Report on potential impacts from disturbance to migratory shorebirds in Darwin:

Defence Housing Australia –
Lee Point Master-planned Urban Development

January 2017

Report to EcOz Environmental Consultants

Amanda Lilleyman
Consultant Ornithologist

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Amanda Lilleyman
Consultant Ornithologist
ABN 52948604732

Suggested citation:

Lilleyman, A. (2016). Report on potential impacts from disturbance to migratory shorebirds in Darwin: Defence Housing Australia – Lee Point Master-planned Urban Development. Report to EcOz Environmental Consultants, Darwin, September 2016.

EXECUTIVE SUMMARY

The Defence Housing Australia (DHA) Lee Point Master-planned Urban Development has the potential to impact migratory shorebirds through increased human access to the important roosting and feeding site Sandy Creek, on the northern beaches of Darwin, Northern Territory. There is the possibility that impacts of increased anthropogenic disturbance (due to a significant increase in the number of beach users) from this housing development will be significant and potentially harm the population of migratory shorebirds. This site is classified as nationally important and supports populations of migratory shorebirds listed under the *Environment Protection and Biodiversity Conservation Act 1999*. It also supports internationally important numbers of the Critically Endangered Great Knot.

This report provides information on the importance of habitat used by migratory shorebirds in Darwin and the numbers of birds and species present in the region. Ways to mitigate potential impacts are suggested, along with management recommendations. These recommendations include a monthly monitoring program conducted in the austral summer months when birds are present; community engagement activities; information about migratory shorebirds on community notice boards; and educational signs along boardwalks and at each beach entry access path.

While the proposed housing development will not lead to a direct loss of habitat for shorebirds, the proponent should consider that this development activity will have other negative effects on the shorebird population, and these combined with past and future habitat loss in the greater Darwin region will work synergistically to deplete the quality of habitat for shorebirds. Given the rapid decline in populations of migratory shorebirds that visit Australia, it is essential that all important non-breeding sites are protected to conserve shorebirds. If these significant impacts remain unchecked, there is grave concern that the impacts of increased visitation to beaches from the DHA housing development will only exacerbate the decline of species.

CONTENTS

1. Introduction

1.1. Migratory shorebird ecology

Most shorebirds in Australia are long-distance migrants that breed in the northern hemisphere and visit Australian shores in their thousands in the austral summer. Their annual migration is determined by the phenology of food availability, reproduction and individual survival. Australia is part of the East Asian-Australasian Flyway (EAAF) for migratory shorebirds (**Figure 1**). On arrival in Australia, shorebirds spend the duration of the austral summer seeking out high-quality food resources on the intertidal zone of coastlines. Tidal cycles dictate foraging and roosting times for most coastal shorebirds that feed on benthic macroinvertebrates on exposed mudflats during low tide. At high tide, when the foraging grounds are submerged, shorebirds retreat to roosts on sandy beaches, mangroves, rocky reefs and ponds, where they typically rest. Roost sites are usually selected for their proximity to feeding grounds to allow for a short commute time, good visibility of potential predators, for thermoneutrality (shallow water to help cool birds down in tropical environments), tide height, and disturbance levels (Rogers *et al.* 2006; Rosa *et al.* 2006; Zharikov and Milton 2009).

Figure 1. The East Asian-Australasian Flyway for migratory shorebirds. Image credit: http://www.roebuckbay.org.au/our-bay/migratory-shorebirds/

Migratory shorebirds use a network of sites in a region for roosting and feeding. Several feeding sites are used to ensure that there is always one available site that the birds can forage at but shorebirds also need available roosting sites above the high tide mark. However, optimising the use of several sites in a region requires that birds monitor conditions at these sites sufficiently to be able to make economic foraging decisions. Conditions are not always ideal and disturbances to shorebirds force birds away from optimal habitat. If shorebirds are disturbed at a site and forced to depart they will travel to a nearby site, but if the refuge site is not available then birds would have to find sub-par habitat, thus increasing energy costs. Foraging theories suggest that shorebirds can learn where good foraging patches are; therefore birds will feed and roost at the best site/s available to them (Charnov 1976). The time spent travelling between feeding sites affects the average rate of capture of prey and thus affects the duration of foraging at a site before the rate of return drops below the average for the environment. If the birds forage at sites close to their roost the costs of commuting are reduced and the deficit can be recouped over a shorter foraging period. Thus, according to the theory, foraging sites close to roost sites should be preferred over sites that are further away if foraging success rates are the same.

1.2. Threats to migratory shorebirds

Migratory shorebirds are a highly threatened group of birds. In the East Asian-Australasian Flyway these birds are rapidly declining due to the loss of intertidal habitat through reclamation development projects in the Yellow Sea region (MacKinnon *et al.* 2012; Moores *et al.* 2016; Murray *et al.* 2014). They also face other threats such as hunting, impacts from climate change and sea-level rise, pollution, and disturbance (Harding *et al.* 2007). In Australia, the key threats to migratory shorebirds are coastal development that destroys habitat, and disturbance that disrupts their normal activities (Harding *et al.* 2007). The proposed development will not impact migratory shorebirds through a loss of habitat, thus the focus in this report will be on the potential impacts to shorebirds from disturbance. Disturbance to shorebirds normally occurs where humans and wildlife co-occur – on beaches shorebirds face anthropogenic disturbances in the form of pedestrian walkers, dogs, fishermen, kite-surfers, boats, low-flying aircraft and skydivers. Natural disturbances are usually by birds of prey flying over flocks of birds.

Disturbance is a recognised threat to shorebirds worldwide (Kirby *et al.* 1993; Rogers *et al.* 2006; Rosa *et al.* 2006). As disturbance can cause shorebirds to depart sites, there is a need for a network of sites that are connected and maintained as suitable habitat for shorebirds. Disturbance to shorebirds can have negative effects and mitigation measures should be considered in the management and conservation of these birds (Lilleyman *et al.* 2016). While disturbances to shorebirds may be short in duration compared to long-distance migration flights, the cumulative effect of daily disturbances has the potential to reduce energy reserves to levels below the threshold that can be replenished daily (Rehfisch *et al.* 1996). Chronic disturbance to shorebirds could be unsustainable and may lead to birds abandoning staging sites that have high rates of disturbance (Lilleyman *et al.* 2016) (refer to **Section 2.3** for more detail).

1.3. Global and national protection of migratory shorebirds

Australia has agreed to protect and conserve migratory shorebirds under several international conservation agreements; the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention), Japan-Australia Migratory Bird Agreement (JAMBA), China-Australia Migratory Bird Agreement (CAMBA) and Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA). These agreements recognise the need to protect shorebirds by cooperating across jurisdictions. Australia has obligations to protect migratory shorebird habitat and maintain sustainable populations when birds are in Australia (Department of the Environment Water Heritage and the Arts 2009). As a consequence of being a signatory to these conventions, migratory shorebirds are classified as **Matters of National Environmental Significance** and are protected under the highest level of national conservation legislation, the Environmental Protection and Biodiversity Conservation Act 1999 (**Table 1**). The EPBC Act "*provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places*" (Department of the Environment 2013). The EPBC Act is the key mechanism for meeting Australia's responsibilities under these agreements. In addition to the EPBC Act, all states and territories have legislation that protects biodiversity and native species (Department of the Environment Water Heritage and the Arts 2009).

Planning for development in Darwin Harbour should be consistent with international agreements and commonwealth legislation.

1.4. Criteria for listing internationally and nationally important habitat for migratory shorebirds

Criteria exist for assessing significant impacts on populations of migratory shorebirds. Proposals that potentially impact migratory shorebirds that are listed under the EPBC Act 1999 need to be assessed according to criteria listed in Commonwealth of Australia (2015a): Internationally important habitat for migratory shorebirds is recognised if the habitat supports at least:

- 1 per cent of the individuals in a population of one species or subspecies of waterbird, or
- A total abundance of at least 20000 waterbirds.

Nationally important habitat for migratory shorebirds is recognised if the habitat supports at least:

- 0.1 per cent of the flyway population of a single species
- 2000 migratory shorebirds, or
- 15 shorebird species.

1.5. Migratory shorebirds and listed Threatened species

Every year, 37 species of migratory shorebird visit Australia, those species are listed in **Table 1**. The EPBC Act listed threatened species considered in this report and their conservation statuses are described in **Table 2**.

