Central Coast Council

Ordinary Council Meeting

Enclosures

Monday, 22 July 2019

Central Coast Council

Enclosures to the

Ordinary Council Meeting

To be held in the Council Chamber
2 Hely Street, Wyong
On Monday, 22 July 2019
Commencing at 6.30pm

INDEX

FLYING-FOX CAMP MANAGEMENT STRATEGY

Central Coast

Flying-fox Management Strategy

April 2019 | Central Coast Council / NSW Department of Industry - Lands & Forestry

Prepared by Hunter Joint Organisation of Councils for Central Coast Council / NSW Department Industry - Lands & Forestry

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Disclaimer

This document has been compiled in good faith, exercising all due care and attention. Strategic Services Australia does not accept responsibility for inaccurate or incomplete information. The basis of the document has been developed from the NSW Office of Environment and Heritage "Flying-fox Camp Management Plan Template 2016".

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We acknowledge the broader input received from Local Council Officers undertaking similar Flying Fox Camp Management Plans in the Hunter Region, as their efforts may have influenced the creation of this Flying-fox Management Strategy.

We acknowledge input by the NSW Office of Environment and Heritage, and consultants Ecosure, in developing the template on which this Flying-fox Management Strategy was based. Peggy Eby also provided advice which was included in the template.

Contents

Acronyms and Abbreviations

ABLV	Australian bat lyssavirus
BFF	Black Flying-fox (*Pteropus alecto*)
BC Act	*Biodiversity Conservation Act* 2016
DI - Lands & Forestry	Department of Industry – Lands & Forestry (NSW)
DoE	Commonwealth Department of the Environment
DPI	Department of Primary Industries (NSW)
EP&A Act	*Environmental Planning and Assessment Act* 1979 (NSW)
EPA	Environment Protection Authority (NSW)
EPBC Act	*Environment Protection and Biodiversity Conservation Act* 1999 (Commonwealth)
GHFF	Grey-headed Flying-fox (*Pteropus poliocephalus*)
the Guideline	Referral Guideline for Management Actions in Grey-headed and Spectacled Flying-fox Camps 2015 (Commonwealth)
HeV	Hendra virus
LGA	local government area
LGNSW	Local Government NSW
LRFF	Little Red Flying-fox (*Pteropus scapulatus*)
MNES	Matters of National Environmental Significance
NPW Act	*National Parks and Wildlife Act* 1974 (NSW)
NPWS	National Parks and Wildlife Service (NSW)
OEH	Office of Environment and Heritage (NSW)
PEPs	Protection of the Environment Policies
POEO Act	*Protection of the Environment Operations Act* 1997 (NSW)
the Policy	Flying-fox Camp Management Policy 2015 (NSW)
SEPPs	State Environmental Planning Policies
SIS	species impact statement
TEC	threatened ecological community

Executive Summary

The Central Coast region is fortunate to be an important part of the home range of three Flying-fox species (also known as mega bats or fruit bats). These animals are a critical component of the rich biodiversity of the area as they are pollinators for a stunning range of native plants and disperse seeds over many kilometres.

As part of the Central Coast Council's commitment to value and protect the environment and the ecosystems that comprise local and regional biodiversity, this Flying-fox Management Strategy has been prepared to guide the management of the species on Council and other land.

There are currently four known active Flying-fox 'camps' (or roosting areas) in the Central Coast LGA. Camps at Watanobbi, Everglades and Wingello Creek are located on Council land. The North Avoca Camp is largely located on a Crown Reserve managed by Department of Industry – Lands & Forestry, although overflow from this Camp moves onto both private and Council land.

Highly mobile fauna such as Flying-foxes cannot be contained in reserves or onto specific land tenures, therefore, a strategic plan for their management must be a collaboration with various government land managers. Consequently, the Department of Industry – Lands & Forestry has partnered with Council in the preparation of the Strategy. Community consultation about available management options is an on-going responsibility of Council to the residents of the Central Coast.

Document Note
The NSW Office of Environment & Heritage is working closely with the Councils of the Hunter and Central Coast Region to develop a Hunter & Central Coast Regional Flying-fox Management Strategy that will seek to provide a regional management context that supports individual Camp Management Plans, and provide greater coordination of resources.
Updated foraging models (from those created for the 2013 *Grey-headed Flying-fox Management Strategy for the Lower Hunter*) will be included in the Hunter & Central Coast Regional Flying-fox Management Strategy (expected to be completed in the latter half of 2017) and may therefore supersede the information provided in Section 3.1.

1 Overview

1.1 Purpose of the Strategy

The Central Coast Flying-fox Management Strategy has been compiled by Hunter Joint Organisation of Councils, utilising the NSW Office of Environment and Heritage's *Flying-fox Camp Management Plan Template* (OEH 2015a) and input from other NSW councils, the Department of Industry – Lands & Forestry (DI - Lands & Forestry) and the Office of Environment and Heritage (OEH).

While the Central Coast Flying-fox Management Strategy has a local focus, collaboration with Hunter Councils Environment Division, OEH and DI - Lands & Forestry is acknowledging that Flying-fox colonies on the Central Coast are part of a broad regional population of three species that extends from South Australia and Victoria to the northern parts of Queensland, Northern Territory and Western Australia. Movement of individuals between camps and even further afield is known to occur, however the factors that influence their movement is not yet well understood.

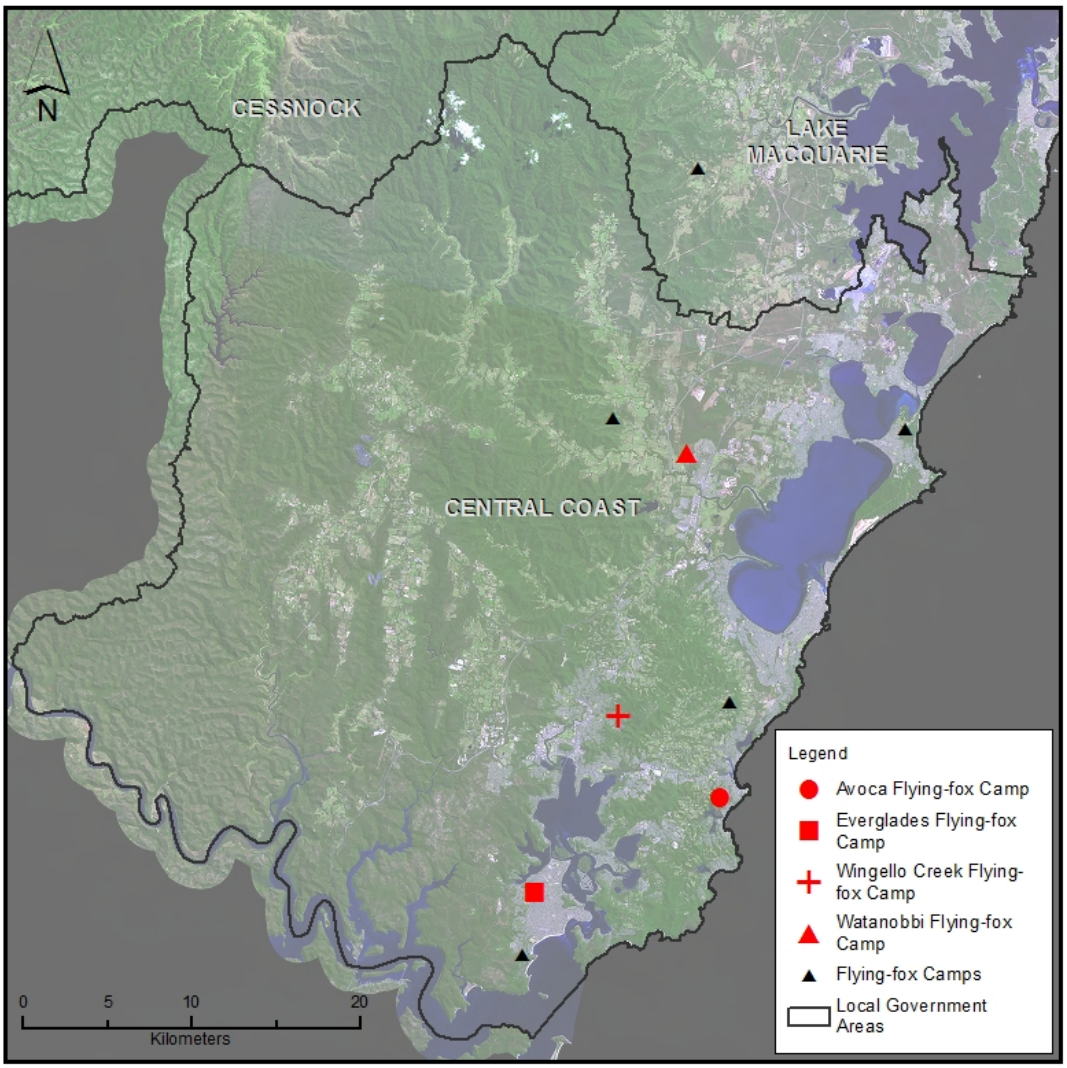
The purpose of this Strategy is to plan for appropriate management actions in accordance with the *Flying-fox Camp Management Policy* (OEH 2015b). This Strategy will enable appropriate land management as per NSW legislation to reduce impacts of Flying-fox camps on Central Coast residents.

As an enduring Strategy, it addresses the known camps, which are currently not causing significant community concern, but will also be applicable in the event of a dramatic increase in the Flying-fox population within the Central Coast Local Government Area (LGA).

This Strategy has been developed as part of a Hunter Regional Project that has developed specific Flying-fox camp management plans for Cessnock City Council, Mid Coast Council, Muswellbrook Council, Singleton Council, Port Stephens Council and Upper Hunter Shire Council. Participating in this project has enabled strong alignment with the actions of other Councils and the creation of active working relationships with these Councils. If a management action undertaken in one jurisdiction affects the roosting behaviour or Flying-foxes, a network of land management / ecology specialists can notify neighbouring Councils of a possible increase in Flying-fox numbers. In addition, Lake Macquarie City Council has recently developed a Camp Management Plan for the Blackalls Park Flying-fox Camp, utilising the State template and processes, and are participating in a regional Flying-fox community education project with all other councils of the region. Central Coast residents can be confident that the actions and information in the Strategy are closely aligned with other NSW councils and current best practice as established by OEH.

There are eight Flying-fox camps known to exist in the LGA (see Map 1), with four of these camps accommodating animals in the past four years. Specific details on the currently occupied sites are provided in this Strategy, but it is noted if any of the historic camps are re-occupied, or new camps are created, they would be managed as per the direction given in this Strategy.

Map 1: Flying-fox Camps in the Central Coast LGA (June 2017)



1.2 Objectives

The Central Coast Flying-fox Management Strategy is an initiative of Central Coast Council (Council) taken on behalf of all land managers of existing camps (including NSW Department of Industry – Lands (DI - Lands & Forestry)).

The Strategy has been developed to provide Council and DI - Lands & Forestry a clear framework for the management of Flying-fox camps in the LGA.

The objectives of this Strategy are to:

- minimise impacts to the community, while conserving Flying-foxes and their habitat; and
- enable land managers and other stakeholders to use a range of suitable management responses to sustainably manage the Flying-fox population.

The Strategy provides details on camp sites, Flying-fox species, community engagement and agreed management actions designed to achieve the above-stated objectives.

The objectives of the Strategy are consistent with the *Flying-fox Camp Management Policy* (OEH 2015b).

1.3 Roles and Responsibilities

There are a number of land managers and organisations responsible for the management of Flying-fox species and the four active Flying-fox camps in the Central Coast LGA.

1.3.1 NSW Office of Environment and Heritage

The Office of Environment and Heritage (OEH) is responsible for administering the *Biodiversity Conservation Act 2016*, and for ensuring the impact of any action affecting threatened species is properly assessed. The Grey-headed Flying-fox is a threatened species as listed under the BC Act. Any applications to disrupt a Flying-fox roosting site (camp) would be assessed by OEH Regional Operations Group Hunter Central Coast (ROG-HCC), Planning and Ecosystems and Threatened Species teams.

1.3.2 NSW Department of Industry - Lands

Some Crown land within the LGA is managed by the NSW Department of Industry – Lands. DI - Lands & Forestry is the primary land manager at the North Avoca Flying-fox Camp and subsequently final decisions about how to manage this site are the responsibility of this Department.

1.3.3 Central Coast Council

The Central Coast Council is the primary land owner responsible for managing the Watanobbi and Wingello Creek Camp sites and subsequently final decisions about how to manage these sites are Council's responsibility. As the representative organisation of the local community, the Central Coast Council plays an active role in developing management actions for all known camp sites.

1.3.4 Private Land Owners

Where Flying-fox camps are located on private property, the land holders are required to protect the Flying-foxes and their habitat in the same way that Councils and State agencies are. It is hoped that this Strategy will assist private land owner's understanding of appropriate management activities and the approvals required for undertaking these activities. The Camp sites of Everglades and North Avoca may include private property.

1.4 Flying-fox Species on the Central Coast

There are three species that comprise the regional Flying-fox population (see Table 1). This Strategy refers to all three species, except when specifically addressing the threatened species, the Grey-headed Flying-fox. More information about the species can be found in Appendix 1: Flying-fox Species Profiles.

Table 1: Flying-fox species occurring on the Central Coast

Species name	Range and photo	Status
Black Flying-fox (*Pteropus alecto*)		Protected under *Biodiversity Conservation Act* 2016
Grey-headed Flying-fox (*Pteropus poliocephalus*)		Listed as Vulnerable under *Environment Protection & Biodiversity Conservation Act* 1999 and *Biodiversity Conservation Act* 2016
Little Red flying-fox (*Pteropus scapulatus*)		Protected under *Biodiversity Conservation Act* 2016

2 Flying-Fox Camps of the Central Coast

Flying-foxes are wild animals and highly dynamic in their migratory movements, search for food and selection process for suitable roosting areas. There is very little understanding on how or why Flying-foxes select certain roosting areas, but recent research suggests that food shortages, and proximity to secure food sources and human settlements are significant factors. The number and size of Flying-fox camps is constantly changing throughout NSW, and it is likely that more changes to camps will occur in the coming years.

Council is aware of a total of eight Flying-fox camps in the LGA (of which only four have had recent occupancy). The camps are identified as follows:

- Watanobbi (last known occupancy 2017)
- Wyoming / Wingello Creek (last known occupancy 2017)
- North Avoca (last known occupancy 2017)
- Everglades (last known occupancy 2017)
- Toukley (last known occupancy 1999)
- Jilliby (last known occupancy 2001)
- Matcham (last known occupancy 2002)
- Umina (last known occupancy 2013 – only 50 individuals)

Following is specific information on the currently occupied camps within the Central Coast LGA.

2.1 Watanobbi Flying-Fox Camp and Surrounds

The Watanobbi Flying-fox Camp is located within a wetland complex associated with Porter's Creek. The reserve covers an area of several hundred hectares and spans a number of land tenures.

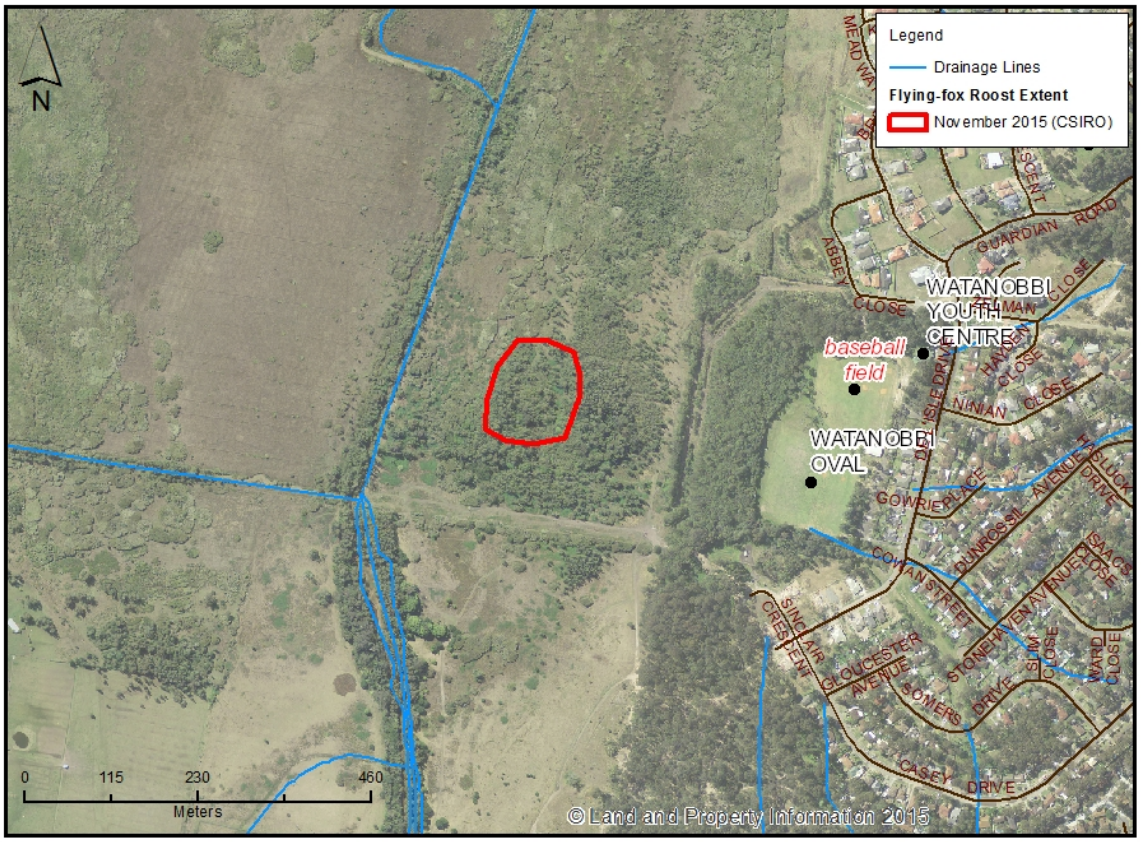
The Flying-fox Camp is located on 1.5 ha of Council-managed land (zoned E2 Environmental Conservation) inside the larger reserve complex. The Camp is located approximately 400 m from the nearest residential development and approximately the same distance from Watanobbi Oval (see Map 2), and is well protected by surrounding dense vegetation and a series of small drainage lines.

The Camp can be accessed by foot or 4WD via an old unsealed disused road at the end of Sinclair Street. There is no formal public access to the reserve or formal walking tracks throughout the reserve.

Porter's Creek runs through the middle of the reserve. The western side of the Creek was used extensively for dairy grazing which resulted in clearing of natural vegetation and channelisation of the wetland. Exotic grasses, annuals and perennials now dominate the area. The vegetation on the eastern side of Porter's Creek also contains widespread and isolated patches of noxious and environmental weeds.

The size and location of the Flying-fox camp has changed over time. Map 2 shows the location as at 2015 (the date of the last CSIRO census data).

Map 2: Watanobbi Flying-fox Camp in the Porter's Creek wetland complex



2.1.1 Vegetation Communities

Two main vegetation communities occur within the south-eastern corner of the reserve which provides suitable roosting habitat:

- Estuarine Swamp Oak Forest – EEC Equivalent: Swamp Oak Floodplain Forest, which is dominated by *Casuarina glauca/Melaleuca ericifolia, Melaleuca stypheloides/ Phragmities australis, Juncus krausii; Baumea juncea; Sporobolus virginicus, Gahnia clarkei, Samolus repens* (Source: Wyong 2016).
- Floodplain Wet Heath- *Banksia oblongifolia, Leptospermum polygalifolium, Melaleuca nodosa, Banksia aemula, Melaleuca seiberi, Leptospermum juniperinum, Aotus ericoides, Leptocarpus tenax, Schoenus brevifolius.* (Wyong 2016).

The Flying Fox colony predominantly favours the Swamp Oak Floodplain Forest. The site contains widespread and isolated pockets of noxious and environmental weeds including Camphor Laurel, Blackberry, Lantana and Small-leaf Privet (in some areas Small-Leafed Privet has almost completely displaced native vegetation). A Rapid Flora Survey was undertaken on 15 November 2016 and recorded the most common species present within the active Camp and is included in Appendix 2: Rapid Vegetation Assessment.

Photograph 1: Regenerating Floodplain Wet Heath, on western outskirts of the Flying Fox Camp

2.1.2 Flying-fox Habitat

Roosting Areas

Grey-headed Flying-foxes were recently observed roosting in Swamp Oak *(Casuarina glauca),* Camphor Laurel and Swamp Mahogany (*Eucalyptus robusta*). Given the size and available roosting habitat, this site has the ability to house many more animals than have been recorded on site to date.

Foraging Areas

The number of flying-foxes present in a camp is primarily driven by the amount and quality of food available in the local area, relative to that available within migration distance (Tidemann 1999; Eby 1991; Roberts et al 2012). Flying-foxes typically feed within 20 km of their roost (Tidemann 1999), and digital maps of feeding habitat for Grey-headed Flying-foxes have been used to summarise feeding resources within 20 km of the Watanobbi camp (Eby and Law 2008).

Approximately 56% of land within 20 km of the site is covered by native forests and woodlands, in patches ranging in size from small remnants to extensive tracts in state forests and conservation reserves. Nearly 5% of native vegetation is warm temperate rainforest containing sparsely-distributed trees and vines that produce fruits known to be consumed by flying-foxes. A further 15% comprises moist forests with rainforest canopy and emergent Turpentine and Sydney Blue Gum. Rainforest fruits produced in these habitats provide consistent food for flying-foxes during late summer and autumn.

Nearly 90% of forested land within 20 km of the Watanobbi camp contains flowering trees visited by the animals. This resource includes extensive tracts of wet sclerophyll forests dominated by Turpentine, Sydney Blue Gum, Mountain Blue Gum, White Mahogany and Blackbutt. In total, 23 species of trees in the flower diet of Grey-headed flying-foxes occur within feeding range of the Watanobbi camp, 19 of these occur in >1% of native vegetation by area (see Table 2). They vary considerably in the amount of nectar they secrete, the frequency and duration of flowering, their seasonal flowering schedules and their area of distribution. Interactions between these characteristics determine the influence they have on the size of the population of animals roosting at Watanobbi. The majority have highly restricted distributions and are likely to have a minor influence on the number of flying-foxes feeding in the area. Six widespread and highly productive species are likely to have a substantial influence (see Table 2).

The majority of influential diet species flower during summer and autumn. The size of the flying-fox population should fluctuate considerably during these months in relation to nectar abundance. Substantial flowering of Blue Gums or Blackbutt should attract relatively large numbers of flying-foxes; and the size of the population is likely to peak during mass flowering of Red Bloodwood or Spotted Gum. In years when the widely-distributed Turpentine flowers well, the period during which the camp is occupied is likely to extend into spring. Native vegetation in the area is unlikely to support populations from late May through August due to the highly-restricted distribution of diet plants that flower in those months. Nonetheless, it is possible for small over-wintering populations to be supported by urban plantings, particularly in years of wide-spread food scarcity in native forests.

Table 2: Characteristics of flowering trees in the diet of the Grey-headed Flying-fox that occur within 20 km of the Watanobbi Camp. Nectar abundance is scored in 4 categories from 0 to 1; the approximate frequency of flowering is also scored in 4 categories relating to % of years; duration of flowering is scored in months. Species likely to play a significant role in determining the number of flying-foxes present in the camp, as assessed by nectar abundance and area of distribution, are highlighted in grey. Species found in <1% of native vegetation have been excluded. See Eby and Law (2008) for further details.

Species	Common Name	% area of native vegetation	flowering characteristics			bi-monthly flowering schedule					
			nectar abundance	frequency (% yrs)	duration (mth)	Dec-Jan	Feb-Mar	Apr-May	Jun-Jul	Aug-Sep	Oct-Nov
Corymbia gummifera	Red Bloodwood	20%	1	0.4	2	X	X				
C. maculata	Spotted Gum	20%	1	0.25	4-6		X	X			
Eucalyptus deanei	Mountain Blue Gum	25%	0.70	0.70	1	X	X	X			
E. pilularis	Blackbutt	25%	1	0.4	2	X	X				
E. saligna	Sydney Blue Gum	40%	0.7	0.7	1	X	X				
Syncarpia glomulifera	Turpentine	45%	0.5	0.7	2					X	X
Angophora costata	Smooth-barked Apple	15%	0.3	0.4	1						X
A. floribunda	Rough-barked Apple	15%	0.5	0.4	1	X					
Banksia serrata	Old Man Banksia	1%	0.5	0.7	2-3	X	X	X			
E. acmenoides	White Mahogany	25%	0.3	0.7	1	X					X
E. fibrosa	Broad-leaved Ironbark	1%	0.7	0.4	2	X					X
E. paniculata	Grey Ironbark	15%	0.7	0.4	3-4	X				X	X
E. piperita	Sydney Peppermint	5%	0.50	0.40	1	X					
E. propinqua	Small-fruited Grey Gum	2%	0.5	0.4	2	X	X				
E. punctata	Large-fruited Grey Gum	1%	0.30	0.70	1	X	X				
E. resinifera	Red Mahogany	2%	0.5	0.4	2	X	X				
E. robusta	Swamp Mahogany	5%	1	1	3			X	X		
E. siderophloia	Grey Ironbark	5%	1	0.7	2	X					X
Melaleuca quinquenervia	Broad-leaved Tea Tree	1%	1	1	3-4		X	X			
						14	**10**	**5**	**1**	**2**	**6**

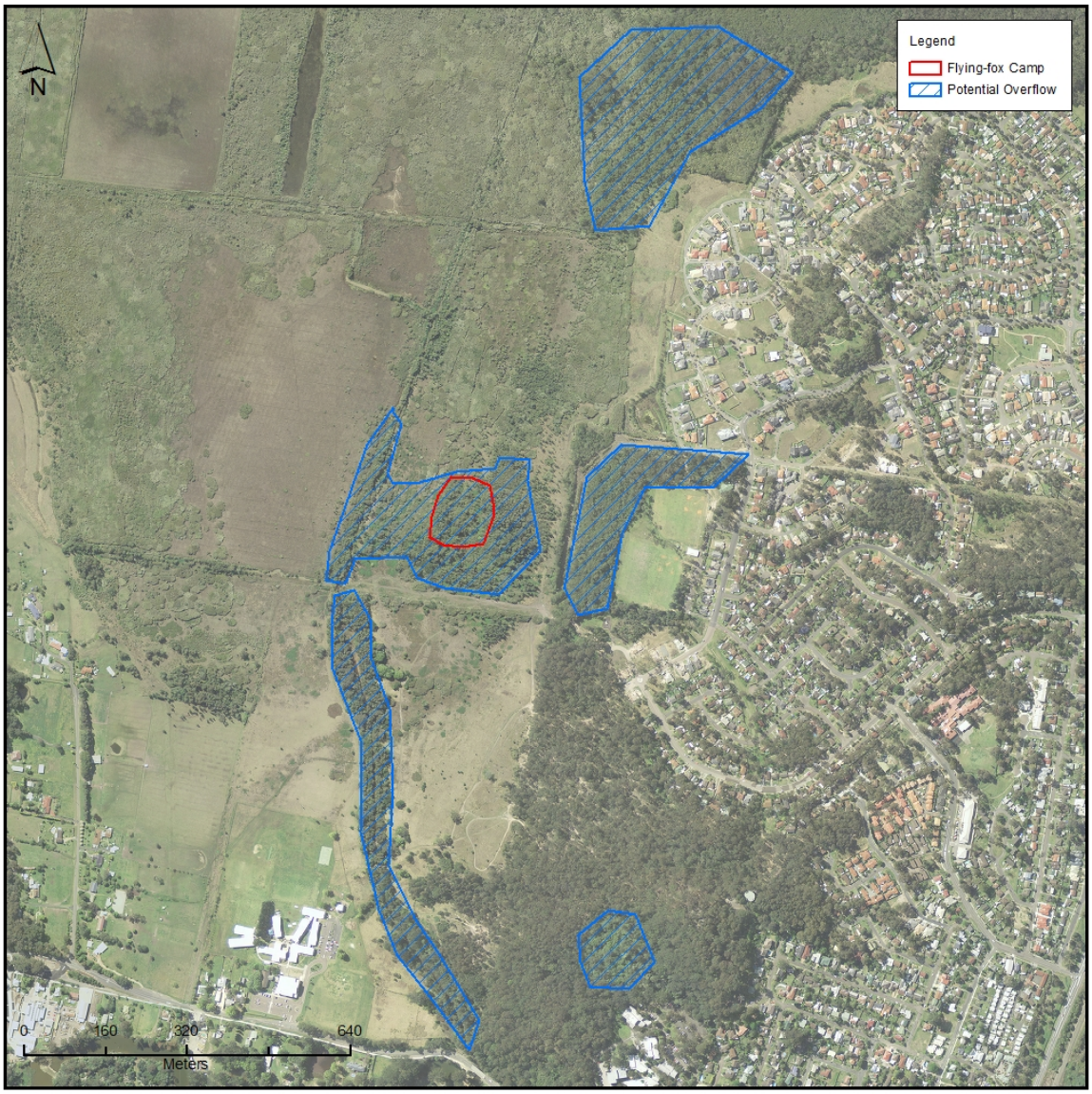
Potential Overflow Roosting Areas

There are a number of areas adjacent to, or within a few kilometres of the Camp which appear to be suitable habitat for Flying-foxes:

- Patches of Paperbark Forest to the north-east of the Camp. There are also patches of potential roosting habitat directly east of the Camp within the residential area;
- Porter's Creek (directly west and south of the Flying-fox Camp) which supports a number of different vegetation communities including Wet Sclerophyll Forest and Swamp Sclerophyll Forest, which are both suitable foraging and roosting habitat.

In addition to these sites, there are a number of heavily vegetated parcels of private land that may prove suitable for Flying-fox roosting and foraging (see Map 3 for details).

Map 3: Potential Flying-fox Camp overflow areas near the Watanobbi Flying-fox Camp



2.1.3 Flying-fox Population at the Watanobbi Flying-fox Camp

CSIRO census information indicates Flying-fox presence at the site varies each year. Most recently, only Grey-headed Flying-foxes have been noted to utilise this Camp, and in relatively small numbers (see Table 3).

Table 3: Flying-fox population data for Watanobbi Camp (source: CSIRO National Flying-fox census)

	Nov-12	Feb-13	May-13	Aug-13	Nov-13	Feb-14	May-14	Aug-14	Nov-14	Feb-15	May-15	Aug-15	Nov-15	Feb-16	May-16	Aug-16
Hunter Camps (all FF species)	15,387	131,768	44,519	23,649	15,172	97,769	27,533	7,681	130,269	335,279	105,926	112,624	138,593	309,962	176,703	66,784
Watanobbi Camp GHFF	-	-	-	-	-	-	-	-	-	-	2387	-	6800	-	-	-
Watanobbi Camp LRFF	-	-	-	-	-	-	-	-	-	-	0	-	0	-	-	-
Watanobbi Camp BFF	-	-	-	-	-	-	-	-	-	-	0	-	0	-	-	-
% of Hunter Region FF in Watanobbi	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2.3%	0%	4.9%	0%	0%	0%

GHFF = Grey Headed Flying-fox; LRFF = Little Red Flying-fox; BFF = Black Flying-fox

Figure 1 provides a graphical presentation of the data presented in Table 3, clearly showing the change in the Flying-fox population at the Watanobbi Camp (and other camps in the LGA) compared to the Flying-fox population at all camps in the Hunter Region.

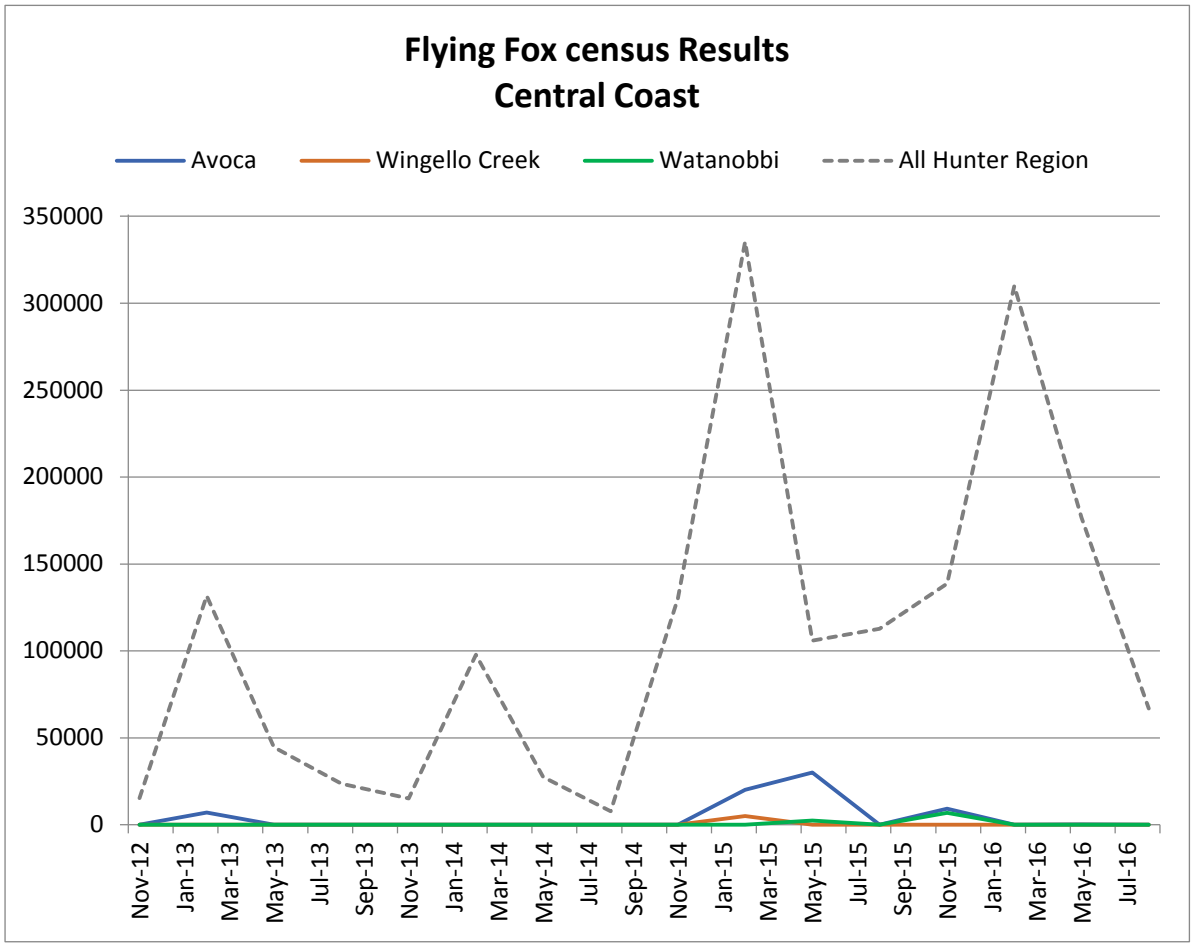


Figure 1: Flying-fox census results for the Central Coast Flying-fox camps compared to the Hunter Region camps. Graph represents all species of Flying-fox counted (Source: CSIRO National Flying-fox census).

