchments

Peak surface water flows (Q100) for each of the four specific sub-catchments using online Regional Flood Frequency Estimation (RFFE) and RORBwin Monte Carlo simulations are shown in ***Table 3*** and ***Figure 7***. The 4 specific sub-catchments are not the same as those similarly named in the RORBwin model. These catchments combined drain ≈38% of the total land surface.

Sub-catchment 4 is the only sub-catchment with an area >0.5 km^2 where RFFE results can be considered reliable but still the distribution of results is wide with peak discharges ranging from 13.6 m^{3}s^{-1} to 99.3 m^{3}s^{-1} and the estimated discharge 37 m^{3}s^{-1} (***Table 3***; ***Figure 8***). RORBwin results for sub-catchment 4 has a similar Q100 discharge (32 m^{3}s^{-1}) as that of the RFFE estimation (***Table 3***; ***Figure 8***).

Table 3. Comparison between RFFE and RORBwin results for the Q100 event for the 4 specific sub- catchments.

Catchment	Area (km^2)	RFFE[3]			RORBwin			
		Mean peak discharge (m^3s^{-1})	5% confidence limit	95% confidence limit	Peak discharge (m^3s^{-1})	Total discharge (ML)	1% AEP Rainfall intensity (mmh^{-1})	1940 annual discharge volume (ML)
1	0.37[1]	25.6	9.83	65.7	17.7	33.5	98.5	555
2	0.29[1]	20.8	7.70	55.5	15.0	28.3		470
3	0.04[1,2]	-	-	-	1.9	3.5		58
4	0.62	37.0	13.6	99.3	32.0	60.5		988
Total	3.28					125.8		2080

[1] Regional Flood Frequency Estimates for catchments with an area less than 0.5 km^2 have lower accuracy.

[2] Catchment 3 was considered too small to estimate discharge using RFFE.

[3] RFFE method is not appropriate in the following:

I. Urban catchments (more than 10% of the catchment affected by residential or urban development)
II. Catchments where large scale land clearing has taken place
III. Catchments which have been significantly affected by agricultural activities, construction of drainage or irrigation infrastructure, soil conservation works or mining activities

[4] An Areal Reduction Factor of 0.87 was applied to the BOM Q100 rainfall intensity by RORBwin.

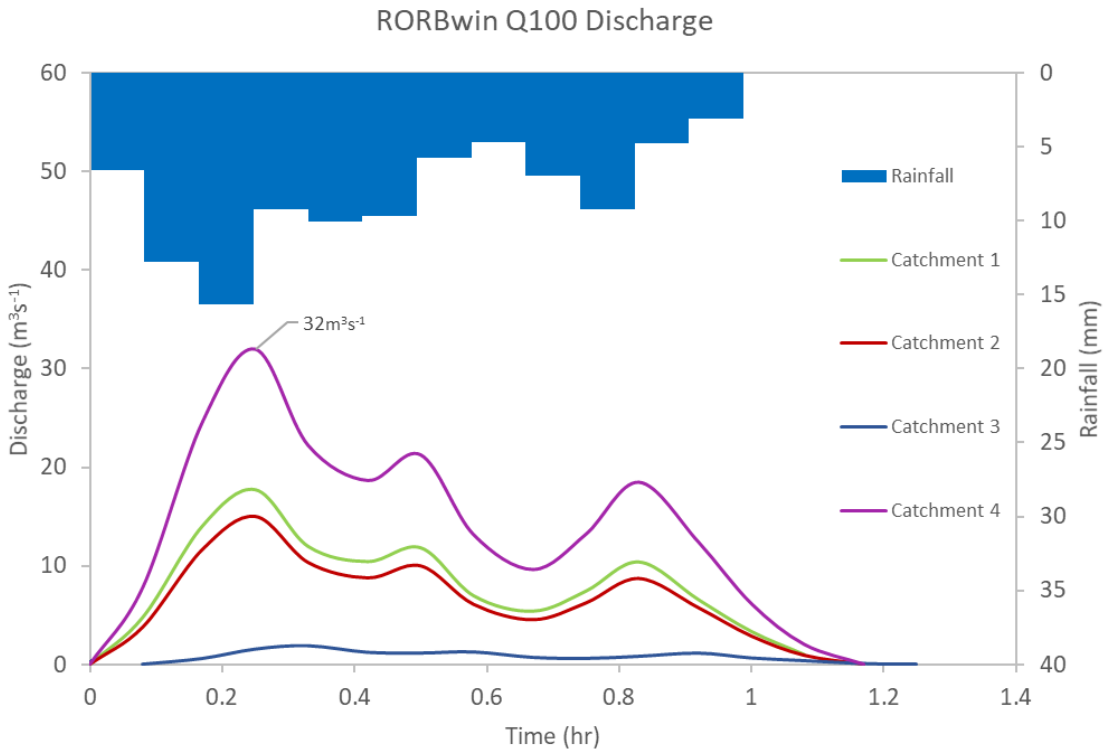


Figure 7. RORBwin simulations for the Q100 storm event in the 4 specific sub-catchments.

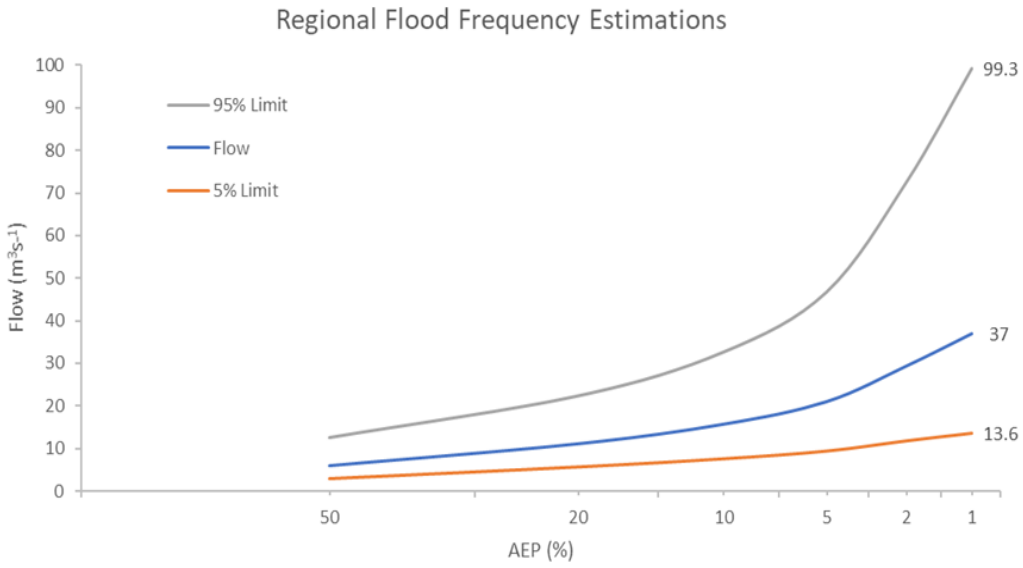


Figure 8. RFFE estimations for sub-catchment 4.

3.3 Desktop review of Q100 Flood/Storm 2100 Primary surge and Q1000 Flood/storm 2100 Secondary surge Assessment Plan

The time series of water surface elevation at the mouth of the study catchment for each simulation are shown in ***Figure 9***. The NT government's predicted water levels for HAT + 100-year surge and HAT + 1000-year surge based on 2010 mean sea level are also shown in the figure:

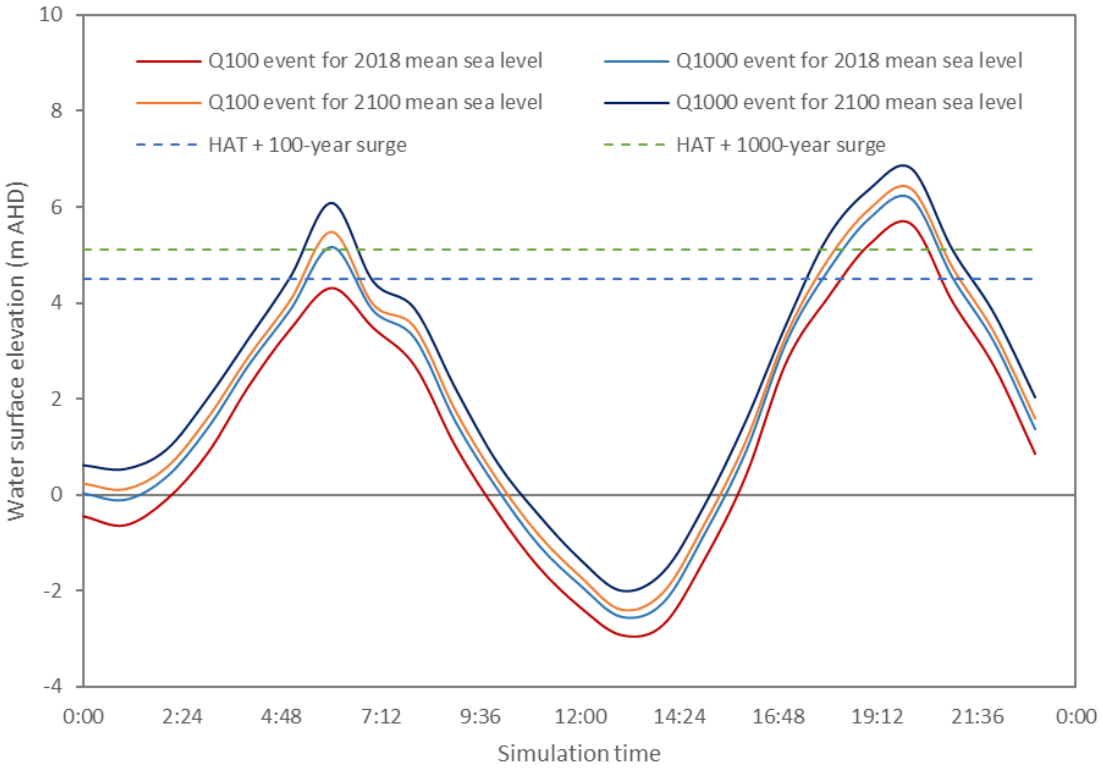


Figure 9. Time series of water surface elevation at the mouth of the study catchment.