Table 1. Conservation status and listing for 37 species of migratory shorebirds in the East Asian-Australasian Flyway. Taxonomy and species order follows Christidis and Boles (2008). *LC = Least Concern; NT = Near Threatened; VU = Vulnerable; EN = Endangered; CR = Critically Endangered. TPWC = Territory Parks and Wildlife Conservation Act.*

Shorebird	Scientific name	EPBC Act	EPBC Mig sp list	TPWC Act	In Darwin Harbour
Pacific Golden Plover	*Pluvialis fulva*	-	protected	-	yes
Grey Plover	*Pluvialis squatarola*	-	protected	-	yes
Little Ringed Plover	*Charadrius dubius*	-	protected	-	yes
Double-banded Plover	*Charadrius bicinctus*	-	protected	-	-
Lesser Sand Plover	*Charadrius mongolus*	EN	protected	VU	yes
Greater Sand Plover	*Charadrius leschenaulltii*	VU	protected	VU	yes
Oriental Plover	*Charadrius veredus*	-	protected	-	yes
Latham's Snipe	*Gallinago hardwickii*	-	protected	-	-
Pin-tailed Snipe	*Gallinago stenura*	-	protected	-	-
Swinhoe's Snipe	*Gallinago megala*	-	protected	-	-
Black-tailed Godwit	*Limosa limosa*	-	protected	-	yes
Bar-tailed Godwit (Northern Siberian)	*Limosa lapponica menzbieri*	CR	protected	VU	yes
Bar-tailed Godwit (Western Alaskan)	*Limosa lapponica baueri*	VU	protected	VU	probable
Little Curlew	*Numenius minutus*	-	protected	-	yes
Whimbrel	*Numenius phaeopus*	-	protected	-	yes
Eastern Curlew	*Numenius madagascariensis*	CR	protected	VU	yes
Terek Sandpiper	*Xenus cinereus*	-	protected	-	yes
Common Sandpiper	*Actitus hypoleucos*	-	protected	-	yes
Grey-tailed Tattler	*Tringa brevipes*	-	protected	-	yes
Wandering Tattler	*Heteroscelus incanus*	-	protected	-	-
Common Greenshank	*Tringa nebularia*	-	protected	-	yes
Marsh Sandpiper	*Tringa stagnatilis*	-	protected	-	yes
Common Redshank	*Tringa totanus*	-	protected	-	-
Wood Sandpiper	*Tringa glareola*	-	protected	-	yes
Ruddy Turnstone	*Arenaria interpres*	-	protected	-	yes

Shorebird	Scientific name	EPBC Act	EPBC Mig sp list	TPWC Act	In Darwin Harbour
Asian Dowitcher	*Limnodromus semipalmatus*	-	protected	VU	yes
Great Knot	*Calidris tenuirostris*	CR	protected	VU	yes
Red Knot	*Calidris canutus*	EN	protected	VU	yes
Sanderling	*Calidris alba*	-	protected	-	yes
Red-necked Stint	*Calidris ruficollis*	-	protected	-	yes
Long-toed Stint	*Calidris subminuta*	-	protected	-	-
Pectoral Sandpiper	*Calidris melanotos*	-	protected	-	-
Sharp-tailed Sandpiper	*Calidris acuminata*	-	protected	-	yes
Curlew Sandpiper	*Calidris ferruginea*	CR	protected	VU	yes
Broad-billed Sandpiper	*Calidris falcinellus*	-	protected	-	-
Ruff	*Philomachus pugnax*	-	protected	-	-
Red-necked Phalarope	*Phalaropus lobatus*	-	protected	-	-
Oriental Pratincole	*Glareola maldivarum*	-	protected	-	-

Table 2. EPBC Act listed threatened species of migratory shorebird, their conservation status, habitat and distribution.

Threatened Species	EPBC Status	TPWC Status	Habitat & Distribution
Charadrius leschenaultii **Greater Sand Plover**	VU	VU	**Habitat:** Inhabits coasts and estuaries with intertidal sand and mudflats as well as nearby beaches, rocky shores, salt lakes, brackish swamps and shallow freshwater wetlands (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide. **Distribution:** Widespread around the Australian coast, less common in the south and inland. In the NT, It has been recorded from most of the coastline (Chatto 2003).
Charadrius mongolus **Lesser Sand Plover**	EN	VU	**Habitat:** Coastal littoral and estuarine, especially large intertidal sandflats or mudflats in sheltered bays, harbours and estuaries, and occasionally sandy ocean beaches, coral reefs, wave-cut rock platforms and rocky outcrops (Marchant and Higgins 1993). Sometimes occurs in short saltmarsh or among mangroves. Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide. **Distribution:** Widespread around the northern Australian coast, less common in the south and inland.
Limosa lapponica **Bar-tailed Godwit**	CR (*menzbieri*) VU (*baueri*)	VU	**Habitat:** Inhabits coasts and estuaries, especially intertidal sandflats and mudflats, and coastal lagoons. Also occurs in saltlakes and brackish wetlands near coasts, sandy ocean beaches, rock platforms, and coral reef-flats (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide. **Distribution:** Widespread around the Australian coast. In the NT they have been reported all along the coastline and were one of the more frequently recorded and abundant species in shorebird surveys by Chatto (2003).
Numenius madagascariensis **Eastern Curlew**	CR	VU	**Habitat:** Inhabits coasts and estuaries, as well as mangroves. Also occurs in saltlakes and brackish wetlands near coasts. Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide (Higgins and Davies 1996). **Distribution:** Widespread in small numbers around the Australian coast. Chatto (2003) considered the more important areas in the NT for the species to be along the coast either side of Darwin, the Millingimbi to Buckingham Bay area, the Roper and Limmen Bight River mouths, and the Port McArthur area.
Limnodromus semipalmatus **Asian Dowitcher**	-	VU	**Habitat:** Occurs in sheltered coastal environments, such as bays, coastal lagoons, estuaries and tidal creeks, also in exposed mudflats or sandflats or at near-coastal swamps, lakes or beaches (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide. **Distribution:** Rare around the northern Australian coast, seldom in the south. In the Northern Territory they have been reported in small numbers in the Darwin region, central coastal Arnhem Land, Blue Mud Bay and the Port McArthur region. They probably occur at a number of other locations on the NT coast, but never in large numbers (Chatto 2003).
Calidris tenuirostris **Great Knot**	CR	VU	**Habitat:** Inhabits sheltered coasts and estuaries with intertidal mudflats and sand-flats, especially in mangrove areas (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide. **Distribution:** Mostly widespread around the northern Australian coast, less common in the south, with few inland records, centred around Alice Springs (Garnett *et al.* 2011).
Calidris canutus **Red Knot**	EN	VU	**Habitat:** Inhabits coasts and estuaries with tidal mudflats (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide. **Distribution:** Widespread around the northern Australian coast, less common in the south, with few inland records (Garnett *et al.* 2011).
Calidris ferruginea **Curlew Sandpiper**	CR	VU	**Habitat:** Inhabits coasts and estuaries, especially intertidal mudflats, as well as beaches, rocky shores and around lakes, dams and floodwaters (Higgins and Davies 1996). Roosts on beaches, rocky outcrops, and ponds above the high water mark at high tide. **Distribution:** Mostly widespread around the northern Australian coast, less common in the south, with few inland records at Alice Springs and Newhaven Station (Chatto 2003).

2. Migratory shorebirds in the Darwin region

2.1. Habitat choice and site availability

The Darwin region supports a high diversity of migratory shorebirds. There have been 25 species of migratory shorebird recorded across a range of monitored sites within the Darwin Harbour region (**refer to Table 1 and Figure 2**). Shorebirds begin arriving in Darwin in August with peaks in September, October and November and then start departing for their northward migration in February and March. A number of sites in Darwin are monitored throughout the year; these are listed in **Table 3**. These sites have been monitored by a local volunteer (Gavin O'Brien) to contribute to the national Shorebirds 2020 program (http://birdlife.org.au/projects/shorebirds-2020) and more recently and intensively for a PhD program through Charles Darwin University (A. Lilleyman et al, unpublished). These sites were selected for monitoring because they are the most important sites for shorebirds in the Darwin region. The monitoring sites all differ in the type and size of suitable habitat for shorebirds, thus supporting differing species assemblages and providing either roosting or feeding habitat (or both). Roost sites are usually selected for their proximity to feeding grounds to allow for a short commute time, good visibility of potential predators, for thermoneutrality (shallow water to help cool birds down in tropical environments), tide height, and disturbance levels (Rogers et al. 2006; Rosa et al. 2006; Zharikov and Milton 2009).