2.1.4 Community Interests and Issues Related to the Camp

Council has not received any complaints in recent years related to the Watanobbi Camp.

2.1.5 Management Activities to Date

There has been no requirement to actively manage this site.

2.2 Wyoming / Wingello Creek Flying-fox Camp and Surrounds

The Flying-fox Camp at Wyoming covers approximately 3 ha in Rainforest Road Reserve, which is located between Blackbutt Street and Rainforest Road, Wyoming (see Map 4). Rainforest Road Reserve is part of a 500 ha complex of Coastal Open Space System (COSS) reserves which includes Rumbalara and Katandra Reserves.

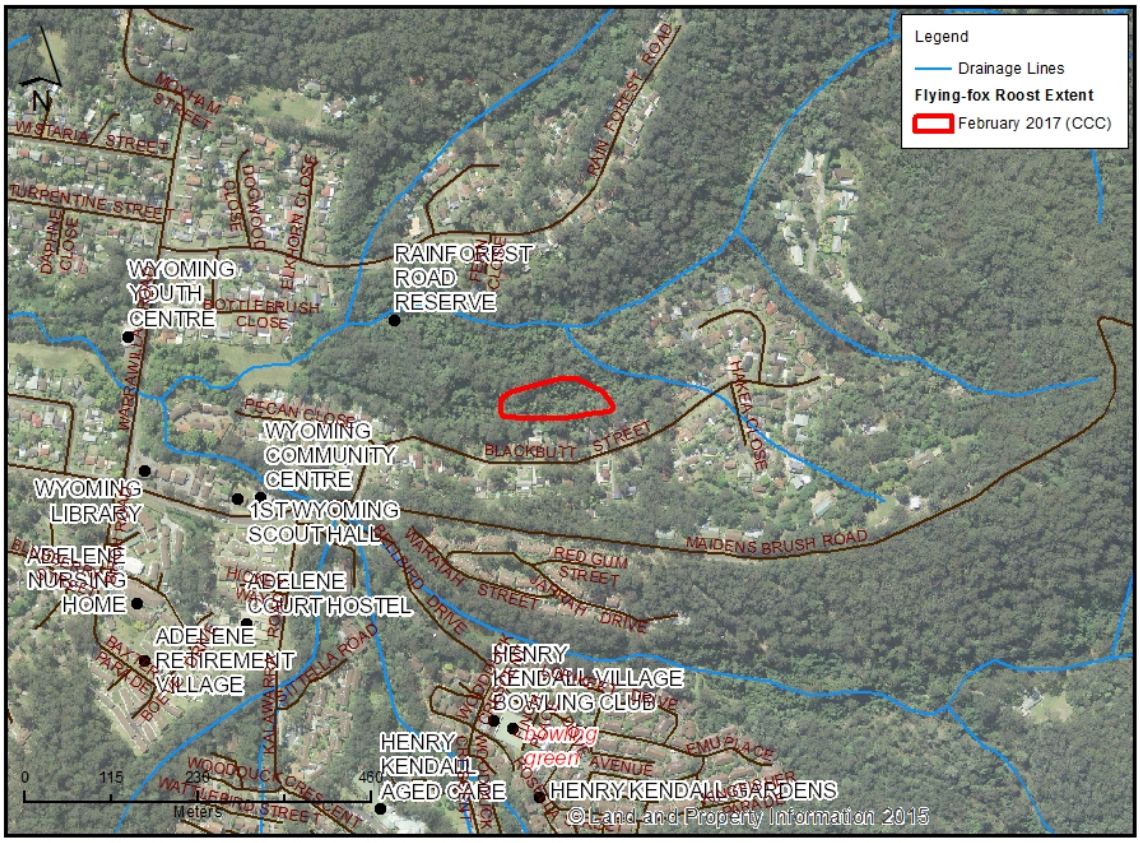
The COSS is a network of largely natural reserves which has been part of the former Gosford City Council's response to biodiversity conservation, heritage protection and the retention of vegetation on ridgelines since the early 1980s. Nature based recreation opportunities which do not adversely impact on the values of the system are encouraged as is the use of the reserves for educational and scientific research uses.

Rainforest Road Reserve covers an area of approximately 12 ha, part of which is located to the north of Rainforest Road, with a narrow strip of the reserve extending to the west and south of the Pecan Close cul-de-sac. The reserve is located on Lot 77 DP 262471 which is owned by Central Coast Council.

The reserve contains dense remnant native vegetation in good condition, consistent with Coastal Warm Temperate – Subtropical Rainforest and Narrabeen Moist Rainforest (Bell 2013). Wingello Creek flows from east to west through the reserve and ultimately flows into Narara Creek to the west of Northern Railway. There is also an unnamed drainage line that runs in a south-east direction through the reserve (refer to Map 4). A flood retarding basin is located on Wingello Creek in the western part of the reserve, which is regularly slashed to prevent the growth of woody and shrubby vegetation.

There is no formal walking or bike track through the reserve. Overall access to the reserve is limited and difficult in some areas as a result of the dense vegetation. Access to the southern part of the reserve is however possible via Blackbutt Street with the northern side of the reserve able to be accessed from Fern Close. Access to the western end of the reserve is possible via a right of way at the end of Pecan Road and Warrawilla Road.

Map 4: Wyoming / Wingello Creek Flying-fox Camp at Wingello Creek



2.2.1 Vegetation Communities

Rainforest Road Reserve, including the part of the reserve where the Flying-fox Camp is located, supports two vegetation communities:

- Coastal Narrabeen Moist Forest – located on the northern and southern sides of the reserve. This is the most dominant vegetation community. (See Photograph 2)
- Coastal Warm Temperate-Sub Tropical Rainforest (Endangered Ecological Community equivalent Lowland Rainforest) – located on the southern edge –where Flying-foxes are roosting and within the center of the reserve

A Rapid Flora Survey was undertaken on 15 November 2016 and recorded the most common species present within the active Camp and is included in Appendix 2: Rapid Vegetation Assessment.

Photograph 2 Southern edge of the reserve - Rapid Flora Survey, dominant species consistent with Coastal Narrabeen Moist Rainforest

2.2.2 Flying-fox Habitat

Roosting Areas

Grey-headed Flying-foxes have been observed roosting:

- within 10 to 20 m of the southern boundary of the reserve, which is relatively open compared to other areas of the Camp;
- in large numbers along the south-eastern edge closest to the property boundaries;
- in smaller groups dispersed across the core of the reserve in a number of different tree species including Turpentine, Pittosporum, the lower branches of Sydney Blue Gums, and Cabbage Tree Palms; and
- approximately 30 m south of Wingello Creek in a dense and protected layer of vegetation comprising vines, shrubs, ferns within both the mid and ground layer.

There is only a single dataset providing details on the roosting location, and this was used to provide the Camp extent in Map 4.

Noise and smell associated with the Flying-fox Camp was less evident during the site visit in November 2016 than at other more open sites. This may be because of the density of the vegetation and the relatively low density of flying-foxes in the reserve.

Foraging Areas

Council's COSS natural reserves comprise a large contiguous areas of bushland containing a number of vegetation communities located to the south, north and east of the Flying-fox Camp. There is a high level of native species richness which has the potential to provide an abundant source of food for Flying-foxes.

The Wyoming Flying-fox Camp is located approximately 7.3 km north-west of the North Avoca Flying-fox Camp, and it is possible that animals from both camps forage in similar areas.

Approximately 55% of land within 20 km of the Wingello Creek site supports native forests and woodlands in patches ranging in size from small remnants to extensive tracts in conservation reserves and state forests. Nearly 3% of native vegetation is warm temperate rainforest containing sparsely-distributed fruiting trees and vines known to be consumed by flying-foxes. A further 8% comprises moist forests with rainforest canopy and emergent Turpentine and Sydney Blue Gum. Rainforest fruits in these habitats provide consistent food for flying-foxes during late summer and autumn.

Approximately 87% of forested land within 20 km of Wingello Creek contains flowering trees visited by the animals. Remnant vegetation immediately surrounding the camp, and to the northwest, contains extensive tracts of wet sclerophyll forests dominated by Turpentine, Sydney Blue Gum and Blackbutt. To the south and west lie dry forests and woodlands on sandstone dominated by species such as Red Bloodwood and Smooth-barked Apple.

In total, 24 species of trees in the flower diet of Grey-headed flying-foxes occur within feeding range of the Wingello Creek camp, 20 of these occur in >1% of native vegetation by area (see Table 4). They vary considerably in the amount of nectar they secrete, the frequency and duration of flowering, their seasonal flowering schedules and their area of distribution. Interactions between these characteristics determine the influence they have on the size of the population of flying-foxes roosting at Wingello Creek. Species with restricted distributions or that produce relatively low volumes of nectar are likely to have a minor influence on the number of flying-foxes feeding in the area. Five widespread and highly productive species are likely to have a substantial influence (see Table 4).

However, significant flowering in 4 species is likely to attract flying-foxes to the Wingello Creek camp during summer and early autumn (see Table 4). The size of the flying-fox population should fluctuate considerably during these months and reach highest number in years when Red Bloodwood flowers heavily. The length of time the camp is occupied is likely to extend to spring in years when the widely-distributed Turpentine flowers well. Native vegetation in the area is unlikely to support winter populations due to the highly-restricted distribution of diet plants that flower in those months. Nonetheless, it is possible for small over-wintering populations to be supported by urban plantings, particularly in years of wide-spread food scarcity in native forests.

Table 4: Characteristics of flowering trees in the diet of Grey-headed Flying-foxes that occur within 20 km of the Wingello Creek Camp. Nectar abundance is scored in 4 categories from 0 to 1; the approximate frequency of flowering is also scored in 4 categories relating to % of years; duration of flowering is scored in months. Species likely to play a significant role in determining the number of flying-foxes present in the camp are highlighted in grey. See Eby and Law (2008) for further details.

Species	Common Name	% area of native vegetation	flowering characteristics			bi-monthly flowering schedule					
			nectar abundance	frequency (% yrs)	duration (mth)	Dec-Jan	Feb-Mar	Apr-May	Jun-Jul	Aug-Sep	Oct-Nov
Corymbia gummifera	Red Bloodwood	35%	1	0.4	2	X	X				
Eucalyptus deanei	Mountain Blue Gum	25%	0.70	0.70	1	X	X				
E. pilularis	Blackbutt	25%	1	0.4	2	X	X				
E. saligna	Sydney Blue Gum	30%	0.7	0.7	1	X	X				
Syncarpia glomulifera	Turpentine	50%	0.5	0.7	2					X	X
Angophora costata	Smooth-barked Apple	30%	0.3	0.4	1						X
A. floribunda	Rough-barked Apple	10%	0.5	0.4	1	X					
Banksia integrifolia	Coast Banksia	1%	0.7	1	4			X	X	X	
B. serrata	Old Man Banksia	10%	0.5	0.7	3	X	X	X			
C. maculata	Spotted Gum	10%	1	0.25	4-6		X	X			
E. acmenoides	White Mahogany	25%	0.3	0.7	1	X					X
E. paniculata	Grey Ironbark	10%	0.7	0.4	3-4	X				X	X
E. piperita	Sydney Peppermint	10%	0.50	0.40	1	X					
E. propinqua	Small-fruited Grey Gum	1%	0.5	0.4	2	X	X				
E. punctata	Large-fruited Grey Gum	5%	0.30	0.70	1	X	X				
E. resinifera	Red Mahogany	2%	0.5	0.4	2	X	X				
E. robusta	Swamp Mahogany	5%	1	1	3			X	X		
E. siderophloia	Grey Ironbark	5%	1	0.7	2	X					X
E. tereticornis	Forest Red Gum	1%	1	1	2					X	X
Melaleuca quinquenervia	Broad-leaved Tea Tree	1%	1	1	3-4		X	X			
						13	**10**	**5**	**2**	**4**	**6**

Potential Overflow Roosting Areas

The native vegetation in the COSS and natural reserves in the Wyoming area is similar in structure to that in the current Camp site. It is possible that other sites within 6 km of the current camp, particularly those near creeks and rivers and with a similar vegetation structure, would provide suitable roosting and foraging habitat and possible camp relocation.

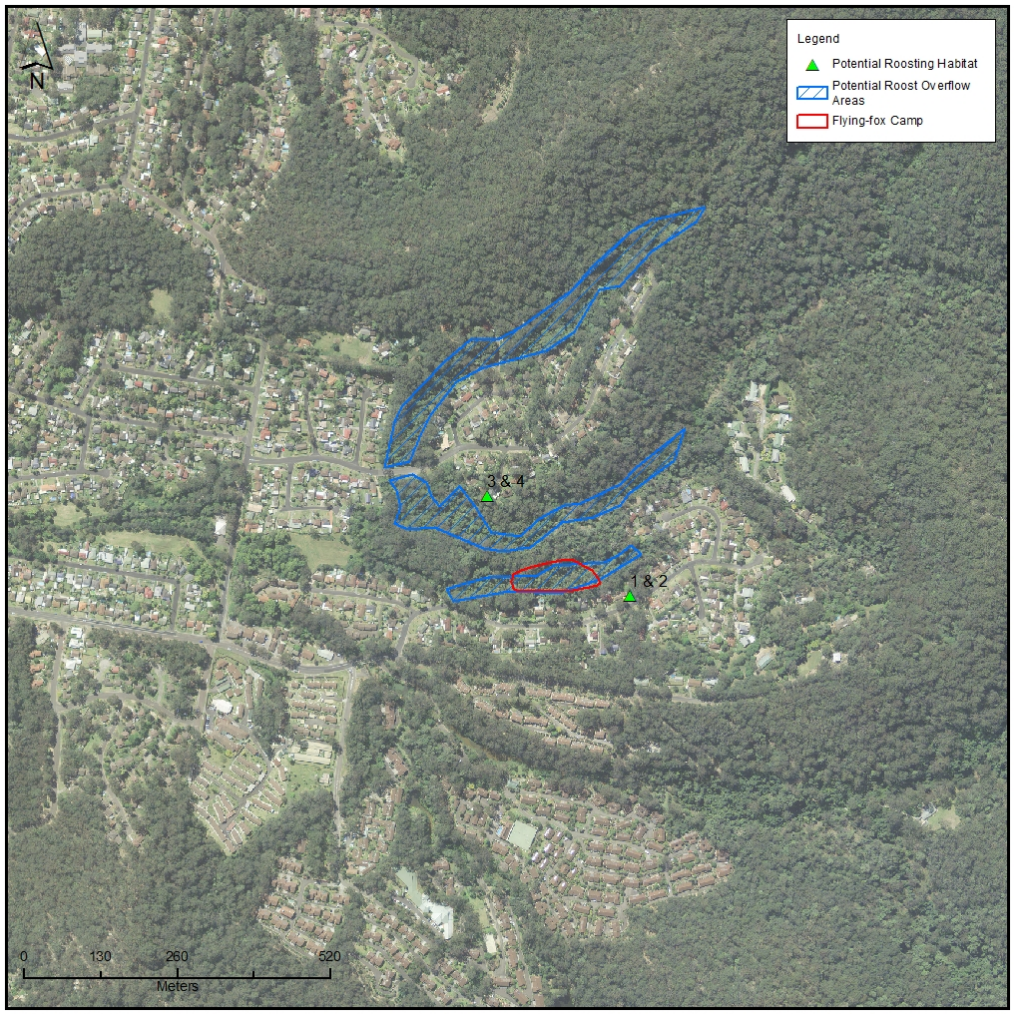
Flying-foxes do not exclusively use roosting trees that are native. Potential roosting habitat species (native and exotic) have been identified on adjacent land and are shown in Table 5 and Map 5.

Table 5: Description of Potential Roosting Overflow Locations adjacent to the Wyoming/Wingello Creek Flying-fox Camp

Site	Species	Roosting/foraging habitat and condition	Roosting/foraging habitat/impact on residential areas and schools
1	Liquidambar	*Liquidambar spp.*	within 5 m of the dwelling
2	Turpentine	*Syncarpia glomulifera*	8 m to the dwelling
3	Weeping Bottle Brush	*Callistemon salignus*	7 m to from the dwelling to the back boundary
4	Jacaranda	*Jacaranda spp.*	within 10 m from the dwelling

There are a number of sites within 1 km of the Camp that contain similar disturbed and regrowth vegetation (on both private and public land) that may also be suitable as Flying-fox habitat and could act as potential overflow sites (refer to Map 5).

Map 5: Potential Flying-fox Camp overflow areas at Wingello Creek Flying-fox Camp



2.2.3 Flying-fox Population at the Wyoming / Wingello Creek Flying-fox Camp

The National Flying-fox Monitoring Viewer identifies the Wyoming Camp as No. 262. The Flying-fox Camp in Rainforest Road Reserve has, based on Flying-fox census data, only been utilised in 2015, when Grey-headed Flying-foxes were counted there (less than 10,000). Council records have the Flying-fox Camp at the Wingello Creek site prior to 2010, suggesting that that Flying-foxes may continue to return to the Camp in the future. Table 6 provides the specific Census results for the Wingello Creek Camp since 2012.

Table 6: Flying-fox population data for Wyoming/Wingello Creek (source: CSIRO National Flying-fox census)

	Nov-12	Feb-13	May-13	Aug-13	Nov-13	Feb-14	May-14	Aug-14	Nov-14	Feb-15	May-15	Aug-15	Nov-15	Feb-16	May-16	Aug-16
Hunter Camps (all FF species)	15,387	131,768	44,519	23,649	15,172	97,769	27,533	7,681	130,269	335,279	105,926	112,624	138,593	309,962	176,703	66,784
Wyoming / Wingello Creek Camp GHFF	-	-	-	-	-	-	-	-	-	5000	-	-	-	-	-	-
Wyoming / Wingello Creek Camp LRFF	-	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-
Wyoming / Wingello Creek Camp BFF	-	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-
% of Hunter Region FF in Wyoming / Wingello Creek	0%	0%	0%	0%	0%	0%	0%	0%	0%	1.5%	0%	0%	0%	0%	0%	0%

GHFF = Grey Headed Flying-fox; LRFF = Little Red Flying-fox; BFF = Black Flying-fox

2.2.4 Community Interests and Issues Related to the Camp

Flying-foxes camps located close to or within private properties have in some communities in the Hunter Region, has resulted in conflict. Records kept by the previous Gosford Council including only three written complaints about the Wyoming / Wingello Creek Flying-fox Camp between 2004 and 2007. It is however possible that unrecorded verbal complaints were received.

Reported community issues at the Wyoming Camps were loss of amenity due to smell and noise, and property devaluation.

2.2.5 Management Activities to Date

There has been no requirement to actively manage this site.

2.3 North Avoca Flying-fox Camp and Surrounds

The Flying-fox camp located at Lake Shore Drive, North Avoca is located on a Crown Reserve on Lot7329 DP 1166146 adjacent to Avoca Lagoon (see Map 6).

The majority of the North Avoca Flying-fox Camp is located on land under the care and control of the DI - Lands & Forestry. During camp occupation, it has been noted that Flying-foxes do sometimes extend onto both private and Council-managed lands, adding a level of complexity to the management of the Camp.

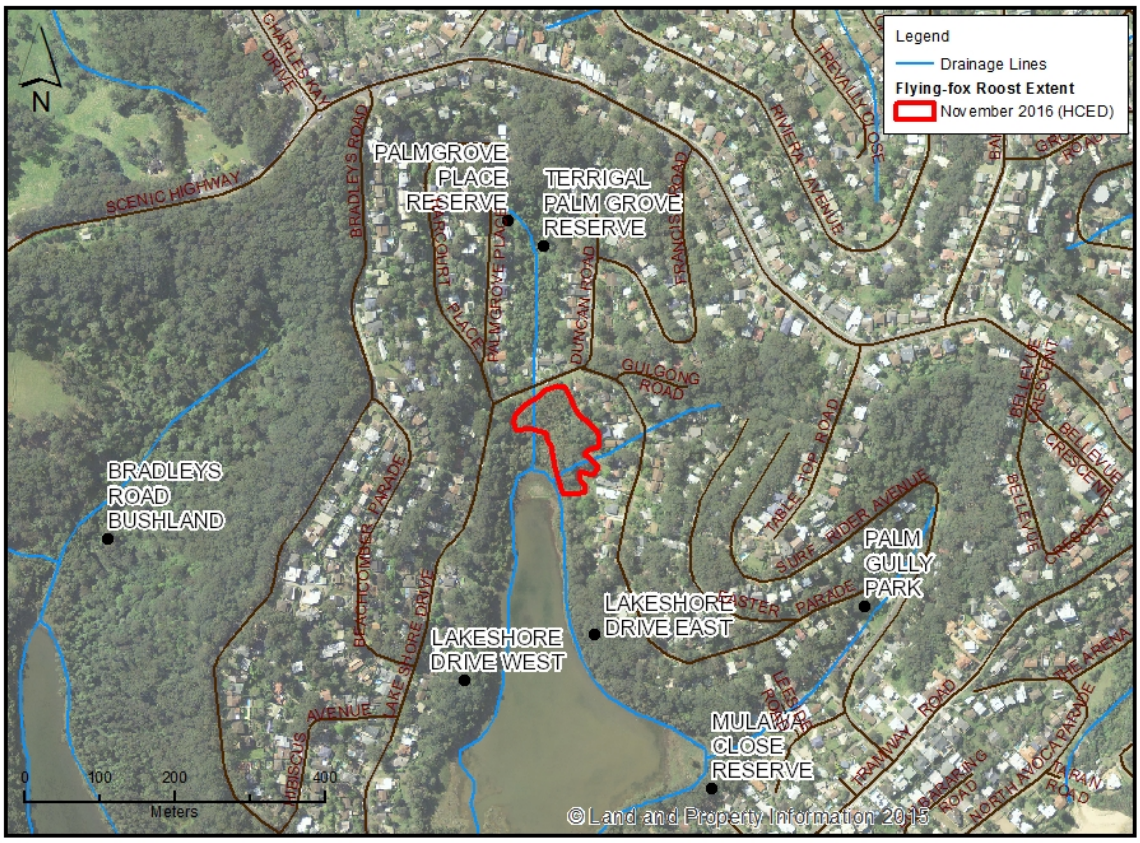
The Crown Reserve covers approximately 2.1 ha and joins the Avoca Lagoon Foreshore Reserves (East and West) which are owned and managed by Central Coast Council. There is also a small parcel of Council owned Operational land to the north-west of the Crown Reserve that covers an area of 0.08 ha (see Map 6).

Access to the Reserve is from Lake Shore Drive. There is an informal walking track that extends through Crown Land on the eastern side of Avoca Lagoon. There is also access from the eastern side of Lake Shore Drive. Neighbouring Council reserves provide suitable Flying-fox roosting habitat.

There are two distinct drainage lines, which both feed into Avoca Lagoon. One runs from Terrigal Palm Grove Reserve on the north side of Lake Foreshore Drive and the second drainage line is located north-east of the Reserve.

The extent and depth of water in the lagoon is influenced by rainfall in the catchment and oceanic conditions. In order to reduce the risk of flooding of private and public infrastructure, there is a defined maximum level that the lagoon can reach before it must be artificially released. Avoca Lagoon typically reaches the level at which it must be released twice per year.

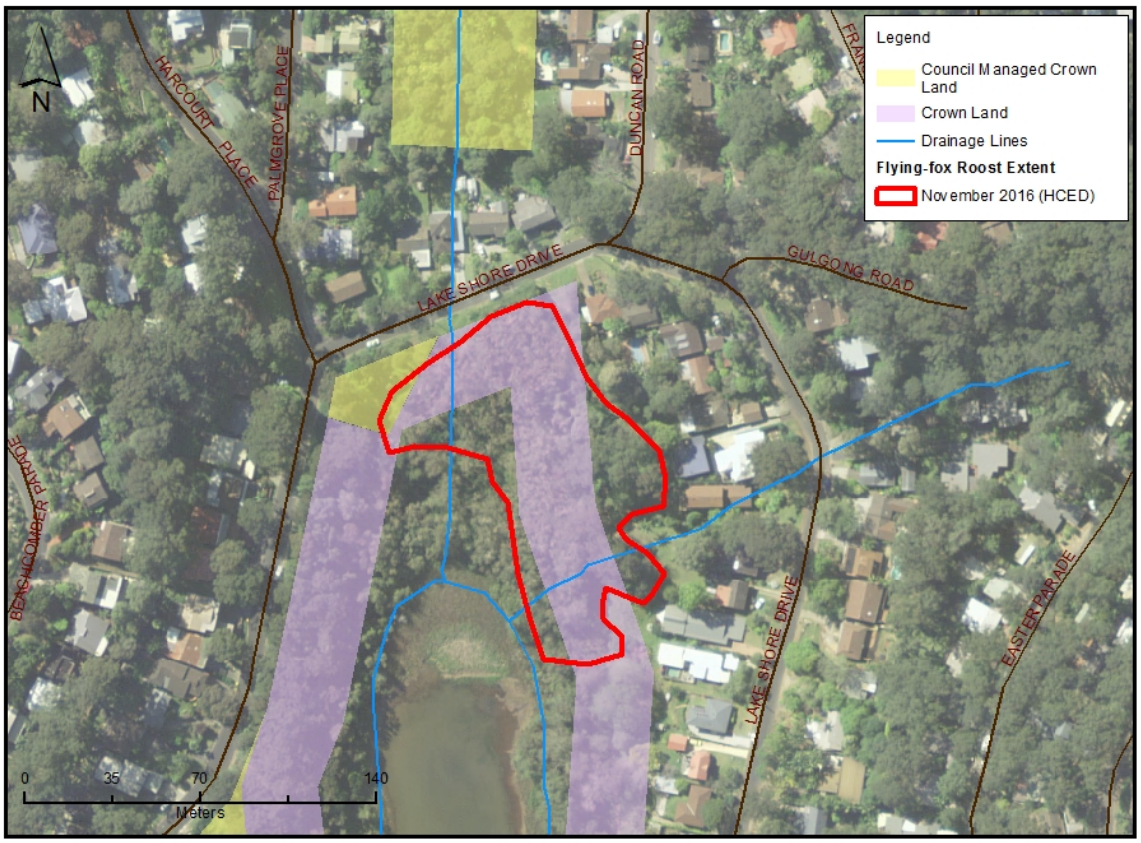
Map 6: North Avoca Flying-fox Camp Boundary



The Flying-fox camp at North Avoca, which covers approximately 1 ha, is identified on the National Flying-fox monitoring viewer as Avoca (No. 520). Both Grey-Headed Flying-foxes and Black Flying-foxes have been recorded as utilising the site.

The North Avoca Flying-fox Camp is known to spread at times across Crown Land managed by DI - Lands & Forestry and managed land (zoned Public Recreation), and surrounded by residential development. Specific detail of land tenure is included in Map 7.

Map 7: Land tenure of the North Avoca Flying-fox Camp and surrounds



It is noted that the information on camp extent at the time of developing this Strategy was from 2016.

2.3.1 Vegetation Communities

Based on the Bell 2013 mapping, there are four vegetation communities present with the Crown Reserve where Flying-foxes are roosting (see Table 7 and Map 8).

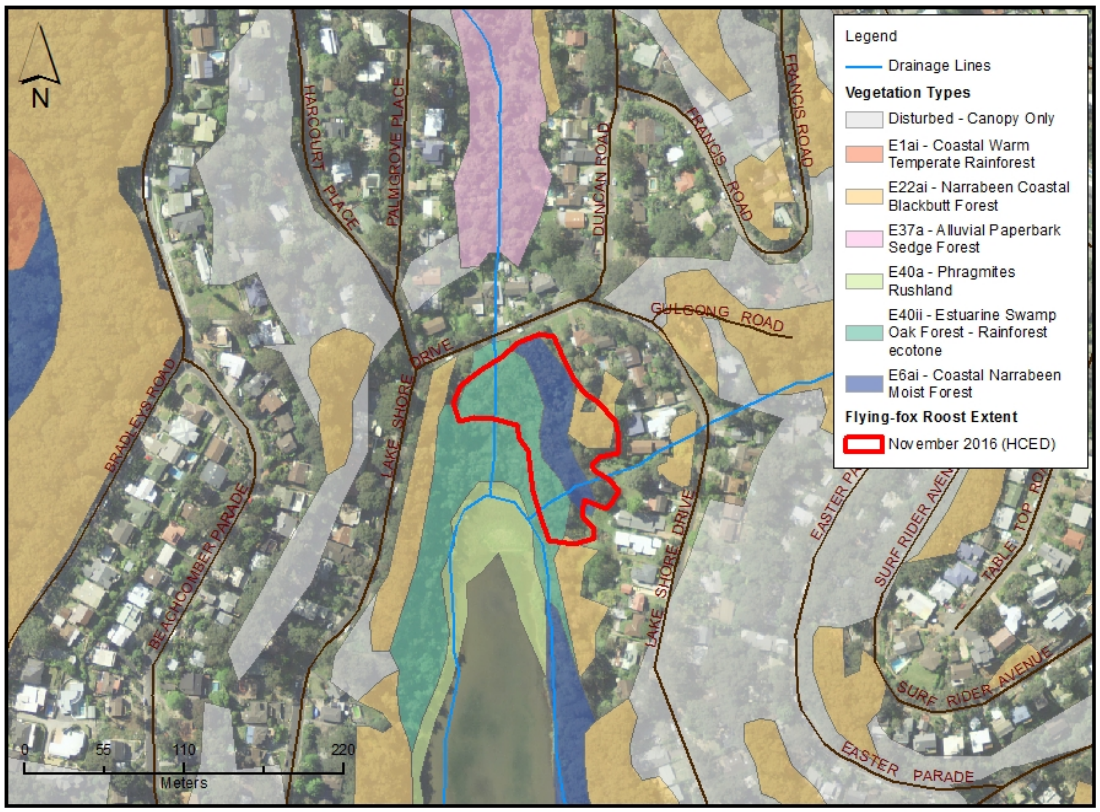
Table 7: Vegetation communities present at the North Avoca Flying-fox Camp

Vegetation Community	Endangered Ecological Equivalent	Location
Swamp Oak Rushland Forest	Swamp Oak Floodplain Forest	Core
Phragmites Rushland	Freshwater Wetland on Coastal Floodplains	Core
Narrabeen Coastal Blackbutt Forest		Eastern side of reserve and south eastern side of reserve
Coastal Narrabeen Moist Forest		Western side of reserve

Dominant plant species recorded within the Flying-fox Camp (i.e. on the northern side of the reserve) are included in Appendix 2: Rapid Vegetation Assessment. It was observed that 90% of the canopy was dead or severely defoliated, providing limited suitable roosting habitat (see Photograph 3 and Photograph 4). A number of reasons may have contributed to the decline of this vegetation community including:

- intermittent increase in Flying-fox numbers roosting within a confined area as a result of regionally abundant food resources; or
- severe widespread infestation of Morning Glory contributing to the decline of the mid and upper stratum.

Map 8: Vegetation types at the North Avoca Flying-fox Camp and surrounds



The mid-storey and upper-storey particularly along the periphery of the Crown Reserve is widespread with Morning Glory infestations preventing recruitment of suitable Flying-fox habitat trees (see Photograph 3).

Photograph 3: Widespread Morning Glory infestations throughout camp site

Photograph 4: Grey-Headed Flying-fox roosting in dead *Melaleuca stypheloides* (Prickly-leaved Tea Tree) on the northern side of the Crown Reserve

2.3.2 Flying-fox Habitat

Roosting Areas

Flying-foxes have been seasonally roosting at the North Avoca site for a minimum of 10 years. In the past this site has been utilised as a seasonal camp and also a maternity roost. Flying-foxes have on occasion left for a few weeks at a time. In mid-2016, most of the Flying-foxes disappeared with approximately 200 remaining in the reserve.

Most Flying-fox activity is observed between February and May each year (during mating season). Historically the site is home to a few thousand Flying-foxes, but a record number of animals were recorded in May 2015 with over 30,000 animals counted in the Census.

Grey-headed Flying-foxes are observed to roost predominantly within the core part of the reserve in dead or severely defoliated *Melaleuca stypheloides*, which is also within close proximity to the waterbody and directly over the drainage line.

Foraging Areas

Foraging habitat identified within the Camp site includes *Alphitonia excelsa* (Red Ash), *Melaleuca quinquenervia* (Broad-leaved Paperbark) and *Archontophoenix cunninghamiana* (Bangalow Palm).

Within 6 km of the Flying-fox Camp large areas of intact contiguous bushland provide important foraging habitat for Flying-foxes. Main foraging areas include:

- Wet Sclerophyll Forests - contain significant foraging species including *Eucalyptus saligna* (Sydney Blue Gum), *Syncarpia glomulifera* (Turpentine) and *Eucalyptus pilularis* (Blackbutt);
- Sydney Coastal Dry Sclerophyll Forest contains important foraging species; *Corymbia gummifera* (Red Bloodwood) and *Eucalyptus pilularis* (Blackbutt); and
- Coastal Swamp Forests dominated by the important winter flowering species *Eucalyptus robusta* (Swamp Mahogany).

Approximately 48% of the land area within 20 km of the Avoca site supports native forests and woodlands, in patches ranging in size from small remnants to extensive tracts in conservation reserves and state forests. Nearly 3% of native vegetation is floristically diverse warm temperate-subtropical rainforest containing trees and vines that produce fruit known to be consumed by flying-foxes. A further 8% comprises moist forests with rainforest canopy and emergent Turpentine and Sydney Blue Gum. Rainforest fruits in these habitats provide consistent food for flying-foxes during late summer and autumn.

Approximately 75% of forested land within 20km of Avoca contains flowering trees visited by the animals. Remnant vegetation immediately surrounding the camp, and to the northwest, contains extensive tracts of wet sclerophyll forests dominated by Turpentine, Sydney Blue Gum and Blackbutt. To the south and west lie dry forests and woodlands on sandstone dominated by species such as Red Bloodwood and Smooth-barked Apple.