The maximum water surface elevation at the mouth of the study catchment (Outlet ***Figure 2***) for each simulation were used to draw the Q100 primary and Q1000 secondary tidal surge inundation zones for 2018 and 2100 mean sea levels in an inundation map. Three scenarios have been included in the inundation map (

Figure 10):

- Predicted HAT plus Q100 primary tidal surge level and Q1000 secondary tidal surge level in 2010 acquired from government records,
- The Q100 flood/storm event primary tidal surge local inundation zone and Q1000 flood/storm event secondary tidal surge local inundation zone (HEC-RAS modelling result), and
- Primary and Secondary tidal surge inundation zone for predicted mean seal level at 2100 (HEC-RAS modelling result).

The model showed that the predicted maximum water level at the confluence of the two estuaries with the Elizabeth River/East Arm (outlet of the combined catchments of Kitty hawk Estate) during a Q100 flood/storm event for 2018 is approximately 5.7 m AHD (●Outlet, ***Figure 2***). This is 1.2 m higher than the NT government's predicted HAT + Q100 tidal surge level (4.5 m AHD) for 2010 (

Figure 10). Similarly, the predicted maximum water (6.2 m AHD) level during a Q1000 flood/storm event for 2018 is 1.1 m higher than the NT government's HAT + Q1000 tidal surge level (5.1 m AHD) for 2010. We hypothesise that this is due to flood water being trapped in the study catchment by a rising tide. For 2100 scenarios (mean sea level), the predicted maximum water surface elevations for Q100 and Q1000 events are 6.4 m AHD and 6.8 m AHD which are 0.7 m and 0.6 m higher than 2018 scenarios. The inundation zone caused by the 2100 Q1000 water surface elevation (6.8 m AHD) could extend into the Kittyhawk Estate site area by up to 307m (***Figure 11***).

It is also important to note the influence of the Elizabeth River water flowing past the mouth of the study catchments. The model simulations indicate that some of this water is "pushed" into the catchments by the incoming tide. This is seen in flow patterns observed from the modelling results showing velocity arrows of flow during a rising tide (***Figure 12***).

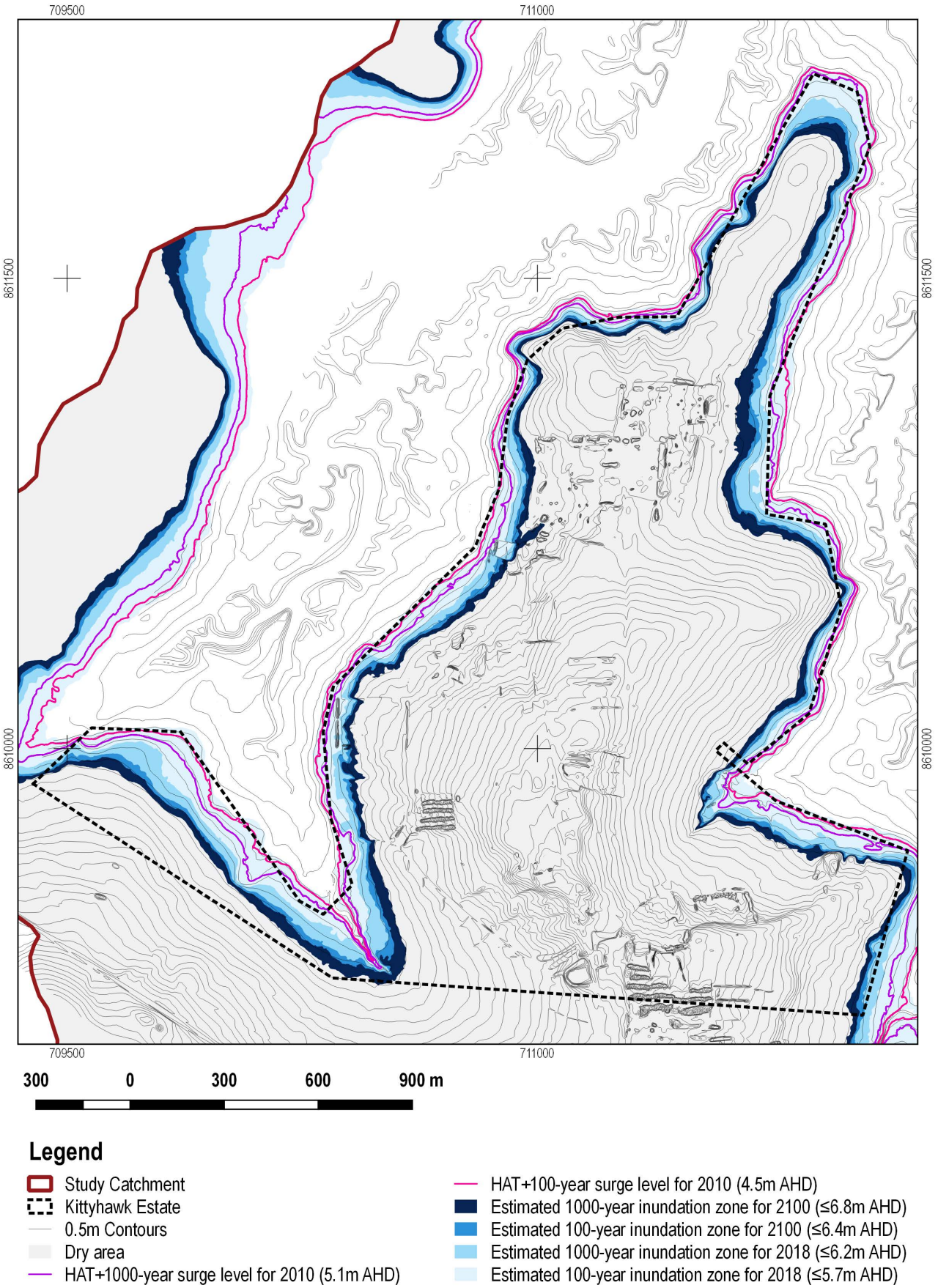


Figure 10. Map of inundation zones.

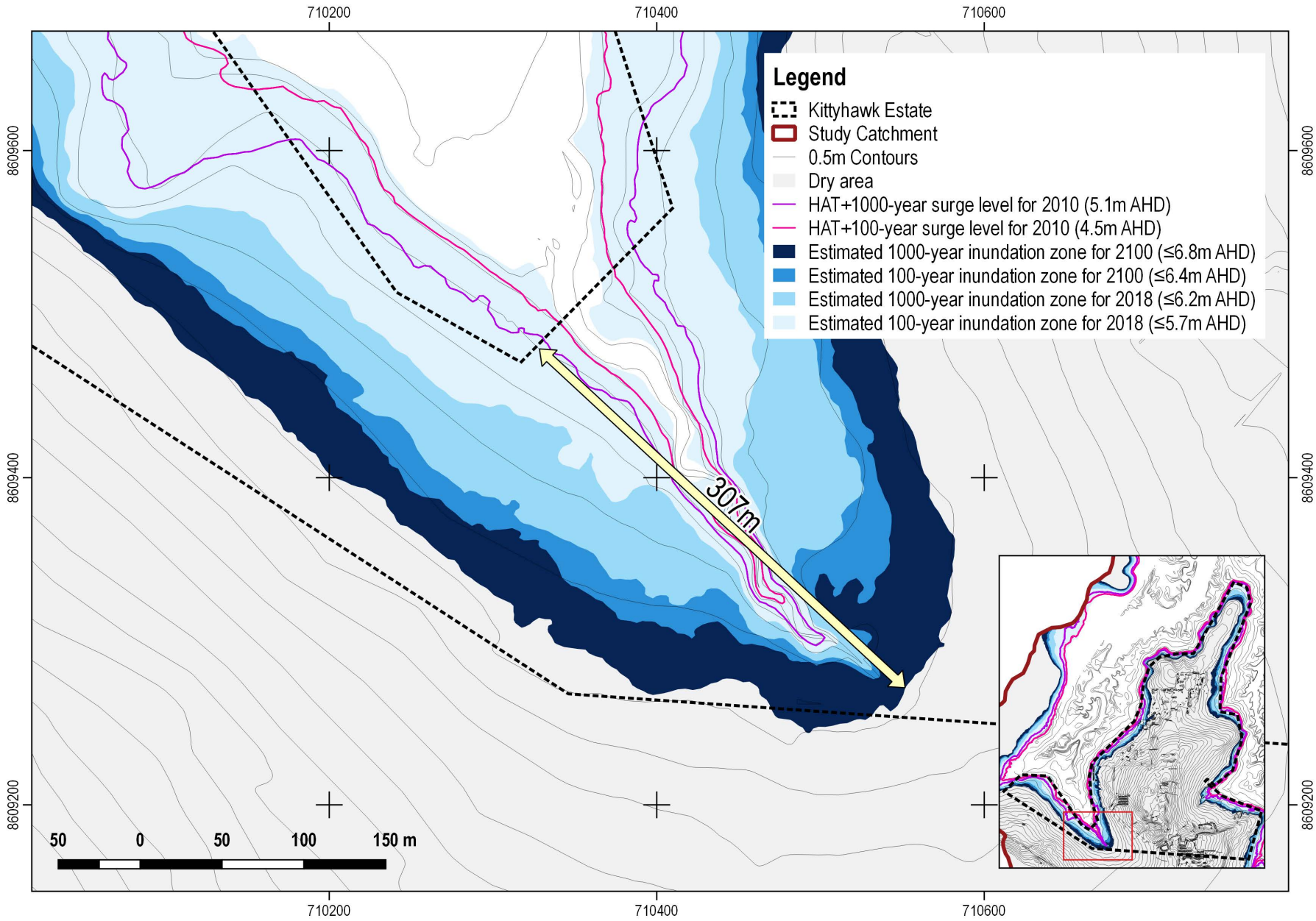


Figure 11. The maximum distance of inundation zone invading Kittyhawk Estate site area.