The following tables (**Table 3-4**) have been compiled using data gathered as part of the PhD project (by the author) on migratory shorebirds in Darwin Harbour. The data were collected from 2013 – 2016 and the study sites were more intensively studied than previous survey work done for the Shorebirds 2020 program. This dataset, despite being shorter in duration, was selected instead of long-term monitoring data, because it will better represent the current state of Sandy Creek as a site of importance for migratory shorebirds.

As part of the PhD on migratory shorebirds in Darwin Harbour, Amanda Lilleyman surveyed for shorebirds across all of the roosting and feeding sites listed in **Table 3**. Roost surveys were conducted during spring high tides (every fortnight) during tides of >6.5 m during day light hours. All shorebirds and waterbirds were identified and counted. All disturbances to shorebirds and disturbance stimuli at the monitoring sites were recorded. Foraging surveys were conducted during falling low tides from 5.5 m. All shorebirds were identified and counted. These methods meet EPBC Act survey requirements for detecting migratory shorebirds as outlined in the EPBC Act Policy Statement 3.21

Note: The two subspecies of Bar-tailed Godwit are known to occur in the Darwin region but were not distinguished apart during the 2013-2016 surveys. Additional expert opinion has been sought and subspecies menzbieri is more common in the area but baueri is probable. As such, all references to counts of Bar-tailed Godwit are at the species level, but for the purpose of conserving this species, all actions should be taken to conserve individuals at both subspecies levels (i.e.: ***critically endangered and vulnerable****).*

Table 3. Monitoring site descriptions, EPBC Act listed threatened migratory shorebird species recorded at the sites.

Site	Description	Max. number of birds (date)	Max. number of species (date)	EPBC Act listed Threatened species recorded at this site
Lee Point-Buffalo Creek	One of the most important sites for migratory shorebirds in the Darwin region. Situated within the Casuarina Coastal Reserve (CCR) and managed by the Parks and Wildlife Commission Northern Territory. Important for feeding and roosting. Extensive sandy beach connected to sandflats where thousands of shorebirds feed at low tide. Shorebirds can roost anywhere along the stretch of beach but are generally found closer to the Buffalo Creek end. Shorebirds that roost and feed at Lee Point have been recorded moving between this site and saltpans in the Shoal Bay region to the East. It is likely that shorebirds also use the extensive beach between Tree Point and Gunn Point, but surveys at Tree Point/Gunn Point reveal high human disturbance and space constraints from high spring tides. These factors and low shorebird numbers make it unlikely that this site is of equal importance to the Lee Point and northern beaches sites.	7423 (January 2016)	16 (September 2015 and February 2016)	Lesser Sand Plover Greater Sand Plover Bar-tailed Godwit Eastern Curlew Great Knot Red Knot Curlew Sandpiper
Sandy Creek	Supports a similar assemblage of shorebirds as Lee Point but since previous monitoring in 2011, 2012, Sandy Creek has been used as a refuge site if birds are disturbed at Lee Point or Nightcliff Rocks. The available space to roost at Sandy Creek is constrained by high spring tides and birds are forced to leave the site if the tide is too high. Shorebirds roost along the western side of the creek, in front of the mangroves and Casuarina trees. Shorebirds also feed at low tide at Sandy Creek. This site is situated within the Casuarina Coastal Reserve (CCR) and managed by the Parks and Wildlife Commission Northern Territory.	4903 (October 2015)	14 (September 2014)	Lesser Sand Plover Greater Sand Plover Bar-tailed Godwit Eastern Curlew Great Knot Red Knot
Nightcliff Rocks	Small rocky outcrop out from the urban 'Sunset Park' in the suburb of Nightcliff. Shorebirds often roost on the rocks furthest from land and human activity. This site has high human traffic and disturbances to shorebirds are common. Recently the City of Darwin constructed a seawall and fence atop the land edge. It is predicted that this fence will act as a barrier to humans and will discourage access to the rocky platform. High spring tides can cover this entire platform making it unsuitable for roosting shorebirds.	3084 (December 2013)	15 (December 2013 and November 2015)	Lesser Sand Plover Greater Sand Plover Bar-tailed Godwit Eastern Curlew Great Knot Red Knot
East Point	Similar to Nightcliff Rocks with rocky platforms bordering the land. Similarly to Nightcliff Rocks, high spring tides can cover this entire platform making it unsuitable for roosting shorebirds. East Point is mostly used as a roost site but some species have been recorded foraging amongst the rocks.	2611 (February 2015)	14 (October-November 2015 and February-March 2015)	Lesser Sand Plover Greater Sand Plover Bar-tailed Godwit Eastern Curlew Great Knot Red Knot

Spot on Marine	Large saltpan surrounded by mangroves that experiences tidal flow on tides above 7 metres. This site is used for roosting only but can become unsuitable for roosting during particularly high spring tides.	1651 (March 2015)	10 (March 2014)	Greater Sand Plover Bar-tailed Godwit Eastern Curlew Great Knot Red Knot
Ludmilla Bay	Extensive sandflat system where shorebirds and waterbirds feed during low tide. This site is not considered suitable for roosting due to the tide covering most of the sandflat. This site is not available at all tide heights, but is often used by foraging shorebirds during the austral summer. Shorebirds that forage at Ludmilla Bay at low tide will often roost at East Point or Nightcliff Rocks at high tide. This site is commonly used for recreational activities during low tides. This site is currently not well protected and is at risk of being developed for commercial purposes.	2150 (March 2015)	9 (January 2015)	Lesser Sand Plover Greater Sand Plover Bar-tailed Godwit Eastern Curlew Great Knot Red Knot
East Arm Wharf	East Arm Wharf (Darwin Port) is a man-made site with several dredge-spoil ponds within the fenced boundary. Darwin Port is within Darwin Harbour and the site is used for importing and exporting goods from the wharf berths. The dredge ponds are shallow, muddy ponds with clear visibility of surroundings and access to the harbour mudflats for feeding at low tide. The dredge ponds are used for roosting at high tide and some shorebirds feed in the freshwater ponds during all tide heights. This roost site is available to shorebirds at all tide heights and is particularly important as a refuge site from harsh monsoonal weather conditions in January and February of the wet season. East Arm Wharf is a privately owned site; it is owned by Darwin Port and is managed so that access is restricted to the public. Shorebirds that roost at East Arm Wharf feed nearby on the mudflats of Darwin Harbour.	1036 (November 2015)	17 (September 2014)	Lesser Sand Plover Greater Sand Plover Bar-tailed Godwit Eastern Curlew Great Knot Red Knot Curlew Sandpiper