In total, 23 species of trees in the flower diet of Grey-headed flying-foxes occur within feeding range of the Avoca camp, 20 of these occur in >1% of native vegetation by area (see Table 8). They vary considerably in the amount of nectar they secrete, the frequency and duration of flowering, their seasonal flowering schedules and their area of distribution. Interactions between these characteristics determine the influence they have on the size of the population of flying-foxes roosting at Avoca. Species with restricted distributions or that produce relatively low volumes of nectar are likely to have a minor influence on the number of flying-foxes feeding in the area. Five widespread and highly productive species are likely to have a substantial influence (see Table 8).

Native vegetation within 12 km of the North Avoca camp is primarily wet sclerophyll forest dominated by Turpentine, Sydney Blue Gum, Blackbutt and Mountain Blue Gum. Significant flowering in these 4 species is likely to attract flying-foxes to the Avoca camp during spring, summer and early autumn (see Table 8). The size of the flying-fox population should fluctuate considerably during these months. Forests and woodlands containing the highly productive species, Red Bloodwood, occur >12km from the camp, but may attract large numbers of flying-foxes in years when it flowers heavily. Native vegetation in the area is unlikely to support winter populations due to the highly-restricted distribution of diet plants that flower in those months. Nonetheless, it is possible for small over-wintering populations to be supported by urban plantings, particularly in years when food is scarce in native forests.

Table 8: Characteristics of flowering trees in the diet of Grey-headed Flying-foxes that occur within 20 km of the North Avoca Camp. Nectar abundance is scored in 4 categories from 0 to 1; the approximate frequency of flowering is also scored in 4 categories relating to % of years; duration of flowering is scored in months. Species likely to play a significant role in determining the number of flying-foxes present in the camp, as assessed by nectar abundance and area of distribution, are highlighted in grey. Species found in <1% of native vegetation have been excluded. See Eby and Law (2008) for further details.

Species	Common Name	% area of native vegetation	flowering characteristics			bi-monthly flowering schedule					
			nectar abundance	frequency (% yrs)	duration (mth)	Dec-Jan	Feb-Mar	Apr-May	Jun-Jul	Aug-Sep	Oct-Nov
Corymbia gummifera	Red Bloodwood	20%	1	0.4	2	X	X				
Eucalyptus deanei	Mountain Blue Gum	25%	0.70	0.70	1	X	X				
E. pilularis	Blackbutt	30%	1	0.4	2	X	X				
E. saligna	Sydney Blue Gum	30%	0.7	0.7	1	X	X				
Syncarpia glomulifera	Turpentine	50%	0.5	0.7	2					X	X
Angophora costata	Smooth-barked Apple	25%	0.3	0.4	1						X
A. floribunda	Rough-barked Apple	10%	0.5	0.4	1	X					
Banksia integrifolia	Coast Banksia	1%	0.7	1	4			X	X	X	
B. serrata	Old Man Banksia	2%	0.5	0.7	3	X	X	X			
C. maculata	Spotted Gum	10%	1	0.25	4-6		X	X			
Eucaluptus acmenoides	White Mahogany	30%	0.3	0.7	1	X					X
E. paniculata	Grey Ironbark	10%	0.7	0.4	3-4	X				X	X
E. piperita	Sydney Peppermint	5%	0.50	0.40	1	X					
E. propinqua	Small-fruited Grey Gum	1%	0.5	0.4	2	X	X				
E. punctata	Large-fruited Grey Gum	5%	0.30	0.70	1	X	X				
E. resinifera	Red Mahogany	2%	0.5	0.4	2	X	X				
E. robusta	Swamp Mahogany	5%	1	1	3			X	X		
E. siderophloia	Grey Ironbark	10%	1	0.7	2	X					X
E. tereticornis	Forest Red Gum	1%	1	1	2					X	X
Melaleuca quinquenervia	Broad-leaved Tea Tree	2%	1	1	3-4		X	X			
						13	**10**	**5**	**2**	**4**	**6**

Potential Overflow Roosting Areas

Flying-foxes have been observed roosting in Forest Oak (*Allocasuarina torulosa*) on private property immediately east of the Crown Reserve. A number of properties east of the Crown Reserve contain mature exotic and native tree species that could potentially provide suitable Flying-fox roosting habitat. There is also potential roosting habitat within the Avoca Lagoon Foreshore Reserve, which is comprised of Casuarina Swamp Woodland.

The potential roosting habitat species (native and exotic) have been identified and are discussed in Table 9, Table 10 and Map 9.

Table 9: Description of Potential Adjacent Roosting Overflow Locations for North Avoca

Site Number	Species	Roosting/foraging habitat and condition	Roosting/foraging habitat/impact on residential areas and schools
Potential overflow areas adjacent to the Flying-fox Camp			
1	*Allocasuarina torulosa*	Forest Oak	Flying-foxes roosting in overhanging trees on private property. The tree is on Crown Reserve
2	*Liquidambar spp.*	Liquidambar	Roosting
3	*Jacaranda mimosifolia*	Jacaranda	Roosting in Jacaranda
4	*Araucaria heterophylla*	Norfolk Island Pine	Not currently roosting
5	*Grevillea robusta*	Silky Oak	Not currently roosting

Table 10: Description of Potential Roosting Overflow Locations within 1km of the North Avoca Flying-fox Camp

Site Number	Reserve Name	Location	Roosting/foraging habitat/impact on residential areas and schools
Potential overflow areas within 1 km of the Flying-fox Camp			
1	Terrigal Palmgrove Reserve	Lake Foreshore Drive - 100m north of Crown Reserve	Southern half of the reserve is bound by private property along the western and eastern side of the reserve
2	Bradley's Road Bushland	Bradley's Road directly 500 m east of the Crown Land Flying-fox camp	Residential dwellings directly behind the reserve and opposite Bradley's Road
3	Avoca Lagoon Foreshore Reserve	Approximately 200 m south of the Crown Reserve	Immediately adjacent to the reserve

Within a 6 km radius of the Flying-fox Camp, potential roosting sites include:

- to the south, a number of low lying coastal reserves containing suitable roosting habitat including *Melaleuca sieberi*, Flax-leaved Paperbark (*Melaleuca linariifolia),* Prickly Leaved Tea Tree (*Melaleuca stypheloides)*, Cabbage Tree Palm (*Livistona australis),* Swamp Oak (*Casuarina glauca)* and Forest Oak (*Allocasuarina torulosa)* which are part of Coastal Swamp Forests and Coastal Narrabeen Moist Forest;
- to the east of the Camp predominantly on rural properties there are a number of suitable roosting sites along drainage lines containing Coastal Warm Temperate – Subtropical Rainforest; and
- to the north in Terrigal and surrounding suburbs there a number recreational parks, schools and residential properties containing suitable Flying-fox roosting habitat.

Map 9: Potential Flying-fox camp overflow areas at the North Avoca Flying-fox Camp

2.3.3 Flying-fox Population at the North Avoca Flying-fox Camp

Over the past four years, the North Avoca Camp has been the largest on the Central Coast with the numbers of Flying-foxes counted in the May 2015 census in the order of 30,000 individuals (See Table 11).

Table 11: Flying-fox population data for the North Avoca Camp (source: CSIRO National Flying-fox census)

	Nov-12	Feb-13	May-13	Aug-13	Nov-13	Feb-14	May-14	Aug-14	Nov-14	Feb-15	May-15	Aug-15	Nov-15	Feb-16	May-16	Aug-16
Hunter Camps (all FF species)	15,387	131,768	44,519	23,649	15,172	97,769	27,533	7,681	130,269	335,279	105,926	112,624	138,593	309,962	176,703	66,784
North Avoca Camp GHFF	-	7000	-	-	-	-	-	-	-	20000	30000	-	8400	-	200	-
North Avoca Camp LRFF	-	0	-	-	-	-	-	-	-	0	0	-	0	-	0	-
North Avoca Camp BFF	-	0	-	-	-	-	-	-	-	0	0	-	900	-	0	-
% of Hunter Region FF in North Avoca	0.0	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	28.3	0.0	6.7	0.0	0.1	0.0

GHFF = Grey Headed Flying-fox; LRFF = Little Red Flying-fox; BFF = Black Flying-fox

2.3.4 Community Interests and Issues Related to the Camp

The total number of complaints per year remains low (around 6 per year) varying depending on location, time of year and numbers of Flying-foxes in the Camp.

Community issues at the North Avoca Camp as reported to Council are loss of amenity due to smell and noise, and the potential of property devaluation.

DI - Lands & Forestry has primary responsibility for the management of the land where the North Avoca Flying-fox Camp is located. DI - Lands & Forestry advised that the main community complaints they received relate to:

- impacts to the native vegetation from roosting Flying-foxes;
- weed management; and
- dangerous trees on the property boundary (not necessarily related to Flying-foxes).

2.3.5 Management Activities to Date

No active management activities have been undertaken at this site, although routine land management activities (e.g. removal of dangerous trees) has occurred as required.

2.4 Everglades Wetlands Flying-fox Camp and Surrounds

The Everglades Wetland precinct historically was a sandplain consisting of a series of freshwater and salt water wetlands and exposed sandflats (Brown 2005). From the 1950s to the 1980s most of the wetlands of the sandplains were filled in for urban development. During this time there was also significant infill of Everglades Wetland to enable the development of a golf course.

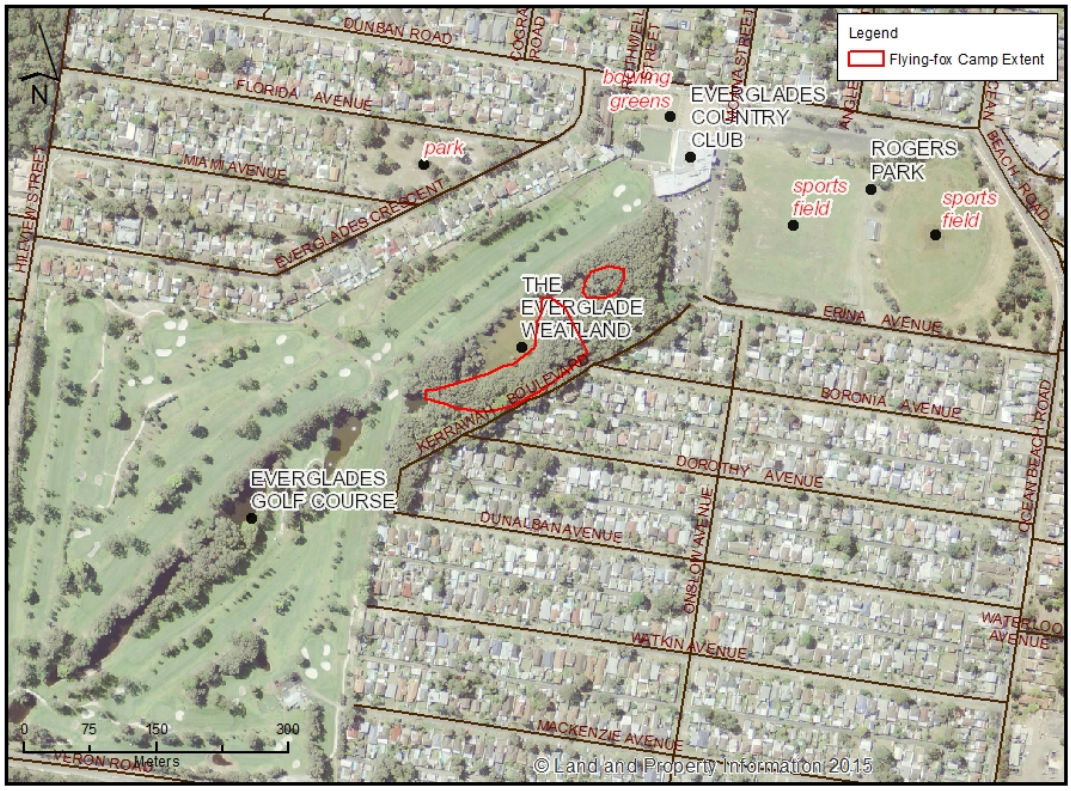
There are four distinct land parcels found in the precinct:

- The Everglades Wetlands reserve is Crown Land under care, control and management of Council (approximately 3 ha of which 0.8 ha is currently underwater). There are no formal access tracks to the Reserve, although a number of informal tracks are present. It is possible to walk along the southern periphery of the reserve along Kerrawah Boulevard;
- the carpark boundary incorporates a formal carpark and a small area of bushland along the western boundary – is Council owned land;
- Everglades Golf Course - south-west of the Wetland Reserve – is Crown land on lease from the Crown to the Everglades Country Club and consists of a series of lagoons immediately south west of the Wetland Reserve. This parcel of land is mostly cleared but does contain a number of mature Melaleucas; and
- Everglades Golf Course – Freehold land owned by Everglades Country Club.

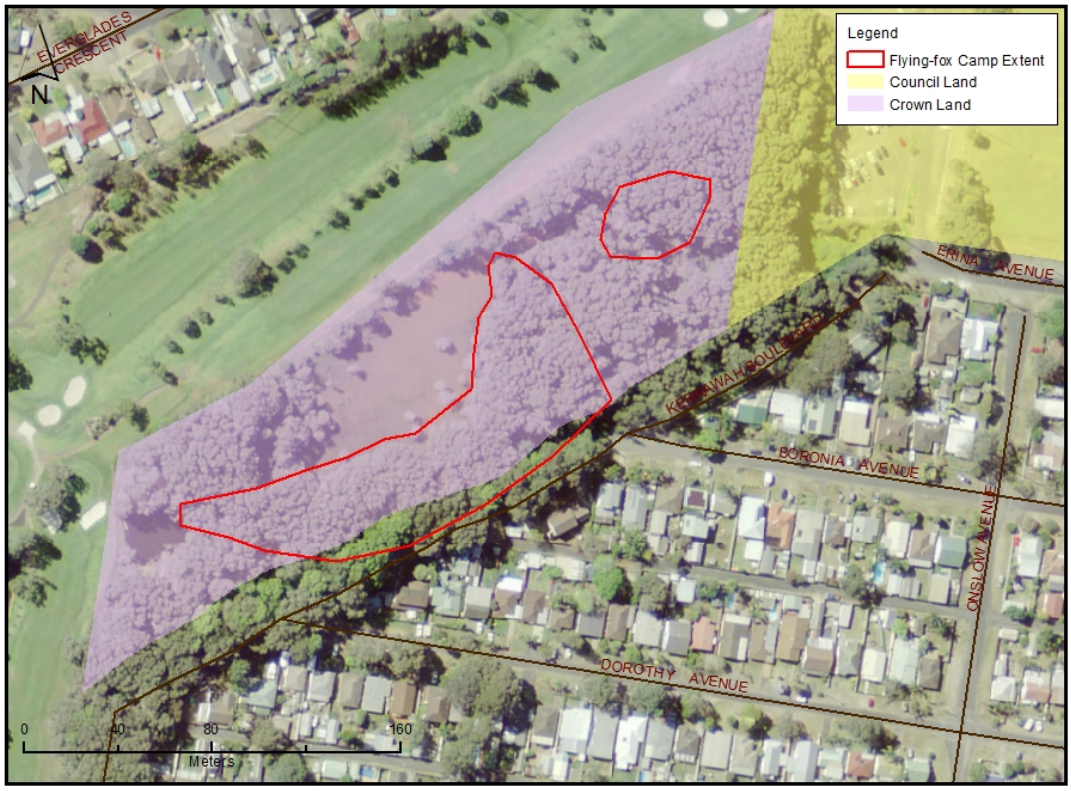
There has been a Bushcare Group active in the Everglades Wetlands for twenty-one years. Central Coast Council and the Bushcare group have been successful in receiving funding from Local Land Services to assist with the restoration and rehabilitation in the Wetlands. The works undertaken with the current and previous grant funds complements the on-going community volunteer bush regeneration works and Council funded contract bush regeneration to restore the native vegetation in the Wetlands.

The arrival of the Grey-headed Flying-foxes has coincided with widespread flowering of Red Bloodwood (*Corymbia gummifera*) in the Hunter and Central Coast region. While the Flying-fox camp is largely located on the Everglades Wetlands land parcel, Flying-foxes have also been observed roosting in Melaleuca trees between the Wetlands and residential developments along Kerrawah Boulevard (see Map 10 and Map 11).

Map 10: Everglades Wetlands Flying-fox Camp Boundary



Map 11: Land tenure of the Everglades Wetlands Flying-fox Camp and surrounds. The Crown land is managed by Council



2.4.1 Vegetation Communities

The entire reserve contains two endangered ecological communities:

- Swamp Sclerophyll Forest (*Typha Rushlands*) located in the centre of the reserve; and
- Freshwater Wetlands (*Broad-leaved Paperbark –Swamp Oak – Saw Sedge Swamp Forests on Coastal Lowlands of the Central Coast and Lower North Coast*) throughout the reserve.

The overall condition of the reserve ranges from poor to good, there is a well-established and mature canopy layer comprising of species including Broad-leaved Paperbark (*Melaleuca quinquenervia*), Swamp Oak (*Casuarina glauca*) and Swamp Mahogany (*Eucalyptus robusta*). The mid-storey is sparse with evidence of native regeneration including Bleeding Heart (*Homalanthus populifolius*), Sandpaper Fig (*Ficus coronata*) and Wild Yellow Jasmine (*Pittosporum revolutum*).

The ground layer has been disturbed particularly along the periphery of the reserve and intermittently through the core of the reserve. Some areas are dominated by introduced species such as Panic Grass (*Ehrharta erecta*) and Fishbone Fern (*Nephrolepis cordifolia*) as well as a number of introduced annual ground covers and grasses (Photograph 5). Native ground cover and mid-storey regeneration is evident throughout the reserve particularly in areas where the Bushcare group has worked (Photograph 6).

A Rapid Flora Survey was undertaken on 15 November 2016 and recorded the most common species present within the active Camp and is included in Appendix 2: Rapid Vegetation Assessment.

2.4.2 Flying-fox Habitat

Roosting Areas

Grey-headed Flying-foxes were observed roosting in well-established mature Broad-leaved Paperbark, Swamp Mahogany and Swamp Oak.

Flying-foxes were observed roosting in two distinct groups. The main group was roosting on the southern side of Boronia Road and a smaller splinter group was roosting on the northern side of Boronia Road.

In 2017, 2700 individuals were estimated to use the camp. The entire reserve contains potential roosting habitat suggesting that there is capacity for a significant increase in Flying-fox numbers.

Photograph 5: Stand of mature Camphor Laurel and Fishbone Fern under-storey along southern boundary

Photograph 6: Melaleuca Forest

Foraging Areas

Both Swamp Mahogany and Broad-leaved Paperbark are high priority food sources that are widespread across the Reserve. These species also occur within the golf course and the carpark areas.

The site is located in a transition zone between wet sclerophyll forests to the north and east, and dry forests and woodlands on Hawkesbury sandstone to the south and west. Turpentine, Sydney Blue Gum, Blackbutt and Mountain Blue Gum dominate the moist forests. Red Bloodwood, Smooth-barked Apple and Sydney Peppermint dominate slopes and ridges on sandstone.

Approximately 67% of land within 20 km of the Everglades camp supports native forests and woodlands. Extensive tracts occur in conservation reserves, notably Brisbane Water and Ku-ring-gai Chase National Parks. Nearly 5% of native vegetation comprises warm temperate rainforest and moist forests with rainforest canopies containing trees and vines that produce fruit known to be consumed by flying-foxes. Rainforest fruits in these habitats provide consistent food for the animals during late summer and autumn.

Approximately 82% of forested land within 20 km of the Everglades Wetland Camp contains flowering trees visited by flying-foxes. In total, 23 species of trees in the flower diet of Grey-headed flying-foxes occur within feeding range of the site, 20 of these occur in >1% of native vegetation by area (see Table 12). They vary considerably in the amount of nectar they secrete, the frequency and duration of flowering, their seasonal flowering schedules and their area of distribution. Interactions between these characteristics determine the influence they have on the size of the population of flying-foxes roosting at the site. Species with restricted distributions or that produce relatively low volumes of nectar are likely to have a minor influence on the number of flying-foxes feeding in the area. Three widespread and highly productive species are likely to have a substantial influence (see Table 12).

Significant flowering of Red Bloodwood and Sydney Peppermint is likely to attract flying-foxes to the Everglades camp during summer and early autumn. The size of the flying-fox population should fluctuate considerably during these months and potentially will reach relatively large numbers in years of mass flowering of Red Bloodwood. Significant flowering of Turpentine may attract flying-foxes during spring. Native vegetation in the area is unlikely to support winter populations due to the highly-restricted distribution of diet plants that flower in those months. Nonetheless, it is possible for small over-wintering populations to be supported by urban plantings, particularly in years when food is scarce in native forests.

Table 12: Characteristics of flowering trees in the diet of Grey-headed Flying-foxes that occur within 20 km of the Everglades Wetland Camp. Nectar abundance is scored in 4 categories from 0 to 1; the approximate frequency of flowering is also scored in 4 categories relating to % of years; duration of flowering is scored in months. Species likely to play a significant role in determining the number of flying-foxes present in the camp, as assessed by nectar abundance and area of distribution, are highlighted in grey. Species found in <1% of native vegetation have been excluded. See Eby and Law (2008) for further details.

Species	Common Name	% area of native vegetation	flowering characteristics			bi-monthly flowering schedule					
			nectar abundance	frequency (% yrs)	duration (mth)	Dec-Jan	Feb-Mar	Apr-May	Jun-Jul	Aug-Sep	Oct-Nov
C. gummifera	Red Bloodwood	50%	1	0.4	2	X	X				
E. piperita	Sydney Peppermint	20%	0.50	0.40	1	X					
Syncarpia glomulifera	Turpentine	35%	0.5	0.7	2					X	X
Angophora costata	Smooth-barked Apple	40%	0.3	0.4	1						X
A. floribunda	Rough-barked Apple	10%	0.5	0.4	1	X					
Banksia integrifolia	Coast Banksia	1%	0.7	1	4			X	X	X	
B. serrata	Old Man Banksia	1%	0.5	0.7	3	X	X	X			
Corymbia eximia	Yellow Bloodwood	1%	0.7	0.4	1						X
C. maculata	Spotted Gum	5%	1	0.25	4-6		X	X			
Eucaluptus acmenoides	White Mahogany	15%	0.3	0.7	1	X					X
E. botryoides	Bangalay	1%	0.5	0.7	1	X					
E. deanei	Mountain Blue Gum	15%	0.70	0.70	1	X	X				
E. paniculata	Grey Ironbark	10%	0.7	0.4	3-4	X				X	X
E. pilularis	Blackbutt	15%	1	0.4	2	X	X				
E. punctata	Large-fruited Grey Gum	15%	0.30	0.70	1	X	X				
E. robusta	Swamp Mahogany	1%	1	1	3			X	X		
E. saligna	Sydney Blue Gum	15%	0.7	0.7	1	X	X				
E. siderophloia	Grey Ironbark	5%	1	0.7	2	X					X
E. tereticornis	Forest Red Gum	5%	1	1	2					X	X
Melaleuca quinquenervia	Broad-leaved Tea Tree	1%	1	1	3-4		X	X			
						12	**8**	**5**	**2**	**4**	**7**

Potential Overflow Roosting Areas

Much of the vegetation throughout the low lying coastal foreshore areas of Woy Woy has been cleared for urban development. This has reduced potential suitable roosting habitat for Flying-foxes in this area. There are a few remaining remnant bushland parcels containing Swamp Oak Woodland and suitable foraging and roosting habitat and include:

- Everglades Golf Course immediately south west of the Flying-fox camp which is dominated by Broad-leaved Paperbark and Swamp Mahogany;
- a small drainage reserve approximately 500 m south west of the Flying -fox camp;
- a small Council drainage reserve on Warrumunga Road, Woy Woy bound by residential dwellings, approximately 800 m south west of the Flying-fox camp;
- residential properties directly east of the Flying-fox camp contains suitable roosting and foraging species including Jacaranda, mango trees, fig trees and avocado trees; and
- residential properties to the north where there is native vegetation regrowth providing potential foraging and roosting habitat.

A number of potential roosting habitat species (native and exotic) have been identified adjacent to the camp and are discussed in Table 13 and Map 12.

Table 13: Description of Potential Roosting Overflow Locations Adjacent to the Everglades Wetland Flying-fox Camp

Site Number	Species	Roosting/foraging habitat and condition	Roosting/foraging habitat/impact on residential areas and schools
1	*Melaleuca quinquenervia*	Broad-leaved Paperbark	Flying-foxes currently not roosting
2	*Ficus coronata*	Sandpaper Fig	Within the road reserve opposite the Everglade Wetlands
3	*Cinnamomum camphora*	Camphor Laurel	Flying-foxes roosting in Camphor Laurel in the reserve
4	*Melaleuca quinquenervia,* *Jacaranda mimosifolia*	Broad-leaved Paperbark Jacaranda	Flying-foxes currently not roosting

Map 12: Potential Flying-fox camp overflow areas at the Everglades Wetland Flying-fox Camp

2.4.3 Flying-fox Population at the Everglades Wetlands Flying-fox Camp

Grey-headed Flying-foxes were observed roosting at this site for the first time in February 2017. Greater Sydney Local Land Services completed an initial count estimating that there were between 800 to 1000 Grey-headed Flying-foxes. There are anecdotal reports that flying-foxes last camped in the Everglades Wetlands around 2002, however the camp is reported to have remained 'a short time only'. There are also reports that Grey-headed Flying-foxes regularly foraged in the vegetation along Kahibah Creek.

2.4.4 Community Interests and Issues Related to the Camp

While no complaints have been received by Council about the Everglades Wetland Camp, Council has worked in partnership with local wildlife rehabilitators to hold sessions in April 2017 to inform the community about the ecology and behaviour of Flying-foxes as well as the possible reasons that the camp has been reactivated. The information sessions have been well attended by the local community, with no conflict with the Camp being articulated at those sessions.

2.4.5 Management Activities to Date

There have been no 'on-ground' management activities specifically aimed at management for the Everglades Wetlands Flying-fox Camp. Community bush regeneration by the local Bushcare group has however aimed to improve the condition of the native vegetation and habitat at Everglades Wetlands for over twenty years. Bush regeneration works have been suspended while the Camp is active. This situation will be reviewed when the Flying-foxes are no longer using the Everglades Wetlands Camp.

2.5 Historic Camps in the Central Coast LGA

In addition to the four Flying-fox camps discussed above, there are a number of other historical camps that are included in the CSIRO Flying-fox census, or noted on the NSW Atlas of Living Australia. These camps are located in:

- Toukley - last known occupancy 1999 where 3,000 individuals were counted (data retrieved from BioNet);
- Jilliby - last known occupancy 2001 where 20,000 individuals were counted (data retrieved from BioNet);
- Matcham - last known occupancy 2002 where 50,000 individuals were counted (data retrieved from BioNet); and
- Umina - last known occupancy 2013 – only 50 individuals were counted (data retrieved from Flying-fox census).

Although these camps have not supported a Flying-fox population in recent years, they may in the future. Management required at the sites will be as per the management actions outlined in Table 18.

2.6 Potential New Camps in the Central Coast LGA (or Unknown Existing Camps)

As new Flying-fox camps are established in the Central Coast LGA, they will fall under the controls of this Strategy and any management activities required to be undertaken will be drawn from the approved management actions included in Table 17.

3 Context

3.1 Flying-fox Ecology, Threats and Human Health Considerations

3.1.1 Ecological Role of Flying-foxes

Flying-foxes, along with some birds, make a unique contribution to ecosystem health through their ability to move seeds and pollen over long distances (Southerton et al. 2004). This contributes directly to the reproduction, regeneration and viability of forest ecosystems (DoE 2016a).

It is estimated that a single Flying-fox can disperse up to 60,000 seeds in one night (ELW&P 2015). Some plants, particularly *Corymbia spp*., have adaptations suggesting they rely more heavily on nocturnal visitors such as bats for pollination than daytime pollinators (Southerton et al. 2004).

Grey-headed Flying-foxes may travel 100 km in a single night with a foraging radius of up to 50 km from their camp (McConkey et al. 2012), and have been recorded travelling over 500 km in two days between camps (Roberts et al. 2012). In comparison bees, another important pollinator, move much shorter foraging distances of generally less than one kilometer (Zurbuchen et al. 2010).

Long-distance seed dispersal and pollination makes Flying-foxes critical to the long-term persistence of many plant communities (Westcott et al. 2008; McConkey et al. 2012), including eucalypt forests, rainforests, woodlands and wetlands (Roberts et al. 2006). Seeds that are able to germinate away from their parent plant have a greater chance of growing into a mature plant (EHP 2012). Long-distance dispersal also allows genetic material to be spread between forest patches that would normally be geographically isolated (Parry-Jones & Augee 1992; Eby 1991; Roberts 2006). This genetic diversity allows species to adapt to environmental change and respond to disease pathogens. Transfer of genetic material between forest patches is particularly important in the context of contemporary fragmented landscapes.

Flying-foxes are considered ‘keystone’ species given their contribution to the health, longevity and diversity among and between vegetation communities. These ecological services ultimately protect the long-term health and biodiversity of Australia’s bushland and wetlands. In turn, native forests act as carbon sinks, provide habitat for other fauna and flora, stabilise river systems and catchments, add value to production of hardwood timber, honey and fruit (e.g. bananas and mangoes) (Fujita 1991), and provide recreational and tourism opportunities worth millions of dollars each year (EHP 2012; ELW&P 2015).

More details on the three Flying-fox species are included in Appendix 1: Flying-fox Species Profiles.

3.1.2 Flying-foxes in Urban Areas

Flying-foxes appear to be roosting and foraging in urban areas more frequently. There are many possible drivers for this, as summarised by Tait et al. (2014):

- loss of native habitat and urban expansion
- opportunities presented by year-round food availability from native and exotic species found in expanding urban areas (e.g. flowering of Spotted Gums, Red Bloodwood, and Broad-leaved Paperbark)
- disturbance events such as drought, fires, cyclones (typically food and water sources are more secure around human settlements)
- human disturbance or culling at non-urban roosts or orchards (making roosts where these activities are not occurring more attractive)

- urban effects on local climate (in winter months, urban roosts may be warmer than rural camps due to the 'heat island' effect)
- refuge from predation (less predators reside in urban settings)
- movement advantages, e.g. ease of maneuvering in flight due to the open nature of the habitat or ease of navigation due to landmarks and lighting

3.1.3 Flying-foxes Under Threat

Flying-foxes roosting and foraging in urban areas more frequently can give the impression that their populations are increasing; however, the Grey-headed Flying-fox is in decline across its range and in 2001 was listed as Vulnerable by both the Australian Government and the NSW Government.

Counts over the previous decade suggest that the national population may have declined by up to 30%. It is also estimated that the population would continue to decrease by at least 20% in the next three Flying-fox generations given the continuation of the current rate of habitat loss and culling.

The main threat to Grey-headed Flying-foxes is clearing or modification of native vegetation. This threatening process removes appropriate roosting and breeding sites and limits the availability of natural food resources, particularly winter–spring feeding habitat in north-eastern NSW. The urbanisation of the coastal plains of south-eastern Queensland and northern NSW has seen the removal of annually-reliable winter feeding sites, and this threatening process continues.

There is a wide range of ongoing threats to the national survival (possibility of extinction) of the Grey-headed Flying-fox species, including:

- habitat loss and degradation
- conflict with humans (including culling at orchards)
- infrastructure-related mortality (e.g. entanglement in barbed wire fencing and fruit netting, power line electrocution, etc.)
- predation by native and introduced animals
- exposure to extreme natural events such as cyclones, drought and heat waves

Flying-foxes have limited capacity to respond to these threats and recover from large population losses due to their slow sexual maturation, small litter size, long gestation and extended maternal dependence (McIlwee & Martin 2002).

3.1.4 Flying-foxes and Heat Stress

Heat stress affects Flying-foxes when temperatures reach 42°C or more. Over the past two decades, a number of documented heat stress events have resulted in significant Flying-fox mortality.

While there is conflicting advice about how or whether to intervene during a heat stress event at a Flying-fox camp, it should be noted that human presence in a camp at such times can increase the stress and activity levels of Flying-foxes present, potentially leading to greater harm. Any response to a heat stress event should be undertaken as an organised and monitored response. It is recommended that data is collected after the heat stress event and provided to scientists able to analyse the data and to help the Office of Environment and Heritage share best practice management techniques as they are developed. The data collected will help improve future advice. on intervention during these

When ambient temperatures rise above 35°C Flying-foxes tend to alter their behaviour to reduce exposure to heat. A range of behaviours may be exhibited, depending on multiple variables in their environment. The impacts of heat stress events are likely to vary site by site, and can depend on

conditions in the preceding days. Ambient temperature alone may thus not be a sound indicator of a heat stress event, and Flying-fox behaviour may provide more reliable information. As flying-foxes experience heat stress, they are likely to exhibit a series of behaviours indicating progressive impact of that stress, including:

- clustering or clumping;
- panting;
- licking wrists and wing membranes;
- descending to lower levels of vegetation or to the ground.

Some of these behaviours may occur outside of heat stress events.

Black Flying-foxes tend to start dying above ~42°C, and Grey-headed Flying-foxes above ~43°C

3.1.5 Approval to Assist Flying-foxes During Heat Stress Events

One must be licensed to rehabilitate fauna under the *Biodiversity Conservation Act 2016* to undertake any assistance activities. Any licence (or Statutory role) must specifically endorse the person or group as being able to care for Flying-foxes.

What to do in a Heat Stress Event

During a heat stress event, Flying-foxes will likely occupy the coolest microhabitats available to them at that temperature, and disturbance may move Flying-foxes into less desirable locations. Great care should be taken to avoid unnecessarily disturbing Flying-foxes at this time.

- **Spraying animals in the camp** - Spraying of specific individuals by hand can cool highly distressed animals. However, care must be taken not to disturb other Flying-foxes, as this may cause them to leave the shelter of their relatively cool microhabitats and increase their body temperature, further stressing them.

  Flying-foxes should not be approached if they show any indication that they are trying to move away or escape from the presence of the sprayer. Highly heat-stressed individuals that do not respond to spraying should be observed for 15 minutes before undertaking a second round of spraying. The individual may then be removed from the camp after a period of observation by experienced wildlife rehabilitators for further treatment.