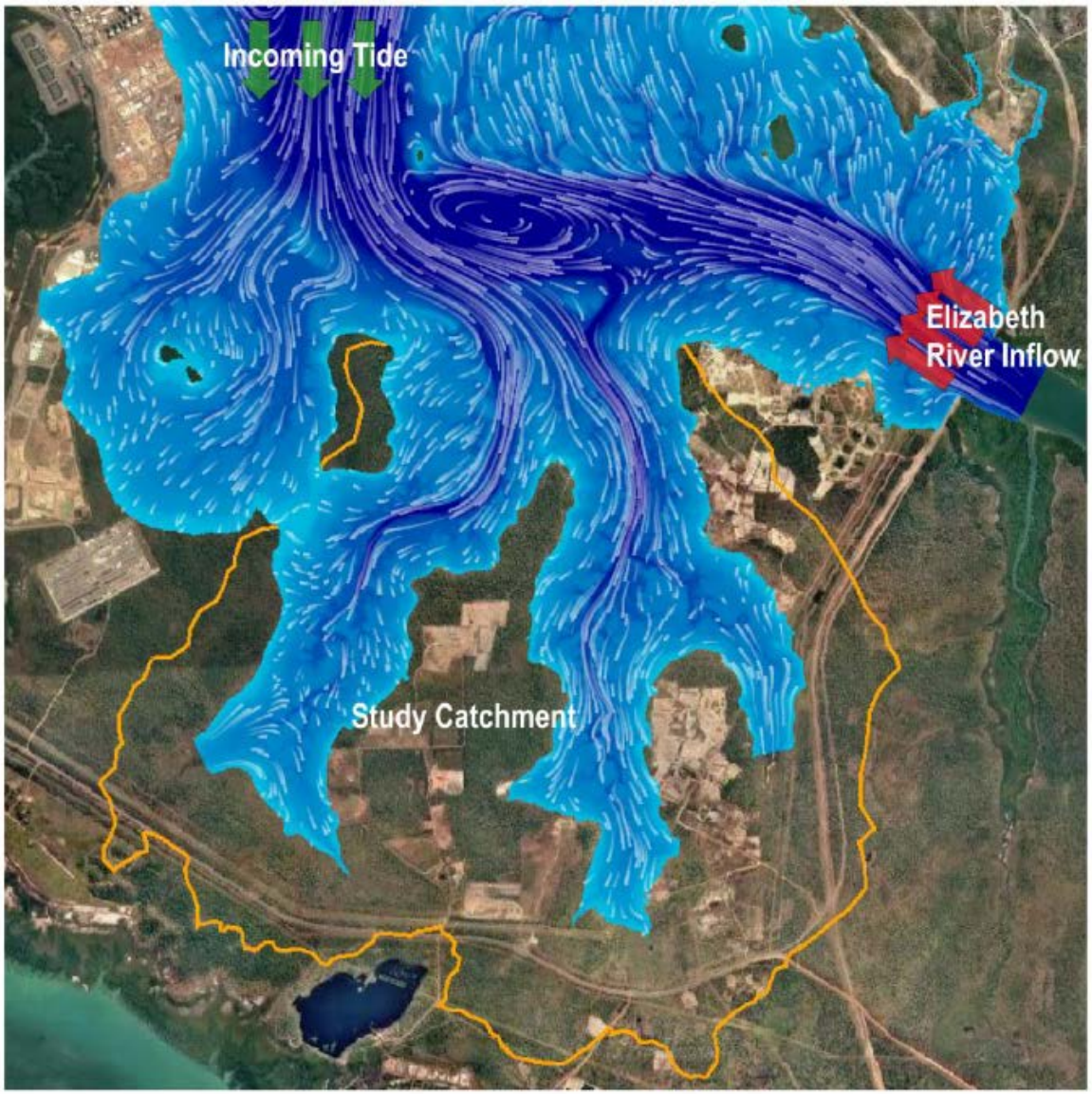


Figure 12. HEC-RAS modelling result showing velocity vectors during the rising tide and the effects of Elizabeth River input and the Kittyhawk Estate storm outflow.

4. Conclusions and Recommendations

4.1 Surface hydrology

There was favourable comparison between RFFE and RORBwin peak discharges for the Q100 storm event. Therefore, it is considered that the parameter values for RORBwin modelling are appropriate for this initial study. The total discharge from the 4 specific sub-catchments assessed is only as small percentage (9%) of the total discharge from the combined estuaries. Developing the most accurate model possible is important because hydrology simulations are the basis of the hydrodynamic inundation modelling.

4.2 Inundation extent

The 2018 Q100 storm floodwater has a considerable influence on the extent of inundation in the study catchment, increasing maximum predicted water level by up to 1.2 m higher than the 2010 Q100 NT government level of 4.5 m AHD due to water being trapped by a rising tide. It is also seen in Q1000 flood/storm event modelling result which is 1.1 m higher than the 2010 Q1000 NT government level of 5.1 m AHD. When 2100 sea level rise predictions are considered the Q100 and Q1000 maximum water level becomes 1.9 m and 1.8 m higher than the 2010 Q100 and Q1000 NT Government levels (4.5 m AHD and 5.1 m AHD respectively) Water could extend inland in the site area by up to 307 m (***Figure 11***).

The HEC-RAS model is not calibrated or validated to a measured water elevation graph or observed inundation extent due to the limitation of time of this study and data availability.

4.3 Recommendations for further analysis

Depending on the required level of certainty required in later phases of the development of Kittyhawk Estate we suggest consideration of the following:

Digital Elevation Model/Contours

The coverage of the 0.5 m contours/DEM should be extended to cover the complete area of the two estuary catchments. This will allow more accurate modelling and therefor more confidence in the inundation levels. This 1-m DEM used here is a resample of a 5-m DEM, so it is more detailed but no more accurate than the 5-m DEM. That is, the inundation levels using the resample 1-m DEM are ±5m.

Bathymetry

A bathymetric survey should be conducted to confirm water depths in the study catchments and extend the available harbour bathymetry. More detailed bathymetry can be merged with the DEM improving the accuracy of simulations. Presently the available bathymetry is 10m resolution which results in ±10m error.

Elizabeth River Effects

This initial study indicated the effects that the Elizabeth River may have on the inundation in the study catchments (***Figure 12***). The RFFE peak discharge used in this study is used as a constant discharge during the storm event period and this may over-predict inundation levels. To improve the accuracy and confidence in the simulations, the available NTG river gauging data and rainfall data for the Elizabeth

River should be used to calibrate the RORBwin and HEC-RAS models to give more confidence in the accuracy of the results. The benefit of this is that a continuous hydrograph that varies with the temporal pattern of rainfall applied can be produced giving more accurate simulation results.

The Elizabeth River comprises several catchments flowing into the main channel along its course to the mouths of the Kittyhawk Estate estuaries. These Elizabeth River sub-catchments deliver large volumes of water to East Arm increasing the flow in the river. That may have considerable influence on local inundation in the study catchments. A RORBwin model should be created for each of the sub-catchments and the probable maximum peak discharge for the Q100 and Q1000 flood events determined at the mouth of each sub-catchment where it enters the main Elizabeth River channel for inclusion in the inundation modelling.

Model Calibration to Tide Heights

The HEC-RAS 2D model should be calibrated to available Darwin Harbour tide levels. The placement of tide gauges in the study catchments would enable local calibration greatly increasing the accuracy of the inundation modelling.

Effect of very Rare Storm Events

RORBwin modelling should be conducted to determine peak flows of very rare storm events occurring at the peak of the Q100 and Q1000 tidal surges. The storm events would include 200, 500, and 2000y events (Q200, Q500, Q2000).

Contaminant and Sediment Plume Dispersion Modelling

The above work would result in a well-calibrated HEC-RAS 2D model or data that could be used to calibrate another hydrodynamic model. Such a model could be used in studies to assess sediment or contaminant plume dispersion in the estuaries that may result during the construction phase of future projects.

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RELIANCE, USES and LIMITATIONS

This study, report and analyses have been based on the information available to EnviroConsult Australia Pty Ltd at the time of preparation. EnviroConsult Australia Pty Ltd accepts responsibility for the report and its conclusions to the extent that the information was sufficient and accurate at the time of preparation. EnviroConsult Australia Pty Ltd does not take responsibility for errors and omissions due to incorrect information or information not available to at the time of preparation of the study, report or analyses.

Description	Author	Reviewer	Approved for Issue		
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Threatened Species Survey Report

Kittyhawk Estate

NT Land Development Corporation

www.ecoz.com.au

DOCUMENT CONTROL RECORD

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Author	Jenny Lewis, Stephen Reynolds, David van den Hoek and Glen Ewers

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EXECUTIVE SUMMARY

The Land Development Corporation propose developing an industrial estate on the Middle Arm Peninsula, 15 km south-east of Darwin. The area being considered constitutes two parcels of land that total 335 ha and are collectively referred to as Kittyhawk Estate.

To inform planning approvals, EcOz Environmental Consultants was engaged to undertake and report on a threatened flora and fauna species survey within Kittyhawk Estate. Twelve species were targeted using survey methodologies informed by existing guidelines and/or designed in consultation with the Flora and Fauna Division of DENR.

Camera surveys at Kittyhawk Estate confirmed the presence of one threatened fauna species – Black-footed Tree-rat (*Mesembriomys gouldii gouldii*) – in areas of intact woodland across the Kittyhawk Estate. A potential Water Mouse (*Xeromys myoides*) was detected at a site in the south of Kittyhawk Estate near a creekline. DENR undertook a follow-up targeted survey for that species in late March, with results not yet released.

Two threatened flora species were recorded – Darwin Cycad (*Cycas armstrongii*) at moderate to low densities across Kittyhawk Estate, *Typhonium praetermissum* in five patches (including one very large one) in the south and centre.

No other threatened species considered using desktop analysis as having a reasonable likelihood of occurring were detected.