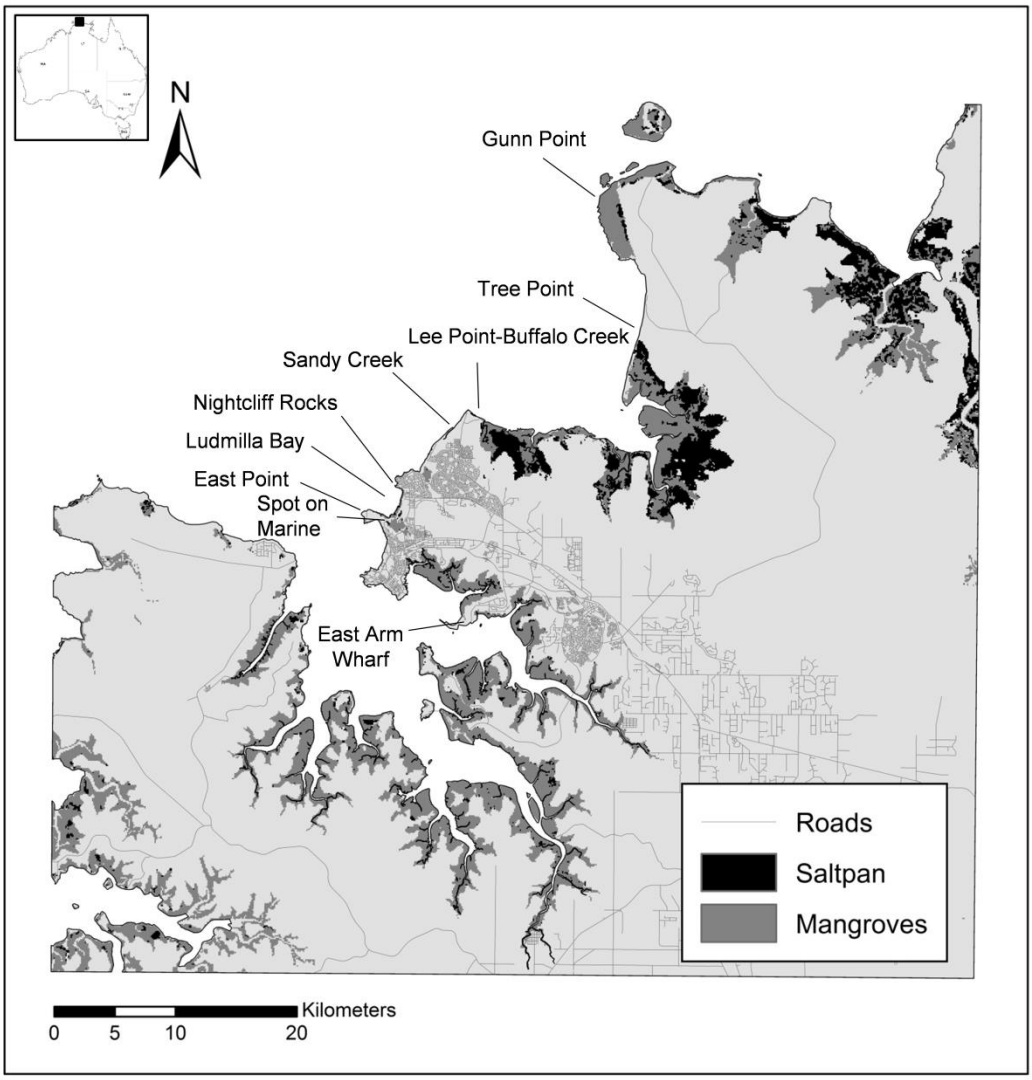

Figure 2. Map displaying the monitored shorebird roosting and feeding sites in the Darwin Harbour region.

2.2. Importance of the northern beaches of Darwin for migratory shorebirds

Sandy Creek and Lee Point-Buffalo Creek both meet EPBC Act criteria (**Section 1.4 of this report**) to be listed as nationally and internationally important habitat (Commonwealth of Australia 2015a). **Table 4** lists the importance of these sites and the corresponding shorebird values. **Table 5** lists all migratory shorebird species present at Sandy Creek, the maximum count, number of times recorded at the site, and thresholds for internationally and nationally important numbers for species.

Buffalo Creek is the preferred feeding site for shorebirds on the northern beaches of Darwin, and because of this most birds roost close by at Lee Point or Sandy Creek (see **Figure 2 and 3** for roosting and feeding sites at Lee Point-Buffalo Creek and Sandy Creek). <u>These sites are all within 3 km to the proposed DHA housing development.</u>

Figure 3. Roosting and feeding areas for migratory shorebirds at Sandy Creek and Lee Point-Buffalo Creek. Image credit: EcOz environmental consultants.

Table 4. Importance of Sandy Creek and Lee Point-Buffalo Creek for migratory shorebirds.

Site	Meets EPBC national threshold?	No. surveys performed (2013-2016)	Largest congregation (species and year)	Most abundant species
Sandy Creek	**Yes.** Sandy Creek meets two of the criteria for listing as nationally important habitat. Supports nationally and internationally important numbers of Critically Endangered Great Knot. Supports nationally important populations of Greater Sand Plover, Great Knot, Red Knot, and Sanderling.	55	Sandy Creek, being a smaller roost site and not being able to support as many individuals as Lee Point-Buffalo Creek, had its largest congregation of shorebirds in October 2015, with 4903 individuals of 13 species and also supported 4110 individuals of 10 species in March 2015. During the 2013 to 2016 surveys at Sandy Creek, there was one occasion where 14 species of shorebird were recorded in September 2014, but three occasions where 13 species were recorded.	The most abundant species at Sandy Creek were Great Knot, Greater Sand Plover, Red Knot, Sanderling, and Red-necked Stint (in descending order). Despite these high abundances, the species most frequently recorded at the site were Eastern Curlew, Grey Plover, Greater Sand Plover, Sanderling, and Whimbrel and Bar-tailed Godwit to a lesser extent.
Lee Point-Buffalo Creek	**Yes.** Lee Point-Buffalo Creek meets all criteria for listing as nationally important habitat for migratory shorebirds. Supports nationally and internationally important numbers of Critically Endangered Great Knot. Supports nationally important populations of Greater Sand Plover, Terek Sandpiper, Grey-tailed Tattler, Great Knot, Red Knot, and Sanderling.	162	7423 with 15 species of shorebird present in January 2016; February 2016 had 6399 individuals of 16 species; and November 2015 had 6269 individuals of 15 species	The most abundant species at Lee Point-Buffalo Creek were Great Knot, Greater Sand Plover, Red Knot, Terek Sandpiper, Red-necked Stint, Sanderling, and Common Sandpiper (in descending order). At Lee Point, Greater Sand Plovers were most commonly recorded, and then Great Knot, Eastern Curlew, Grey Plover, Sanderling, Red-necked Stint, and to a lesser extent, Whimbrel and Grey-tailed Tattler.

Table 5. Migratory shorebird species recorded at Sandy Creek, maximum count, numbers of times recorded at the site, and thresholds for internationally and nationally important numbers for species.
Note: species that were not recorded at Sandy Creek during the 2013-2016 survey period are not included in the table. Shaded grey = EPBC Act listed threatened species.

Shorebird	Maximum count	No. times counted	% present in counts	1 % threshold	0.1 % threshold
Pacific Golden Plover	12	3	5	1250	125
Grey Plover	14	39	71	790	79
Lesser Sand Plover	31	7	13	1470	147
Greater Sand Plover	980	37	67	1660	166
Oriental Plover	1	1	2	2320	232
Black-tailed Godwit	14	3	5	1470	147
Bar-tailed Godwit	13	34	62	3000	300
Whimbrel	8	34	62	640	64
Eastern Curlew	8	44	80	310	31
Terek Sandpiper	4	8	15	460	46
Common Sandpiper	3	15	27	2520	252
Grey-tailed Tattler	9	12	22	610	61
Common Greenshank	6	20	36	660	66
Marsh Sandpiper	5	1	2	940	94
Ruddy Turnstone	17	6	11	300	30
Great Knot	4640	28	51	3250	325
Red Knot	390	15	27	1010	101
Sanderling	139	36	65	340	34
Red-necked Stint	114	21	38	4660	466
Sharp-tailed Sandpiper	3	2	4	850	85

High tide roost surveys have been performed at Sandy Creek and Lee Point by Amanda Lilleyman and Gavin O'Brien (experienced shorebird volunteer researcher) simultaneously to determine movement and activity between these sites. Records suggest that shorebirds move between these two sites at high tide if there is a disturbance at a site and the birds are seeking refuge elsewhere, or if the tide becomes too high at Sandy Creek and the birds have no space to roost, they usually fly to Lee Point. As part of the PhD study (A. Lilleyman et al, unpublished) on shorebirds in Darwin, an extensive catching and banding exercise has allowed individual birds to be tracked and resighted across the monitored sites from 2014 to 2016. There was high site fidelity of tagged shorebirds returning to sites in Darwin after the 2015 breeding season (between seasons), and high site fidelity within the austral summer season with records of individual birds feeding at low tide at Buffalo Creek and Sandy Creek and then roosting at high tide at Lee Point and at the Sandy Creek roost (within season).

While shorebirds usually select Buffalo Creek tidal flats at low tide for feeding, the extensive tidal flats along Sandy Creek beach are important feeding grounds at certain times of the year, possibly due

to unreliable food resources at other sites. High numbers of shorebirds (>500) have been recorded feeding at Sandy Creek in March 2015 (**Figure 4-5**). This was 10 days before most shorebirds departed Darwin for their northward migration, suggesting that this was an important feeding site in the 2015 austral summer season.

Figure 4. Migratory shorebirds feeding at Sandy Creek intertidal sandflats in March 2015, 10 days before departing for their northward migration. Photo credit: Amanda Lilleyman, 2015.