- **Removing animals from a camp and rehydration therapy** - Animals that are severely affected by a heat stress event may need intensive cooling and rehydration. In some cases this may necessitate removal of the animal from the camp to a quiet and shady location.

3.1.6 Human Health

Flying-foxes, like all animals, carry bacteria and other microorganisms in their guts, some of which are potentially pathogenic to other species. Direct contact with faecal material should be avoided and general hygiene measures taken to reduce the low risk of gastrointestinal and other disease.

Contamination of water supplies by any animal excreta (birds, amphibians and mammals such as Flying-foxes) poses a health risk to humans. Household tanks should be designed to minimise potential contamination, such as using first flush diverters to divert contaminants before they enter water tanks. Trimming vegetation overhanging the catchment area (e.g. the roof of a house) will also reduce wildlife activity and associated potential contamination. Tanks should also be appropriately maintained and flushed, and catchment areas regularly cleaned to remove potential contaminants.

Public water supplies are regularly monitored for harmful microorganisms, and are filtered and disinfected before being distributed. Management plans for community supplies should consider

whether any large congregation of animals, including Flying-foxes, occurs near the supply or catchment area. Where they do occur, increased frequency of monitoring should be considered to ensure early detection and management of contaminants.

Flying-foxes, like all animals, carry pathogens that may pose human health risks. Many of these are viruses which cause only asymptomatic infections in Flying-foxes themselves but may cause significant disease in other animals that are exposed. In Australia the most well-defined of these include Australian bat lyssavirus (ABLV), Hendra virus (HeV) and Menangle virus. Specific information on these viruses is provided in Appendix 3: Human and Animal Health.

Outside of an occupational cohort, including wildlife rehabilitators and vets, human exposure to these viruses is extremely rare and similarly transmission rates and incidence of human infection are very low. In addition, HeV infection in humans apparently requires transfer from an infected intermediate equine host and direct transmission from bats to humans has not been reported. Thus despite the fact that human infection with these agents can be fatal, the probability of infection is extremely low and the overall public health risk is judged to be low (Qld Health 2016).

More detail on diseases and Flying-foxes is included in Appendix 3: Human and Animal Health.

3.2 Flying-fox Population Statistics

3.2.1 Grey-headed Flying-fox National Population

Fly-out counts are acknowledged by the scientific community to be the best method currently available of obtaining reliable and reproducible estimates of abundance (if not actual population counts) for Flying-foxes. The available data for 1989 and 1998-2001 has been obtained using the same survey techniques that are widely acknowledged to be appropriate for estimating the abundance of this species.

The data available from the fly-out counts conducted should be regarded as estimates of abundance, rather than precise population counts.

The surveys of 1998-2001 have been much more comprehensive than the 1989 survey in terms of the number of roosts and extent of geographical range included. Despite the significantly increased knowledge of the species roost sites and survey effort, the estimates of abundance obtained indicate a decline in the abundance of the species. Using the maximum estimate from the 1998-2001 surveys (400,000) and the minimum estimate of abundance in 1989 (566,000), the rate of decline of Grey-headed Flying-foxes since 1989 has been in the order of 30%.

A number of experts commented that the projected habitat clearance in northern NSW is the primary ongoing threat to Grey-headed Flying-foxes. One expert stated that annually reliable winter resources are limited in distribution to a narrow coastal strip in northern NSW and Queensland. These coastal areas are targeted for intensive residential development to cater for a projected 25% increase in the human population over the next decade.

3.2.2 Central Coast Flying-fox Population

The National Flying-fox Monitoring Program commenced on the Central Coast in 2013 and includes four Camps of Watanobbi, North Avoca, Everglades, and Wyoming. The site of the Wambina Nature Reserve Camp has also been included in the surveys since 2013 however Flying-foxes have not been recorded at this site since commencement surveys. OEH staff, local council, volunteer ecologists and wildlife rehabilitators assist with the count. The program aimed to establish a reliable benchmark on the size of Flying-fox populations in 2013 and monitor population trends in subsequent years.

The numbers of Flying-foxes (of all species) recorded since 2013 demonstrate a substantial fluctuation in population across the four camps. Factors outside the local area and indeed the region may affect the numbers of individuals in a camp at any one time. Since the breaking of the drought (and food shortage) in 2010, the Lower Hunter Region of NSW has experienced a number of Eucalyptus flowering events. This is likely to have attracted a large number of Flying-foxes to the region at these times.

The most common species recorded in the Central Coast Council area is the Grey-headed Flying-fox with Black Flying-foxes also observed at the North Avoca Camp.

3.3 Legislative and Regulatory Context

It is acknowledged that at the time of preparing this Management Strategy, the NSW State Government was preparing to overhaul environmental protection legislation and some of the references below are likely to change post July 2017.

The Grey-Headed Flying-fox is listed as a Vulnerable species under the *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act) and is therefore considered a 'Matter of National Environmental Significance' and is protected under Commonwealth law.

In 2001, the Grey-headed Flying-fox was listed as a Vulnerable species under the NSW *Threatened Species Conservation Act* 1995 (now the *Biodiversity Conservation Act 2016*). This listing was based on scientific evidence indicating a significant decline in the population of the species and that it is "likely to become endangered unless the circumstances and factors threatening its survival or evolutionary development cease to operate" (NSW Scientific Committee 2001).

This means that if present processes continue the species could become extinct. A draft national recovery plan has also been prepared for the species (DECCW 2009, Geolink 2013). Provisions in the *Biodiversity Conservation Act* 2016 and *Environmental Planning and Assessment Act* 1979 mean that actions likely to adversely affect the species generally require approval or licensing, and that potential impacts on the species require assessment.

OEH prepared the *Flying-fox Camp Management Policy* in 2015, which is intended to empower land managers, primarily local councils, to work with their communities to manage Flying-fox camps effectively. It provides the framework within which OEH will make regulatory decisions. The Policy encourages local councils and other land managers to prepare camp management plans for sites where the local community is affected.

There are numerous State-based legislative instruments that manage and control actions related to Flying-foxes and their habitat, these are discussed below, and in Appendix 4: Summary of Key Legislation

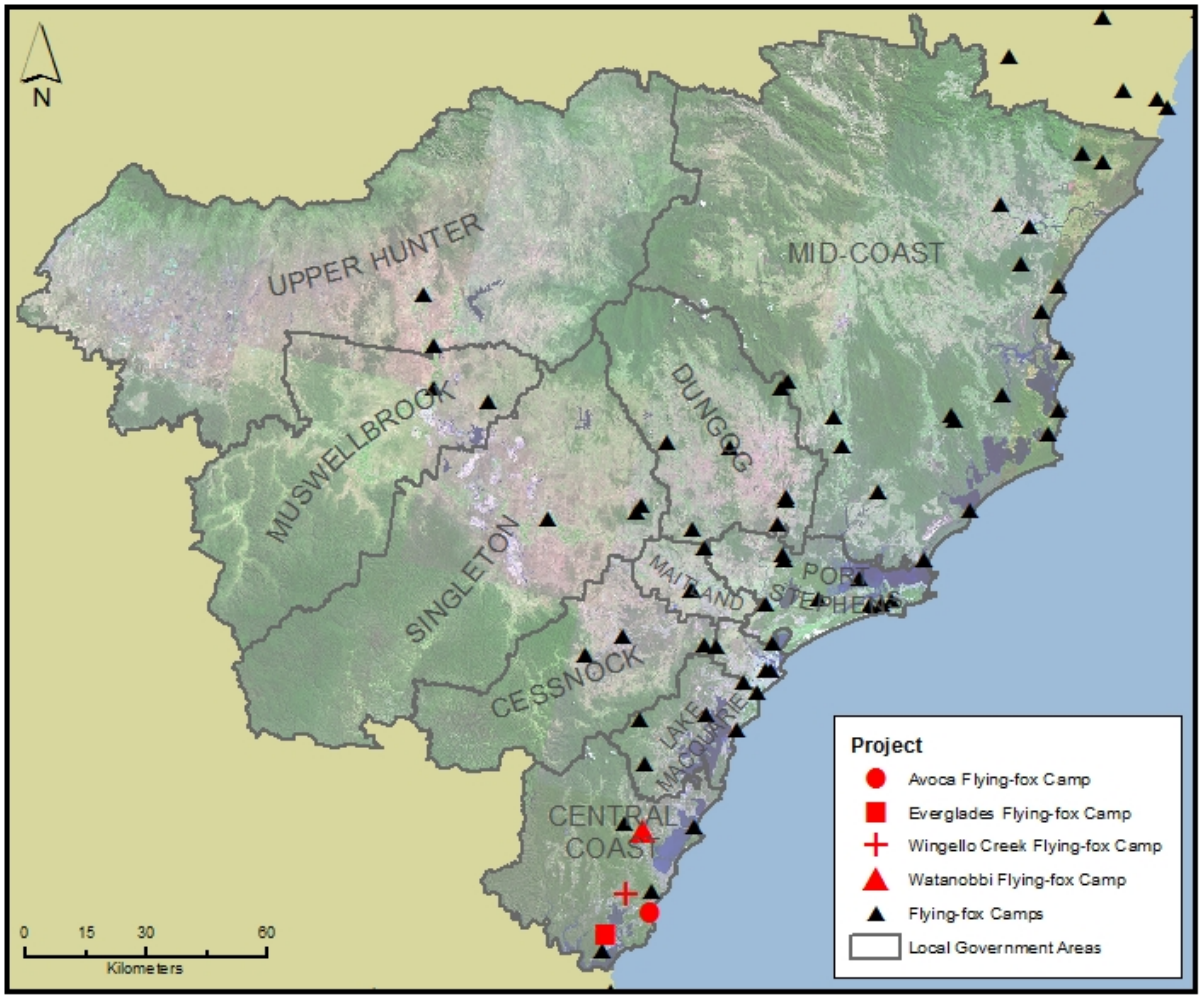
1.1

3.4 Regional Context

The Hunter & Central Coast region is home to 58 known Flying-fox camps (see Map 13), 53 of which have observed Flying-foxes roosting in them since 2012. It is highly likely that there are additional camps throughout the vegetated areas (private land and National Parks / State Forest) of the region that are well away from human settlements and are currently unaccounted in the CSIRO National Flying-fox camp Census.

The 2013 *Grey-headed Flying-fox Management Strategy for the Lower Hunter* developed by GEOlink stated that in the Lower Hunter there were six camps considered critical to Flying-fox survival in the Lower Hunter (these being: Millfield, Martinsville, Morisset, Blackbutt Reserve, Anna Bay, Medowie and Tocal). None of these critical sites are managed via a Camp Management Plan and are currently not subject to conflict with human settlements.

Map 13: Known Flying-fox Camps throughout the Hunter & Central Coast region



The 2013 Strategy also stated that a further six camps (Black Hill, Belmont, Glenrock, Hannan Street, Italia Road and Raymond Terrace) were not critical to survival in the Lower Hunter, and reflecting on changes in Flying-fox roosting patterns in the past 4 years we now know that Black Hill and Hannan Street are no longer utilised as camps, and the Raymond Terrace Camp is now listed as a Nationally Significant site given the number of Flying-foxes now utilising the site for roosting and mating / maternity activities.

During 2012-2017, Flying-fox roosting patterns have changed rapidly throughout the region, with a number of previously important camps being abandoned and small camps becoming much more significant for roosting and breeding of Flying-foxes. The development of local Camp Management Plans and a Regional Strategy will assist councils to address community concerns and work to reduce the possibility of new areas of conflict arising with increased growth of the Central Coast and Hunter Regions.

Ongoing research into Flying-fox behaviour appears to indicate that food shortages precede the abandonment of traditional camps and the creation of new camps. Following the 2010 Flying-fox food shortage (associated with a severe drought in NSW), the number of camps in Sydney increased from 7 to 22. Occupancy of these new camps did not appear to reduce when food supply increased, suggesting that once roosting and feeding patterns change, the roosting behaviour has been adapted and in most cases does not revert back to previous behaviour. This has also played out in the Hunter Region.

Overall the location and extent of Flying-fox camps in NSW has changed significantly since 2002. At that time camps were mostly found in the north of the State, however, in 2015 following food shortages and subsequent flowering events, the Flying-fox population spread south and west. A number of new camps were created inland and on the NSW South Coast. Since 2015, the majority of new camps created have been in vegetated areas quite close to urban areas.

Regional Flying-fox Foraging Preferences

Work is currently being undertaken to identify key Flying-fox foraging areas throughout the region to progress work conducted by GEOLink in 2013. The incorporation of this information into Council's land use plans (and equivalent planning documents) will assist Council to, where possible, preserve areas of high value Flying-fox foraging vegetation, and potentially protect areas suitable for Flying-fox roosting (i.e. not be located in close proximity to human settlements). Although Flying-foxes are wild animals and it is not possible to predict where they will choose to roost, if there are no alternatives to the current conflict camp sites, it can be guaranteed the animals will not move of their own accord.

Flying-foxes have a preference for different native plants, which are productive in each bi-month, although species richness varies through the year. Broad seasonal patterns in the number of productive species are in keeping with other regional areas (Eby & Law 2008). The greatest proportion of dietary species flowers in December and January (14 species, 52%) and species richness reaches low levels from late autumn to early spring (4 species, 15%). Table 14 provides details on the Bi-monthly flowering phenologies of GHFF diet plants found in the Lower Hunter & Central Coast region (based on 2013 vegetation data).

Specific foraging preference assessment has been conducted on the known Camps in Central Coast with details of these provided in earlier sections of this Management Strategy (see Section 2.1.2 for details on Watanobbi; Section 2.2.2 for details on Wyoming / Wingello Creek; Section 2.3.2 for details on North Avoca; and Section 2.4.2 for details on Everglades).

Table 14: Bi-monthly flowering phenologies of GHFF diet plants found in the Lower Hunter & Central Coast region (source: Geolink 2013)

Species	Dec-Jan	Feb-Mar	Apr-May	Jun-Jul	Aug-Sep	Oct-Nov
Angophora costata						X
A. floribunda	X					
Banksia integrifolia			X	X	X	
Corymbia eximia						X
C. gummifera		X				
C. maculata		X	X	X		
Eucalyptus acmenoides	X					X
E. albens				X	X	
E. amplifolia						X
E. botryoides	X					
E. camaldulensis	X					
E. deanii	X	X				
E. fibrosa	X					X
E. longifolia			X			
E. moluccana		X				
E. paniculata	X					X
E. parramattensis	X					
E. pilularis	X	X				
E. piperita	X					
E. punctata	X	X				
E. resinifera	X	X				
E. robusta			X	X		
E. saligna	X	X				
E. siderophloia	X					X
E. tereticornis					X	X
M. quinquenervia		X	X			
S. glomulifera					X	X

Based on Table 14, there are only 6 species of tree that flower in winter that are preferential food sources for Grey-headed Flying-foxes, as such these species should be subject to protection to assist with Grey-headed Flying-fox survival in the region.

Additionally, a large number of fruit trees are preferred feed trees for Flying-foxes, with 38 species of rainforest trees and lianas in the fruit diet of Grey-headed Flying-foxes occurring within the Lower Hunter & Central Coast region (see Table 15).

Table 15: Fruits in the diet of GHFF that occur in the Lower Hunter & Central Coast region (source: Geolink 2013)

Family Name	Species Name	Common Name
GYMNOSPERMAE		
Podocarpaceae	*Podocarpus elatus*	Plum Pine
ANGIOSPERMAE		
Apocynaceae	*Melodinus australis*	Southern Melodinus
Arecaceae	*Archontophoenix cunninghamiana*	Bangalow Palm
	Livistona australis	Cabbage Palm
Avicenniaceae	*Avicennia marina*	Grey Mangrove
Caprifoliaceae	*Sambucus australasica*	Yellow Elderberry
Chenopodiaceae	*Rhagodia candolleana*	Seaberry Saltbush
Cunoniaceae	*Schizomeria ovata*	Crabapple
Ebenaceae	*Diospyros pentamera*	Myrtle Ebony
Ehretiaceae	*Ehretia acuminata*	Koda
Elaeocarpaceae	*Elaeocarpus obovatus*	Hard Quandong
	E. reticulatus	Blueberry Ash
Escalloniacae	*Polyosma cunninghamii*	Featherwood
Icacinaceae	*Pennantia cunninghamii*	Brown Beech
Meliaceae	*Melia azedarach*	White Cedar
Monimiaceae	*Hedycarya angustifolia*	Native Mulberry
Moraceae	*Ficus coronata*	Creek Sandpaper Fig
	F. fraseri	Sandpaper Fig
	F. macrophylla	Moreton Bay Fig
	F. obliqua	Small-leaved Fig
	F. rubiginosa	Rusty Fig

Based on the foraging modeling, there is evidence to suggest likely food shortages during the winter months. The chance of large (short term) population increases in January – to April due to flowering events should be expected.

If Council wanted to reduce possible impacts on Flying-foxes due to food shortages in Winter months (and potentially reduce conflict with residents due to Flying-foxes foraging in back yards) the opportunity exists to undertake planting and restoration of reserves that support winter flowering plant species, such as *Banksia integrifolia*, *Corymbia maculata*, *Eucalyptus albens*, and *Eucalyptus robusta.*

4 Community Consultation

4.1 Methods

Community consultation with respect to Flying-fox camp management on the Central Coast shall be undertaken in accordance with the Central Coast Council Engagement Framework. The principles of planned community engagement activities are to:

- Listen to the needs and aspirations of the community;
- Understand the opinions, views, interests, issues and potential barriers to participation and be consistent in the approach to engagement;
- Understand the values and rights of each individual and be open and clear about what is being asked;
- Respond – be genuine, consider and value the input and close the loop with feedback; and
- Learn from each other, value strengths and build relationships with trust and integrity.

Council is proposing an online survey tool designed specifically to address general Flying-fox management issues (called Flying Fox Engage). The survey seeks to:

- inform the community about the Flying-fox Management Strategy and its objectives;
- gather feedback from the community (those directly impacted or just interested) on the options available around Flying-fox camp management;
- collect useable information on how those options might be enacted (tangible information relating to “how to”);
- to improve awareness and manage expectations around the management of Flying-fox camps locally; and
- to give the community a sense of control in the management of camps, helping to reduce the potential for outrage when action takes place.

There are a number of additional engagement methods available to Council depending on the purpose of the engagement. Where Council seeks to engage with communities affected by the presence of Flying-foxes, the engagement methods will be drawn from the following options:

- Face-to-face (e.g. door-knocking, group discussion, drop-in centres, facilitated sessions or conferences);
- On-line (e.g. website, social media, e-panels, ask the experts, online surveys); and
- Passive (signage, articles, media, pamphlets).

4.2 Stakeholders / Interest Groups

There are a range of stakeholders and interest groups who may be directly or indirectly affected by Flying-fox camps in the LGA. The groups in Table 16 are identified as the audience for the community engagement outlined above.

Table 16: Stakeholders and groups with an interest in Flying-foxes on the Central Coast

Audience	Justification
All residents and visitors to the Central Coast	Flying-fox roosting and foraging can be heard and seen by many in the community at various times of the year
Residents living in proximity to a camp	Potential for negative interactions between residents and flying-foxes
Business owners in proximity to a camp	Potential for negative interactions between business owners and their customers and flying-foxes
Civic leaders and influencers (including local, state and federal politicians)	Civic leaders need to be responsive to community concerns and manage legislative risk through Council's management activities
Indigenous community	Significance of Flying-foxes in local indigenous heritage held by the Bahtabah Local Aboriginal Land Council, Biraban Local Aboriginal Land Councils and the Darkinjung Local Aboriginal Land Council
Schools in proximity to a camp (administration, teachers, parents and students)	Potential for health concerns
Hospitals, medical practices, Dept. of Health	Interested in human health issues related to Flying-fox / human contact in general
Equine facilities within 20 km of a camp and equine veterinarians	Hendra virus risk and appropriate mitigation measures can be communicated
Orchardists and fruit growers within 20 km of a camp	Flying-foxes can cause crop damage
Airport managers	Aircraft can accidently strike Flying-foxes
Wildlife rehabilitators, rehabilitators and conservation organisations	Provides support to bats through promotion, protection, information, nurture and conservation activities
Researchers that have an interest in Flying-fox behaviour, biology and conservation	Information gathered by the community or Council can support research programs

Audience	Justification
Media • Newcastle Herald • Central Coast Express Advocate • Community News • ABC Local Radio • SEA FM • STAR FM • 2GO	Local media should be encouraged to deliver timely and correct information to the Central Coast community

5 Management Opportunities

5.1 Management Approach by Central Coast Council

Flying-fox Culling
All Flying-fox species are protected species under the *Biodiversity Conservation Act 2016*, and the Grey-Headed Flying-fox is both a federally listed and NSW listed threatened species, and as such, culling of any Flying-foxes is an unlawful activity.
Culling is not considered a viable camp management action as it is inconsistent with the:

- Commonwealth *Environment Protection & Biodiversity Conservation Act* 1999;
-
- NSW *Biodiversity Conservation Act* 2016
- *Firearms Act* 1996 or section 96G of the *Crimes Act* 1900;
- NSW Flying-fox Management Policy 2015; and
- objectives of this Management Strategy.

Culling is considered scientifically ineffective (due to the mobility of the species) and not a preferred management option by the majority of the Central Coast community.

Central Coast Council has developed this LGA-wide strategy to guide the management of Flying-fox conflict issues and to ensure that a consistent approach to addressing issues is applied throughout the LGA regardless of which camp is causing the conflict.

To ensure all appropriate options are available for consideration, this section of the Flying-fox Management Strategy provides details on the available management activities, and details from Council as to whether they are considered suitable for use on the Central Coast (see Table 17). Council has, through the development of this Strategy, assessed the currently occupied camps and management issues that could be applied to develop a list of Strategic Management Actions (see Table 18) and have determined the “trigger” or “catalyst” necessary for Council to consider

implementing the management action. Further detail on all Camp Management Options is included in Appendix 5: Camp Management Options.

The intent of this Strategy is to signal to the community the conditions that need to be present prior to any given management action being undertaken. It is noted that the Strategy and the management actions (and their triggers) will be reviewed annually, or if there is a significant change to Flying-fox behaviour in the LGA (see Section 7 for specific details).

5.2 Analysis of Camp Management Options

The *NSW Flying-fox Camp Management Policy 2015* and *Camp Management Plan Template 2016* provide details on acceptable management activities to manage and mitigate human / bat conflict at camp sites. The management actions are grouped into three levels, as discussed following.

Routine camp management actions (Level 1 actions)

Routine camp management includes actions such as:

- removal of tree limbs or whole trees that pose a genuine health and safety risk, as determined by a qualified arborist;
- weed removal, including removal of priority weeds under the *Biosecurity Act* 2015 or species listed as undesirable by a council;
- trimming of under-storey vegetation or the planting of vegetation;
- minor habitat augmentation for the benefit of the roosting animals;
- mowing of grass and similar grounds-keeping actions that will not create a disturbance to roosting Flying-foxes (by avoiding critical times of the year such as birthing); and
- application of mulch or removal of leaf litter or other material on the ground.

Creation of buffers (Level 2 actions)

Creation of buffers can be effective as management actions to nudge Flying-fox populations away from urban settlements. The intention is to create a physical or visual separation from the camp and actively manage vegetation structure and composition to discourage Flying-foxes from roosting close to built areas.

Actions include:

- clearing or trimming canopy trees at the camp boundary to create a buffer; and
- disturbing animals at the boundary of the camp to encourage roosting away from human settlement.

Camp disturbance or dispersal (Level 3 actions)

Camp dispersal is an action that aims to intentionally move entire camps from one location to another by clearing vegetation or dispersing animals through disturbance by noise, water, smoke or light.

In a review of past flying-fox dispersal actions between 1990 and 2013, Roberts and Eby (2013) found that dispersal attempts were not successful in reducing the number of flying-foxes in a local area, even with substantial financial resourcing. Camp dispersal is challenging for a number of reasons:

- it can be expensive and requires an on-going financial commitment;

- dispersal may result in relocating the animals to nearby vegetation rather than resolving the issue and conflict locally. Past disturbances in Australia have always failed to remove Flying-foxes from the local area;
- it is not possible to predict where replacement caps would form;
- attempts to disperse camps are often contentious in the local community;
- disturbing Flying-foxes may have an adverse impact on animal health; and
- the cumulative impacts of Flying-fox camp dispersals may negatively impact on the conservation of the species and the ecosystem services Flying-foxes provide.

Table 17 provides details on the various management options available, an assessment of cost and effectiveness of the action to address the various conflict issues. Table 17 also provides details of the assessment undertaken by DI - Lands & Forestry and Council as to the suitability of the actions to be included in the Management Strategy. Section 5.3: Strategic Management Actions, provides details of the management actions that will be undertaken through the implementation of the Management Strategy.

Table 17: Analysis of management options

Management Option	Relevant Impacts	Cost	Advantages	Disadvantages	Suitability Determination
Level 1 Actions					
Education and awareness programs	Fear of disease Noise Smell Faecal drop	$	Low cost, promotes conservation of FFs, contributes to attitude change which may reduce general need for camp intervention, increasing awareness and providing options for landholders to reduce impacts can be an effective long-term solution, can be undertaken quickly, will not impact on ecological or amenity value of the site.	Education and advice itself will not mitigate all issues, and may be seen as not doing enough.	This action was deemed suitable.
Property modification (e.g. car cover, pool cover, clothesline cover, air conditioners, double glaze windows, etc.)	Noise Smell Faecal drop Health/wellbeing Property devaluation Lost rental return	$–$$	Property modification is one of the most effective ways to reduce amenity impacts of a camp without dispersal (and associated risks), relatively low cost, promotes conservation of FFs, can be undertaken quickly, will not impact on the site, may add value to the property.	May be cost-prohibitive for private landholders, unlikely to fully mitigate amenity issues in outdoor areas. Costs could be borne through Council / DI - Lands & Forestry receiving funding support through grants enabling cost sharing or resident subsidies.	This action was deemed suitable for residents adjacent to the camp. It is noted that should funding become available, these subsidies can be further explored.

Management Option	Relevant Impacts	Cost	Advantages	Disadvantages	Suitability Determination
Service subsidies (e.g. access to water gurney, etc.)	Noise Smell Faecal drop Health/wellbeing Property devaluation Lost rental return	$–$$	May encourage tolerance of living near a camp, promotes conservation of FFs, can be undertaken quickly, will not impact on the site, would reduce the need for property modification.	May be costly across multiple properties and would incur ongoing costs, may set unrealistic community expectations for other community issues, effort required to determine who would receive subsidies.	This action was deemed suitable for residents adjacent to the camp. It is noted that should funding become available, these subsidies can be further explored.
Routine camp management	Health/wellbeing	$	Will allow property maintenance, likely to improve habitat, could improve public perception of the site, will ensure safety risks of a public site can be managed. Weed removal has the potential to reduce roost availability and reduce numbers of roosting FFs. To avoid this, weed removal should be staged and alternative roost habitat planted, otherwise activities may constitute a Level 3 action.	Will not generally mitigate amenity impacts for nearby landholders.	This action was deemed suitable.
Provision of artificial roosting habitat	All	$–$$	If successful in attracting FFs away from high conflict areas, artificial roosting habitat in low conflict areas will assist in mitigating all impacts, generally low cost, can be undertaken quickly, promotes FF conservation.	Would need to be combined with other measures (e.g. buffers/alternative habitat creation) to mitigate impacts, previous attempts have had limited success. Ongoing maintenance of structures may be required.	This action may be suitable, although limited success has been experienced by Camp Managers to date. Remains an option for consideration.
Protocols to manage incidents	Health/wellbeing	$	Low cost, will reduce actual risk of negative human/pet–FF interactions, promotes conservation of FFs, can be undertaken quickly, will not impact the site.	Will not generally mitigate amenity impacts.	This action will be included as a risk management response by all responsible land managers.

Management Option	Relevant Impacts	Cost	Advantages	Disadvantages	Suitability Determination
Research	All	$	Supporting research to improve understanding may contribute to more effectively mitigating all impacts, promotes FF conservation.	Generally cannot be undertaken quickly, management trials may require further cost input.	This action was deemed more suitable to be included in a regional strategy or plan.
Appropriate land-use planning	All	$	Likely to reduce future conflict, promotes FF conservation. Identification of degraded sites that may be suitable for long-term rehabilitation for FFs could facilitate offset strategies should clearing be required under Level 2 actions.	Will not generally mitigate current impacts, land-use restrictions may impact the landholder.	This action was deemed suitable.
Do nothing	Nil	Nil	No resource expenditure.	Will not mitigate impacts and unlikely to be considered acceptable by the community.	This action is likely to be employed at sites where there is no Flying-fox / human conflict.
Level 2 Actions					
Buffers through vegetation removal	Noise Smell Health/wellbeing Property devaluation Lost rental return	$–$$	Will reduce impacts, promotes FF conservation, can be undertaken quickly, limited maintenance costs.	Will impact the site, will not generally eliminate impacts, vegetation removal may not be favoured by the community.	This action was deemed suitable, however its applicability at particular sites may be limited.

Management Option	Relevant Impacts	Cost	Advantages	Disadvantages	Suitability Determination
Buffers without vegetation removal (visual, noise or smell deterrents)	Noise Smell Health/wellbeing Damage to vegetation Property devaluation Lost rental return	$$	Successful creation of a buffer will reduce impacts, promotes FF conservation, can be undertaken quickly, options without vegetation removal may be preferred by the community.	May impact the site, buffers will not generally eliminate impacts, maintenance costs may be significant, often logistically difficult, limited trials so likely effectiveness unknown.	This action was deemed suitable, however its applicability at particular sites may be limited.
Level 3 Actions					
Nudging	All	$$–$$$	If nudging is successful this may mitigate all impacts.	Costly, FFs will continue attempting to re-colonise the area unless combined with habitat modification/ deterrents. Experience at other camps is that this option has had limited success.	Refer to Flying-fox Camp Management Code of Practice 2018 for authorisation required.
Passive dispersal through vegetation management	All at that site but not generally appropriate for amenity impacts only (see Section 8)	$$–$$$	If successful can mitigate all impacts at that site, compared with active dispersal: less stress on FFs, less ongoing cost, less restrictive in timing with ability for evening vegetation removal.	Costly, will impact site, risk of removing habitat before outcome known, potential to splinter the camp creating problems at other locations (although less than active dispersal), potential welfare impacts, disturbance to community, negative public perception, unknown conservation impacts, unpredictability makes budgeting and risk assessment difficult, may increase disease risk (see Section 7.1), potential to impact on aircraft safety.	This action was deemed unsuitable.

Management Option	Relevant Impacts	Cost	Advantages	Disadvantages	Suitability Determination
Passive dispersal through water management	All at that site but not generally appropriate for amenity impacts only (see Section 8)	$$–$$$	Potential advantages as per with passive dispersal through vegetation removal, however likelihood of success unknown.	Potential disadvantages as per passive dispersal through vegetation removal, however likelihood of success unknown.	This action was deemed unsuitable.
Active dispersal	All at that site but not generally appropriate for amenity impacts only	$$$	If successful can mitigate all impacts at that site, often stated as the preferred method for impacted community members.	May be very costly, often unsuccessful, ongoing dispersal generally required unless combined with habitat modification, potential to splinter the camp creating problems in other locations, potential for significant animal welfare impacts, disturbance to community, negative public perception, unknown conservation impacts, unpredictability makes budgeting and risk assessment difficult, may increase disease risk (see Section 7.1), potential to impact on aircraft safety.	This action was deemed unsuitable.

5.3 Strategic Management Actions

The strategic management priorities included in Table 18 have been determined after consideration of ecological requirements, legislative / policy controls, and land manager responsibilities. The actions have been grouped into the major thematic areas of:

- Governance
- Routine Management
- Infrastructure
- Restoration and Rehabilitation
- Monitoring
- Flying-fox Species Management
- Resident Assistance
- Community Education

The actions included in Table 18 are directly linked to the management actions discussed in Table 17, but have been identified as potential options for implementation at any Flying-fox camps requiring active management, depending on conditions and funding provision. Responsibility for the implementation of these actions will be shared across the various land managers as required. Details of these responsibilities are included in the table.

The management actions included in Table 18 are subject to change following community consultation and any of the review triggers established in Section 7 Evaluation and Review.