TABLE OF CONTENTS

Appendices

Tables

Figures

Acknowledgements

The authors are grateful to Nick Cuff and Brydie Hill from the Flora and Fauna Division of DENR for their input into the design of flora and fauna surveys, respectively.

1 INTRODUCTION

The Land Development Corporation (LDC) propose developing an industrial estate on the Middle Arm Peninsula, 15 km south-east of Darwin – see Figure 1-1. The area being considered constitutes two parcels of land – Sections 1900 and 1902 Hundred of Ayers – see Figure 1-2. These are referred to collectively as 'Kittyhawk Estate' (hereafter Kittyhawk) and total 335 ha.

The development requires approval under the NT Planning Scheme. To inform the Development Application, EcOz Environmental Consultants (EcOz) was engaged to undertake and report on a threatened species survey within Kittyhawk.

An assessment of vegetation and habitats was undertaken as part of a pre-feasibility analysis of the project. Using that information, and in consultation with the Flora and Fauna Division of the Department of the Environment and Natural Resources (DENR), a group of terrestrial flora and fauna species was identified as a target for the threatened species survey – see Table 1-1. These species are the focus of this report. The threatened species survey was limited to the extent of Kittyhawk. Migratory and marine species were not surveyed.

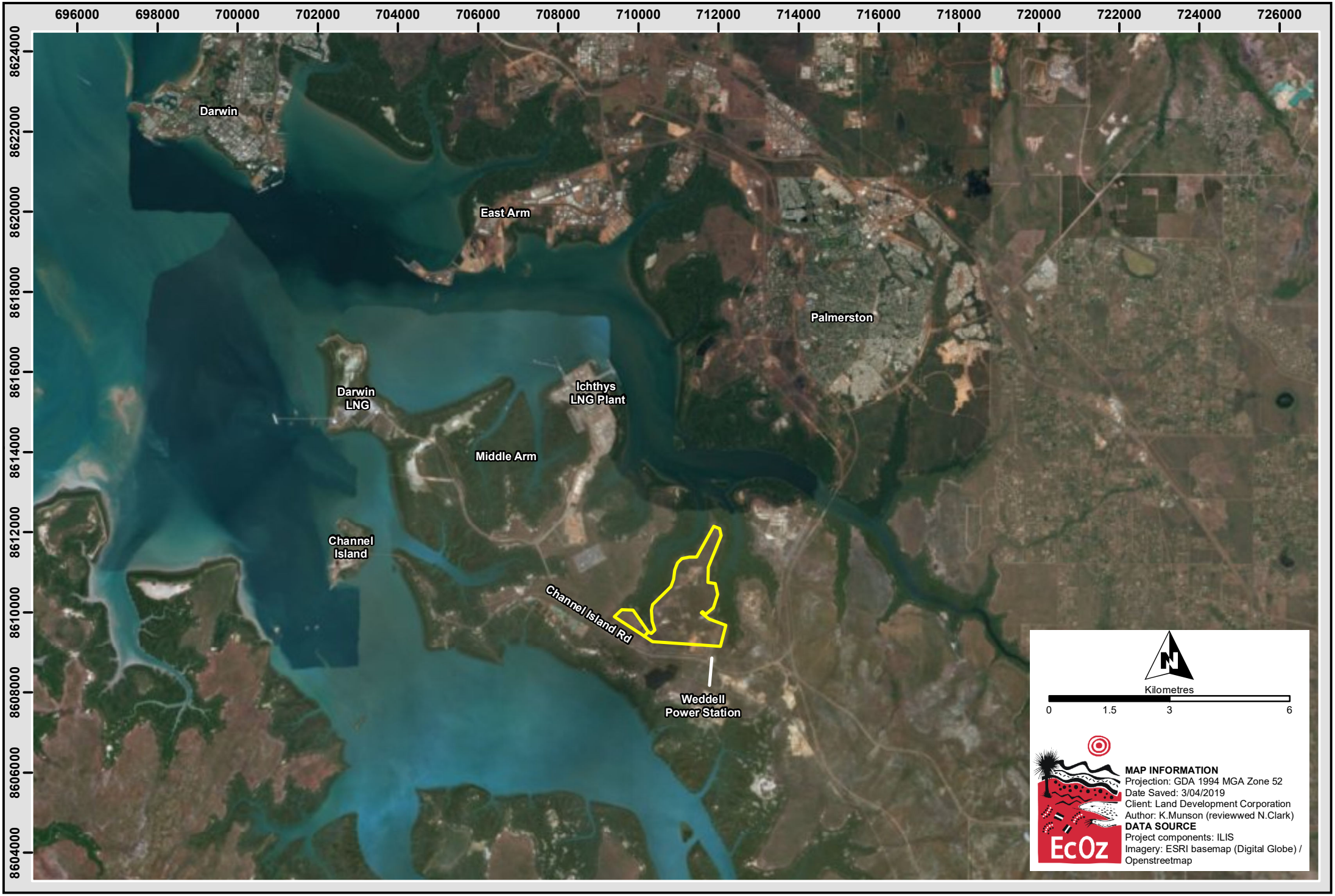
Table 1-1. Threatened species targeted

Common name	Scientific name	Group	Status[1]	
			Cwlth	NT
Masked Owl (northern subspecies)	*Tyto novaehollandiae kimberli*	Bird	VU	VU
Black-footed Tree-rat (Kimberley and mainland Northern Territory subspecies)	*Mesembriomys gouldii gouldii*	Mammal	EN	VU
Fawn Antechinus	*Antechinus bellus*		EN	VU
Pale Field-rat	*Rattus tunneyi*		-	VU
Bare-rumped Sheathtail Bat	*Saccolaimus saccolaimus nudicluniatus*		VU	-
Mertens' Water Monitor	*Varanus mertensi*	Reptile	-	VU
Mitchell's Water Monitor	*Varanus mitchelli*		-	VU
Floodplain Monitor	*Varanus panoptes*		-	VU
Howard River Toadlet	*Uperoleia daviesae*	Amphibian	-	VU
-	*Atalaya brevialata*	Plant	CE	-
Darwin Cycad	*Cycas armstrongii*		-	VU
-	*Typhonium praetermissum*		-	VU

[1] Conservation status under the Commonwealth's *Environment Protection and Biodiversity Conservation Act* (1999) and under the Northern Territory's *Territory Parks and Wildlife Conservation Act*: CE = Critically Endangered, EN = Endangered, VU = Vulnerable

This survey report presents the following:

- A desktop review of the existing environment (climate, bioregion, land types, vegetation communities and threatening processes).
- Summaries of the key ecological requirements of the threatened species targeted for surveying.
- The methods and results of targeted threatened species surveys within Kittyhawk.



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ18223 - Kittyhawk Estate Environmental Approvals\01 Project Files\Threatened species report\Figure 1 Map showing Kittyhawk Estate location.mxd

Figure 1-1. Map showing Kittyhawk Estate location

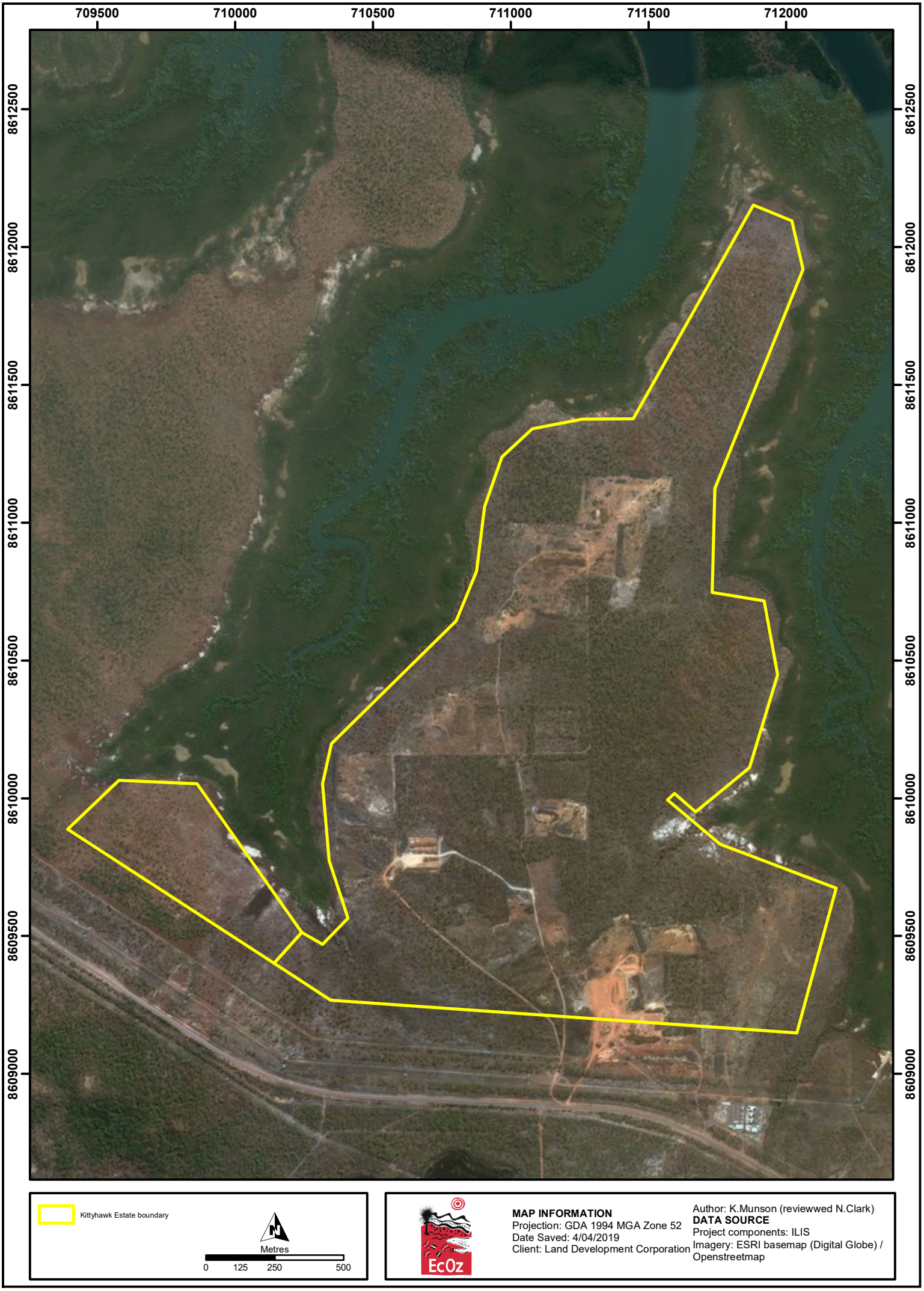


Figure 1-2. Aerial image of Kittyhawk Estate

2 ENVIRONMENTAL CONTEXT

The existing environmental values within Kittyhawk are described in this section. That information was a basis for the design of the threatened species surveys discussed in Section 4. The information for this section comes from desktop databases and reports.