Figure 5. Migratory shorebirds feeding at Sandy Creek intertidal sandflats in March 2015, 10 days before departing for their northward migration. Photo credit: Amanda Lilleyman, 2015.

2.3. Disturbance to shorebirds in Darwin

When shorebirds are disturbed at high-tide roosts they use energy that would otherwise be reserved for foraging and maintaining fat reserves. Alarm flights incur a higher rate of energy usage than resting, as birds take off rapidly, must ascend and descend, and undertake flapping flight – all of which have high energy costs (Nudds and Bryant 2000). The Casuarina Coastal Reserve, where Sandy Creek and Lee Point-Buffalo Creek sit, has an annual visitation rate of over one million users (Parks and Wildlife Commission 2016). This level of human recreation use unavoidably places an increased pressure on shorebirds that use this coastline. The effects of disturbance on shorebirds at a Lee Point-Buffalo Creek were measured and the rates of anthropogenic and natural disturbance were quantified in a research project by Amanda Lilleyman in 2011 and 2012. These results were recently published and have been used to inform management of shorebirds within the Casuarina Coastal Reserve by the NT Parks and Wildlife Commission.

Anthropogenic disturbance is additional to the background level of natural disturbance, and negatively affects shorebirds by forcing them to use energy reserves that would otherwise accumulate for the long-distance migration flight (Lilleyman et al. 2016). Migratory shorebirds were recorded flying away from humans when disturbed, and these alarm flights were longer in the period when shorebirds had recently arrived in Darwin from their southward migration (Lilleyman et al. 2016). It was suggested that the level of anthropogenic disturbance might indirectly decrease the survival likelihood of shorebirds by inducing high costs of predator avoidance behaviours at the high-tide roost. This is problematic as shorebirds that are disturbed may seek refuge elsewhere, such as Sandy Creek, but this site is also experiencing higher rates of disturbance. Lilleyman et al. (2016) stated that "*the compounded effects of an increase in disturbances and increased time spent in alarm flight negatively affect migratory shorebirds at an important roost site near Darwin*" and that these disturbances on the non-breeding grounds could "*place additional and unsustainable pressures on populations that are already experiencing major declines*".

3. Migratory shorebird management

Increased anthropogenic disturbance to shorebirds is the main potential impact from this development proposal. Increased disturbance to shorebirds at this site has the potential to harm the population.

3.1 Impact mitigation – disturbance

The Commonwealth Government's Wildlife Conservation Plan for Migratory Shorebirds states that "*Disturbance which renders an area unusable is equivalent to habitat loss and can exacerbate population declines. Disturbance is greatest where increasing human populations and development pressures may have an impact on important habitats*" (Commonwealth of Australia 2015b). Anthropogenic disturbance is considered a high risk to shorebirds that requires mitigation action and an adaptive management plan, and the precautionary principle should be applied (Commonwealth of Australia 2015b; Department of the Environment Water Heritage and the Arts 2009). The Background paper to the EPBC Act policy statement 3.21 suggests that "*it is important to consider the combined effects of disturbance with other threats when assessing the likely impact*" (Department of the Environment Water Heritage and the Arts 2009). The Proponent should consider this when planning mitigation to the potential impacts to shorebirds from disturbance.

Shorebirds are prone to the effects of anthropogenic disturbances as most coastal shorebirds roost and feed along beaches where humans co-occur. By increasing and improving the access to the Sandy Creek beach it is likely that pedestrian traffic will increase disturbances to shorebirds that also use this beach. Shorebirds roost on beaches because they have nowhere else to go while the tide is high. If humans or dogs approach the birds then it is most likely that the birds will take flight in response to the disturbance. The distance at which birds take flight from disturbance stimuli is referred to as the flight-initiation distance (FID) and these FIDs have been quantified for shorebirds in Australia and the world (for a full review see Weston *et al.* 2012), and more recently in Darwin (Lilleyman *et al*. 2016). In Darwin, FID measurements for Great Knots and Greater Sand Plovers were estimated, and from this the safe buffer distance that humans should keep from birds is a minimum of 100 m (Lilleyman *et al.* 2016). Flight-initiation distances were not recorded for other larger species in this study but it is predicted that the current buffer zones will not be sufficient to protect larger shorebirds such as Far Eastern Curlew (Lilleyman *et al.* 2016). Other studies suggest a greater buffer distance is required for larger shorebirds (Glover *et al.* 2011).

The current Casuarina Coastal Reserve Plan of Management states that there is a 100 m buffer zone either side of Sandy Creek where dogs should be leashed but there are no signs within the area to this effect, thus visitors to the reserve are not aware of zoning regulations and continue to cause disturbances to shorebirds (Parks and Wildlife Commission Northern Territory 2016). This buffer distance does not adequately protect all shorebirds using the Sandy Creek roost as some species, such as Far Eastern Curlew roost between Sandy Creek and the Casuarina Surf Life Saving Club. Further to this, four-wheel drive vehicles are often recorded illegally driving along the beach to gain access to

popular fishing locations at Sandy Creek. This illegal act disturbs shorebirds on the beach and is destructive to the beach ecosystem. As a first step in managing disturbances and prohibited vehicle access, the Parks and Wildlife Commission NT could improve the security of fences and gates that lead to unauthorised vehicle entry to the beach.

Most shorebirds that roost at Sandy Creek use the sandbanks on the western side of the creek and the shore along Casuarina beach; however some birds have been recorded roosting on the eastern side of the creek. Because shorebirds prefer to roost on the western side, it is recommended that any new access paths from the proposed housing development site through the CCR be positioned on the north-eastern side of Sandy Creek. Information signs would enhance the visitor experience through education about the natural environment, historical and cultural values, and would also help to protect biodiversity. Educational signs about shorebirds and the need to minimise disturbance are an effective management tool, and has been shown to decrease disturbance rates to shorebirds (Burger 2004). Access tracks to the beach should have educational signs at the beginning, throughout and at the endpoint of the track (on the beach) to inform visitors of the environmental and biological values of the CCR. See **Figure 6** for examples of educational signs.

Additionally, barrier fencing positioned on the western side of Sandy Creek at 100 m from the mouth of the creek would protect shorebirds by alerting humans to the presence of birds on the beach. The barrier fencing (water and salt resistant/protected) should be perpendicular to the tide line and extend from the dune to approximately 10 – 20 metres across the sand (see example in **Figure 7**). The Proponent will need to consider the costs associated with maintaining the barrier fence – including corrosion from saltwater, vandalism and natural weathering of materials. In the instance that any of these issues arise, then the Proponent should replace the fence or parts of the fence. Protecting the shorebirds through serious management measures outweighs the possibility of the barrier fencing not lasting a long time in harsh tropical conditions.

Figure 6. Examples of educational signs about migratory shorebirds. Signs are from Moreton Bay in Queensland. Image credit: jappliedecologyblog.wordpress.com and www.visitmoretonbayregion.com.au

Figure 7. Example of a wire rope fence that could be constructed on the beach to protect migratory shorebirds from anthropogenic disturbance. Image credit:

https://redoubtreporter.wordpress.com/2010/02/17/fence-for-dunes-hits-barriers-%E2%80%94-efforts-to-protect-kasilof-beach-more-complex-than-anticipated/

3.2 Impact mitigation – community education

A community awareness program on shorebirds and their use of Sandy Creek as a roost will help protect the birds and the habitat they depend on. Implementing a community awareness and engagement program is an essential part of managing threatened species in an urbanised environment. As anthropogenic disturbance is considered a high risk to shorebirds with negative impacts on individuals, ensuring that the Sandy Creek roost is protected is crucial to managing the population.

As well as a number of educational signs along access tracks and on the beach, community awareness can be achieved by delivering information pamphlets to local residents of the housing development, and by providing information sessions to raise awareness about dog zoning and safe buffer distances from shorebirds. Local organisations, with the support of Parks and Wildlife Commission NT have previously held successful community engagement events at Lee Point and Sandy Creek to raise the profile of these remarkable, yet highly threatened birds. These events included: sessions where people could learn about the birds then view them through binoculars and spotting telescopes; BBQs with dogs invited to show support for dog walking as a recreational activity, but with an emphasis on using *correct* dog zoning areas; and inviting community members to be involved with regular survey monitoring with the aim that they then become advocates for shorebirds (**Figure 8** shows a dog attending the 'Darwin Doggie Dinner' – educational event held at Lee Point in 2011.