Table 18: Management Actions

Action ID	Issue	Actions & guidelines	Responsibility	Trigger / Catalyst for commencement	Council Budget
1. Resident Assistance					
1.1	Car / clothes-line / swimming pool covers	Provision of these items based upon selection criteria during times of high population occupancy	Council	For residents within 500 m of a camp that has > 20,000 FFs	Subject to grants and other funding
1.2	Access to gurney / water cleaners to remove bat excrement	Access provided only when trigger reached	Council	For residents within 500 m of a camp that has > 50,000 FFs	Subject to grants and other funding

Action ID	Issue	Actions & guidelines	Responsibility	Trigger / Catalyst for commencement	Council Budget
1.3	Subsidy support for affected residents to install double glazed windows or air-conditioners	Access provided only when trigger reached	Council	For residents within 500 m of a camp that has > 50,000 FFs	Subject to grants and other funding
2. Community Education / Engagement					
2.1	Community Consultation (Flying Fox Engage)	Online survey	Council	Immediately and when assessed as being required in future	Staff time
2.2	Community Education Kit (written resources)	Develop a kit to assist residents to understand FF movement patterns and reduce conflicts with camps	Council and Hunter JO	Immediately	Staff time
2.3	Face-to-face engagement through "pop up" consultation sessions	Answer questions and listen to community concerns about FF	Council	On-going as required	Staff time
2.4	Landcare group engagement	Advise groups on the legislative requirements for working near FF camps	Council	Immediately	Staff time
3. Restoration & Rehabilitation					
3.1	Assess native recruitment potential away from boundary	Assessment of vegetation condition improvement in core of site, to make boundary less attractive for roosting (e.g. plant *Casuarina glauca*)	Land manager	A site assessment recommends that a buffer is needed	Subject to grant or other funding
3.2	Develop site action plan in consultation with OEH to encourage Flying-fox roosting habitat	Identify and target high priority noxious and environmental weeds to encourage regeneration of roosting habitat	Land manager	A site assessment recommends that the site could be improved for FF habitat	As funds are available

Action ID	Issue	Actions & guidelines	Responsibility	Trigger / Catalyst for commencement	Council Budget
3.3	Implement Site Action Plans to improve Flying - fox habitat	Planting of suitable roosting habitat in cleared and highly disturbed areas	Land manager	A site assessment recommends that the site could be improved for FF habitat	As funds are available
4. Infrastructure					
4.1	Signage	Interpretive Signage	Land manager	High potential for FF-human interactions becomes apparent	Subject to grant or other funding
4.2	Artificial roosts	Natural or artificial structures installed into camp	Land manager	A site assessment recommends that the site could be improved for FF habitat	As funds are available
5. Flying-fox Species Management					
5.1	Flying-fox rehabilitator response	Respond to calls of injured or dead Flying-foxes	Rehabilitator organisations	Report of injured or stressed animals	Not required
5.2	Rehabilitator alerts (notification of upcoming events, e.g management activities, heat stress, etc.)	Notification of residents and Rehabilitators of any events that will impact on camp site or Flying-fox population	OEH and other networks	Predicted or known events	Not required
6. Routine Maintenance					
6.1	Land Management/ Weed Control	Develop a protocol for routine land management activities near camps	Council	A site assessment recommends that land management activities may have an impact on the camp	Staff time
6.2	Dangerous Trees	Assess impacts on camp and consider required approvals	Land manager	Dangerous trees are reported or noticed upon asset inspections	Staff time
6.3	Cleaning of Excrement	Use of high pressure water cleaners to remove faecal matter from sidewalks, etc	Land manager	When necessary	Maintenance budget
7. Monitoring					

Action ID	Issue	Actions & guidelines	Responsibility	Trigger / Catalyst for commencement	Council Budget
7.1	Flying-fox Census	Quarterly Flying-fox animal counts to assist with determining likely national population	CSIRO / Council	Quarterly	Staff time
7.2	Wildlife / Rehabilitation data collection	Collection and provision of count information, and other data collected when responding to calls	Wildlife / Rehabilitation	Opportunistic	Not required
7.3	Central Coast Bird Observers data collection	Collection and provision of count information, and other data collected	Central Coast Bird Observers	Opportunistic	Not required
7.4	Central Coast Council management data	Collection and dissemination of data related to Flying-foxes, and vegetation that may impact on local or regional Flying-fox populations	Council	Opportunistic	Staff time
8. Governance					
8.1	Land Use Planning	Provision of spatial information on camps and foraging habitat for planning assessments	Council	As soon as the information is available	Staff time
8.2	Develop and implement Vegetation Management Plans for camp sites	Develop comprehensive Vegetation Management Plans for all camps to manage the control of priority noxious and environmental weeds and address potential environmental management issues (such as nutrient runoff and sedimentation)	Council	As deemed necessary for each camp location	Staff time
8.3	Flying-fox Management Strategy review	Review in 4 years / when FF numbers increase past current capacity	Council	5 yearly	Staff time

Action ID	Issue	Actions & guidelines	Responsibility	Trigger / Catalyst for commencement	Council Budget
8.4	Protocol Development	Fire Management	Council / RFS	2019 commencement	Hunter JO funding
		Heat Stress	Council / OEH		
		Community Response to dead / injured animals	Wildlife Rehabilitators		
		School	Council / Department of Education		
		Hospital	Council / Department of Health		
		Equine	Council / Equine Industry		
		Viticulture	Council / Viticulture Industry		
		Routine Maintenance	Council / OEH		
8.5	Development of Camp Management Plans at specific sites	Use OEH template to develop management actions	Land Manager (in consultation with Council if not on Council land)	If the population and human conflict issues warrant a specific management plan	Staff time

If any of the management actions included in Table 18 require either DI - Lands & Forestry or Council to have authorisation from the Environmental Agency head, this must be sourced prior to works being undertaken.

Management controls on the implementation of any action that directly impacts on the camp and the Flying-foxes are included in Appendix 6: Management Controls and Guidelines. Details of the Protocol for managing dead or injured Flying-foxes is included in Appendix 7: Example Flying-fox Rescue Protocol.

6 Impact Assessment

The majority of actions considered appropriate for application in the Central Coast region are considered Level 1 (routine management actions) as the Land Managers have determined the cost and ongoing issues with Level 3 management actions including nudging, dispersal or culling are inappropriate for use in the LGA and will not be undertaken whilst this current Flying-fox Management Strategy is in force. Giving consideration to the various land managers/ownership, the following guidance is given for any activities undertaken inside or adjacent to Flying-fox camps on the Central Coast (Table 19).

Table 19: Environmental approvals required for various management actions

Land Tenure	Land Management Responsibility	Type of Action	Consent required
Council	Council	Level 1, 2 and 3 actions authorised by the Flying-fox Camp Management Code of Practice	No additional approval needed
		Actions not authorized by the the Flying-fox Camp Management Code of Practice	Biodiversity Conservation Licence under the BC Act
Crown	DI-Lands or other	Level 1, 2 and 3 actions authorised by the Flying-fox Camp Management Code of Practice	No additional approval needed
		Actions not authorized by the the Flying-fox Camp Management Code of Practice	Biodiversity Conservation Licence under the BC Act
	Council	Level 1, 2 and 3 actions authorised by the Flying-fox Camp Management Code of Practice	No additional approval needed
		Actions not authorized by the the Flying-fox Camp Management Code of Practice	Biodiversity Conservation Licence under the BC Act
Private	Private	Level 1	No approval if the action is covered in this Strategy (unless there is chance of harm to Grey-headed Flying-foxes or their habitat). See below.
		Level 2 and 3	A Biodiversity Conservation Licence under the BC Act may provide a defense against compliance action for harm to threatened species, populations, or communities or their habitats. It is up to the proponent to assess the risk of harm to threatened biodiversity. A BC licence may not be required if the assessment indicates that the works or activities are unlikely to

			cause harm; or if an existing consent, approval, or certificate, for example, provides a defense against compliance action if harm occurs.

7 Evaluation and Review

7.1 Triggers for Strategy Review

The Strategy will have a scheduled review 4-yearly (or if Council resolves to review earlier), which will include evaluation of management actions undertaken.

The following may trigger a reactive review of the Strategy:

- changes to relevant policy/legislation;
- new management techniques becoming available;
- outcomes of research that may influence the Strategy;
- incidents associated with a camp;
- community feedback on the Strategy; or
- establishment of a new camp that requires different management actions than those included in the Strategy.

7.2 Approval Processes

Any substantial changes to the Strategy or the Strategy Management Actions will be managed through normal Council processes required to amend strategic documents. Any recommended changes to the Strategy should receive concurrence from the NSW Department of Industry – Lands prior to being submitted to Council for approval.

8 Strategy Administration

This Strategy has been developed in partnership by Council and DI - Lands & Forestry. As land managers and the organisations responsible for servicing the local community, the Strategy will be jointly managed by all parties as detailed below.

8.1 Monitoring and Access

Council and DI - Lands & Forestry will continue to allow site access to CSIRO, LLS and Council to undertake the quarterly Flying-fox Census activities. Wildlife Rehabilitators will be able to access the sites as required to attend to the animals, and record information of relevance to Council, OEH and CSIRO.

Additional monitoring and data collection will occur as opportunities arise.

8.2 Communication

Council and Department of Industry - Lands & Forestry will communicate regularly on management activities across camp sites and the Flying-fox population in the region.

8.3 Funding Commitment

Central Coast Council, and the Department of Industry – Lands & Forestry both have responsibilities to ensure appropriate funding is available to undertake management actions included in this plan. The Plan will operate from 2017 – 2027 and therefore each organisation should ensure funding is identified to finance the management actions listed in camp management plans.

However, DI – Lands & Forestry can only commit funds to areas of critical risk such as public safety issues. Departmental funding will be dependent on application to the DI – Lands & Forestry administered Public Reserves Management Fund Program. Submissions to this program are prioritised on a State-wide basis.

It is expected that an annual work plan, including budget items will be developed by the project team and implemented as required.

9 References and Additional Resources

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Appendix 1: Flying-fox Species Profiles

Black flying-fox (*Pteropus alecto*)

Figure 2: Black Flying-fox indicative species distribution, adapted from OEH 2015a

The Black Flying-fox (BFF) (Figure 2) has traditionally occurred throughout coastal areas from Shark Bay in Western Australia, across Northern Australia, down through Queensland and into NSW (Churchill 2008; OEH 2015a). Since it was first described there has been a substantial southerly shift by the BFF (Webb & Tidemann 1995). This shift has consequently led to an increase in indirect competition with the threatened GHFF, which appears to be favouring the BFF (DoE 2016a).

They forage on the fruit and blossoms of native and introduced plants (Churchill 2008; OEH 2015a), including orchard species at times.

BFF are largely nomadic animals with movement and local distribution influenced by climatic variability and the flowering and fruiting patterns of their preferred food plants. Feeding commonly occurs within 20 km of the camp site (Markus & Hall 2004).

BFF usually roost beside a creek or river in a wide range of warm and moist habitats, including lowland rainforest gullies, coastal stringybark forests and mangroves. During the breeding season camp sizes can change significantly in response to the availability of food and the arrival of animals from other areas.

Grey-headed Flying-fox (*Pteropus poliocephalus*)

Figure 3: Grey-headed flying-fox indicative species distribution, adapted from OEH 2015a

The grey-headed flying-fox (GHFF) (Figure 3) is found throughout eastern Australia, generally within 200 km of the coast, from Finch Hatton in Queensland to Melbourne, Victoria (OEH 2015d). This species now ranges into South Australia and has been observed in Tasmania (DoE 2016a). It requires foraging resources and camp sites within rainforests, open forests, closed and open woodlands (including melaleuca swamps and banksia woodlands). This species is also found throughout urban and agricultural areas where food trees exist and will raid orchards at times, especially when other food is scarce (OEH 2015a).

All the GHFF in Australia are regarded as one population that moves around freely within its entire national range (Webb & Tidemann 1996; DoE 2015). GHFF may travel up to 100 km in a single night with a foraging radius of up to 50 km from their camp (McConkey et al. 2012). They have been recorded travelling over 500 km over 48 hours when moving from one camp to another (Roberts et al. 2012). GHFF generally show a high level of fidelity to camp sites, returning year after year to the same site, and have been recorded returning to the same branch of a particular tree (SEQ Catchments 2012). This may be one of the reasons Flying-foxes continue to return to small urban bushland blocks that may be remnants of historically-used larger tracts of vegetation.

The GHFF population has a generally annual southerly movement in spring and summer, with their return to the coastal forests of north-east NSW and south-east Queensland in winter (Ratcliffe 1932; Eby 1991; Parry-Jones & Augee 1992; Roberts et al. 2012). This results in large fluctuations in the number of GHFF in NSW, ranging from as few as 20% of the total population in winter up to around 75% of the total population in summer (Eby 2000). They are widespread throughout their range during summer, but in spring and winter are uncommon in the south. In autumn they occupy primarily coastal lowland camps and are uncommon inland and on the south coast of NSW (DECCW 2009).

There is evidence the GHFF population declined by up to 30% between 1989 and 2000 (Birt 2000; Richards 2000 cited in OEH 2011a). There is a wide range of ongoing threats to the survival of the GHFF, including habitat loss and degradation, deliberate destruction associated with the commercial horticulture industry, conflict with humans, infrastructure-related mortality (e.g. entanglement in barbed wire fencing and fruit netting, power line electrocution, etc.) and competition and hybridisation with the BFF (DECCW 2009). For these reasons it is listed as vulnerable to extinction under NSW and federal legislation (see Section 4).

Little red flying-fox (*Pteropus scapulatus*)

Figure 4: Little red flying-fox indicative species distribution, adapted from OEH 2015a

The little red flying-fox (LRFF) (Figure 4) is widely distributed throughout northern and eastern Australia, with populations occurring across northern Australia and down the east coast into Victoria.

The LRFF forages almost exclusively on nectar and pollen, although will eat fruit at times and occasionally raids orchards (Australian Museum 2010). LRFF often move sub-continental distances in search of sporadic food supplies. The LRFF has the most nomadic distribution, strongly influenced by availability of food resources (predominantly the flowering of eucalypt species) (Churchill 2008), which means the duration of their stay in any one place is generally very short.

Habitat preferences of this species are quite diverse and range from semi-arid areas to tropical and temperate areas, and can include sclerophyll woodland, melaleuca swamplands, bamboo, mangroves and occasionally orchards (IUCN 2015). LRFF are frequently associated with other *Pteropus* species. In some colonies, LRFF individuals can number many hundreds of thousands and they are unique among *Pteropus* species in their habit of clustering in dense bunches on a single branch. As a result, the weight of roosting individuals can break large branches and cause significant structural damage to roost trees, in addition to elevating soil nutrient levels through faecal material (SEQ Catchments 2012).

Throughout its range, populations within an area or occupying a camp can fluctuate widely. There is a general migration pattern in LRFF, whereby large congregations of over one million individuals can be found in northern camp sites (e.g. Northern Territory, North Queensland) during key breeding periods (Vardon & Tidemann 1999). LRFF travel south to visit the coastal areas of south-east Queensland and NSW during the summer months. Outside these periods LRFF undertake regular movements from north to south during winter–spring (July–October) (Milne & Pavey 2011).

Reproduction

Black and grey-headed flying-foxes

Males initiate contact with females in January with peak conception occurring around March to April/May; this mating season represents the period of peak camp occupancy (Markus 2002). Young (usually a single pup) are born six months later from September to November (Churchill 2008). The birth season becomes progressively earlier, albeit by a few weeks, in more northerly populations (McGuckin & Blackshaw 1991), however out of season breeding is common with births occurring later in the year.

Young are highly dependent on their mother for food and thermoregulation. Young are suckled and carried by the mother until approximately four weeks of age (Markus & Blackshaw 2002). At this time they are left at the camp during the night in a crèche until they begin foraging with their mother in January and February (Churchill 2008) and are usually weaned by six months of age around March. Sexual maturity is reached at two years of age with a life expectancy up to 20 years in the wild (Pierson & Rainey 1992).

As such, the critical reproductive period for GHFF and BFF is generally from August (when females are in final trimester) to the end of peak conception around April. Dependent pups are usually present from September to March (see Figure 5).

Little red flying-fox

The LRFF breeds approximately six months out of phase with the other flying-foxes. Peak conception occurs around October to November, with young born between March and June (McGuckin & Blackshaw 1991; Churchill 2008) (Figure 5). Young are carried by their mother for approximately one month then left at the camp while she forages (Churchill 2008). Suckling occurs for several months while young are learning how to forage. LRFF generally birth and rear young in temperate areas (rarely in NSW).

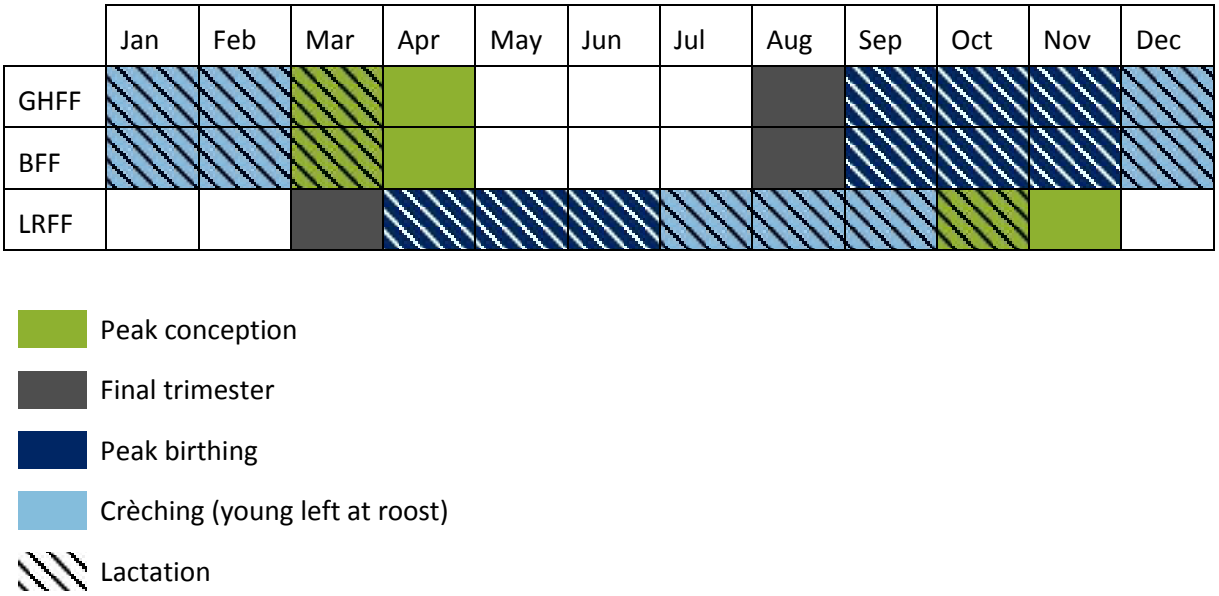


Figure 5: Indicative flying-fox reproductive cycle. Note that LRFF rarely birth and rear young in NSW. The breeding season of all species is variable between years and location, and expert assessment is required to accurately determine phases in the breeding cycle and inform appropriate management timing.

Appendix 2: Rapid Vegetation Assessment

The rapid vegetation assessments undertaken identified the dominant species present throughout the various stratum, as described below.

Watanobbi Camp

Species	Common Name	Stratum	Percentage Cover*
Rubus fruticosus	Blackberry	Ground	4
Casuarina glauca	Swamp Oak	Upper	3
Melaleuca sieberi	-	Mid	2
Ligustrum sinense	Small-leaf Privet	Mid	1
Cinnamomum camphora	Camphor Laurel	Upper	1
Carex appressa	Tall Sedge	Ground	1
Commelina cyanea	Scurvy Grass	Ground	2
Persicaria decipens	Slender Knotweed	Ground	2
Pteridium esculentum	Bracken Fern	Mid	3
Melaleuca nodosa	Prickly-leaved Paperbark	Mid	1
Other Species recorded outside the 20 x 20m quadrat			
Ligustrum sinense	Small-leaved Privet	Upper	5
Cinnamomum camphora	Camphor laurel	Upper	3
Parsonsia straminea	Common Silkpod	Upper	2
Casuarina glauca	Swamp Oak	Upper	2
Melaleuca spp.	Paperbark	Mid	2
Ligustrum sinense	Small-leaf Privet	Mid	2
Ligustrum sinense	Small-leaf Privet	Ground	4

*= Exotic Species, Percentage Cover - 1= <5%, 2=5-25%, 3=25-50%, 4=50-75%, 5=>75%, += Endangered species

Wyoming / Wingello Creek Camp

Species	Common Name	Stratum	Percentage Cover*
Syncarpia glomulifera	Turpentine	Upper	1
Livistona australis	Cabbage Tree Palm	Upper	3
Archontophoenix cunninghamiana	Bangalow Palm	Upper	2
Eucalytus saligna	Sydney Blue Gum	Upper	1
Cissus antarctica	Water Vine	Mid	3

*= Exotic Species, Percentage Cover - 1= <5%, 2=5-25%, 3=25-50%, 4=50-75%, 5=>75%, += Endangered species

North Avoca Camp

Species	Common Name	Stratum	Percentage Cover*
Melaleuca stypheloides	Prickly-leaved Tea Tree	Upper	2
Allocasuarina torulosa	Forest Oak	Upper	2
Archontophoenix cunninghamiana	Bangalow Palm	Upper	2
Melaleuca quinquenervia	Broad-leaved Paperbark	Upper	1
Casuarina glauca	Swamp Oak	Upper	2
Ipomea indica	Morning Glory	Mid	4
*Solanum mauritianum	Wild Tobacco	Mid	2
**Verbena bonariensis*	Purpletop	Mid	1
Phragmites australis		Mid	2
Alphitonia excelsa	Red Ash	Mid	
Parsonsia straminea	Common Silkpod	Mid	
+Melaleuca biconvexa	Biconvex Paperbark	Mid	1
Musa spp.	Banana Plant	Mid	1

*= Exotic Species, Percentage Cover - 1= <5%, 2=5-25%, 3=25-50%, 4=50-75%, 5=>75%, += Endangered species

Everglades Camp

Species	Common Name	Stratum	Percentage Cover*
Melaleuca quinquenervia	Broad-leaved Paperbark	Upper	4
Ficus coronata	Sandpaper Fig	Mid	2
Casuarina glauca	Swamp Oak	Upper	1
Hydrocotylebonariensis	Large-leaved Pennywort	Ground	3
Commelina cynaea	Scurvy Weed	Ground	2
Glochidion ferdinandi	Cheese Tree	Mid	1
Livistona australis	Cabbage Tree Palm	Ground	1
Viola hederacea	Ivy-leaved Violet	Ground	3
Persicaria decipens	Slender Knotweed	Ground	3
Other Species recorded outside the 20 x 20m quadrat			
Eucalyptus robusta	Swamp Mahogany	Upper	
Pteridium esculentum	Bracken Fern	Ground	
Breynia oblongifolia	Coffee Bush	Mid	
Cinnsmomum camphora	Camphor Laurel	Upper	
Homalanthus populifolius	Bleeding Heart	Mid	
Pittosporum revolutum	Sweet Pittosporum	Mid	

*= Exotic Species, Percentage Cover - 1= <5%, 2=5-25%, 3=25-50%, 4=50-75%, 5=>75%, += Endangered species

Appendix 3: Human and Animal Health

Flying-foxes, like all animals, carry pathogens that may pose human health risks. Many of these are viruses which cause only asymptomatic infections in Flying-foxes themselves but may cause significant disease in other animals that are exposed. In Australia the most well-defined of these include Australian bat lyssavirus (ABLV), Hendra virus (HeV) and Menangle virus.

Outside of an occupational cohort, including wildlife rehabilitators and vets, human exposure to these viruses is extremely rare and similarly transmission rates and incidence of human infection are very low. In addition, HeV infection in humans apparently requires transfer from an infected intermediate equine host and direct transmission from bats to humans has not been reported. Thus despite the fact that human infection with these agents can be fatal, the probability of infection is extremely low and the overall public health risk is judged to be low (Qld Health 2016).

Disease and flying-fox management

A recent study at several camps before, during and after disturbance (Edson et al. 2015) showed no statistical association between HeV prevalence and flying-fox disturbance. However the consequences of chronic or ongoing disturbance and harassment and its effect on HeV infection were not within the scope of the study and are therefore unknown.

The effects of stress are linked to increased susceptibility and expression of disease in both humans (AIHW 2012) and animals (Henry & Stephens-Larson 1985; Aich et. al. 2009), including reduced immunity to disease.

Therefore it can be assumed that management actions which may cause stress (e.g. dispersal), particularly over a prolonged period or at times where other stressors are increased (e.g. food shortages, habitat fragmentation, etc.), are likely to increase the susceptibility and prevalence of disease within the flying-fox population, and consequently the risk of transfer to humans.

Furthermore, management actions or natural environmental changes may increase disease risk by:

- forcing flying-foxes into closer proximity to one another, increasing the probability of disease transfer between individuals and within the population
- resulting in abortions and/or dropped young if inappropriate methods are used during critical periods of the breeding cycle. This will increase the likelihood of direct interaction between flying-foxes and the public, and potential for disease exposure
- adoption of inhumane methods with potential to cause injury which would increase the likelihood of the community coming into contact with injured/dying flying-foxes.

The potential to increase disease risk should be carefully considered as part of a full risk assessment when determining the appropriate level of management and the associated mitigation measures required.

Australian bat lyssavirus

ABLV is a rabies-like virus that may be found in all flying-fox species on mainland Australia. It has also been found in an insectivorous microbat and it is assumed it may be carried by any bat species. The probability of human infection with ABLV is very low with less than 1% of the flying-fox population being affected (DPI 2013) and transmission requiring direct contact with an infected animal that is secreting the virus. In Australia three people have died from ABLV infection since the virus was identified in 1996 (NSW Health 2013).

Domestic animals are also at risk if exposed to ABLV. In 2013, ABLV infections were identified in two horses (Shinwari et al. 2014). There have been no confirmed cases of ABLV in dogs in Australia; however, transmission is possible (McCall et al. 2005) and consultation with a veterinarian should be sought if exposure is suspected.

Transmission of the virus from bats to humans is through a bite or scratch, but may have potential to be transferred if bat saliva directly contacts the eyes, nose, mouth or broken skin. ABLV is unlikely to survive in the environment for more than a few hours, especially in dry environments that are exposed to sunlight (NSW Health 2013).

Transmission of closely related viruses suggests that contact or exposure to bat faeces, urine or blood does not pose a risk of exposure to ABLV, nor does living, playing or walking near bat roosting areas (NSW Health 2013).

The incubation period in humans is assumed similar to rabies and variable between two weeks and several years. Similarly the disease in humans presents essentially the same clinical picture as classical rabies. Once clinical signs have developed the infection is invariably fatal. However, infection can easily be prevented by avoiding direct contact with bats (i.e. handling). Pre-exposure vaccination provides reliable protection from the disease for people who are likely to have direct contact with bats, and it is generally a mandatory workplace health and safety requirement that all persons working with bats receive pre-vaccination and have their level of protection regularly assessed. Like classical rabies, ABLV infection in humans also appears to be effectively treated using post-exposure vaccination and so any person who suspects they have been exposed should seek immediate medical treatment. Post-exposure vaccination is usually ineffective once clinical manifestations of the disease have commenced.

If a person is bitten or scratched by a bat they should:

- wash the wound with soap and water for at least five minutes (do not scrub)
- contact their doctor immediately to arrange for post-exposure vaccinations.

If bat saliva contacts the eyes, nose, mouth or an open wound, flush thoroughly with water and seek immediate medical advice.

Hendra virus

Flying-foxes are the natural host for Hendra virus (HeV), which can be transmitted from flying-foxes to horses. Infected horses sometimes amplify the virus and can then transmit it to other horses, humans and on two occasions, dogs (DPI 2014). There is no evidence that the virus can be passed directly from flying-foxes to humans or to dogs (AVA 2015). Clinical studies have shown cats, pigs, ferrets and guinea pigs can carry the infection (DPI 2015a).

Although the virus is periodically present in flying-fox populations across Australia, the likelihood of horses becoming infected is low and consequently human infection is extremely rare. Horses are thought to contract the disease after ingesting forage or water contaminated primarily with flying-fox urine (CDC 2014).

Humans may contract the disease after close contact with an infected horse. HeV infection in humans presents as a serious and often fatal respiratory and/or neurological disease and there is currently no effective post-exposure treatment or vaccine available for people. The mortality rate in horses is greater than 70% (DPI 2014). Since 1994, 81 horses have died and four of the seven people infected with HeV have lost their lives (DPI 2014).

Previous studies have shown that HeV spillover events have been associated with foraging flying-foxes rather than camp locations. Therefore risk is considered similar at any location within the range of flying-fox species and all horse owners should be vigilant. Vaccination of horses can protect

horses and subsequently humans from infection (DPI 2014), as can appropriate horse husbandry (e.g. covering food and water troughs, fencing flying-fox foraging trees in paddocks, etc.).

Although all human cases of HeV to date have been contracted from infected horses and direct transmission from bats to humans has not yet been reported, particular care should be taken by select occupational groups that could be uniquely exposed. For example, persons who may be exposed to high levels of HeV via aerosol of heavily contaminated substrate should consider additional PPE (e.g. respiratory filters), and potentially dampening down dry dusty substrate.

Menangle virus

Menangle virus (also known as bat paramyxovirus no. 2) was first isolated from stillborn piglets from a NSW piggery in 1997. Little is known about the epidemiology of this virus, except that it has been recorded in flying-foxes, pigs and humans (AVA 2015). The virus caused reproductive failure in pigs and severe febrile (flu-like) illness in two piggery workers employed at the same Menangle piggery where the virus was recorded (AVA 2015). The virus is thought to have been transmitted to the pigs from flying-foxes via an oral–faecal matter route (AVA 2015). Flying-foxes had been recorded flying over the pig yards prior to the occurrence of disease symptoms. The two infected piggery workers made a full recovery and this has been the only case of Menangle virus recorded in Australia.

General health considerations

Flying-foxes, like all animals, carry bacteria and other microorganisms in their guts, some of which are potentially pathogenic to other species. Direct contact with faecal material should be avoided and general hygiene measures taken to reduce the low risk of gastrointestinal and other disease.

Contamination of water supplies by any animal excreta (birds, amphibians and mammals such as flying-foxes) poses a health risk to humans. Household tanks should be designed to minimise potential contamination, such as using first flush diverters to divert contaminants before they enter water tanks. Trimming vegetation overhanging the catchment area (e.g. the roof of a house) will also reduce wildlife activity and associated potential contamination. Tanks should also be appropriately maintained and flushed, and catchment areas regularly cleaned to remove potential contaminants.

Public water supplies are regularly monitored for harmful microorganisms, and are filtered and disinfected before being distributed. Management plans for community supplies should consider whether any large congregation of animals, including flying-foxes, occurs near the supply or catchment area. Where they do occur, increased frequency of monitoring should be considered to ensure early detection and management of contaminants.

Appendix 4: Summary of Key Legislation

OEH recommends that councils and other land managers prepare a Camp Management Plan, regardless of the legislation under which the proposed management activities are to be assessed. This will ensure that the land manager and surrounding communities are clear about the proposed management, and that appropriate consideration is given to the conservation and welfare of threatened species, the needs and interests of the surrounding community, and a range of other factors.

Local Government Legislation

Local government is required to prepare planning schemes (including Environmental Planning Instruments and Development Control Plans) consistent with provisions under the *Environmental Planning and Assessment Act* 1979 (EP&A Act).

Local Environment Plans are environmental planning instruments that are legal documents and that relate to a local government area. Other environmental planning instruments, such as State Environmental Planning Policies (SEPPs), may relate to the whole or part of the state. A development control plan provides detailed planning and design guidelines to support the planning controls in a Local Environment Plan, but they are not legal documents.

Planning schemes enable a local government authority to manage growth and change in their local government area (LGA) through land use and administrative definitions, zones, overlays, infrastructure planning provisions, assessment codes and other administrative provisions. A planning scheme identifies the kind of development requiring approval, as well as zoning all areas within the LGA based on the environmental values and development requirements of that land. Planning schemes could potentially include a Flying-fox habitat overlay, and may designate some habitat as Flying-fox conservation areas.

State Government Legislation

Flying-fox Camp Management Policy 2015

The Flying-fox Camp Management Policy 2015 (the Policy) has been developed to empower land managers, primarily local councils, to work with their communities to manage Flying-fox camps effectively. It provides the framework within which OEH will make regulatory decisions. In particular, the Policy strongly encourages local councils and other land managers to prepare Camp Management Plans for sites where the local community is affected.

Biodiversity Conservation Act 2016

The purpose of the *Biodiversity Conservation Act* 2016 (BC Act) is to conserve biodiversity and maintain a healthy, productive and resilient environment. The Grey-headed Flying-fox is listed as threatened under the BC Act (see also Why the Grey-headed Flying-fox is listed as a threatened species).

An assessment of impacts is required for any threatened species or their habitat or ecological community that may be impacted by actions proposed in the Plan.

Section 6.12 of the Act requires that a Biodiversity Development Assessment Report is prepared to assess whether the proposed action is likely to have a significant effect on any threatened species or their habitats, or ecological community (note, this is therefore not just applicable to flying-foxes). A species impact statement (SIS) is an available option to the proponent for activities under Part 5 of the EP&A Act. (Appendix A in the Policy provides a flow chart for this process).

National Parks and Wildlife Act 1974

The *National Parks and Wildlife Act 1974* (NPW Act) provides for the conservation of nature, objects, places or features of cultural value and the management of land reserved under this Act.

Note that OEH is unlikely to support any actions proposed in a Camp Management Plan that involves dispersal of Flying-foxes from lands under National Parks and Wildlife Service (NPWS) control.

Prevention of Cruelty to Animals Act 1979

It may be an offence under this Act if there is evidence of unreasonable/unnecessary torment associated with management activities. Adhering to welfare and conservation measures provided in Section 10.3 will ensure compliance with this Act.

Environmental Planning and Assessment Act 1979

The objects of the *Environmental Planning and Assessment Act 1979* (EP&A Act) are to encourage proper management, development and conservation of resources, for the purpose of the social and economic welfare of the community and a better environment. It also aims to share responsibility for environmental planning between different levels of government and promote public participation in environmental planning and assessment.

The EP&A Act is administered by the NSW Department of Planning and Environment.

Development control plans under the Act should consider flying-fox camps so that planning, design and construction of future developments is appropriate to avoid future conflict.

Development under Part 4 of the Act does not require licensing under the BC Act.

Where public authorities such as local councils undertake development under Part 5 of the EP&A Act (known as 'development without consent' or 'activity'), assessment and licensing under the BC Act may not be required. However a full consideration of the development's potential impacts on threatened species will be required in all cases.

Where flying-fox camps occur on private land, land owners are not eligible to apply for development under Part 5 of the EP&A Act. Private land owners should contact Council to explore management options for camps that occur on private land.

Rural Fires Act 1997

The objects of this Act are to prevent, mitigate and suppress bushfires and coordinate bush firefighting, while protecting persons from injury or death, and reduce property damage from fire. A permit is generally required from the Rural Fire Service for any fires in the open that are lit during the local Bush Fire Danger Period as determined each year. This may be relevant for fires used to disperse Flying-foxes, or for any burning associated with vegetation management.

Protection of the Environment Operations Act 1997

The main object of *the Protection of the Environment Operations Act 1997* (POEO Act) is to set out explicit protection of the environment polices (PEPs) and adopt more innovative approaches to reducing pollution.

The use of smoke as a dispersal mechanism may constitute 'chemical production' under Schedule 1, clause 8 of the POEO Act, so this type of dispersal activity may require a licence under Chapter 3 of the Act.

The POEO Act also regulates noise including 'offensive noise'. The Protection of the Environment Operations (Noise Control) Regulation 2008 (Part 4, Division 2) provides information on the types of noise that can be 'offensive' and for which the Environment Protection Authority (EPA) can issue fines. This may include noise generated as a part of dispersal activities. It is best to discuss the types of noise makers and the sound levels and times these will be generated, along with identified noise receptors, with Council prior to any dispersal. Detailed advice and guidance on noise regulation can be found in the EPA's Noise guide for local government (EPA 2013).

Crown Lands Act 1989

The principles of Crown land management include the observance of environmental protection principles and the conservation of its natural resources, including water, soil, flora, fauna and scenic quality. Any works on land that is held or reserved under the *Crown Lands Act 1989* (including vegetation management and dispersal activities) are an offence under the Act without prior authorisation obtained through the Department of Industry - Lands & Forestry.