2.1 Land use

Kittyhawk is located within the Middle Arm Industrial Precinct, which is bounded by the Elizabeth River to the north, Channel Island Road to the south, INPEX Ichthys Onshore LNG Facility and Darwin LNG to the west, and historic gravel extraction industries to the east.

Gravel extraction has occurred across much of Kittyhawk historically. Approximately 90 hectares (i.e. 27 %) remains significantly disturbed by that activity, with additional areas re-vegetating after historical disturbance.

2.2 Climate

The region has a tropical climate with a distinct Dry season (approximately April to October) and Wet season (November to March). The Wet season is reliable, although variable in duration and level of rainfall. Moreover, rainfall distribution is unpredictable because it is derived from thunderstorms, cyclones and monsoonal trough conditions. Humidity, maximum and minimum temperatures are typically highest in the Wet season. Annual evaporation greatly exceeds annual rainfall.

The closest long-term Bureau of Meteorology (BOM) climate station is at Channel Island (station number 014009) approximately eight kilometres west of Kittyhawk. The annual average rainfall recorded at that station is 1631 mm. The wettest months are January (405 mm average rainfall) through to March (329 mm). Temperature records taken from the Darwin Airport (station number 014015) located approximately 18 km north-west of Kittyhawk, show mean maximum temperatures range between 30.6°C in July to 33.3°C in October and November.

Prevailing wind directions are generally north-west during the Wet season, and south-east during the Dry season. The region can experience cyclones, typically between the months of November and April. BOM cyclone data portal shows that since 2000, five cyclones have passed within 50 km of Kittyhawk Estate.

2.3 Bioregion

A bioregion – of which there are 85 in Australia – is a broad area of land with largely similar climate, geology, landform, native vegetation and species (NRPPC 2009). Kittyhawk Estate occurs within the Darwin Coastal bioregion, which occupies 27,800 km^2 along the north-western coastline of the NT (Baker et al. 2005). The bioregion extends from the Fitzmaurice River where it enters Joseph Bonaparte Gulf (near the WA-NT border) to west of Cobourg Peninsula. The bioregion includes coastal and near-coastal areas and generally extends 40 to 50 kilometres inland.

The Darwin Coastal bioregion comprises gently undulating plains on lateritised Cretaceous sandstones and siltstones. Soils are primarily sandy and loamy red and yellow earths and siliceous sands, but there are also extensive areas of hydrosols (cracking clays) on floodplains and relatively shallow sandsheet areas in the Darwin hinterland.

The most notable vegetation feature is the extensive and diverse floodplain environment associated with the lower reaches of the many large river systems (e.g. the Daly River, West Alligator and East Alligator). There are also substantial areas of mangroves, patches of rainforest, and riparian vegetation fringing the rivers. Inland from the coast, the dominant vegetation type is *Eucalyptus* tall open forest, typically dominated by Darwin Woolybutt (*Eucalyptus miniata*) and Darwin Stringybark (*Eucalyptus tetrodonta*).

2.4 Surface water

Kittyhawk lies within the Finniss River catchment. There are minor drainages within Kittyhawk, with one on the eastern border and one in the south-west. These flow during the Wet season and are reduced to remnant pools in the Dry season. Surface moisture also exists in seepage areas at the interface between upland savanna habitats and the landward margin of the mangroves in the Wet season, and in the upper portions of drainages.

2.5 Significant areas

The NT Government has identified Sites of Conservation Significance (SOCS) – the most important sites for biodiversity conservation for the NT. These are described in Harrison et al. (2009). Kittyhawk occurs within the Darwin Harbour SOCS, which is considered to be of International Significance. The large indented embayment supports a range of estuarine, freshwater and terrestrial environments, including 5% of the NT's entire mangrove area. Mangrove habitats are discussed further in Section 0.

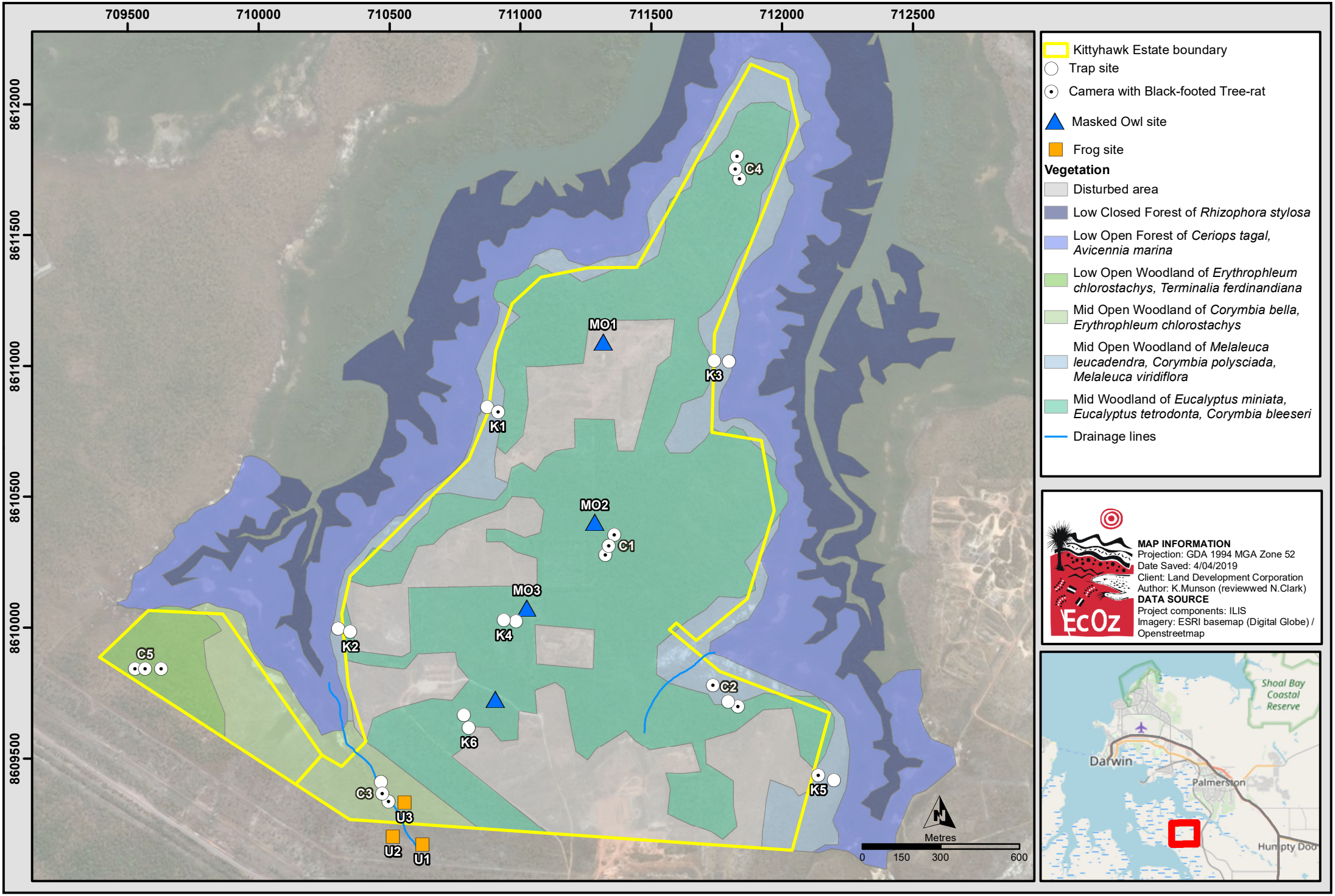
2.6 Vegetation

2.6.1 General

Vegetation mapping was undertaken by EcOz in 2018 – see Figure 2-1. In addition to heavily disturbed / cleared areas, there are four main vegetation types occurring within Kittyhawk – see Table 2-1.

Table 2-1. Vegetation communities within Kittyhawk

Description	Area (ha)	Proportion of Kittyhawk
Mid woodland of *Eucalyptus miniata, Eucalyptus tetrodonta, Corymbia bleeseri* over *Livistona humilis, Cycas armstrongii, Erythrophleum chlorostachys* over tussock grassland of *Heteropogon triticeus, Sorghum intrans, Chrysopogon fallax*.	181.0	54%
Low open woodland of *Erythrophleum chlorostachys, Terminalia ferdinandiana* over *Lophostemon lactifluus, Corymbia polysciada, Pandanus spiralis* over tussock grassland of *Themeda triandra, Chrysopogon fallax*.	12.2	4%
Mid open woodland of *Corymbia bella, Erythrophleum chlorostachys* over *Planchonia careya, Pandanus spiralis, Vitex glabrata* over closed tussock grassland of *Heteropogon triticeus, Germainia grandiflora, Themeda triandra*	23.9	7%
Mid open woodland of *Melaleuca leucadendra, Corymbia polysciada, Melaleuca viridiflora* over *Melaleuca viridiflora, Pandanus spiralis, Planchonia careya* over closed tussock grassland of *Germainia grandiflora, Themeda triandra, Dapsilanthus* sp.	27.5	8%
Disturbed	90.8	27%



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ18223 - Kittyhawk Estate Environmental Approvals\01 Project Files\Threatened species report\Figure 2 Map showing Kittyhawk Estate vegetation and fauna survey locations.mxd

Figure 2-1. Map showing the vegetation types and fauna survey locations within Kittyhawk Estate

2.6.2 Sensitive and significant vegetation

In the NT, sensitive vegetation types are those considered significant under the *Land Clearing Guidelines* (DNRETAS 2010) due to their unique and/or inherently high biodiversity values. They are rainforest, vine thicket, closed forest or riparian vegetation, mangroves, monsoon vine forest, sand sheet heath and vegetation containing large trees with hollows suitable for fauna. These vegetation types are unique to the NT and/or have inherently high biodiversity values.