Figure 8. A dog attending the 'Darwin Doggie Dinner' at Lee Point in 2011; held by volunteers and the Northern Territory Field Naturalists' Club Inc. Image credit: Peter Kyne.

4. Monitoring program

The fieldwork component of the PhD on migratory shorebirds in Darwin has finished and all current shorebird monitoring is performed by one volunteer in the region. There is no guarantee that this level of monitoring will continue into the future, thus it is critical that a new and more robust monitoring program be developed.

A well designed community awareness program needs to be coupled with regular monitoring of shorebird numbers and disturbance rates to determine the efficacy of the program. A monitoring program should be developed to detect any significant changes in shorebird usage of Sandy Creek. It is recommended that this program detects significant changes in the population that are attributable to the impacts of the development and not external or regional factors. Therefore it is recommended that the program intensively surveys two sites (Sandy Creek and Lee Point) that are expected to be exposed to higher rates of anthropogenic disturbance as a result of the DHA housing development. It is also recommended that an additional three sites are surveyed (Nightcliff Rocks, East Point and Spot on Marine) so that the wider Darwin region shorebird population is adequately surveyed. It is important that any variation in species and abundances are detected over the migration months. Therefore all months during the austral summer season when shorebirds are expected to occur in

Darwin should be included in the monitoring program, as northern Australia is a known staging site for shorebirds during northward and southward migration (Commonwealth of Australia 2015a). The population of shorebirds in Darwin varies over the summer months and it is important to monitor those months – which include the southern migration period, the core non-breeding period and the northern migration period.

Monitoring data from this period should be compared against Shorebirds 2020 data and the data presented here in this report to detect any local changes to shorebirds at the monitoring sites.

It is expected that uptake of houses in the DHA development area will be staggered and the increased use of the CCR, Sandy Creek and Lee Point beaches will take some time; therefore the duration of the monitoring program should reflect the uptake of houses within the development and it should start once all houses have been taken up. The monitoring program should then remain in place for five years. A monitoring period of five years will be sufficient to detect local changes to the shorebird population that are due to the DHA housing development.

The survey methodology outlined in section **4.1 Methodology** exceeds EPBC Act survey requirements for detecting migratory shorebirds as outlined in the EPBC Act Policy Statement 3.21 (see **Table 6** for survey guidelines) (Commonwealth of Australia 2015a; Department of the Environment Water Heritage and the Arts 2009). The outcomes of the monitoring program should be reviewed and evaluated using the steps outlined in **Figure 9**. Resources for the monitoring program are listed in the **Appendices**.

The aim of the monitoring program is to quantify the magnitude of impact of disturbances to migratory shorebirds associated with the proposed development (Commonwealth of Australia 2015a). A significant impact on the regional population of migratory shorebirds would be: 1) a decrease in the size of the population (outlined in **section 4.2**) that visits the northern beaches of Darwin each year that cannot be reasonably attributed to other factors or broader population trends and; 2) an increase in the number of disturbances (>10 per survey session) that these shorebirds are exposed to at the monitoring sites.

Table 6. Survey Guidelines for migratory shorebirds set out in the EPBC Act Policy Statement 3.21 (Commonwealth of Australia 2015a).

Coverage	Timing	Effort	Minimum data requirements
- All of the habitat thought to be used by the same population of shorebirds. - The entire area of contiguous habitat where shorebirds may occur.	- The months when the majority of migratory shorebirds are present in the area. - Numbers of shorebirds may vary during these months, particularly in the north of the country, due to presence of additional shorebirds during inbound and outbound migration at the beginning and end of the non-breeding season. Local knowledge should be sought to determine optimum survey times. - The northern hemisphere breeding season (mid-April to mid-August) to obtain data on non-breeding; non-migrating populations of immature migratory shorebirds.	- Four surveys for roosting shorebirds during the period when the majority of shorebirds are present in the area - Replicate surveys over this period are important to measure population variability. Some areas will meet the importance criteria only during the migration periods when many birds are temporarily stopping over. In most cases, one survey in December, two surveys in January, and one survey in February will be adequate.	- *Shorebird statistics relating to roosting areas:* total abundance (total number of birds present across all species); species richness (number of species observed); species abundance (number of birds of each species present). - *Shorebird behaviour*: activity (roosting, foraging); foraging location (spatial data of the area used by shorebirds for feeding to enable mapping of foraging habitat). - *Survey conditions*: date, time of day; tide height; weather conditions (temperature, precipitation, wind speed & direction). - Number of observers and experience level. - Method used to conduct the survey. - *The following habitat characteristics may also be useful*: dominant landform type; hydrology; dominant terrestrial and aquatic vegetation types; intertidal substrate characteristics; invasive species; current disturbance regime; presence of suitable nocturnal roosting areas.
	Surveys for roosting shorebirds should be conducted as close to the time of high tide as practicable and at a maximum of no more than two hours either side of high tide (unless local knowledge indicates a more suitable time).	One survey during the northern hemisphere breeding season to capture data on birds that remain in Australia during the breeding season.	

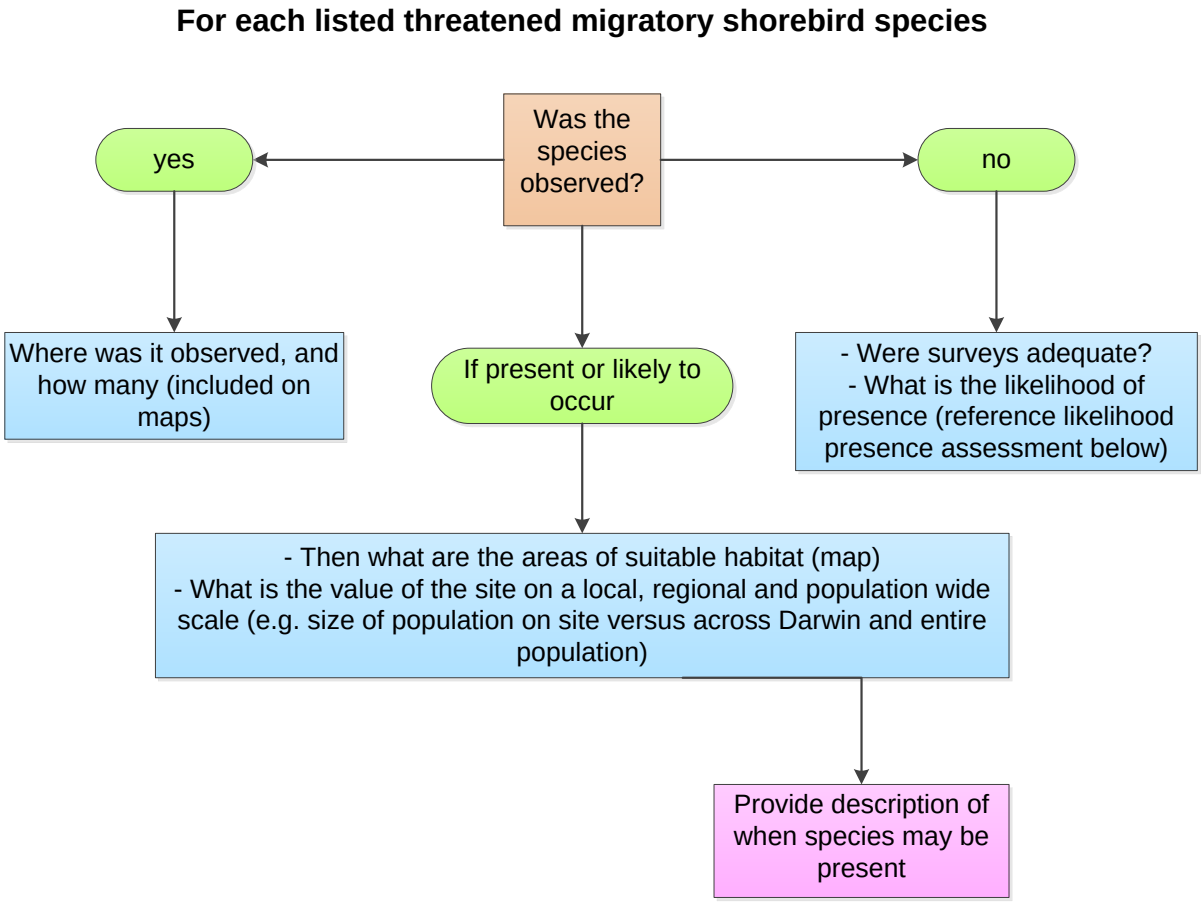

Figure 9. Flow chart for evaluating monitoring survey program for migratory shorebirds.