Local Government Act 1993

The primary purpose of this Act is to provide the legal framework for an effective, efficient and environmentally responsible, open system of local government. Most relevant to flying-fox management is that it also provides encouragement for the effective participation of local communities in the affairs of local government and sets out guidance on the use and management of community land which may be applicable to land which requires management of Flying-foxes.

State Environmental Planning Policies

SEPPs are environmental planning instruments which address specific planning issues within NSW. These SEPPs often remove power from local councils in order to control specific types of development or development in specific areas. SEPPs often transfer decision-making from Council to the Planning Minister. While there may be others, some of the SEPPs likely to apply at some flying-fox camps are outlined below.

SEPP – Coastal Management

This policy provides additional protection for coastal wetlands by requiring development consent to be obtained before any clearing, draining, filling or construction of levees can occur on a mapped wetland. Camps are unlikely to fall within the bounds of a SEPP 14 wetland, but additional restrictions for vegetation management in these areas may be required if they do.

SEPP 19 – Bushland in Urban Areas

The aim of this policy is to protect and preserve bushland within urban areas which are defined in Schedule 1 of the SEPP. Broadly, this covers most LGAs within the Greater Sydney Region. It does not cover:

- land reserved or dedicated under the *National Parks and Wildlife Act 1974*
- state forests, flora reserves or timber reserves under the *Forestry Act 1916*
- land to which SEPP (Western Sydney Parklands) 2009 applies.

Bushland within the designated LGAs may not be disturbed without the consent of the council unless the disturbance is for: bushfire hazard reduction, facilitating recreational use of the bushland in accordance with a plan of management referred to in clause 8 of the policy and essential infrastructure such as electricity, sewerage, gas or main roads. If the land owned by the proponent is

zoned as SEPP 19 bushland, council approval would be required under this SEPP. Council should be contacted to discuss any potential disturbance associated with camp management.

Commonwealth Government Legislation

Environment Protection and Biodiversity Conservation Act 1999

The Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides protection for the environment, specifically matters of national environmental significance (MNES). A referral to the Commonwealth DoE is required under the EPBC Act for any action that is likely to significantly impact on an MNES.

MNES under the EPBC Act that relate to Flying-foxes include:

- world heritage sites (where those sites contain Flying-fox camps or foraging habitat)
- wetlands of international importance (where those wetlands contain Flying-fox camps or foraging habitat)
- nationally threatened species and ecological communities.

The Grey-headed Flying-fox (*Pteropus poliocephalus*; GHFF) is listed as a vulnerable species under the EPBC Act, meaning it is an MNES. It is also considered to have a single national population. DoE has developed the Referral guideline for management actions in GHFF and SFF[1] camps (DoE 2015) (the Guideline) to guide whether referral is required for actions pertaining to the GHFF.

The Guideline defines a nationally important GHFF camp as one that has either:

- contained ≥10,000 GHFF in more than one year in the last 10 years, or
- been occupied by more than 2500 GHFF permanently or seasonally every year for the last 10 years.

Provided that management at nationally important camps follows the mitigation standards below, DoE has determined that a significant impact to the population is unlikely, and referral is not likely to be required.

Referral will be required if a significant impact to any other MNES is considered likely as a result of management actions outlined in the Plan. Self-assessable criteria are available in the Significant Impact Guidelines 1.1 (DoE 2013) to assist in determining whether a significant impact is likely; otherwise consultation with DoE will be required.

Mitigation standards

- The action must not occur if the camp contains females that are in the late stages of pregnancy or have dependent young that cannot fly on their own.
- The action must not occur during or immediately after climatic extremes (heat stress event2, cyclone event3), or during a period of significant food stress4.
- Disturbance must be carried out using non-lethal means, such as acoustic, visual and/or physical disturbance or use of smoke.

[1] spectacled flying-fox (*P. conspicillatus*)

[2] A 'heat stress event' is defined for the purposes of the Australian Government's Referral guideline for management actions in GHFF and SFF camps as a day on which the maximum temperature does (or is predicted to) meet or exceed 38°C.

[3] A 'cyclone event' is defined as a cyclone that is identified by the Australian Bureau of Meteorology (www.bom.gov.au/cyclone/index.shtml).

[4] Food stress events may be apparent if large numbers of low body weight animals are being reported by wildlife carers in the region.

- Disturbance activities must be limited to a maximum of 2.5 hours in any 12 hour period, preferably at or before sunrise or at sunset.
- Trees are not felled, lopped or have large branches removed when flying-foxes are in or near to a tree and likely to be harmed.
- The action must be supervised by a person with knowledge and experience relevant to the management of flying-foxes and their habitat, who can identify dependent young and is aware of climatic extremes and food stress events. This person must make an assessment of the relevant conditions and advise the proponent whether the activity can go ahead consistent with these standards.

Appendix 5: Camp Management Options

Following is a description of the various Camp Management Options discussed in Section 5 of the Flying-fox Management Strategy.

Level 1 actions: routine camp management

Education and awareness programs

This management option involves undertaking a comprehensive and targeted flying-fox education and awareness program to provide accurate information to the local community about flying-foxes.

Such a program would include managing risk and alleviating concern about health and safety issues associated with flying-foxes, options available to reduce impacts from roosting and foraging flying-foxes, an up-to-date program of works being undertaken at the camp, and information about flying-fox numbers and flying-fox behaviour at the camp.

Residents should also be made aware that faecal drop and noise at night is mainly associated with plants that provide food, independent of camp location. Staged removal of foraging species such as fruit trees and palms from residential yards, or management of fruit (e.g. bagging, pruning) will greatly assist in mitigating this issue.

Collecting and providing information should always be the first response to community concerns in an attempt to alleviate issues without the need to actively manage flying-foxes or their habitat. Where it is determined that management is required, education should similarly be a key component of any approach. See also Section 3 and incorporate an education and awareness program into any community engagement plan.

Figure 1: Possible components of an education program

An education program may include components shown in Figure 1.

The likelihood of improving community understanding of flying-fox issues is high. However, the extent to which that understanding will help alleviate conflict issues is probably less so. Extensive education for decision-makers, the media and the broader community may be required to overcome negative attitudes towards flying-foxes.

It should be stressed that a long-term solution to the issue resides with better understanding flying-fox ecology and applying that understanding to careful urban planning and development.

Property modification without subsidies

The managers of land on which a flying-fox camp is located would promote or encourage the adoption of certain actions on properties adjacent or near to the camp to minimise impacts from roosting and foraging flying-foxes (note that approval may be required for some activities, refer to Section 4 for further information):

- Create visual/sound/smell barriers with fencing or hedges. To avoid attracting flying-foxes, species selected for hedging should not produce edible fruit or nectar-exuding flowers, should grow in dense formation between two and five metres (Roberts 2006) (or be maintained at less than 5 metres). Vegetation that produces fragrant flowers can assist in masking camp odour where this is of concern.
- Manage foraging trees (i.e. plants that produce fruit/nectar-exuding flowers) within properties through pruning/covering with bags or wildlife friendly netting, early removal of fruit, or tree replacement.

- Cover vehicles, structures and clothes lines where faecal contamination is an issue, or remove washing from the line before dawn/dusk.
- Move or cover eating areas (e.g. BBQs and tables) within close proximity to a camp or foraging tree to avoid contamination by flying-foxes.
- Install double-glazed windows, insulation and use air-conditioners when needed to reduce noise disturbance and smell associated with a nearby camp.
- Follow horse husbandry and property management guidelines provided at the NSW Department of Primary Industries Hendra virus web page (DPI 2015a).
- Include suitable buffers and other provisions (e.g. covered car parks) in planning of new developments.
- Turn off lighting at night which may assist flying-fox navigation and increase fly-over impacts.
- Consider removable covers for swimming pools and ensure working filter and regular chlorine treatment.
- Appropriately manage rainwater tanks, including installing first-flush systems.
- Avoid disturbing flying-foxes during the day as this will increase camp noise.

The cost would be borne by the person or organisation who modifies the property; however, opportunities for funding assistance (e.g. environment grants) may be available for management activities that reduce the need to actively manage a camp.

Property modification subsidies

Fully funding or providing subsidies to property owners for property modifications may be considered (subject to State Government Funding) to manage the impacts of the flying-foxes. Providing subsidies to install infrastructure may improve the value of the property, which may also offset concerns regarding perceived or actual property value or rental return losses.

The level and type of subsidy would need to be agreed to by the entity responsible for managing the flying-fox camp.

Service subsidies

This management option involves providing property owners with a subsidy to help manage impacts on the property and lifestyle of residents (may be considered subject to State Government Funding). The types of services that could be subsidised include clothes washing, cleaning outside areas and property, car washing or power bills.

Critical thresholds of flying-fox numbers at a camp and distance to a camp may be used to determine when subsidies would apply.

Routine camp maintenance and operational activities

Examples of routine camp management actions are provided in the Policy. These include:

- removal of tree limbs or whole trees that pose a genuine health and safety risk, as determined by a qualified arborist
- weed removal, including removal of priority weeds under the *Biosecurity Act* 2015, or species listed as undesirable by a council
- trimming of understorey vegetation or the planting of vegetation
- minor habitat augmentation for the benefit of the roosting animals

- mowing of grass and similar grounds-keeping actions that will not create a major disturbance to roosting flying-foxes
- application of mulch or removal of leaf litter or other material on the ground.

Protocols should be developed for carrying out operations that may disturb flying-foxes, which can result in excess camp noise. Such protocols could include limiting the use of disturbing activities to certain days or certain times of day in the areas adjacent to the camp, and advising adjacent residents of activity days. Such activities could include lawn-mowing, using chainsaws, whipper-snippers, using generators and testing alarms or sirens.

Revegetation and land management to create alternative habitat

This management option involves revegetating and managing land to create alternative flying-fox roosting habitat through improving and extending existing low-conflict camps or developing new roosting habitat in areas away from human settlement.

Selecting new sites and attempting to attract flying-foxes to them has had limited success in the past, and ideally habitat at known camp sites would be dedicated as a flying-fox reserve. However, if a staged and long-term approach is used to make unsuitable current camps less attractive, whilst concurrently improving appropriate sites, it is a viable option (particularly for the transient and less selective LRFF). Supporting further research into flying-fox camp preferences may improve the potential to create new flying-fox habitat.

When improving a site for a designated flying-fox camp, preferred habitat characteristics detailed in Section 6.4 should be considered.

Foraging trees planted amongst and surrounding roost trees (excluding in/near horse paddocks) may help to attract flying-foxes to a desired site. They will also assist with reducing foraging impacts in residential areas. Consideration should be given to tree species that will provide year-round food, increasing the attractiveness of the designated site. Depending on the site, the potential negative impacts to a natural area will need to be considered if introducing non-indigenous plant species.

The presence of a water source is likely to increase the attractiveness of an alternative camp location. Supply of an artificial water source should be considered if unavailable naturally, however this may be cost-prohibitive.

Potential habitat mapping using camp preferences (see Section 6.4) and suitable land tenure can assist in initial alternative site selection. A feasibility study would then be required prior to site designation to assess likelihood of success and determine the warranted level of resource allocated to habitat improvement.

Provision of artificial roosting habitat

This management option involves constructing artificial structures to augment roosting habitat in current camp sites or to provide new roosting habitat. Trials using suspended ropes have been of limited success as flying-foxes only used the structures that were very close to the available natural roosting habitat. It is thought that the structure of the vegetation below and around the ropes is important.

Protocols to manage incidents

This management option involves implementing protocols for managing incidents or situations specific to particular camps. Such protocols may include 'bat watch' patrols at sites that host vulnerable people, management of pets at sites popular for walking dogs or heat stress incidents (when the camp is subjected to extremely high temperatures leading to flying-foxes changing their behaviour and/or dying).

Participation in research

This management option involves participating in research to improve knowledge of flying-fox ecology to address the large gaps in our knowledge about flying-fox habits and behaviours and why they choose certain sites for roosting. Further research and knowledge sharing at local, regional and national levels will enhance our understanding and management of flying-fox camps.

Appropriate land-use planning

Land-use planning instruments may be able to be used to ensure adequate distances are maintained between future residential developments and existing or historical flying-fox camps. While this management option will not assist in the resolution of existing land-use conflict, it may prevent issues for future residents.

Property acquisition

Property acquisition may be considered if negative impacts cannot be sufficiently mitigated using other measures. This option will clearly be extremely expensive, however is likely to be more effective than dispersal and in the long-term may be less costly.

Do nothing

The management option to 'do nothing' involves not undertaking any management actions in relation to the flying-fox camp and leaving the situation and site in its current state.

Level 2 actions: in-situ management

Buffers

Buffers can be created through vegetation removal and/or the installation of permanent/semi-permanent deterrents.

Creating buffers may involve planting low-growing or spiky plants between residents or other conflict areas and the flying-fox camp. Such plantings can create a visual buffer between the camp and residences or make areas of the camp inaccessible to humans.

Buffers greater than 300 metres are likely to be required to fully mitigate amenity impacts (SEQ Catchments 2012). The usefulness of a buffer to mitigate odour and noise impacts generally declines if the camp is within 50 metres of human habitation (SEQ Catchments 2012), however any buffer will assist and should be as wide as the site allows.

Buffers through vegetation removal

Vegetation removal aims to alter the area of the buffer habitat sufficiently so that it is no longer suitable as a camp. The amount required to be removed varies between sites and camps, ranging from some weed removal to removal of most of the canopy vegetation.

Any vegetation removal should be done using a staged approach, with the aim of removing as little native vegetation as possible. This is of particular importance at sites with other values (e.g. ecological or amenity), and in some instances the removal of any native vegetation will not be appropriate. Thorough site assessment (further to desktop searches) will inform whether vegetation management is suitable (e.g. can impacts to other wildlife and/or the community be avoided?).

Removing vegetation can also increase visibility into the camp and noise issues for neighbouring residents which may create further conflict.

Suitable experts should be consulted to assist selective vegetation trimming/removal to minimise vegetation loss and associated impacts.

The importance of under- and mid-storey vegetation in the buffer area for flying-foxes during heat stress events also requires consideration.

Buffers without vegetation removal

Permanent or semi-permanent deterrents can be used to make buffer areas unattractive to flying-foxes for roosting, without the need for vegetation removal. This is often an attractive option where vegetation has high ecological or amenity value.

While many deterrents have been trialled in the past with limited success, there are some options worthy of further investigation:

- Visual deterrents – Visual deterrents such as plastic bags, fluoro vests (GeoLINK 2012) and balloons (Ecosure 2016, pers. comm.) in roost trees have shown to have localised effects, with flying-foxes deterred from roosting within 1–10 metres of the deterrents. The type and placement of visual deterrents would need to be varied regularly to avoid habituation.
- Noise emitters on timers – Noise needs to be random, varied and unexpected to avoid flying-foxes habituating. As such these emitters would need to be portable, on varying timers and a diverse array of noises would be required. It is likely to require some level of additional disturbance to maintain its effectiveness, and ways to avoid disturbing flying-foxes from desirable areas would need to be identified. This is also likely to be disruptive to nearby residents.
- Smell deterrents – For example, bagged python excrement hung in trees has previously had a localised effect (GeoLINK 2012). The smell of certain deterrents may also impact nearby residents, and there is potential for flying-foxes to habituate.
- Canopy-mounted water sprinklers – This method has been effective in deterring flying-foxes during dispersals (Ecosure personal experience), and a current trial in Queensland is showing promise for keeping flying-foxes out of designated buffer zones. This option can be logistically difficult (installation and water sourcing) and may be cost-prohibitive. Design and use of sprinklers need to be considerate of animal welfare and features of the site. For example, misting may increase humidity and exacerbate heat stress events, and overuse may impact other environmental values of the site.

Note that any deterrent with a high risk of causing inadvertent dispersal may be considered a Level 3 action.

The use of visual deterrents, in the absence of effective maintenance, could potentially lead to an increase in rubbish in the natural environment.

Noise attenuation fencing

Noise attenuation fencing could be installed in areas where the camp is particularly close to residents. This may also assist with odour reduction, and perspex fencing could be investigated to assist fence amenity. Although expensive to install, this option could negate the need for habitat modification, maintaining the ecological values of the site, and may be more cost-effective than ongoing management.

Level 3 actions: disturbance or dispersal

Nudging

Noise and other low intensity active disturbance restricted to certain areas of the camp can be used to encourage flying-foxes away from high conflict areas. This technique aims to actively ‘nudge’ flying-foxes from one area to another, while allowing them to remain at the camp site.

Unless the area of the camp is very large, nudging should not be done early in the morning as this may lead to inadvertent temporary dispersal of flying-foxes from the entire camp site and increased stress on the animals. Disturbance during the day should be limited in frequency and duration (e.g. up to four times per day for up to 10 minutes each) to avoid welfare impacts. As with dispersal, it is also critical to avoid periods when dependent young are present (as identified by a flying-fox expert).

Dispersal

Dispersal aims to encourage a camp to move to another location, through either disturbance or habitat modification. However, experience shows that flying-foxes rarely move more than 600m from the original camp site.

There is a range of potential risks, costs and legal implications that are greatly increased with dispersal (compared with in-situ management as above). These include:

- impact on animal welfare and flying-fox conservation;
- splintering the camp into other locations nearby that are equally or more problematic;
- shifting the issue to another area within the locality;
- impact on habitat value;
- effects on the flying-fox population, including disease status and associated public health risk;
- impacts to nearby residents associated with ongoing dispersal attempts;
- excessive initial and/or ongoing capacity and financial investment;
- negative public perception and backlash;
- increased aircraft strike risk associated with changed flying-fox movement patterns; and
- unsuccessful management requiring multiple attempts, which may exacerbate all of the above.

Despite these risks, there are some situations where camp dispersal may be considered. Dispersal can broadly be categorised as 'passive' or 'active' as detailed below.

Passive dispersal

Removing vegetation in a staged manner can be used to passively disperse a camp, by gradually making the habitat unattractive so that flying-foxes will disperse of their own accord over time with little stress (rather than being more forcefully moved with noise, smoke, etc.). This is less stressful to flying-foxes, and greatly reduces the risk of splinter colonies forming in other locations (as flying-foxes are more likely to move to other known sites within their camp network when not being forced to move immediately, as in active dispersal).

Generally, a significant proportion of vegetation needs to be removed in order to achieve dispersal of flying-foxes from a camp or to prevent camp re-establishment. For example, 400 flying-foxes abandoned a camp in Bundall, Queensland once 70% of the canopy/mid-storey and 90% of the understorey had been removed (Ecosure 2011). The animals did not leave the local area and formed 3 new camps with no reduction in the population size or resolution to the community conflict (Roberts and Eby 2013). Ongoing maintenance of the site is required to prevent vegetation structure returning to levels favourable for colonisation by flying-foxes. Importantly, at nationally important camps (defined in Section 4.2.1) sufficient vegetation must be retained to accommodate the maximum number of flying-foxes recorded at the site.

This option may be preferable in situations where the vegetation is of relatively low ecological and amenity value, and alternative known permanent camps are located nearby with capacity to absorb

the additional flying-foxes. While the likelihood of splinter colonies forming is lower than with active dispersal, if they do form following vegetation modification there will no longer be an option to encourage flying-foxes back to the original site. This must be carefully considered before modifying habitat.

There is also potential to make a camp site unattractive by removing access to water sources. However at the time of writing this method had not been trialled so the likelihood of this causing a camp to be abandoned is unknown. It would also likely only be effective where there are no alternative water sources in the vicinity of the camp.

Active dispersal through disturbance

Dispersal is more effective when a wide range of tools are used on a randomised schedule with animals less likely to habituate (Ecosure pers. obs. 1997–2015). Each dispersal team member should have at least one visual and one aural tool that can be used at different locations on different days (and preferably swapped regularly for alternate tools). Exact location of these and positioning of personnel will need to be determined on a daily basis in response to flying-fox movement and behaviour, as well as prevailing weather conditions (e.g. wind direction for smoke drums).

Active dispersal will be disruptive for nearby residents given the timing and nature of activities, and this needs to be considered during planning and community consultation.

This method does not explicitly use habitat modification as a means to disperse the camp, however if dispersal is successful, some level of habitat modification should be considered. This will reduce the likelihood of flying-foxes attempting to re-establish the camp and the need for follow-up dispersal as a result. Ecological and aesthetic values will need to be considered for the site, with options for modifying habitat the same as those detailed for buffers above.

Early dispersal before a camp is established at a new location

This management option involves monitoring local vegetation for signs of flying-foxes roosting in the daylight hours and then undertaking active or passive dispersal options to discourage the animals from establishing a new camp. Even though there may only be a few animals initially using the site, this option is still treated as a dispersal activity, however it may be simpler to achieve dispersal at these new sites than it would in an established camp. It may also avoid considerable issues and management effort required should the camp be allowed to establish in an inappropriate location.

It is important that flying-foxes feeding overnight in vegetation are not mistaken for animals establishing a camp.

Maintenance dispersal

Maintenance dispersal refers to active disturbance following a successful dispersal to prevent the camp from re-establishing. It differs from initial dispersal by aiming to discourage occasional over-flying individuals from returning, rather than attempting to actively disperse animals that have been recently roosting at the site. As such, maintenance dispersal may have fewer timing restrictions than initial dispersal, provided that appropriate mitigation measures are in place (see Section 10).

Unlawful activities

Culling

Culling is addressed here as it is often raised by community members as a preferred management method; however, culling is contrary to the purpose of the BC Act and will not be permitted as a method to manage flying-fox camps.

Appendix 6: Management Controls and Guidelines

Stop work triggers

The management program will cease and will not recommence or progress to subsequent levels without consulting OEH if:

- any of the animal welfare triggers occur on more than two days during the program, such as unacceptable levels of stress (see Table 20)
- there is a flying-fox injury or death
- a new camp/camps appear to be establishing
- impacts are created or exacerbated at other locations
- there appears to be potential for conservation impacts (e.g. reduction in breeding success identified through independent monitoring)
- standard measures to avoid impacts (detailed in Section 10.3) cannot be met.

Management may also be terminated at any time if:

- unintended impacts are created for the community around the camp
- allocated resources are exhausted.

Dispersal will cease if:

- in the opinion of the land manager or OEH, there is ongoing proliferation of splinter colonies in unsuitable locations (as determined by the land manager or OEH)
- splinter camps become established in inappropriate locations and for ecological, social or other reasons, a dispersal at the splinter location is not appropriate (as determined by the land manager or OEH).

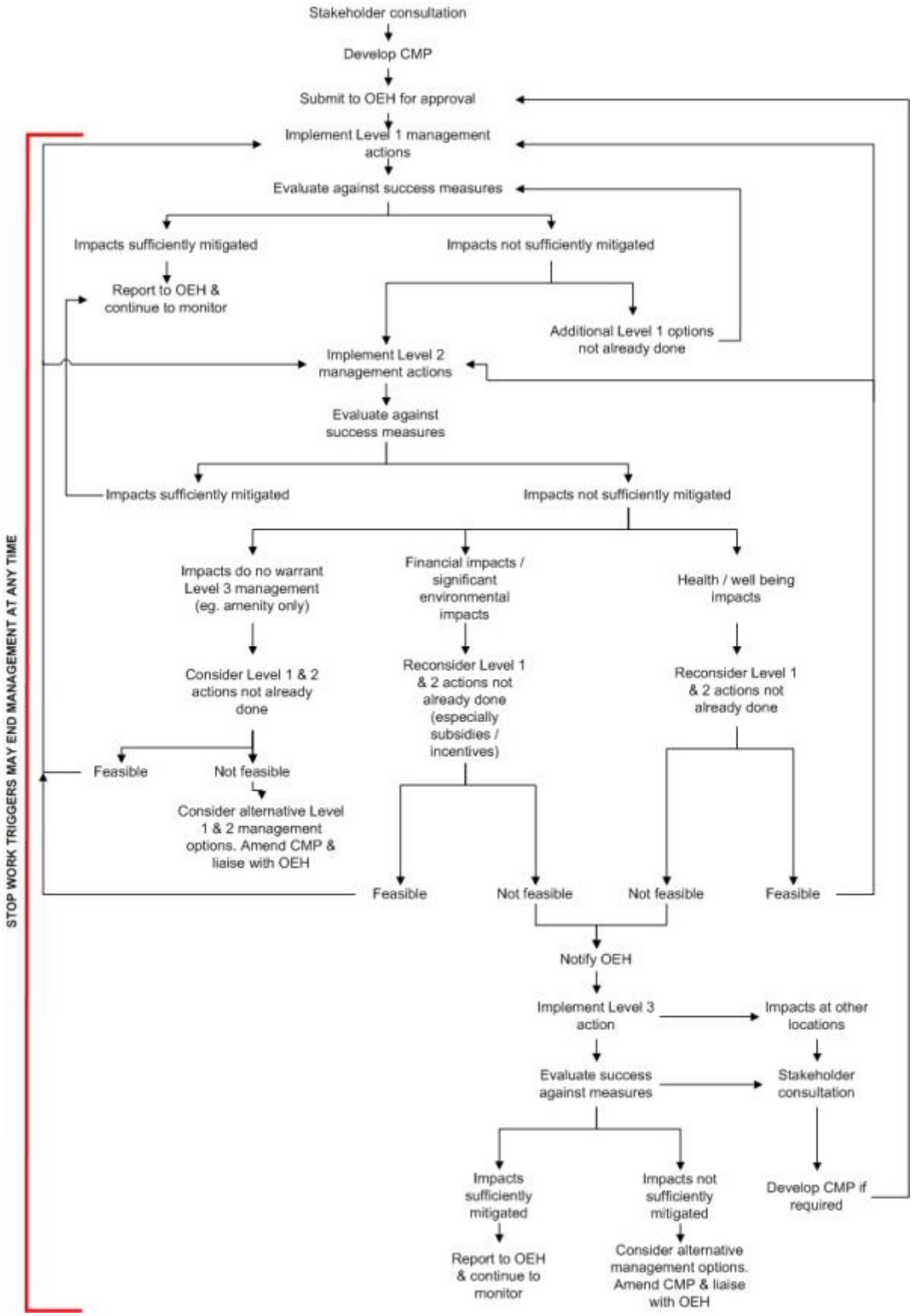
If a dispersal program is stopped it may be permanently abandoned and other strategies considered, or reassessed and resumed in consultation with OEH.

Planned action for potential impacts during management

Table 20: A person with experience in flying-fox behaviour will monitor for welfare triggers and direct works in accordance with the criteria below

Welfare trigger	Signs	Action
Unacceptable levels of stress	If any individual is observed: panting saliva spreading located on or within 2 m of the ground	Works to cease for the day.
Fatigue	In-situ management more than 30% of the camp takes flight individuals are in flight for more than 5 minutes flying-foxes appear to be leaving the camp Dispersal low flying laboured flight settling despite dispersal efforts	In-situ management Works to cease and recommence only when flying-foxes have settled* / move to alternative locations at least 50 m from roosting animals. Dispersal Works to cease for the day.
Injury/death	a flying-fox appears to have been injured/killed on site (including aborted foetuses) any flying-fox death is reported within 1 km of the dispersal site that appears to be related to the dispersal females in final trimester dependent/crèching young present loss of condition evident	Works to cease immediately and OEH notified AND rescheduled OR adapted sufficiently so that significant impacts (e.g. death/injury) are highly unlikely to occur, as confirmed by an independent expert) OR stopped indefinitely and alternative management options investigated.

* maximum of two unsuccessful attempts to recommence work before ceasing for the day.


Stakeholder consultation
Develop CMP
Submit to OEH for approval
Implement Level 1 management actions
Evaluate against success measures
Impacts sufficiently mitigated
Impacts not sufficiently mitigated
Report to OEH & continue to monitor
Additional Level 1 options not already done
Implement Level 2 management actions
Evaluate against success measures
Impacts sufficiently mitigated
Impacts not sufficiently mitigated
Impacts do no warrant Level 3 management (eg. amenity only)
Financial impacts / significant environmental impacts
Health / well being impacts
Consider Level 1 & 2 actions not already done
Reconsider Level 1 & 2 actions not already done (especially subsidies / incentives)
Reconsider Level 1 & 2 actions not already done
Feasible
Not feasible
Consider alternative Level 1 & 2 management options. Amend CMP & liaise with OEH
Feasible
Not feasible
Not feasible
Feasible
Notify OEH
Implement Level 3 action
Impacts at other locations
Evaluate success against measures
Stakeholder consultation
Impacts sufficiently mitigated
Impacts not sufficiently mitigated
Develop CMP if required
Report to OEH & continue to monitor
Consider alternative management options. Amend CMP & liaise with OEH
STOP WORK TRIGGERS MAY END MANAGEMENT AT ANY TIME

Standard Measures to Avoid Impacts

The following mitigation measures will be complied with at all times during Plan implementation.

All Management Activities

- All personnel will be appropriately experienced, trained and inducted. Induction will include each person's responsibilities under this Plan.
- All personnel will be briefed prior to the action commencing each day, and debriefed at the end of the day.
- Works will cease and OEH consulted in accordance with the 'stop work triggers' section of the Plan.
- Large crews will be avoided where possible.
- The use of loud machinery and equipment that produces sudden impacts/noise will be limited. Where loud equipment (e.g. chainsaws) is required they will be started away from the camp and allowed to run for a short time to allow flying-foxes to adjust.
- Activities that may disturb flying-foxes at any time during the year will begin as far from the camp as possible, working towards the camp gradually to allow flying-foxes to habituate.
- Any activity likely to disturb flying-foxes so that they take flight will be avoided during the day during the sensitive GHFF/BFF birthing period (i.e. when females are in final trimester or the majority are carrying pups, generally August – December) and avoided altogether during crèching (generally November/December to February). Where works cannot be done at night after fly-out during these periods, it is preferable they are undertaken in the late afternoon close to or at fly-out. If this is also not possible, a person experienced in flying-fox behaviour will monitor the camp for at least the first two scheduled actions (or as otherwise deemed to be required by that person) to ensure impacts are not excessive and advise on the most appropriate methods (e.g. required buffer distances, approach, etc.).
- OEH will be immediately contacted if LRFF are present between March and October, or are identified as being in final trimester / with dependent young.
- Non-critical maintenance activities will ideally be scheduled when the camp is naturally empty. Where this is not possible (e.g. at permanently occupied camps) they will be scheduled for the best period for that camp (e.g. when the camp is seasonally lower in numbers and breeding will not be interrupted, or during the non-breeding season, generally May to July).
- Works will not take place in periods of adverse weather including strong winds, sustained heavy rains, in very cold temperatures or during periods of likely population stress (e.g. food bottlenecks). Wildlife rehabilitators will be consulted to determine whether the population appears to be under stress.
- Works will be postponed on days predicted to exceed 35°C (or ideally 30°C), and for one day following a day that reached ≥35°C. If an actual heat stress event has been recorded at the camp or at nearby camps, a rest period of several weeks will be scheduled to allow affected flying-foxes to fully recover. See the OEH fact sheet on 'Responding to heat stress in flying-fox camps'.

- Evening works may commence after fly-out. Noise generated by the works should create a first stage disturbance, with any remaining flying-foxes taking flight. Works should be paused at this stage to monitor for any remaining flying-foxes (including crèching young, although December – February should be avoided for this reason) and ensure they will not be impacted. All Level 1 and 2 works (including pack up) will cease by 0100 to ensure flying-foxes returning early in the morning are not inadvertently dispersed. Works associated with Level 3 actions may continue provided flying-foxes are not at risk of being harmed.
- If impacts at other sites are considered, in OEH's opinion, to be a result of management actions under this Plan, assistance will be provided by the proponent to the relevant land manager to ameliorate impacts. Details of this assistance are to be developed in consultation with OEH.
- Any proposed variations to works detailed in the Plan will be approved, in writing, by OEH before any new works occur.
- OEH may require changes to methods or cessation of management activities at any time.
- Ensure management actions and results are recorded to inform future planning. See the OEH fact sheet on Monitoring, evaluating and reporting.

It is the responsibility of the land manager and contractors to conduct a risk assessment and determine workplace health and safety requirements; however, minimum requirements are provided following.

Human safety

- All personnel to wear protective clothing including long sleeves and pants; additional items such as eye protection and a hat are also recommended. People working under the camp should wash their clothes daily. Appropriate hygiene practices will be adopted such as washing hands with soap and water before eating/smoking.
- All personnel who may come into contact with flying-foxes will be vaccinated against Australian bat lyssavirus with current titre.
- A wash station will be available on site during works along with an anti-viral antiseptic (e.g. Betadine) should someone be bitten or scratched.
- Details of the nearest hospital or doctor who can provide post-exposure prophylaxis will be kept on site.

Post-works

- Reports for Level 1 actions will be provided to OEH annually. Reports for Level 2 and 3 actions will be submitted to OEH one month after commencement of works and then quarterly for the life of the Plan (up to five years) (for all Level 3 actions and in periods where works have occurred for Level 2 actions). Each report is to include:
    - results of pre- and post-work population monitoring
    - any information on new camps that have formed in the area
    - impacts at other locations that may have resulted from management, and suggested amelioration measures

- an assessment of how the flying-foxes reacted to the works, with particular detail on the most extreme response and average response, outlining any recommendations for what aspects of the works went well and what aspects did not work well
- further management actions planned including a schedule of works
- an assessment of how the community responded to the works, including details on the number and nature of complaints before and after the works
- detail on any compensatory plantings undertaken or required
- expenditure (financial and in-kind costs)
- Plan evaluation and review (see Section 12).

All Level 2 and 3 Actions

Prior to works

- Residents adjacent to the camp will be individually notified one week prior to on-ground works commencing. This will include information on what to do if an injured or orphaned flying-fox is observed, a reminder not to participate in or interfere with the program, and details on how to report unusual flying-fox behaviour/daytime sightings. Relevant contact details will be provided (e.g. Program Coordinator). Resident requests for retention of vegetation and other concerns relating to the program will be taken into consideration.
- Where the Plan is being implemented by Council, information will be placed on Council's website along with contact information.
- OEH will be notified at least 48 hours before works commence.
- A protocol, in accordance with the NSW Code of Practice for Injured, Sick and Orphaned Flying-foxes (OEH 2012), for flying-fox rescue will be developed including contact details of rescue and rehabilitation organisations. This protocol will be made available to all relevant staff, residents and volunteers prior to the action commencing. See Appendix 7: Example Flying-fox Rescue Protocol for an example protocol.
- A licensed wildlife rehabilitator will be notified prior to beginning works in the event that rescue/care is required.
- Monitoring
- A flying-fox expert (identified in section 13.3) will undertake an on-site population assessment prior to, during works and after works have been completed, including:
  - number of each species
  - ratio of females in final trimester
  - approximate age of any pups present including whether they are attached or likely to be crèched
  - visual health assessment
  - mortalities.
- Counts will be done at least:
  - once immediately prior to works
  - daily during works

- immediately following completion
- one month following completion
- 12 months following completion.