Large hollow-bearing trees occur within Kittyhawk. Tree hollows provide valuable habitat for fauna. In the NT, a *Eucalypt* forest that has trees with five or more *Eucalypt* stems greater than 50 cm in diameter at breast height (dbh) per hectare, and/or 30 or more *Eucalypt* stems greater than 40 cm dbh per hectare is considered to be of high value for biodiversity (DNRETAS 2010). The latter grouping occurs within the *Eucalyptus miniata / E. tetrodonta / Corymbia bleeseri* woodland in the centre of Kittyhawk. There are also small stands of large hollow-bearing trees scattered across the site.

Riparian vegetation is 'a distinct forest community occurring on the banks of rivers or streams that directly influences the adjacent water body' (DENR 2018a). When in good condition, riparian vegetation is considered a sensitive vegetation type as it supports a unique selection of habitat features that may be relied upon by a range of flora and fauna species. The small ephemeral creek in the south-west of Kittyhawk Estate (Figure 2-1) contains some riparian species, but it does not constitute a distinct riparian vegetation community (Figure 2-2).

The upper coastal borders of Kittyhawk are adjacent to the landward margin of mangrove vegetation. This vegetation type contains unique and highly specialised animals and plants, including many species restricted to these environments (DENR 2018b). However, there are no mangroves within Kittyhawk.

Figure 2-2. Photograph of riparian vegetation in the south-west of Kittyhawk Estate

2.7 Past surveys

Two previous fauna surveys have included sites within Kittyhawk:

- In mid 2001, at least two sites of a regional fauna survey undertaken by the then Biodiversity Unit of the NT Government were located within Kittyhawk. One in the centre of Kittyhawk recorded Fawn Antechinus (*Antechinus bellus*); one on the southern boundary recorded Fawn Antechinus and Black-footed Tree-rat (*Mesembriomys gouldii gouldii*).
- In early 2014, Stokeld and Gillespie (2015) surveyed for small mammals across the Darwin region using cameras and traps. There were three survey sites on Middle Arm, including one in the centre-south of Kittyhawk. At the site further to the west of Kittyhawk, Black-footed Tree-rat and Pale Field-rat (*Rattus tunneyi*) were both recorded. Within Kittyhawk, however, no threatened mammals were detected.

2.8 Existing threatening processes

There are a number of threatening processes to biodiversity as a consequence of human presence in the region.

2.8.1 Fire

Fires are a regular occurrence in the bioregion. Using regional fire history and fire scar mapping obtained through the Northern Australia and Rangelands Fire Information website, an analysis of fire history in Kittyhawk shows it experienced frequent fire activity between 2000 and 2017, with fires more frequent in the southern areas (see Figure 2-3). Most areas burnt at least 5 to 8 times in that period. A small area in the north has not been burnt since 2008.

In very early January 2019, a fire was deliberately lit in the south and centre of Kittyhawk in order to clear undergrowth and facilitate access for land surveyors. The approximate extent of that fire was 230 ha, as shown on Figure 2-3.

Late Dry season fires are typically hotter than those occurring earlier in the Dry season. They are often anthropogenic in origin and their effect on native flora and fauna is usually more detrimental because of their higher intensity. The majority of Kittyhawk has only experienced one late burn since 2008, but there have been two in the southern region and three in a small patch in the south-west.

2.8.2 Weeds

Some species of introduced flora are declared to be weeds under the NT *Weeds Management Act* because of the harm they can cause. The Commonwealth Government has also categorised some species as Weeds of National Significance (WoNS), and the NT Weed Management Branch has identified priority weed species based on their high risk specific to the Darwin region. Class A weeds are to be eradicated by land owners and occupiers. Class B weeds must have their growth and spread controlled by land owners and occupiers. The remaining introduced flora species are referred to as *environmental weeds*.

Two declared weeds have been recorded within Kittyhawk):

- Gamba Grass (*Andropogon gayanus*) – a Class A weed and WoNS, this was the most common weed, observed within disturbed areas across Kittyhawk. Gamba Grass is able to form very dense thickets, which dramatically alter the structure of native communities and decrease biodiversity (NTG 2018). It also threatens native vegetation as it can rapidly grow bigger and taller than native grasses, and creates high fuel loads that promote late and intense fires. Such fires are capable of killing most trees, even fire-tolerant Eucalypts.

- Perennial Mission Grass (*Cenchrus polystachios*) – a Class B weed occurring in scattered patches within disturbed areas.

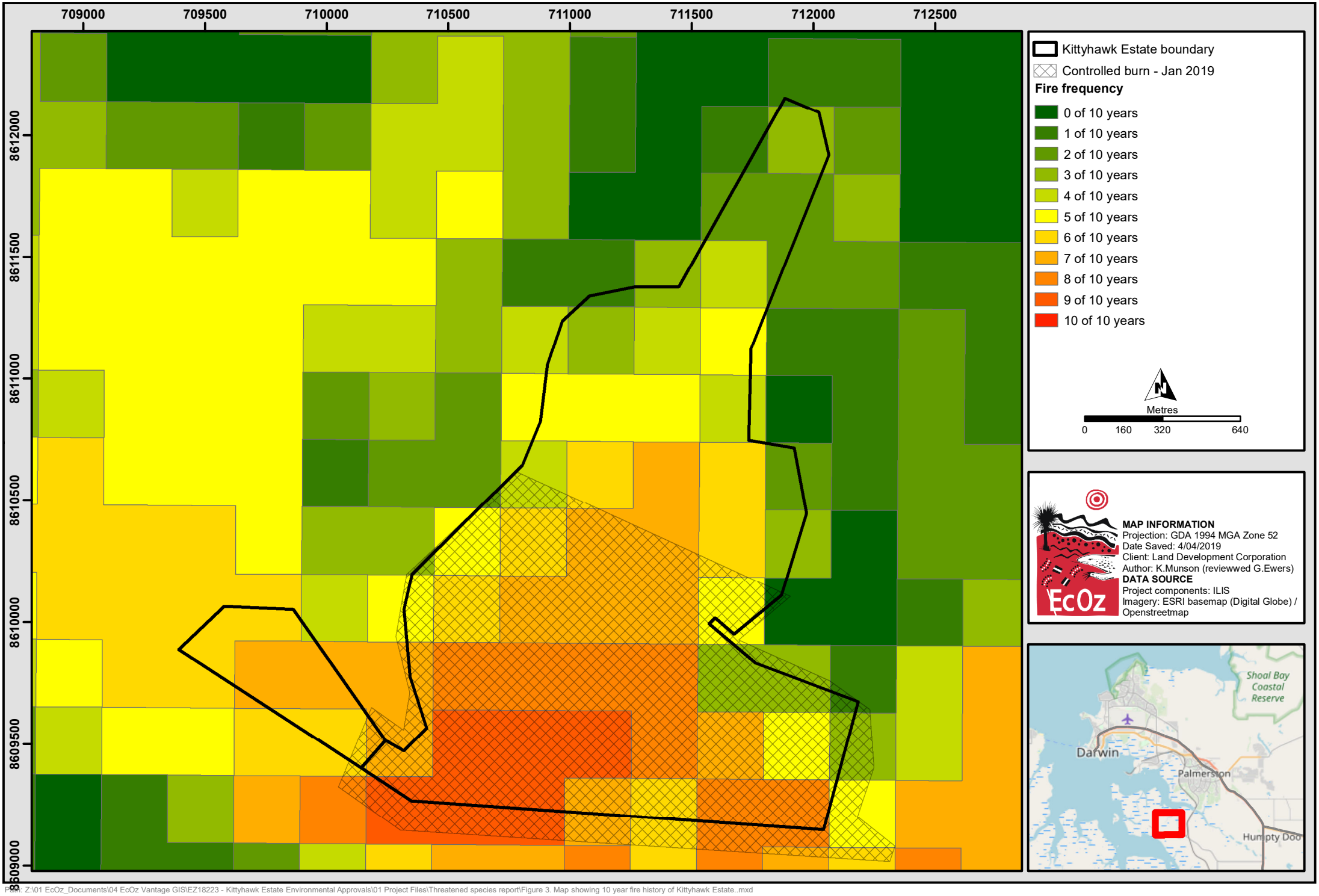
There are also environmental weeds present, most notably Wild Passionfruit (*Passiflora foetida*) along the edges of disturbed areas.

2.8.3 Introduced fauna

The introduced fauna species listed in Table 2-2 are those considered by the authors to be most likely to occur within Kittyhawk. Cane Toads, Feral Cats and Feral Pigs are each listed as a Key Threatening Process under the *EPBC Act*.