4.1. Methodology

The shorebird monitoring program should consist of one survey per month from September through to April each austral summer season at the following sites: Sandy Creek and Lee Point [performed simultaneously; e.g.: two personnel], East Point, Nightcliff Rocks, and Spot on Marine (**Table 7-8; see Appendices for suggested resources**). Migratory shorebirds begin arriving in Darwin from August and depart as late as May the following year. An additional survey in July each year should be performed at all monitoring sites to capture information on shorebirds that remain at the survey sites during the northern hemisphere breeding season. The surveys should be performed at high tides of >6.5 m during the spring tide cycle, and during daylight hours. Surveys should be conducted two hours either side of the peak of the high tide. The semi-diurnal tides mean that two high tides occur per day, usually with one in the morning (sunrise) and one in the evening (sunset). Surveys should be conducted for a minimum duration of two hours. All shorebirds and all other waterbirds should be identified and counted. Shorebird activity should be recorded (foraging, roosting). The start and end time of the survey should be recorded. Any changes to the environment should be recorded. Surveys can be performed by one person (the observer) per site. The observer should be competent in shorebird identification and counting techniques. The observer should perform the survey from a

distance of 100 m or more so as not to cause a disturbance. The observer should use binoculars and a zoom spotting scope of 20-60 x magnification. Survey areas for Lee Point and Sandy Creek are outlined in **Figure 10** and the other three sites are shown in **Figure 2**.

All disturbances and potential disturbances to shorebirds and other birds should be recorded. If the disturbance stimulus is close enough to the flock of birds it should be recorded as a disturbance and the response (flight, walking away, no response) of the birds should be recorded. If the disturbance stimulus is not close enough to cause a disturbance then it should be recorded as a potential disturbance (i.e.: this is the no response category and is simply a measure of the number of people using the beach and additionally helps in creating appropriate buffer zones through recording the distance of the stimulus to the birds). The time of the disturbance should be recorded along with the details (e.g.: human [walking, running, cycling etc.], human with dog [leashed or unleashed], vehicle on the beach, kite surfer, aircraft, bird of prey) and the number of each disturbance stimuli. The observer should also record where the disturbance stimulus entered the beach from (if possible) and the exit point (which access path).

Table 7. Survey timing, guidelines and effort for the migratory shorebird monitoring program.

Month	Guidelines	Effort
September October November December January February March April	Perform shorebird surveys simultaneously at Sandy Creek and Lee Point. Perform surveys at Nightcliff Rocks, East Point and Spot on Marine during the same spring tide cycle as Lee Point an Sandy Creek. Count all shorebirds (species and abundance) and all other birds in the survey area. Record all disturbances and potential disturbances to shorebirds and other birds. Record any physical changes to the environment.	1 high tide survey at 5 sites for 2 hours, each month = 10 hours per month = 80 survey hours per austral summer season
July	As above	1 high tide survey at 5 sites for 2 hours for the month of July. = 10 hours
Total survey hours per season		**90**

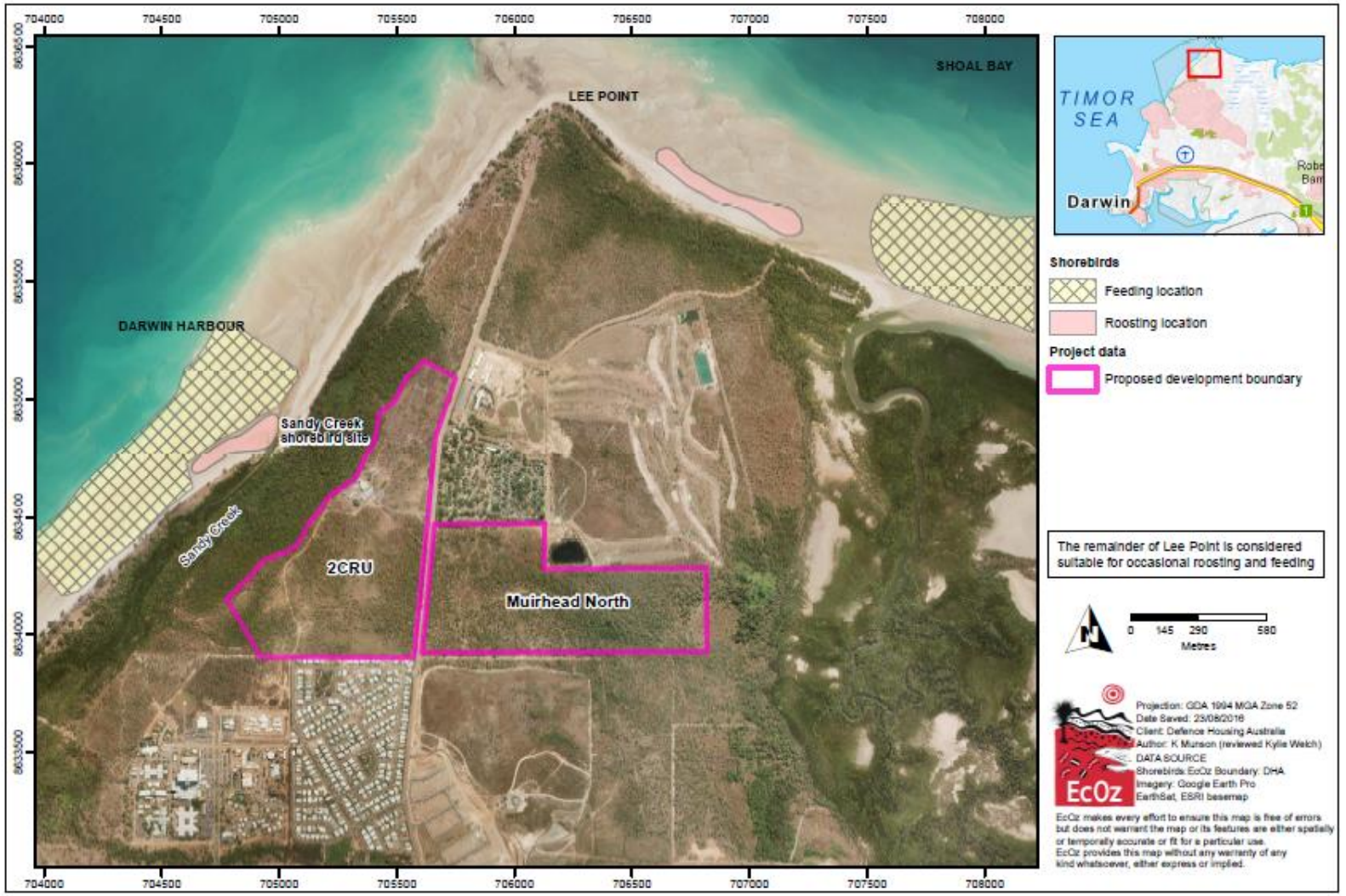

Figure 10. Roosting and feeding areas for migratory shorebirds at Sandy Creek and Lee Point-Buffalo Creek. Image credit: EcOz environmental consultants.

4.2. Triggers and responses to trigger exceedances

Monthly survey monitoring data should be reviewed to detect any significant changes in the shorebird subpopulation for both Sandy Creek and Lee Point (following the steps outlined in **Figure 11**). The Proponent should review monitoring data for the five monitoring sites and calculate the combined population of shorebirds for the northern beaches region. If shorebirds are detected at all sites but not at Sandy Creek then this will cause a trigger to check the total abundance data. If the total abundance of shorebirds for Lee Point or Sandy Creek is >4000 individuals (from October to November) then that trigger is terminated. If it is <4000 individuals across all five sites then this will cause a trigger and the Proponent should investigate if the population changes are attributable to a site specific event at Sandy Creek or other environmental changes in the Darwin region.

If the monitoring guidelines are not followed and surveys are performed on tides lower than 6.5 m then there is the chance that shorebirds will not be sighted during the surveys. It is important that these guidelines are followed to fully represent the shorebird population in the Darwin region.