During works

- A flying-fox expert (identified in section 13.3) will attend the site as often as OEH considers necessary to monitor flying-fox behaviour and ensure compliance with the Plan and the Policy. They must also be able to identify pregnant females, flightless young, individuals in poor health and be aware of climatic extremes and food stress events. This person will make an assessment of the relevant conditions and advise the supervisor/proponent whether the activity can go ahead.
- Deterrents in buffer areas will be assessed by a flying-fox expert so those that may cause inadvertent dispersal (e.g. canopy-mounted sprinklers) are not used during fly-in.
- At least one flying-fox rest day with no active management will be scheduled fortnightly, preferably weekly. Static deterrents (e.g. canopy-mounted sprinklers) may still be used on rest days.

Vegetation Trimming / Removal

- Dead wood and hollows will be retained on site where possible as habitat.
- Vegetation chipping is to be undertaken as far away from roosting flying-foxes as possible (at least 100 metres).

Canopy Vegetation Trimming / Removal

Prior to works

- Trees to be removed or lopped will be clearly marked (e.g. with flagging tape) prior to works commencing, to avoid unintentionally impacting trees to be retained.

During works

- Any tree lopping, trimming or removal is undertaken under the supervision of a suitably qualified arborist (minimum qualification of Certificate III in Horticulture (Arboriculture) who is a member of an appropriate professional body such as the National Arborists Association).
- Trimming will be in accordance with relevant Australian Standards (e.g. AS4373 Pruning of Amenity Trees), and best practice techniques used to remove vegetation in a way that avoids impacting other fauna and remaining habitat.
- No tree in which a flying-fox is roosting will be trimmed or removed. Works may continue in trees adjacent to roost trees only where a person experienced in flying-fox behaviour assesses that no flying-foxes are at risk of being harmed. A person experienced in flying-fox behaviour is to remain on site to monitor, when canopy trimming/removal is required within 50 metres of roosting flying-foxes.
- While most females are likely to be carrying young (generally September – January) vegetation removal within 50 metres of the camp will only be done in the evening after fly-out, unless otherwise advised by a flying-fox expert.

- Tree removal as part of management will be offset at a ratio of at least 2:1. Where threatened vegetation removal is required, the land manager will prepare an Offset Strategy to outline a program of restoration works in other locations (in addition to existing programs). The strategy will be submitted to OEH for approval at least two months prior to commencing works.

Bush Regeneration

- All works will be carried out by suitably qualified and experienced bush regenerators, with at least one supervisor knowledgeable about flying-fox habitat requirements (and how to retain them for Level 1 and 2 actions) and trained in working under a camp.
- Vegetation modification, including weed removal, will not alter the conditions of the site such that it becomes unsuitable flying-fox habitat for Level 1 and 2 actions.
- Weed removal should follow a mosaic pattern, maintaining refuges in the mid- and lower storeys at all times.
- Weed control in the core habitat area will be undertaken using hand tools only (or in the evening after fly-out while crèching young are not present).
- Species selected for revegetation will be consistent with the habitat on site, and in buffer areas or conflict areas should be restricted to small shrubs/under-storey species to reduce the need for further roost tree management in the future.

Appendix 7: Example Flying-fox Rescue Protocol

Development of a flying-fox rescue protocol may be conditioned as part of a section 91 licence or section 95 certificate. The following may be used as a template, and this may be proactively submitted with your Plan.

Note that a protocol does not negate the requirement to have a licensed rehabilitator present at times specified above. When developing such a protocol you should seek input from the rehabilitator you plan to work with to ensure the protocol aligns with their preferred rescue approach.

Reference documents:

OEH 2012, NSW Code of Practice for Injured, Sick and Orphaned Flying-foxes, Office of Environment and Heritage, Sydney.

OEH 2011b, NSW Code of Practice for Injured, Sick and Orphaned Protected Fauna, Office of Environment and Heritage, Sydney.

Purpose

These work instructions are intended for Australian bat lyssavirus (ABLV)-vaccinated fauna spotter catchers (FSCs) or wildlife rescue personnel on site during dispersal activities to monitor, capture or provide first aid treatment for sick or injured flying-foxes that may require human intervention for their survival. Flying-fox rescue must only be attempted by personnel trained and experienced in flying-fox rescue and handling.

This work instruction provides rescuers with information regarding capture and first aid until a flying-fox is in the specialist care of a veterinarian or person qualified in wildlife rehabilitation.

Requirements

FSC and wildlife rescue personnel involved in flying-fox rescue must:

- be trained and experienced in rescue and handling
- be vaccinated against ABLV (titre levels checked at least once every two years)
- be aware of the hazards and risks of coming into contact with all bats
- utilise appropriate PPE and equipment for capture, transport and treatment of flying-foxes
- undertake a risk assessment before carrying out a rescue – do not endanger yourself or others during a rescue
- have the contact details for a local veterinarian or bat rehabilitator who will accept the sick or injured flying-fox.

Human first aid

All bats in Australia should be viewed as potentially infected with ABLV. If bitten or scratched by a bat, immediately wash the wound with soap and water (do not scrub) and continue for at least five minutes, followed by application of an antiseptic with anti-viral action (e.g. Betadine), and immediate medical attention (post-exposure vaccinations may be required). Similarly medical attention should be immediately sought if exposed to an animal's saliva or excreta through the eyes, nose or mouth.

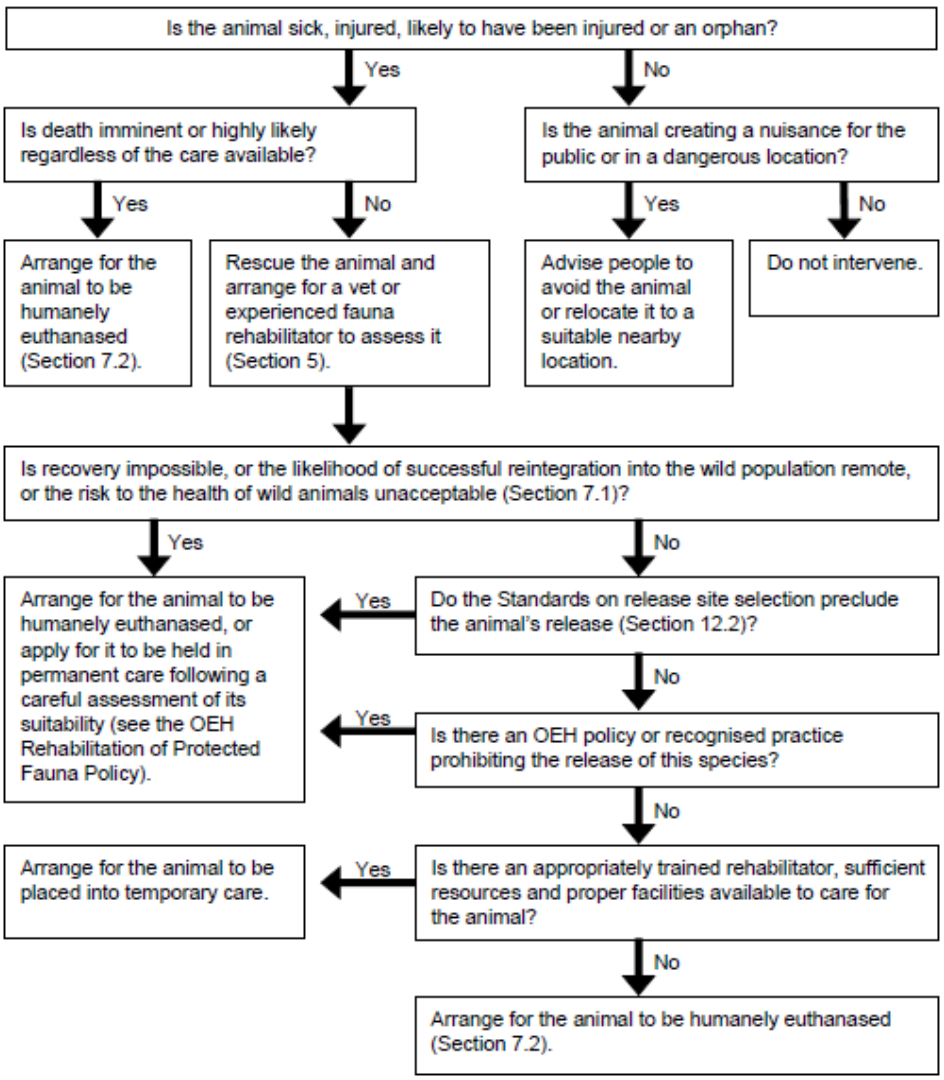
Equipment

- lidded plastic carry basket or 'pet-pack' with bedding (juveniles) / transport container with hanging perch, tall enough for bat to hang without hitting its head (in accordance with Section 5.1 of the NSW Code of Practice for Injured, Sick and Orphaned Flying-foxes (OEH 2012))
- warm water bottle / cold brick
- wraps /towels
- teats for small bottle
- extension pole or broom
- bat first aid kit – juice drink/glucose powder, syringes, cloths for wounds, Betadine/saline, dummy for baby bats. FFs only to be offered liquids under advice from a licensed wildlife rehabilitator.

Work instructions

Case assessment

Observe, assess and then determine if/what intervention is required using the decision tree in the NSW Code of Practice for Injured, Sick and Orphaned Protected Fauna (OEH 2011), included overleaf.



Personnel should approach stressed flying-foxes cautiously. If flying-foxes panic or fly this will waste energy; retreat and continue to monitor behaviour.

1. Dehydration: Eyes dull or depressed in skull, change to skin elasticity, skin stays pinched, animal cold, wing membranes dry, mouth dry.
2. Heat stress: wing fanning, shade seeking, clustering/clumping, salivating, panting, roosting at the base of trees, on the ground, falling from tree.
3. Obvious injury: bleeding, broken bones.

Rescue instructions

As per Section 4 of the NSW Code of Practice for Injured, Sick and Orphaned Flying-foxes (OEH 2012):

i. The objective is to rescue a flying-fox while minimising further stress and injury to the animal.

ii. Before a rescue attempt, rescuers must assess the risks to the flying-fox from environmental hazards and from capture.

iii. Rescuers must employ the correct rescue equipment for the condition and location of the flying-fox, and be trained in its use.

Example scenarios

1. Bat low in tree:
   - quickly place towel around bat before it can move away
   - grab hold of feet, toes may curl over rescuers fingers
   - place in carry basket / transport container.

2. Bat high in tree:
   - place pole wrapped in towel in front of bat
   - coax bat onto towel
   - once on towel, quickly move away from branches and lower to ground
   - once on ground, cover with towel and place into carry basket / transport container.

3. A bat caught on barbed wire fence:
   - two people only – one to restrain with towel, while the other untangles
   - put towels on the wire strands under or around to avoid further entanglement
   - if the membrane has dried onto wire, syringe or spray water onto wing
   - use pliers or wire cutter if necessary.

Animal first aid

Physical assessment: Keep animal wrapped and head covered, only expose one part at a time. Examine head. Unwrap one wing and extend. Wrap and extend other wing. Check legs. Examine front and back of body.

Dehydration: Offer water/juice (low acid juice only, e.g. apple/mango) orally with syringe (under supervision/advice from licensed wildlife rehabilitator ONLY).

Heat stress: Reduce temperature in heat exhausted bats by spraying wings with tepid water.

Hypothermia: May be seen in pups separated from mother – keep head covered and warm core body temperature slowly by placing near (not on) warm water bottle covered by towel.

Bleeding: Clean wounds with room temperature saline or diluted Betadine.

Transport to veterinarian / wildlife rehabilitator

See Section 5 of the NSW Code of Practice for Injured, Sick and Orphaned Flying-foxes (OEH 2012) summarised below.

Objective

To transport a flying-fox so as to minimise further stress and injury to the animal.

Standards

a. The transport container must be tall enough for the flying-fox to hang by its feet without hitting its head on the floor.
b. The container must be designed, set up and secured to prevent injuries to the flying-fox. The sides of the container must prevent the flying-fox from poking its head or wings out.
c. The container must be designed to prevent the flying-fox from escaping.
d. The flying-fox must be allowed to hang by its feet from the top of the container or if it is unable to hang, wrapped in material (e.g. sheet or flannel) and placed in a sling so its feet are higher than its head.
e. The container must be kept at a temperature which is appropriate for the age and condition of the flying-fox. A range of 25–27°C is appropriate for an adult. A temperature of 28°C is appropriate for an orphan. A cool or warm water bottle may be required.
f. The container must be ventilated so air can circulate around the flying-fox.
g. The container must minimise light, noise and vibrations and prevent contact with young children and pets.
h. During transport, a container holding a flying-fox must have a clearly visible warning label that says 'Warning – live bat'.
i. A flying-fox must not be transported in the back of an uncovered utility vehicle or a car boot that is separate from the main cabin.

Guidelines

- Flying-fox transport should be the sole purpose of the trip and undertaken in the shortest possible time.
- The fauna rehabilitation group's contact details should be written on the transport container in case of an emergency.

Terrigal Catchment Audit

Initial water quality investigation report

Contents

COVER: ANDY SMITH PHOTOGRAPHY

Glossary of Terms

Ammonia (NH_3): A simple compound of nitrogen which may originate from sewage discharge but may also be a product of decomposition of industrial waste, organic material, pet waste, wildlife waste, fertilisers or atmospheric inputs (Brady & Well, 1996; Wetzel, 2001, Brady & Well, 1996, Brasseur et al., 1999). Ammonia can be toxic to aquatic organisms (e.g. fish) under certain circumstances and is a source of nitrogen for plants including algae. In nature, ammonia is rapidly converted to other nitrogen compounds.

Bather shedding: Shedding of faecal material from bathers/ swimmers.

Closed-circuit television (CCTV): A remote controlled video camera with wheel attachment that is driven inside underground stormwater and sewer pipes to investigate defects. The camera can pan, tilt and rotate for easy identification of defects, along junctions and around manholes.

Catchment: An area of land that drains towards a waterway, whether that is a creek, river, lagoon, estuary or the ocean.

Diffuse source pollution: Pollution that arises from a range of different contributing sources in a catchment. This can include runoff from urban areas, agricultural lands and forestry, especially during heavy rainfall when surface flow is more likely to occur.

Effluent: Liquid waste.

Enterococci: A type of bacteria that grows in the gut of warm blooded animals – whilst it could come from humans, it could also come from wildlife and birds, dogs, cats, rabbits, pigs or livestock that are farmed in the local catchment area.

Erosion: Wearing away of earth or rock by the effects of rain, wind, sea or rivers or by the action of toxic substances.

Eutrophication: The enrichment of water by nutrients, especially compounds of nitrogen and/ or phosphorus, which cause accelerated growth of phytoplankton, macroalgae and higher forms of plant life. This excess growth upsets the natural balance and ecological processes within a waterway.

Groundwater: Water that occupies pores and crevices in rock and soil, below the surface and above a layer of impermeable material. Groundwater flows slowly through the ground towards natural waterways.

Groundwater intrusion: Groundwater seeps into damaged, dislodged or cracked pipes and increases the volume of water within the stormwater or sewer network.

Illegal connections to sewer: Where sewer pipes from private land are connected to the stormwater system instead of the sewer system. Illegal connections can be difficult to detect and owners may not even know they exist.

Latent pollution: Pollution that lays dormant in the environment, but may be reintroduced through natural processes such as resuspension by wind and wave action.

NATA accredited: National Association of Testing Authorities, accredited testing as a rigorous basis for proving compliance with the RCM, C-tick and international EMC regulations.

Nutrient: An element or chemical essential for growth, e.g. phosphorus, nitrogen, silica, oxygen, carbon.

On-site sewer management (OSSM): Any system that processes wastewater and disposes of the effluent within the premises. The main types of on-site sewage management systems are pump-out systems, aerated wastewater treatment systems, septic tank systems, commercial systems and other miscellaneous systems such as composting systems. There are over 8000 OSSM systems on the Central Coast.

Overflows (see sewer overflows)

pH; The acidity or alkalinity of a substance, often water.

Private sewer pump station: A sewage pump system located on private land that discharge to a nominated discharge point into Council's sewer main.

Point source pollution: Pollution that arises from a well-defined point, typically the end of a discharge pipe, but may include other significant sources from a single location.

Potable water: Treated and drinkable tap water.

Relining pipes: Old or damaged sewer pipes can be relined to renew them and increase the life of the asset.

Receiving waters: A natural waterbody within a catchment.

Salinity: Both soil and natural waters can become saline. Hence, salinity can be described as either soil salinity or water salinity. Water salinity changes in concentration over space and time due to salt sources, water dilution and water movement.

Sewer: An underground pipe for conveying domestic water and waste material.

Sewer dry weather overflow: Failures within the sewer network during dry weather can result in untreated effluent being discharged to the environment.

Sewer wet weather overflow: Failures within the sewer network during rainfall can result in untreated effluent being discharged to the environment. In some cases, the sewer network has designated sewer overflow points.

Sewer choke: A blockage in the sewer network. This can be caused for example, by items being incorrectly flushed, like nappies, paper towel and wet wipes.

Sewer cracks: Aging infrastructure and natural ground movement can affect the integrity of sewer pipes. This can result in cracks or dislodged joints between pipes. Being underground, these are difficult to detect and can be challenging and costly to rectify.

Sewage: Domestic wastewater originating from our homes and businesses. This includes water from kitchens, laundries, bathrooms and toilets. Sewage is collected through Central Coast Council's 2490km network of sewer pipes and 324 pumping stations for treatment at one of eight treatment plants. Most sewage undergoes secondary treatment and is discharged into the ocean at Winney Bay in the south or Norah Head or Wonga Point ocean outfalls in the north.

Stormwater: Water from urban areas, that flows through a series of gutters and drains often discharging to a natural waterway. Stormwater can carry with it a range of different pollutants.

Systematic sampling: Sampling in a logical pattern, moving throughout an investigation area over time to establish a clear understanding of the patterns observed in the variables being measured.

Trace pharmaceuticals: Tiny amounts of pharmaceuticals, such as caffeine, antibiotics and other medications present in sewage. Measuring trace pharmaceuticals in stormwater can be an indicator of sewer contamination.

Turbidity: A measure of water clarity or cloudiness. Elevated turbidity is caused by increased amounts of sand, silt, clay and microalgae suspended in the water. Long periods of high turbidity will negatively affect waterway health.

Water quality guidelines: A set of expected water quality values for specific waterway types/uses, including water for recreation and natural waterways. In NSW, these include the National Health and Medical Research Councils Guidelines for Managing Risks in Recreational Water (NHMRC 2008) and Australian and New Zealand Environment and Conservation Council (ANZECC) guidelines.

Executive summary

Central Coast Council participates in the NSW Beachwatch Partnership Program (Beachwatch) – a water quality monitoring program designed to provide information on recreational water quality (swim safety). Data collected by Council as part of the program are used to inform the annual *NSW State of the Beaches Report*.

Since 2011-12, Terrigal Beach has received a "Poor" rating in the *NSW State of the Beaches Report*. Beachwatch uses long-term environmental trends to highlight areas of concern, which may then trigger further investigation. The program is not comprehensive enough to determine the source or scale of the factors affecting water quality.

In January 2019, Council commenced the Terrigal Catchment Audit. The aim of the audit is to assess microbial contamination as a risk to swim safety. Although microbial contamination may correlate with other factors that affect environmental health (e.g. elevated nutrient levels and suspended solids), the current report does not address broader environmental health concerns. These aspects will be captured as part of the ongoing investigations undertaken in tandem with the NSW Government.

This report provides background information on the Beachwatch program and provides key concepts and terminology to understand microbial risk, water monitoring and management. The report then provides the scope of the initial, and major, audit programs.

The initial audit establishes a robust monitoring program at 12 locations– one in Terrigal Lagoon, six along Terrigal Beach stretching from the lagoon to the "7 drains", one in the rockpool and four along Terrigal Haven. Samples taken from the stormwater pipes that discharge to the beach are paired with immediately adjacent ocean samples to assess the impact of stormwater on ocean microbial contamination. This report will provide a summary of results of enterococci count samples collected on 20 separate days from each of the 12 paired locations between January and May 2019. The intention is to collect 100 days of samples to achieve an adequate sample size as required by the *Guidelines for Managing Risks in Recreational Waters 2008* (NHMRC 2008).

Between January and May 2019, samples were collected on 20 separate days. This data set informs the initial audit.

Outcomes from the initial audit indicate:

- Between January and May 2019, Terrigal Beach and Terrigal Haven were rated as "Good" for swimming 94% and 84% of the time during dry and wet weather respectively.

- During dry weather, stormwater flows can occur for a variety of reasons including but not limited to garden watering systems, car washing, natural groundwater and underground springs. To date, dry weather flows were found to have some degree of microbial contamination at all stormwater pipes discharging to the beach, however this contamination varied and did not correspond to elevated results at the paired ocean locations (the beach). Consequently, there was minimal risk to swim safety associated with dry weather flows from stormwater drains. This is likely a result of low discharge volumes and effective dilution with ocean waters. Investigations are ongoing to assess if this remains the case long-term (a larger sample size is required) and during localised increases in population (e.g. long-weekends and school holidays). The NSW Government program will build upon this information by using more sophisticated methods to estimate volumes and potential sources of contamination (human, other animal).

- Regardless of the initial results which indicate minimal to no impact on recreational swim safety (swimming, surfing, canoeing etc) in dry weather, catchment water quality and infrastructure investigations are being undertaken to assess potential sources of microbial contamination in stormwater, and where possible reduce the likelihood of cross-contamination between sewer and stormwater networks by upgrading infrastructure as required.

- Initial water quality samples from the catchment have led to the development of a *Priority Sub-catchment Sampling and Investigation Works Program* which is detailed in the report. Major investigations of stormwater will continue throughout the 2019-2020 financial year. The priorities identified in this document may change in future as more information comes to hand.

- As a result of initial CCTV inspections of stormwater and sewer networks, a number of pipes in the Terrigal Beach and Terrigal Haven catchment areas have been identified as being in poor condition. Details are provided in the *Infrastructure outcomes* section. Whilst these pipes did not increase beach microbial presence and therefore did not pose a swim safety risk, they have been placed on a works program for upgrade.

- Council recommends that people do not swim within 3 days of rainfall at Terrigal Beach. Lagoon openings often coincides with rainfall events which increases the likelihood of beach microbial contamination. During wet weather, the ocean sites adjacent to the stormwater drains at Terrigal Beach T3-T9 ("7 drains") showed an increase in microbial contamination. Also when the lagoon was opened there was increased microbial contamination along Terrigal Beach.

The current report comments on initial outcomes only. Initial outcomes are based on a small sample size of 20 days between January and May 2019, continuing investigations may find new and unpredicted results which may change the outcomes of the audit. Consequently, although minimal to no risk to swim safety from stormwater pipes has been detected in the initial audit, further data may prove this outcome to be incorrect. Council is continuing to sample and assess the water quality at Terrigal Beach and Terrigal Haven to build a detailed understanding of water quality under different conditions, and is working alongside the NSW Government to build a larger monitoring program.

The currently initial report does not report on other environmental impacts from stormwater, having a major focus on microbial contamination to assess swim safety. However, reducing microbial input into stormwater and receiving waters also reduces the other chemicals present in sewer such as excess nutrients, cleaning liquids (Aboul-Kassim and Simoneit 1993), micro-plastics (Napper and Thompson 2016), hormones (Adeel *et. al.* 2017), all which can have a negative environmental impact if they enter receiving waters.

Background information

Beachwatch water quality monitoring on the Central Coast

Since 2002, the former Gosford City and Wyong Shire Councils participated in the Beachwatch Partnership Program (Beachwatch) – which was established and is overseen by the NSW Government (former Office of Environment and Heritage - OEH). Beachwatch is guided by the Australian Government's National Health and Medical Research Council's *Guidelines for Managing Risks in Recreational Waters 2008* (NHMRC 2008). Central Coast Council has continued this involvement since its inception in 2016.

Council currently monitors 32 designated swimming sites, including 15 ocean beaches, three ocean baths/rock pools, four coastal lagoons and 10 estuarine netted baths. At each swimming site, water samples are collected by Council staff and tested for Enterococci, a group of bacteria common to the faecal matter of warm blooded animals. These bacteria indicate stormwater, sewage or animal faecal contamination. Sampling occurs once a week during the swimming season from September to April, and fortnightly outside of the swimming season.

After sampling, quality controlled and accredited laboratories analyse the samples, taking 24-48 hours to process and culture the bacteria. Based on the results, a grade is calculated for each site and the information is then uploaded to Central Coast Council's website: centralcoast.nsw.gov.au/beachwatch.

The data from this monitoring program are provided to the NSW Government and each year the *NSW State of the Beaches Report* is produced for all participating NSW Council areas. The data is available from the NSW Government website at: environment.nsw.gov.au. The *NSW State of the Beaches Report*, grades each swimming site as "Very Good", "Good", "Fair", "Poor" or "Very Poor" (NHMRC 2008). These Beach Suitability Grades provide a long-term assessment of how suitable a beach is for swimming (Table 1). The grades are determined from the most recent 100 water quality results (two to four years' worth of data depending on the sampling frequency) and using an estimated risk assessment of potential pollution sources (sanitary inspection). The *NSW State of the Beaches Report* highlights areas where further investigation may be required. It does not measure the impact or scale of a problem, nor specific pollution sources and how they influence recreational swim safety.

Based on water quality results from past data, the NSW Government uses rainfall to predict the likelihood of microbial contamination at all beaches and displays these predictions daily on their website: environment.nsw.gov.au/beachmapp/

Table 1: Beach suitability grading in the Australian Government's National Health and Medical Research Council's *Guidelines for Managing Risks in Recreational Waters 2008.*

Rating	Enterococci category(colony forming units per 100ml)	Category	Description
* * * *	<41	Good	Good: microbial levels are safe for bathing according to NHMRC guidelines.
* * *	41–200	Fair	Fair: microbial levels indicate an increased risk of illness to bathers, particularly those with lower immune function such as the elderly and young children.
* *	201–500	Poor	Poor and Bad: microbial levels indicate a substantially increased risk of illness to bathers.
*	>500	Bad	

General catchment pollution sources

Stormwater network

A catchment is an area of land that surrounds and slopes towards a waterway. When rain falls in a catchment, it flows downhill by force of gravity from the upper hills and slopes, through valleys and across floodplains in small streams, creeks and rivers, into lagoons, estuaries and the ocean. Water from catchments can also travel through the ground, moving slowly via groundwater aquifers to the receiving waters.

Historically, rain would have fallen in forested or wetland areas, filtered into the ground and flowed slowly across the land bringing only small amounts of soil and debris. Landuse, including clearing of land, agriculture, industry and urbanisation can affect the quality and quantity of water coming from a catchment. Nowadays, the intensity of development, loss of vegetation and increases in hard surfaces means that water flows more quickly, and collects more pollution than would naturally occur, depositing these pollutants into downstream waterways.

The runoff from urban areas is known as stormwater. Stormwater runoff transports a range of different pollutants such as pet and wildlife droppings, loose soil, grass clippings, fertiliser from gardens, detergents and car oils to the receiving water. It is the cumulative effect of our daily activities that has the greatest effect on water quality. The pollution from each household or business may seem insignificant, but multiplied by thousands of households and businesses, the concentration of pollution reaching our waterways quickly magnifies. In many locations, stormwater is untreated, meaning that catchment pollution flows directly to our waterways and swimming sites.

Dry weather stormwater flows

During dry weather, stormwater drains may flow for a number of reasons. Groundwater and underground springs can naturally seep into stormwater drains, particularly in aging suburbs with permeable or cracked stormwater infrastructure. In addition, drinking quality water may make its way into the stormwater network. Watering grass/gardens, hosing paths/driveways, washing cars on driveways instead of lawns, draining pool water into stormwater, pumping out underground water storage sumps from large buildings and carparks, and discharging drinking quality water from fire sprinkler tests can all cause dry weather flows. These flows may occur intermittently, resulting in some dry days and some flowing days. Each stormwater pipe is influenced differently by these baseline flows. The quantity and quality of water depends on catchment characteristics and the uneven distribution of flow among culverts due to their varying hydraulics. Although these are potential sources of general catchment pollution and act as a conduit, they are not the cause of microbial contamination.

In any urban catchment it is possible that illegal sewer connections are present where sewage flows untreated into the stormwater network. These would also result in dry weather flows, however, these instances are relatively rare and such connections should show signs of waste debris such as toilet paper and faeces. It is more likely that sewer lines (private or public) can be cracked, where sewage solids remain within the sewer system but sewage liquids flow into groundwater or the stormwater system.

Sewer network – public and private

The network of stormwater drains and pipes is separate to the sewer system. On the Central Coast, sewage is transported through a 2490 km network of sewer pipes and 324 pumping stations for treatment at one of eight treatment plants. Sewer pipes carry domestic, commercial and industrial wastewater from bathrooms, laundries, kitchens and toilets to a treatment plant (or septic tank) where harmful contaminants are removed before the treated effluent is released into the environment. Most sewage undergoes secondary treatment and is discharged into the ocean outfalls at Winnie Bay (south of Avoca), Norah Head or Wonga Point.

Raw sewage contains pollutants such as bleach, drain and toilet cleaning liquids and hormones from 'the pill', all of which can have a negative environmental impact if entering receiving waters untreated (Aboul-Kassim and Simoneit 1993, Adeel *et. al.* 2017, Napper and Thompson 2016). This initial report does not comment on other environmental impacts from stormwater, having a major focus on microbial contamination to assess swim safety. Environmental impacts of contaminated stormwater may be addressed in later reports by Council alongside the NSW Government as part of the overall audit program.

There are a number of possible sources of microbial contamination at any beach, estuary and lagoon environment, and these may directly affect the Beachwatch results.

Microbial pollutants may enter the environment from point or diffuse sources, or may be latent in the system:

- Sewer overflows – overflows that occur on private land or from a Council system, generally as a result of system blockages (can be caused by tree roots or flushing of inappropriate items) or overloads.
- Whilst Council has approved systems and processes in place to maintain the sewer network, overflows can happen from time to time. Sewer overflows from public infrastructure can occur within Council's sewer network due to a fault or at planned overflow locations. In exceptional cases, sewer systems are designed to overflow with the effluent being discharged to specific locations where it soaks into the ground, or is diluted by the receiving water and treated by the sun. Overflows can occur due to blackouts affecting pump stations, due to sewer pipe infiltration from groundwater, illegal connections from private buildings with stormwater connected to sewer, or due to blockages caused by materials.
- Sewer chokes – Private overflows occur in private sewer systems on private land, and are thus managed privately, however, if Council becomes aware of a private overflow, Central Coast Council may become involved to help prevent environmental impact. In private infrastructure, overflows often occur due to blockages of the sewer network which may be caused by incorrectly flushed items (sanitary items, wet wipes and rubbish), tree roots and sediment or debris, and cause sewage to be discharged to the environment.
- Private and public sewer mains – damaged underground pipes, due to aging or dislodgement, which then allow sewer to infiltrate groundwater or cross contaminate nearby pipes.
- Illegal connections – where private sewer infrastructure is illegally connected to the stormwater network and bypasses the sewer network (unlikely but possible).
- Groundwater infiltration – where slow sewer leaks make their way through groundwater and can seep into stormwater drains, or directly into waterways.
- Private septic systems – improperly managed or serviced on-site sewer management systems (OSSM) can result in effluent being discharged to the environment. Council monitors over 8000 on-site sewage management systems on the Central Coast however due to the number of systems, not every system can be monitored every year.
- Animals – domestic and wild animal excrement is a source of microbial contamination (Antilles *et al.*, 2015; Cody *et al.*, 2015; Cox *et al.*, 2005; Ramonaite *et al.*, 2015).

- Sediment – sediment can be a reservoir for Enterococci bacteria. During wet or windy weather, sediment and latent bacteria can be resuspended in the water. It is not currently known how long bacteria can persist in sediment. Recreational users may also resuspend sediment, through disturbance of sediment from watercraft (Bishop, 2007) feet movement or bather shedding where bathers provide the source of microorganisms (Elmir *et al.*, 2007; Graczyk *et al.*, 2010; Stewart et al., 2008). Sediment may also provide bacteria with an opportunity to grow if provided with in favourable conditions (Field & Samadpour, 2007; Muruleedhara *et. al.* 2012; Stewart *et al.*, 2008; Boehm *et al.*, 2009).
- Seaweed and seagrass - seaweed such as kelp and seagrass may also be a reservoir for Enterococci bacteria. These can be dislodged naturally or during rough seas and bring those contaminants to the shore. It is not currently known how long bacteria can survive on seaweed (reviewed in Muruleedhara *et. al.* 2012).
- Sewage pumping stations (SPS) do not normally pose a water quality risk under normal dry weather operating patterns. Abnormal weather conditions such as thunderstorms and high intensity rainfall events provide a greater risk as high flows into the sewer catchment (due to infiltration and illegal stormwater connections to the sewer) can exceed the pump capacity at the SPS creating an overflow to the environment. Additionally power supply failures during thunderstorms can also result in an overflow to the environment as no electricity supply is available to operate the pumps at the SPS. The storage time of the SPS is less than the time required to restore power to the site and consequently an overflow occurs. The greater risk during dry weather and wet weather conditions exists within the sewer network itself due to unidentified tree root ingress and obstructions created by foreign objects such as wet wipes, rags and nappies that have been discharged to the sewer. All these objects act to block or reduce the hydraulic capacity of the sewer main and create the risk of generating an overflow to the environment.
- Private sewage pump stations (PSPS) provide a risk due to the fact that they are generally not monitored by Council's SCADA system, so any deterioration in performance can't be identified. A further risk is that the owner of the PSPS may adopt a 'run to fail' maintenance strategy, which could potentially create an overflow to the environment when a failure occurs, e.g.: pump failure and consequent wet well overflow or a switchboard failure.