Table 2-2. Introduced fauna likely to occur within the project footprint

Common name	Scientific name	Impacts
Wild Dog	*Canis lupus*	Prey on many species of native animals
Feral Cat	*Felis catus*	
Feral Pig	*Sus scrofa*	Physical damage to wetlands
Black Rat	*Rattus rattus*	Compete with native species
Cane Toad	*Rhinella marina*	Population reductions in a range of predatory species (due to poisoning by ingestion)



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ18223 - Kittyhawk Estate Environmental Approvals\01 Project Files\Threatened species report\Figure 3. Map showing 10 year fire history of Kittyhawk Estate..mxd

Figure 2-3. Map showing 10 year fire history of Kittyhawk Estate

3 OVERVIEW OF TARGETED THREATENED SPECIES

This section presents the key ecological requirements of the threatened species identified as having a reasonable likelihood of occurring in Kittyhawk. The conservation status of each of these species is presented in Table 1-1

3.1.1 Mammals

Black-footed Tree-rat

The Kimberley and mainland NT subspecies of Black-footed Tree-rat (*Mesembriomys gouldii gouldii*) is a medium-sized nocturnal rodent that dens mostly in tree hollows, and feeds primarily on fruits and seeds. The species occurs mostly in woodlands and open forests with large trees and a moderately diverse mid-storey in near-coastal areas, but was previously more widespread. The Black-footed Tree-rat generally requires fruit and seed resources – including Pandanus fruits, and fruiting trees and shrubs (Rankmore 2006). The subspecies is thought to be more prevalent in woodlands with infrequent and low intensity fires (Price et al. 2005).

Once found across the north of the Kimberley across to the coast of Gulf of Carpentaria, the range is now contracted to areas near Darwin, south to Litchfield National Park, and around Kakadu National Park (Woinarski et al. 2014). As discussed in Section 2.7, there are records of this species within Kittyhawk and to the west.

The Black-footed Tree-rat has undergone a marked decline in range and abundance, with over 50% of the population estimated to have declined over the last decade (Woinarski et al. 2014).

Fawn Antechinus

The Fawn Antechinus (*Antechinus bellus*) is a small partly-arboreal carnivorous mammal that nests in tree hollows and fallen logs, and feeds mostly on insects. The species has a life history pattern characteristic of the genus, which involves a highly synchronised mating period, following which all males die (Friend 1985). The species primarily occurs in open forests and woodlands dominated by *Eucalyptus miniata* and/or *E. tetrodonta*, particularly where these forests have a relatively dense shrubby understorey (Friend 1985; Friend & Taylor 1985). Fawn Antechinus decline in areas with frequent intense fires (Corbett et al. 2003), but are not necessarily common in areas where fire has been excluded for long periods (>20 years) (Woinarski et al. 2004).

As discussed in Section 2.7, there are records of this species within Kittyhawk from 2001. There are also nearby records from 2001 to the east. The limits of its range are poorly known, but it is suggested that there has been a range contraction as recent surveys have failed to locate any individuals across central and east Arnhem Land (referenced in Woinarski et al. 2014), where it was historically known to occur.

Pale Field-rat

Pale Field-rat (*Rattus tunneyi*) is a medium-sized rodent that was once a widespread species in the Top End (Lewis 2014). Historically, this species occurred in lowland Eucalyptus open forests and grasslands that have sandy surface soil characteristics, but the Pale Field-rat is now recorded primarily in dense vegetation along creeks (Aplin et al. 2008). An area's fire regime seems to have little effect on population numbers (Braithwaite & Griffiths 1996); instead, the level of groundwater irrigating the riparian system and, to a lesser extent, current rainfall have a much stronger influence (Braithwaite & Griffiths 1996). Due to a combination of threats, the overall population of the species is estimated to have declined by up to 30% in the past ten years (Woinarski et al 2014).

As discussed in Section 2.7, there are records of this species to the west of Kittyhawk from 2014, as well as from 2001.

Bare-rumped Sheathtail Bat

Bare-rumped Sheathtail Bat (*Saccolaimus saccolaimus nudicluniatus*) is a large insectivorous bat that occurs in north-eastern Queensland and in the monsoonal tropics of the NT. There have been relatively few records of the species across this wide distribution, which suggest either that the subspecies is rare, that it has a fragmented distribution or that records may also have been confused with closely-related species (TSSC 2016). In the NT, specimens have been collected from Pandanus woodland fringing the sedgelands of the South Alligator River and Eucalyptus tall open forests (Friend & Braithwaite 1986; Churchill 1998) with more recent records from Howard Springs (Milne et al. 2009). Most records occur within near-coastal habitats with one recent exception (Jasper Gorge) 150 km inland (Woinarski et al. 2014). The species forages above the canopy and roosts in deep tree hollows within *Eucalyptus miniata, E. tetrodonta* and *Melaleuca leucadendra* (Churchill 1998). Hollows in these tree species have also been used as breeding roosts (Churchill 1998). The most severe threat to Bare-rumped Sheathtail Bats is habitat loss and fragmentation – in particular the loss of roost trees (Woinarski et al. 2014).

There are very records of this species in the greater Darwin region, and none from Middle Arm.

3.1.2 Reptiles

Water Monitors

Mitchell's Water Monitor (*Varanus mitchelli*) and Mertens' Water Monitor (*Varanus mertensi*) are medium to large-sized semi-aquatic lizards, seldom seen far from water. Both species are typically observed basking on rocks, logs or branches over-hanging rivers, swamps and lagoons throughout its broad range. They occupy both coastal and inlands waters across much of far northern Australia (Christian 2004a & 2004b), and have been recorded in most of the Top End river systems (Ward et al. 2006, Ward 2012). All local populations of these species have experienced significant declines when Cane Toads have invaded because this genus is susceptible to poisoning due to ingestion of the toxic toads.

There are no records of either species of water monitor from Middle Arm, with the nearest records south of the Weddell site.

Floodplain Monitor

The Floodplain Monitor (*Varanus panoptes*) is a large (up to 1.4 m) terrestrial monitor, and is the only threatened reptile species likely to occur within Kittyhawk. The species feeds primarily on small terrestrial vertebrates and insects, and lays a clutch of eggs in a burrow, usually in the Wet season (Ward et al. 2012). The species once occupied a variety of habitats, including coastal beaches, floodplains, grasslands and woodlands, across the extent of northern Australia. However, its propensity to eat Cane Toads and die from the ingested toxins has caused a significant decline in the population. There are local populations at East Point and in Casuarina Coastal Reserve which may persist because they are largely buffered from Cane Toads by both development and salty coastal environments.

3.1.3 Birds

The northern subspecies of Masked Owl (*Tyto novaehollandiae kimberli*) is an owl in the genus Tyto. Such owls have a prominent heart-shaped facial disk. Little is known about the distribution of the northern subspecies of Masked Owl. There are only 100 records for the Northern Territory – mostly on the Cobourg Peninsula; but also Kakadu, Groote Eylandt and scattered across the Top End. There are very few recent records for the greater Darwin region.

The northern subspecies of Masked Owl occurs mainly in Eucalyptus tall open forests (especially those dominated by *E. miniata* and *E. tetrodonta*), but also roosts in monsoon rainforests and forages in more open

vegetation types, including grasslands (Woinarski & Ward 2012). The subspecies usually nests in tree hollows within patches of closed forest (Garnett et al. 2011). DLRM (2010) notes that the subspecies is most vocal in the lead-up to nesting (typically the early Dry season). Additional relevant information from Debus (2009) – who describes the species in general – is that Masked Owls are resident in pairs within a territory up to 3,000 hectares. The species nests in large hollows with an entrance more than 20 cm wide between 10 and 45 m above the ground.

3.1.4 Amphibians

The Howard River Toadlet (*Uperoleia daviesae*) is endemic to sandsheet-type habitats in the Darwin region. The species is patchily distributed within sandsheet areas where it occurs in gently sloping seasonally inundated sites that contain shallow seepage areas, often with small mounds (EcOz 2013; Fisher et al. 2011). Breeding habitat generally overlies laterite, which is relatively impermeable and thus results in pooling of (shallow) water at the surface. The species was only formally described in 2005 (Young et al. 2005), and is the only listed threatened frog species in the NT.

The species has been recorded at sites adjacent to the Howard River and Elizabeth River, but also near Sunday Creek and Scrubby Creek, and in the Weddell area.

3.1.5 Flora

Darwin Cycad

Darwin Cycad (*Cycas armstrongii*) is a medium-sized cycad growing up to 6 m in height. This species is endemic to the NT, and is common and widespread in the Darwin region. 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). The species occurs in open grassy woodlands where adequate draining appears to be a limiting factor (Kerrigan et al. 2006). It also occurs 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 *E. miniata* and *E. tetrodonta* (Liddle 2009).

Atalaya brevialata

Atalaya brevialata is a sub-shrub growing to 45 cm which is woody at the base but has herbaceous aerial parts (Cowie 2014). The species occurs on (deeper) sandy areas overtopped with gravel on the edge of drainage areas near the Elizabeth River at Virginia, and its tributary – Amy's Creek (Cowie 2014). *A. brevialata* is endemic to the Darwin region and has a highly-restricted distribution, occurring mostly along a specific, distinct geological boundary. Suitable habitat is often associated with a narrow band upslope of sandy, poorly drained flats dominated by the small tree *Grevillea pteridifolia* and the rush-like herbaceous plant *Dapsilanthus spathaceus.*

Typhonium praetermissum

The ecology and distribution of *Typhonium praetermissum* is detailed in a separate report presented in Appendix A.

4 SURVEY METHODS

This section presents and justifies the survey methods used to target different groups or species. All surveys were performed under Parks and Wildlife permit # 62714 and Animal Ethics Committee permit approval #A12005.

4.1 Non-volant mammals

Non-volant mammals (i.e. mammals which cannot fly) were surveyed using remote motion-sensor camera traps. Camera trap methodology used in this survey was based on the draft *Camera Trapping Standing Operating Procedure for the Top End Long-Term Monitoring Program* developed by Flora and Fauna Division of DENR.

Installation of cameras was led by Jenny Lewis (who has many years of experience using camera traps, including with the Australian Wildlife Conservancy) and Glen Ewers (who has extensive experience deploying camera traps in the greater Darwin region at sites such as Noonamah Ridge, East Point, Lee Point and Darwin International Airport).

There were two rounds of camera trapping. Kittyhawk is fragmented because of historic gravel extraction activity. The initial round of camera trapping was designed to optimise the detection of threatened species of small mammals within the biggest patches of remnant vegetation. Those cameras were checked after the first few weeks of deployment and it was learnt that Black-footed Tree-rat had been detected at all five sites (see Section 5.1 for more detail). Therefore, to gain an understanding of how the local population of that species may move within Kittyhawk, a second round of camera trapping was undertaken with a focus on potential habitat corridors. This round also surveyed for the species in habitat surrounding Kittyhawk; the results of which are presented in a separate report. Henceforth, the first round of trapping is referred to as *initial*; the second round as *corridor*.