If any triggers are exceeded then the Proponent will need to investigate if conditions at the local sites are attributable to the changes in the shorebird population. After examination of the abundance data, the Proponent should examine the disturbance data to determine the rate of anthropogenic disturbance compared to the background rate of natural disturbance by birds of prey, and compare this against baseline disturbance data reported in Lilleyman *et al.* (2016). For example, if the number of disturbances exceeds 10 alarm flights per survey session, then the Proponent should seek an increase the number of patrols by Parks and Wildlife rangers and City of Darwin council rangers to ensure that visitors to the beach roost sites are abiding by dog zoning regulations and are not disturbing shorebirds in spite of educational signs and barrier fencing.

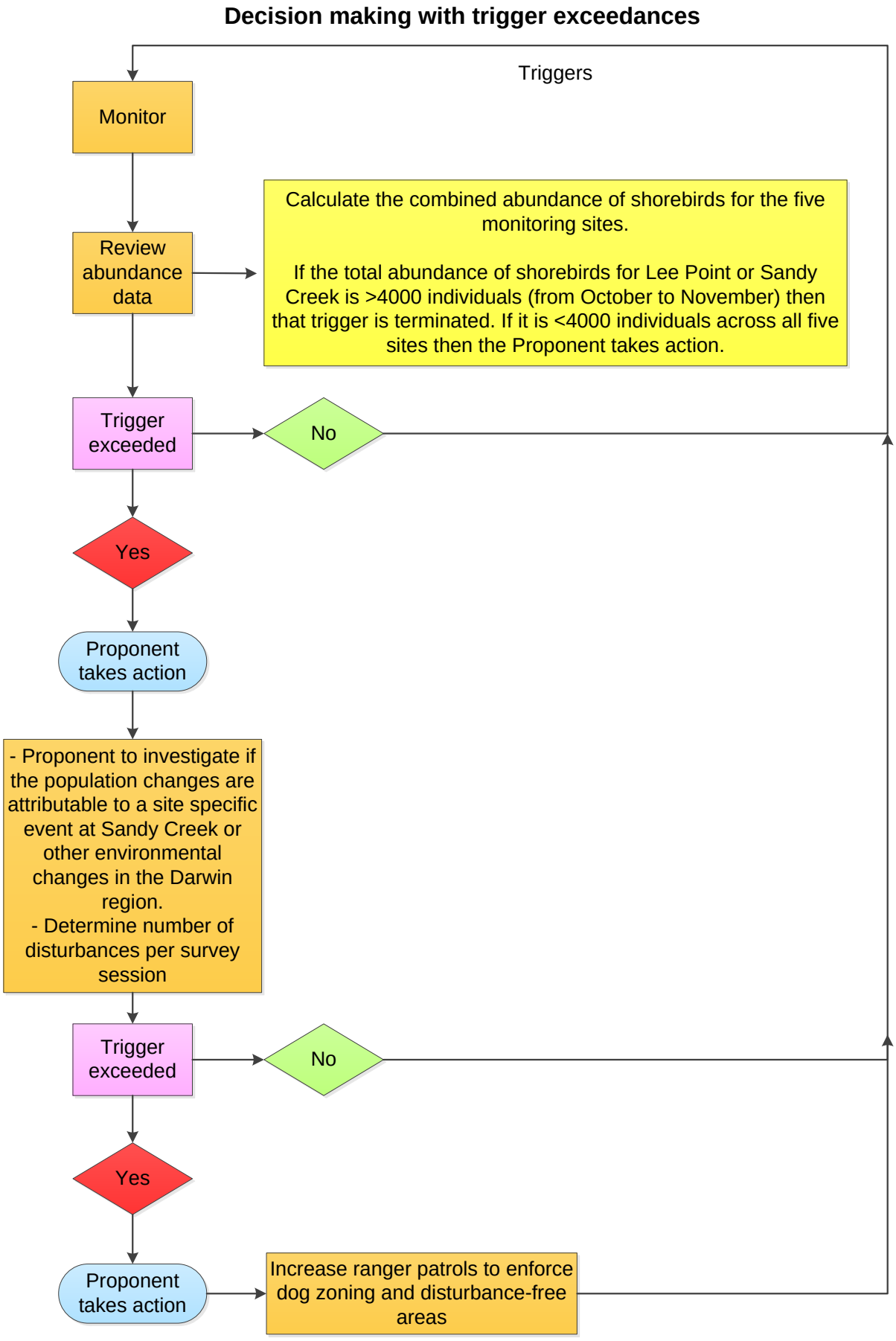

Figure 11. Flow chart to detect significant changes in the migratory shorebird population at Sandy Creek.

5. Recommendations and conclusions

Sandy Creek is considered a site of national importance for migratory shorebirds that visit Australia for the summer season. The site has at times supported internationally important numbers of migratory shorebirds and also acts as an important feeding ground for shorebirds before departing for their northward migration.

Anthropogenic disturbance is the key threatening process to migratory shorebirds in this development context, and this has serious consequences for the shorebird population that visits Darwin every year. As stated in Lilleyman et al. (2016) "*There is concern that with expansion of the Darwin urban centre in northern Australia, disturbances will increase to unsustainable levels for migratory shorebirds and ultimately divert migratory shorebirds from this important non-breeding site*". While the development does not directly impact shorebirds through habitat loss or destruction, it is important for the Proponent to consider cumulative effects of increased anthropogenic disturbances with increasing coastal development in the Darwin region. By following the proposed recommendations, the Proponent will be working towards maintaining and enhancing the environmental and biological values of Sandy Creek to support nationally and internationally important populations of migratory shorebirds.

The potential impacts to migratory shorebirds have been reviewed and considered in this report and it is concluded that there is a very high likelihood that the number of visitors to Sandy Creek and associated beaches will increase, thus increasing the rate of anthropogenic disturbance to shorebirds.. This has consequences, including abandonment of the roost site by shorebirds, increased energy expenditure on alarm flights from disturbances and reduced ability to maintain fat stores for migration and breeding. Therefore the following recommendations are given:

- Access tracks should be positioned to the north-eastern side of Sandy Creek so that **visitation does not increase and impact upon migratory shorebirds** that roost on the western side of Sandy Creek.
- Maintain current **dog zoning regulations** and place educational signs along Sandy Creek beach.
- **Construct barrier fencing** (water and salt resistant/protected) perpendicular to the tide line at the 100 m buffer zone either side of Sandy Creek that will act as a reminder to beach visitors that they are about to enter important shorebird habitat.
- Proponent to liaise with Parks and Wildlife Commission NT and City of Darwin council rangers to develop a **regular schedule to monitor visitation and dog zoning regulation** at the Sandy Creek roost site.
- Proponent to liaise with Parks and Wildlife Commission NT to collaborate on **community engagement programs and events** so that there is one strong key message about shorebird conservation.

- Install **educational signage** at each access path entry and exit point.
- Invite **residents of the DHA** housing development to **join shorebird monitoring surveys and local committees/working groups** that aim to protect the environment (e.g: Casuarina Coastal Reserve Advisory Committee, Landcare group).
- **Follow migratory shorebird monitoring program** and adapt management techniques according to trigger thresholds (**Figure 11**).

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Appendices

Resources for migratory shorebird monitoring program:

Shorebird identification sheets: http://birdlife.org.au/documents/SB-IDsheetsALL.pdf

Shorebirds 2020 field datasheet: http://birdlife.org.au/documents/SB-countform.pdf

Table 8. Suggested field datasheet (with example data) to record disturbances to migratory shorebirds observed during the monitoring program.

Date: 28/11/2015	Site: Sandy Creek	Researcher: Amanda Lilleyman	Tide height (m): 7.2	Tide time: 18:42	Notes: All shorebirds roosting in front on mangroves near the mouth of Sandy Creek.		
Time of disturbance	Duration of disturbance stimulus (mins)	Disturbance type (human, dog, bird of prey etc.)	Shorebird response (flight, walk, no response)	Shorebird species affected	Shorebird species numbers affected (total flock)	Did the affected birds leave the site after the disturbance? (Y/N)	Entry and exit point of disturbance stimulus
17:30	2	Human walking with 2 dogs (leashed)	Flight	Great Knot, Greater Sand Plover, Eastern Curlew and Bar-tailed Godwit	2436	N	Casuarina beach (walking along beach)