Site locations

Note: A representative photograph showing the habitat within each camera site is presented in Appendix E.

Initial

In consultation with DENR, cameras were initially deployed across five sites. Site locations were selected based on the vegetation communities considered most likely to provide habitat for small mammals – with two sites in the most extensive vegetation type (mid *Eucalyptus / Corymbia* woodland) and a single site in each of the others. These are mapped in Figure 2-1. Within each vegetation types, some sites were selected in eco-tones to maximise the probability of detecting a variety of species:

- Site C1 was positioned within mid *Eucalyptus / Corymbia* woodland.
- Site C2 was positioned along an ecotone between mid open *Melaleuca / Corymbia* woodland and a low-lying coastal area.
- Site C3 was positioned adjacent to a creek within mid open *Corymbia / Erythrophleum* woodland in the south-west of Kittyhawk. This site was burnt in early January.
- Site C4 was positioned in mid *Eucalyptus / Corymbia* woodland in the area in the north of Kittyhawk that has a low fire frequency.
- Site C5 was positioned in low open woodland of *Erythrophleum chlorostachys / Terminalia ferdinandiana.*

Site selection was also tailored to maximise geographical spread across Kittyhawk.

Corridors

The second round of camera trapping on Kittyhawk involved six sites. The selection of those sites was based on the links they formed between the initial sites. Each site comprised of two cameras approximately 50 m apart. Where relevant, one of those cameras was placed in the 'best quality' habitat within the site and, for comparison, the other in adjacent habitat not normally considered that preferred by Black-footed Tree-rats. Given the species appears to be widespread and locally-common, the second round of survey presented a good opportunity to determine the degree to which the species may utilise non-optimal habitat.

The six sites are shown in Figure 2-1 and can be grouped thus:

- Two sites were placed within the narrow corridor of remnant woodland that forms the western boundary of Kittyhawk, and joins habitat in the north (Site C4) to that in the south (Site C3):
    - Site K1 was positioned on the north-western edge of Kittyhawk in an approximately 150 m wide corridor of remnant woodland. One camera was located in a narrow stretch of grassland with sparse Melaleuca adjacent to mangroves, the other camera on the ecotone between mid open Melaleuca / Corymbia woodland and mid Eucalyptus / Corymbia woodland.
    - Site K2 was positioned on the western edge of Kittyhawk in an approximately 220 m wide corridor of remnant woodland. One camera was located in a narrow stretch of grassland with sparse Melaleuca adjacent to mangroves, the other camera on the ecotone between th mid open Melaleuca / Corymbia woodland and mid Eucalyptus / Corymbia woodland.
- One site was placed along the eastern boundary of Kittyhawk joining habitat in the north (Site C4) to that in centre-east (Site C1):
    - Site K3 was positioned on the north-eastern edge of Kittyhawk in an approximately 150 m wide corridor of remnant woodland. One camera was located in a narrow stretch of grassland with sparse Melaleuca adjacent to mangroves, the other camera in mid Eucalyptus / Corymbia woodland with a quite dense ground story of grasses, vines and shrubs.
- Two sites were placed in the centre of Kittyhawk linking habitat in the centre-east (Site C1) with that in the south (Site C3). This area was burnt in early January, and so was not considered in the initial round of camera trapping because of the very sparse mid-storey.
    - Site K4 was positioned within the mid Eucalyptus / Corymbia woodland patch that was found to support a large population of the threatened plant species – *Typhonium praetermissum* (see Section 5.6.3).
    - Site K6 was also positioned within the mid Eucalyptus / Corymbia woodland, to the south-west of Site K7.
- The final site was placed at the south-easternmost point of Kittyhawk joining Site C2 with any potential offsite habitat to east:
    - Site K5 was positioned in an approximately 130 m wide corridor of remnant woodland. One camera was located in a narrow stretch of grassland with sparse Melaleuca adjacent to mangroves, the other camera on the ecotone between mid open Melaleuca / Corymbia woodland and mid Eucalyptus / Corymbia woodland.

Site design

Initial

Each site had three cameras (Reconyx HP2W) set in a linear arrangement over approximately 100 m, with a minimum of 30 m between each camera. There was a vertically-set camera at each end, and a horizontally-set camera overlooking a cork board (to create a more homogenous temperature zone, and therefore more

temperature contrast, to improve detectability of small mammals in hot environments – see Figure 4-1 and Figure 4-2).

Camera traps were baited using a mix of peanut butter and oats in a canister positioned within the camera field of view. A drift fence was set in front of the horizontally-set cameras (4m on either side) to further corral small mammals toward the corkboard and bait.

Corridors

Each site had two cameras (KeepGuard KG690) approximately 50 apart, each deployed in the same manner as the vertical cameras were in the initial survey, with the same bait mix. This alternative methodology was employed in consultation with DENR, with EcOz presenting data to DENR showing how had that camera set-up and model had previously been successful in detecting Black-footed Tree-rats at Lee Point and Cyrus Road.

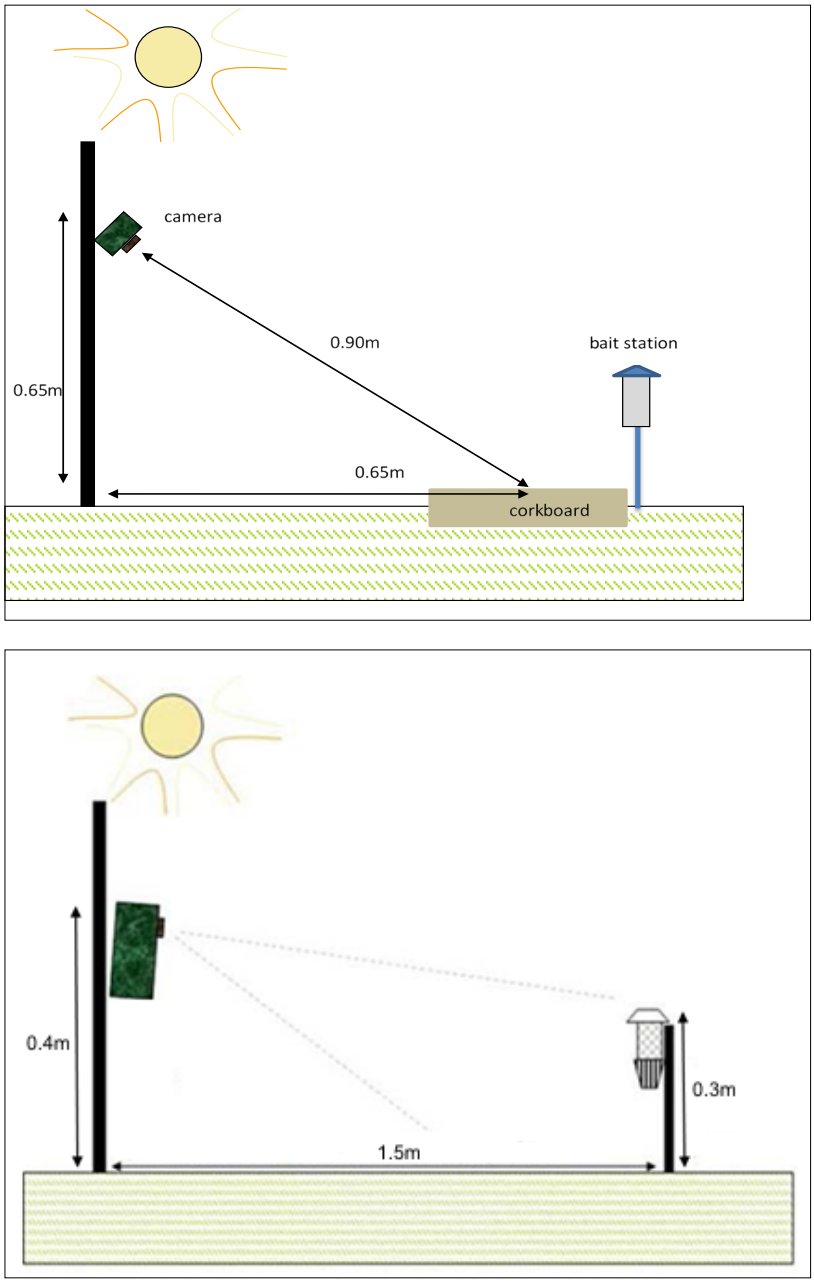


Figure 4-1. Diagrams of camera set-up (top: horizontal camera; right: vertical camera)

Camera programming and field deployment

Initial

Cameras were programmed and deployed in accordance with the DENR *Standing Operating Procedure*. They were deployed for 35 nights, from 17 January to 21 February 2019.

Corridors

Cameras were set to a high sensitivity and to take three photographs (with 1 second interval) per trigger, with a 10 second interval between triggers. They were deployed for 22 nights, from 7 to 28 March 2019.

Figure 4-2. Photographs of exemplar camera set-ups at Site C1 (left: horizontal camera; right: vertical camera)

4.2 Volant mammals

Bat calls were recorded using Wildlife Acoustics SM2BAT+ detectors and Titley Scientific AnaBat Swift detectors, deployed as follows:

- Site C1 – Swift 450057
- Site C2 – Swift 449958
- Site C3 – SM2BAT 11363
- Site C4 – SM2BAT 11085
- Site C5 – Swift 450083

Each bat site corresponded to the centre camera of each camera trap site, in order to maximise geographical coverage of Kittyhawk.

The bat detectors were deployed for 6 to 7 nights, giving a combined effort of 32 trap nights. The detectors were attached to tree trunks approximately 1.5 m above ground, and set to automatically record between sunset and sunrise. Kyle Armstrong (Specialised Zoological) was contracted to analyse the acoustic recordings – methods are described in Appendix C.