Performance of Terrigal Beach and comparison to other beaches in NSW

NSW State of the Beaches Report

Of the 15 ocean beaches monitored on the Central Coast, Terrigal Beach is the only site which has frequently received a Beach Suitability Grade of "Poor". In addition to this, of the 139 ocean beaches monitored and tested throughout NSW, Terrigal

Beach has consistently performed the worst, compared to other NSW ocean beaches which have intermittently received a "Poor" grade in the last eight years (Table 1).

The NSW Office of Environment and Heritage's *State of the Beaches Report* provides the following information in relation to the results for Terrigal Beach:

> *"The Beach Suitability Grade of Poor indicates microbial water quality is susceptible to faecal pollution, particularly after rainfall and occasionally during dry weather conditions, with several potential sources of faecal contamination including discharge from Terrigal Lagoon. Enterococci levels increased with increasing rainfall, occasionally exceeding the safe swimming limit after little or no rainfall, and often after 5mm or more of rainfall." (OEH, 2018).*

Terrigal compared to other beaches in NSW

In dry weather, Terrigal Beach performs slightly worse than Avoca Beach, slightly better than Rose Bay and Malabar Beach and similar to Coogee Beach (See Table 2: Dry weather samples suitable for swimming).

During wet weather Terrigal Beach, like many other beaches in NSW has reduced water quality. The adjacent coastal lagoons, Terrigal Lagoon and Wamberal Lagoon, have the potential to have a major influence on Terrigal Beach water quality when they are opened. Coastal lagoons are separated from the ocean by a sand beach barrier or berm, and can be open or closed depending on prevailing conditions. Lagoons naturally open during large inflows or heavy seas, however Council may manually open the lagoons to prevent flooding in the surrounding suburbs during heavy rainfall. After heavy rainfall, water quality in the lagoons can reduce as a result of stormwater inputs and sewer overflows from the surrounding catchments (DPI, 2019).

During wet weather, and particularly when one or both lagoons are open, the likelihood of microbial contamination along the Terrigal and Wamberal coastline increases in the short-term OEH (2018). As water drains from the lagoon/s, it can enter Terrigal Bay where microbial counts are diluted by oceanic currents and may be treated through sun and salt exposure over time (Kyung *et. al.* 2010). Of the beaches receiving a "Poor" grading (Table 2), Terrigal is the only beach with a coastal lagoon, all other beaches are sheltered ocean sites, except for Rose Bay in Sydney Harbour. The presence of the lagoon and the frequent lagoon opening may be significantly contributing to poor water quality at Terrigal in the *State of the Beaches Report*.

As a general precaution, the Beachwatch program recommends not swimming at any ocean beach sites for one day, or up to three days for estuarine and lagoon sites after heavy rainfall to avoid any effects of stormwater pollution. Council has installed permanent signage at Terrigal Beach to ensure this recommendation is available for

users of Terrigal Beach. The cumulative effect of lagoon opening on beach water quality is the subject of the current NSW Government investigation.

Table 2: Ocean beach suitability grades from the State of the Beaches Reports for Terrigal Beach compared with other similar NSW Ocean Beaches 2011 to 2018. Dry weather samples suitable for swimming are currently only available in the State of the Beaches Report from 2016-2017 onward.

Site	Year	95% percentile Enterococci cfu/100mL	Dry weather samples suitable for swimming	Beach Suitability Grade
Terrigal Beach	2017/2018	220	87%	Poor
	2016/2017	310	85%	Poor
	2015/2016	310		Poor
	2014/2015	280		Poor
	2013/2014	280		Poor
	2012/2013	310		Poor
	2011/2012	350		Poor
Rose Bay	2017/2018	380	79%	Poor
	2016/2017	290	78%	Poor
	2015/2016	190		Good
	2014/2015	185		Good
	2013/2014	220		Poor
	2012/2013	160		Good
	2011/2012	85		Good
Malabar Beach	2017/2018	280	78%	Poor
	2016/2017	380	76%	Poor
	2015/2016	330		Poor
	2014/2015	186		Good
	2013/2014	195		Good
	2012/2013	155		Good
	2011/2012	690		Poor
Coogee Beach	2017/2018	140	85%	Good
	2016/2017	200	94%	Good
	2015/2016	260		Poor
	2014/2015	200		Good
	2013/2014	150		Good
	2012/2013	170		Good
	2011/2012	145		Good
Avoca Beach	2017/2018	165	91%	Good
	2016/2017	220	93%	Poor
	2015/2016	220		Poor
	2014/2015	210		Poor
	2013/2014	160		Good
	2012/2013	180		Good
	2011/2012	195		Good

Water quality and guidelines

Microbial contamination in stormwater is common in Australia and globally

It is well documented that stormwater can be affected by both diffuse and point sources of pollution which originate from natural processes and/or the general activities of the community. Microbial contamination occurs both in developed as well as developing countries (Clark 2003, Schiff and Kinney 2001) and poses a major challenge to water quality management worldwide (WHO 2003). The research undertaken on microbial contamination from Australian and international research provide a basic understanding on the temporal and spatial variability seen in microbial presence. Stormwater can be highly variable spatially (from one place to another), temporally (hour to hour, day to day, month to month) and in response to rainfall (first flush, light rain, heavy rain, flood). Studies have shown that during rainfall, stormwater microbial contamination increases significantly (Schijven & de Roda Husman, 2005; Schijven *et al.*, 2013, Passerat *et al.*, 2011; Khan *et al.*, 2014). Enterococci can also vary spatially due to input location. For example the impact of contaminated stormwater can be highly localised and correlate with distance to pipe (Rippy *et al.*, 2014). This is particularly evident in enclosed embayment's where circulation and thus dilution is reduced (Rippy *et al.*, 2014, Schiff and Kinney, 2001).

Receiving water guidelines

The concentration of pollution in stormwater is generally higher than that found in the receiving waters (fresh or marine) (Davies-Colley, Bell, Donnison 1994, Muruleedhara *et. al.* 2012). because of the effect of dilution and sun/salt treatment. Ideally, water quality in the ocean should be suitable for both environmental and recreational needs. This can be assessed by comparing a range of water quality indicators, to threshold levels set by relevant guidelines. In NSW these include:

The following water quality guidelines can be used to assess water quality for recreational and environmental health in receiving waters such as rivers and oceans:

- NHMRC 2008, Guidelines for Managing Risks in Recreational Water, National Health and Medical Research Council, Canberra. See guidelines in Table 3.
- ANZECC & ARMCANZ 2000, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra. Publications superseded by the revised Water Quality Guidelines, released in 2018 as an online resource.
- There are no universal guidelines or trigger values for stormwater on the Central Coast. Generally, runoff guidelines should address overall pollutant loads (volumes) rather than concentrations as a single point within the catchment.

Table 3: Extract from the National Health and Medical Research Councils Guidelines for Managing Risks in Recreational Water (NHMRC 2008: Page 72. Table 5.7 Basis of derivation of percentile values for determining microbial water-quality assessment categories)

Category[a]	95th percentile value for intestinal enterococci/ 100 mL (rounded values)	Basis of derivation	Estimation of probability
A	≤40	This value is below the NOAEL in most epidemiological studies.	GI illness risk: < 1% AFRI risk: < 0.3% The upper 95th percentile value of 40/100 mL relates to an average probability of less than one case of gastroenteritis in every 100 exposures. The AFRI burden would be negligible.
B	41–200	The 200/100 mL value is above the threshold of illness transmission reported in most epidemiological studies that have attempted to define a NOAEL or LOAEL for GI illness and AFRI.	GI illness risk: 1–5% AFRI risk: 0.3–1.9% The upper 95th percentile value of 200/100 mL relates to an average probability of one case of gastroenteritis in 20 exposures. The AFRI illness rate would be 19 per 1000 exposures or approximately 1 in 50 exposures.
C	201–500	This represents a substantial elevation in the probability of all adverse health outcomes for which dose–response data are available.	GI illness risk: 5–10% AFRI risk: 1.9–3.9% This range of 95th percentile values represents a probability of 1 in 20 to 1 in 10 risk of gastroenteritis for a single exposure. Exposures in this category also suggest a risk of AFRI in the range of 19–39 per 1000 exposures or a range of approximately 1 in 50 to 1 in 25 exposures.
D	> 501	Above this level there may be a significant risk of high levels of illness transmission.	GI illness risk: > 10% AFRI risk: > 3.9% There is a greater than 10% chance of illness per single exposure. The AFRI illness rate at the guideline value of 500 enterococci per 100 mL would be 39 per 1000 exposures or approximately 1 in 25 exposures.

Modified from WHO (2003a); see Kay *et al.* (2004) for further discussion and formulae.
AFRI= acute febrile respiratory illness; GI = gastrointestinal; LOAEL = lowest observed-adverse-effect level; NOAEL = no observed-adverse-effect level.

a Categories A–D are the corresponding microbial assessment categories used as part of the classification procedure

Notes:

1. The 'exposure' in the key studies was a minimum of 10 minutes bathing involving three immersions. This is envisaged to be equivalent to many immersion activities of similar duration but it may underestimate risk for longer periods of water contact or for activities involving higher risks of water ingestion (see also note 7).
2. The 'estimated risk' refers to the excess risk of illness (relative to a group of nonbathers) among a group of bathers who have been exposed to faecally-contaminated recreational water under conditions similar to those in the key studies. The functional form used in the dose-response curve assumes no excess illness outside the range of the data (ie at concentrations above 158 faecal streptococci/100 mL). Thus, while a plateau effect is to be expected, the estimates of illness rate reported above are likely to be underestimates of the actual disease incidence attributable to recreational-water exposure unless the plateau actually occurs at the extremity of the data range.
3. This table relates to protection of 'healthy adult bathers' exposed to marine waters in temperate north European waters.

Stormwater water quality guidelines

The Australian water quality guidelines for receiving waters (rivers, lakes, lagoons) ***cannot*** be used to assess stormwater.

> *"The Water Quality Guidelines are not intended to directly apply to contaminant concentrations in industrial discharges or stormwater quality (unless stormwater systems are regarded as having relevant community value)"* (http://www.waterquality.gov.au/anz-guidelines/about)

Central Coast Council does not recommend that people have direct contact with stormwater.

There are no universal guidelines for stormwater water quality, however, there are processes for determining a guideline for stormwater quality that protects local environments. Stormwater guidelines, when developed, take into account the values being protected, dilution, natural resilience and sensitivity of receiving environments.

Specific guidelines need to be developed based on catchment conditions and the required level of service from the water, for example stormwater harvesting for irrigation or greywater.

Central Coast Council is in open discussions with the NSW Government about developing guidelines for stormwater for the Terrigal area. This process requires site specific research and will take time to develop.

Community concerns

Terrigal Beach is one of the best known beaches on the Central Coast, and is popular with locals and tourists for a range of reasons. Terrigal offers good recreational swimming opportunities, with a Surf Life Saving Club and a sheltered aspect from southerly winds and swell. The beach is very close to amenities such as toilets, showers and a diverse range of cafes, takeaway food shops and restaurants. Nearby, Terrigal Haven contains a boat ramp, fishing charters, picnic and BBQ facilities, sports field, café and restaurants and the iconic Skillion headland. This location is often used for scuba diving and snorkelling along the rock platform. Local swimming groups also swim from Terrigal Beach to Terrigal Haven on a regular basis.

Anecdotal community concerns regarding water quality within the Terrigal Beach area include illness, chemical smell, taste and residue when swimming, increased turbidity, increased algal blooms, loss of aquatic vegetation, notable impacts when the lagoon is opened, and die back of the Norfolk Island Pines (thought to be due to airborne surfactants blowing onshore). These concerns fall into two categories; environmental and human health, however both affect each other. For example, any microbial contamination from sewage can affect human health through increased

exposure to e.g. viruses, however, chemicals in sewage such as detergents and faecal matter also provide nutrients, which can affect the health of marine ecosystems. Consequently, addressing microbial contamination has both a positive effect for the environment and for human health.

Developing a new audit program for Central Coast Council

As a result of the poor water quality rating at Terrigal Beach, a closer investigation is considered necessary. Previous actions have focused on general improvements to Council infrastructure in the Terrigal catchment including improvements to the major sewage transfer system servicing Forresters Beach and Terrigal, as well as the permanent replacement of the temporary sewer main across Terrigal Lagoon to improve the amenity of the lagoon and minimise potential environmental impacts.

More recently, Council has developed the Terrigal Catchment Audit to respond to the long-term poor enterococci results at Terrigal Beach. Planning began in the 2017-18 financial year, with a dedicated staff member appointed in October 2018 to manage the Beachwatch Program as well as design, undertake and manage the new audit program.

In March 2019 the NSW Government joined Council in conducting the audit program, developing a citizen science program and undertaking a specialty regime to compliment the work undertaken by Council.

Based on the investigation design, implementation process and lessons learnt throughout the audit, The Terrigal Catchment Audit will act as a model for future water quality programs aiming to investigate and resolve microbial contamination in catchments identified throughout the *State of the Beaches Report*.

Method

Audit process and adaptive management needs

The process of an audit and water quality improvement program is complex and requires clear steps and processes to track changes in water quality, which in this case includes:

1. Establishing a robust water quality monitoring program to provide a comprehensive understanding of conditions and hotspots for further interrogation.
2. Developing an understanding of the factors driving poor water quality and identifying appropriate actions to address these.
3. Implementing priority actions to address poor water quality.

4. Undertaking a follow-up monitoring program to determine if priority actions have improved water quality.

To assess the levels of microbial contamination, Council along with the NSW Government have designed a sampling and investigation program with the following aims.

1. Determine if stormwater pipes are affecting microbial water quality in the ocean and reducing swim safety at the beach.
2. Determine if, and to what extent, the lagoon openings are affecting swim safety.
3. Determine if stormwater throughout the suburbs is contaminated with microbes from sewer (assess if there are areas of high contamination and areas of low contamination).
4. In areas of high microbial contamination, assess the chance of cross-contamination or illegal connections in stormwater and sewer networks.
5. Undertake remediation actions if issues are found.

The current program takes an adaptive management approach - as results are received from laboratories, and new information comes to hand, the program priorities and actions may shift in response. For example, if the audit detects increased contamination in a specific location, that location will be escalated in the priority list. A detailed breakdown of activities is provided in the Audit Process Flow Chart shown in Figure 1. A number of activities in the flow chart have been started earlier than anticipated and consequently a number of steps in the process are happening concurrently. As discussed, this is subject to change in response to new information. Throughout the audit process the NSW Government are involved in a range of activities, working alongside, and providing advice to, Council. Based on the advice from the NSW Government, the flow chart will be adapted and expanded as the program progresses.

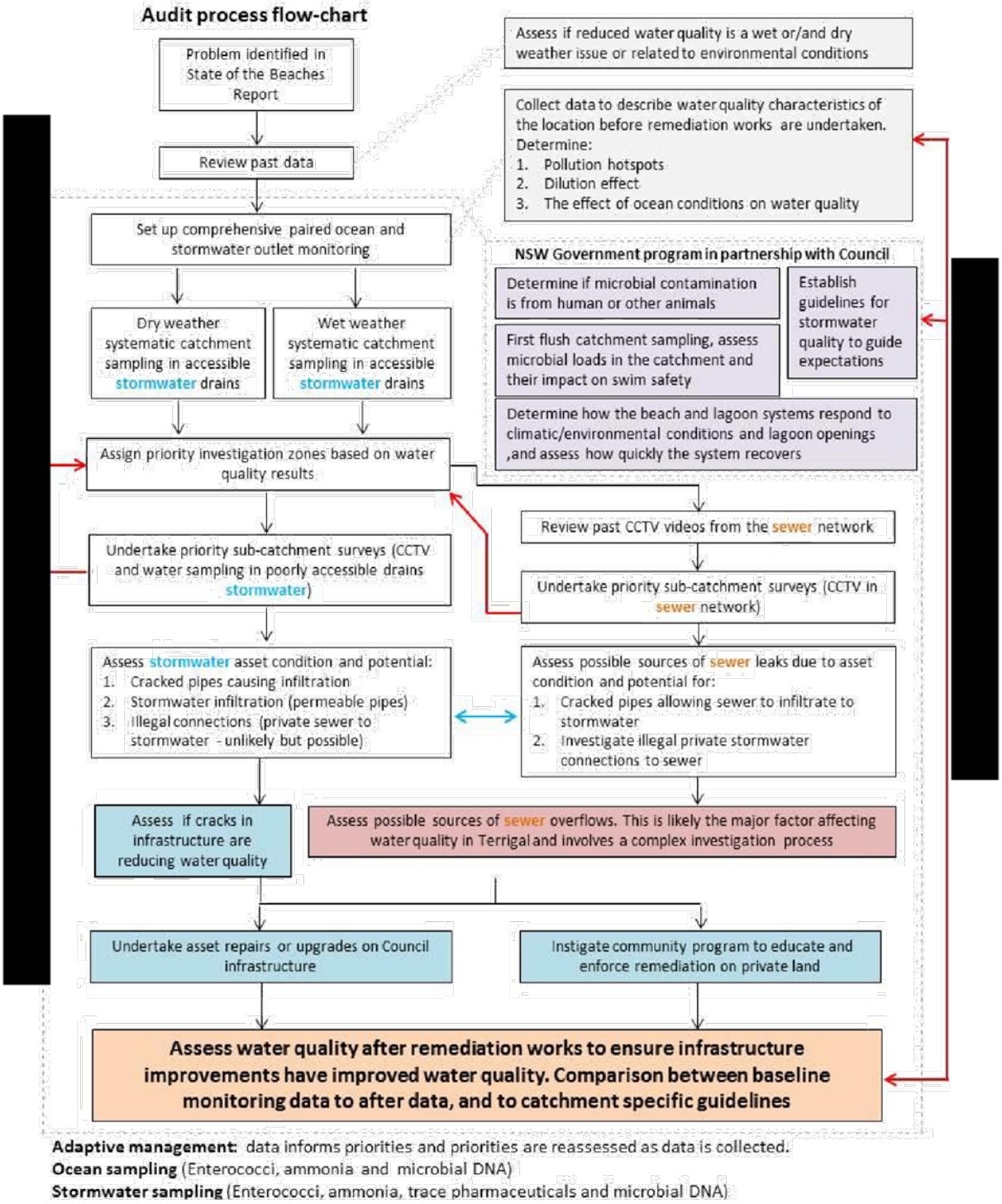


Figure 1: Flow chart of the audit process, investigating microbial sources. This flow chart will be adapted and expanded on as the program progresses and will include more details on the NSW Governments involvement in later reports.

Terrigal catchments

In Terrigal there are three main catchments Terrigal Beach catchment covers an area of approximately 0.6 km^2, Terrigal Haven covers 0.1 km^2 and the catchment of Terrigal Lagoon covers approximately 9.5 km^2 (Figure 2). These catchments are separate from one-another and each have their own characteristics. Stormwater is retained within each of the discrete catchments, and flows via the stormwater network of drains and pipes existing to either the beach or the lagoon. The water from the lagoon catchment does not travel to beach pipes, but instead flows to Terrigal Lagoon, and then on to Terrigal Bay when the lagoon is opened.

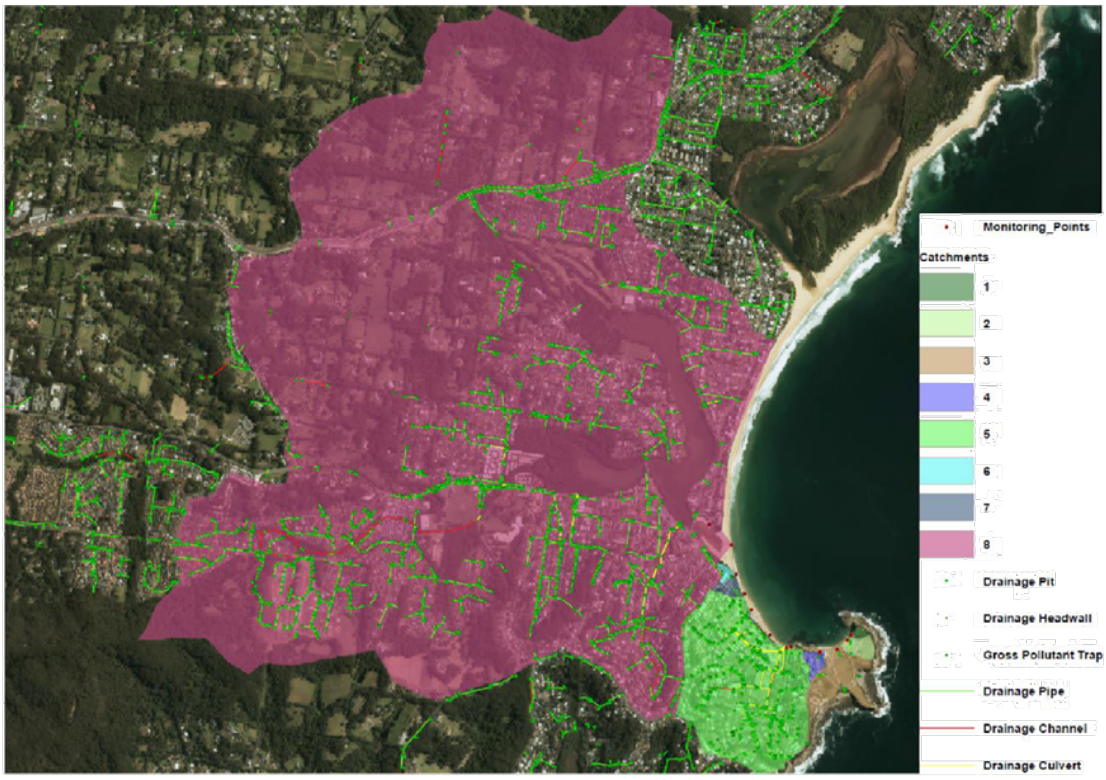


Figure 2: Map of Terrigal indicating eight distinct catchments. One large catchment flows to Terrigal Lagoon (Label 8) and seven smaller catchments (Labels 1-7) that flow to Terrigal Beach and Terrigal Haven.

Terrigal Beach: The Terrigal Beach catchment (Figure 2 Label 5) includes cleared land and urban development, including the town centre. The town centre contains a range of commercial outlets, including restaurants, cafes, bars, cafes and restaurants, medical facilities, a bowling club, and holiday accommodation as well as general and low density residential.

Terrigal Haven: The Terrigal Haven catchment comprises of a minor portion of residential apartments, café's and public recreation area which includes a sports field, boat ramp and dog exercise area (Figure 2 Labels 1, 2, 3, 4).

Terrigal Lagoon: The Terrigal Lagoon catchment comprises of a mix of rural, recreational open space and low density residential development fronting directly to the lagoon foreshore (Figure 2 Label 8).

Possible sources of microbial contamination

Microbial contamination can arise from a range of different sources. According to the State of the Beaches Sanitary Inspection (Figure 3), the following sources may be present:

- discharge from boats
- bather shedding and beach showers
- private and public toilet facilities such as those located at the Terrigal Haven sports field and the Surf Live Saving Club (SLSC)
- sewer overflows/discharges
- sewer chokes
- stormwater - old or damaged stormwater infrastructure which can be cross-contaminated by sewage
- Terrigal Lagoon discharge - the Terrigal Lagoon suitability grade has been classed as Poor to Very Poor for the past six years. The lagoon berm is opened regularly both by Council operations or natural processes to protect low-lying property from localised flooding. Whilst the impacts of opening Terrigal Lagoon, movement of pollutants into Terrigal Bay and resuspension of latent sediment and microbes in Terrigal Bay are poorly understood, this warrants further investigation.

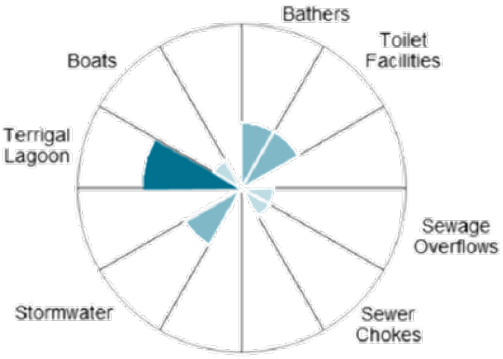


Figure 3: State of the Beaches Report sanitary inspection for Terrigal Beach 2017-2018.

In addition to these possible sources of microbial contamination, the following sources are also possible within a catchment:

- cracked, damaged or dislodged sewer or stormwater pipes in the catchment which may result in sewer ingress to stormwater
- contaminated groundwater, which also may make its way into stormwater or directly to receiving waters
- possible illegal connections of private sewer to stormwater

- on-site sewer management (OSSM) – whilst there are no OSSM systems within the Terrigal Beach catchment, there are OSSM systems in the Terrigal Lagoon catchment
- organic fertilisers applied to gardens, lawns and ovals in the catchment and washed into stormwater during rain
- wildlife and domestic animals – many pelicans, seagulls, ducks, rabbits, bats, cats and dogs are present in the Terrigal Beach and catchment area.
- pet exercise areas – designated dog areas are located in the Haven park area and along the beach between Terrigal and Wamberal beaches
- seaweed – which is thought to be a reservoir for Enterococci bacteria and is regularly suspended in the water and/or deposited on the beach (Muruleedhara et. al. 2012)
- sediment – the action of sediment resuspension in both the lagoon and Terrigal Bay may also generate temporary spikes in microbial levels as microbes such as Enterococci can survive and grow in sediment in suitable conditions (Field & Samadpour, 2007; Muruleedhara *et. al.* 2012; Stewart *et al.,* 2008; Boehm *et al.,* 2009)
- a general observation on the Terrigal sewer network catchments indicate that the overall catchment for the sewer pump station known as SPS Terrigal Major (TMJ) is approximately nine times the size of the Terrigal Beach catchment, which is encompassed by SPS C01 and C02. SPS TMJ transfers sewage from properties in the vicinity of Wamberal Lagoon as well as its own upstream catchment. Parts of the SPS TMJ catchment have been recommended for relining due to sewer chokes and surcharges that have previously occurred. The low lying areas of the sewer network adjacent to Terrigal and Wamberal Lagoons also present the opportunity for groundwater infiltration to the sewer network due to the higher water table generally experienced in coastal areas between sea level and 10m AHD
- in terms of the overall surface catchment for Terrigal Lagoon a portion of the western and north-western catchment is semi-rural, which increases the potential for nutrients related to septic tanks or agricultural use (fertilisers) to migrate to Terrigal Lagoon via surface or overland flow paths.

Due to the long history of development in the Terrigal catchment, it is feasible that microbial contamination is originating from a range of minor diffuse sources throughout the catchments. Old and damaged underground infrastructure can act as a conduit for background levels of pollution to make their way from the suburbs to the beach. It is also feasible that the results are less driven by these background levels, and more closely related to occasional high concentration flows. Pinpointing the source, scale and solutions to the current problem is complex and will take time. It is fundamental to do this well, so that investment in remediation is targeted and effective.

Stormwater pipes in Terrigal Beach and Terrigal Haven

There are twelve stormwater outlets that discharge to the beach within the Terrigal Beach catchment area. Seven are located at the south end of Terrigal Beach near the rockpool, two more discharge onto Terrigal Beach north of the Surf Life Saving Club carpark, and three are located on Terrigal Haven beach.

Terrigal Beach and stormwater outlets

Figure 4: Terrigal Beach Flagged area outside the Surf Life Saving Club

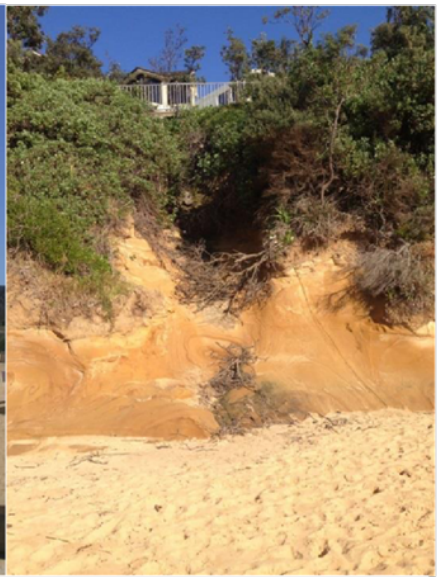


Figure 5: Stormwater drain from Terrigal Drive.

Figure 6: Large stormwater culverts where the majority of stormwater from the catchment exits onto Terrigal Beach.

Terrigal Haven stormwater outlets

Figure 7: Photograph of Terrigal Haven Beach showing moored boats, boat ramp and staff sampling in the audit.

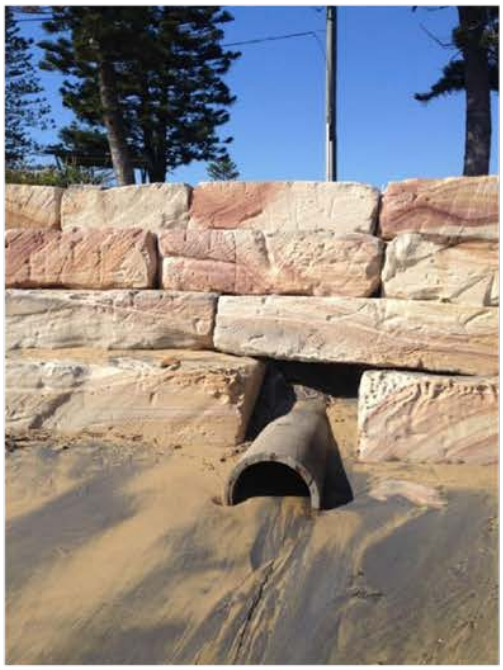


Figure 8: Central stormwater drain entering Terrigal Haven Beach from carparks, streets, oval and beach shower.

Figure 9: Eastern stormwater culverts entering Terrigal Haven Beach from Scenic highway and residential areas.

Figure 10: Western stormwater culvert entering Terrigal Haven Beach from carpark and Terrigal Haven streets near the dog off-leash park.

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Detecting possible sources of microbial contamination

Microbial contamination testing methods

Enterococci bacteria – Sampling and analysing Enterococci is undertaken following the *NHMRC (*2008) guidelines. Testing Enterococci is an indicator only and microbes detected using this method could come from humans, it could also come from dogs, cats, rabbits, pigs or livestock that are farmed in the local catchment area. Testing is assessed in a laboratory under the ISM-Quality Assurance for Microbiology program.

Ammonia – Ammonia is a possible indicator of sewage when tested alongside Enterococci and trace pharmaceuticals. Testing ammonia cannot differentiate between environmentally derived ammonia (Brady & Well, 1996; Wetzel, 2001, Brady & Well, 1996, Brasseur et al., 1999) and sewage sources ammonia. Testing is assessed in a laboratory under the ISM-Quality Assurance for Microbiology program.

Trace pharmaceuticals – Trace pharmaceuticals are a direct indicator of sewage, as pharmaceuticals are excreted into the sewer system through toilets and showers. These tests are useful in stormwater pipes, not ocean samples. Trace pharmaceuticals are tested under the EPA approved method 1694, and directly tests for the following chemicals: 4-acetamidophenol, Atenolol, Atrovastin, b-Estradiol, Caffeine, Carbamazepine, Diclofenac, Dilantin, Estriol, Estrone, Ethynylestradiol, Fluoxetine, Gemfibrozil, Ibuprofen, Ketoprofen, Mestranol, Naproxen, TCEP, Triclosan, Trimethoprim. Testing is assessed in a laboratory accredited by the National Association of Testing Authorities (NATA).

Microbial DNA – This test assesses if microbial contamination is associated with wildlife etc. or sewage input such as *Lachnospiraceae* and *Bacteroidales* bacteria. These tests do not identify individual human DNA, but instead identifies microbes common to the digestive systems of humans or other animals. These tests are being undertaken by the NSW Government and University of Technology Sydney.

Methods used to detect broken infrastructure if contamination is present in stormwater

Stormwater pipes and culverts are inspected through CCTV to identify any defects (cracks, breakages and joint displacements etc.) or illegal connections which may allow contaminants to enter into the stormwater systems. The severity of any defects found are analysed by reviewing the CCTV reports/videos using Water Services Association of Australia (WSAA) codes and Institute of Public Works Engineering Australasia Incorporated (IPWEA) guidelines. Pipes that are identified as poor and very poor and pose high risk, are prioritised for maintenance/renewals or upgrades.

Another method often used to assess catchment contaminant loads input is a paired flow gauge and water auto sampler. This flow gauge attached to the stormwater pipe and can estimate volume rates of water travelling through the pipes. The autosampler is triggered by changes in water height in the pipe measured by the

flow gauge to then take discrete water samples through the hydrograph. Staff collect the water samples and deliver to laboratories for analysis. The use of flow gauges will be a joint effort between Council and the NSW Government and will form a major part of the audit investigation.

Methods used to repair broken infrastructure

Stormwater and sewer infrastructure can be repaired through a process of pipe relining. Relining of pipes is performed to restore the original integrity, and extend the serviceable lifespan, of the main. Relining is performed where the original integrity has been compromised due to tree root intrusion, ground movement (settling and consolidation of the surrounding soil) resulting in joint displacement or outright failure of the pipe material (cracking is common in vitreous clay pipe). The lining can be a resin impregnated fabric that is fed into the pipe and cured in place using hot water or steam. Alternately the lining may be wound PVC products, which are grouted in place inside the parent pipe. The lining is thin so the designed hydraulic capacity (flow rate and flow velocity) is not reduced once the lining of the pipe is completed. Where pipes cannot be relined, they can be dug up and replaced. This ensures sewer pipe capacity is not affected by groundwater intrusion, sewer pipes do not leak underground and stormwater pipes are not susceptible to contamination from groundwater.

Investigation design

Monitoring recreational waters at the beach

As discussed, Beachwatch is designed to highlight a concern using long-term environmental trends. However, the program takes a single sample at a single location on the beach once per week (swimming season) or fortnight (winter). This limited sampling program is not adequate to assess the variability in the water quality experienced by recreational swimmers at Terrigal Beach. For example, different areas of a beach may experience different levels of pollution, due to varying proximity to pollution sources, such as the lagoon or stormwater outlets.

The Terrigal Catchment Audit aims to comprehensively monitor water quality at six ocean beach locations along Terrigal Beach, stretching from the lagoon south to the rock platform. The audit also samples the children's ocean bath (rockpool). In addition, the audit monitors four ocean beach locations at Terrigal Haven (Figure 11).

Comprehensively sampling of the beach and embayment provides detailed information on the variability in swimming conditions at the beach. The NSW Government is providing Council with samples from off-shore as a part of a larger study of swimming conditions in the embayment. The study undertaken by the NSW Government will also account for nutrient input, turbidity and algae blooms to assess the broader environmental aspects of the Terrigal area.

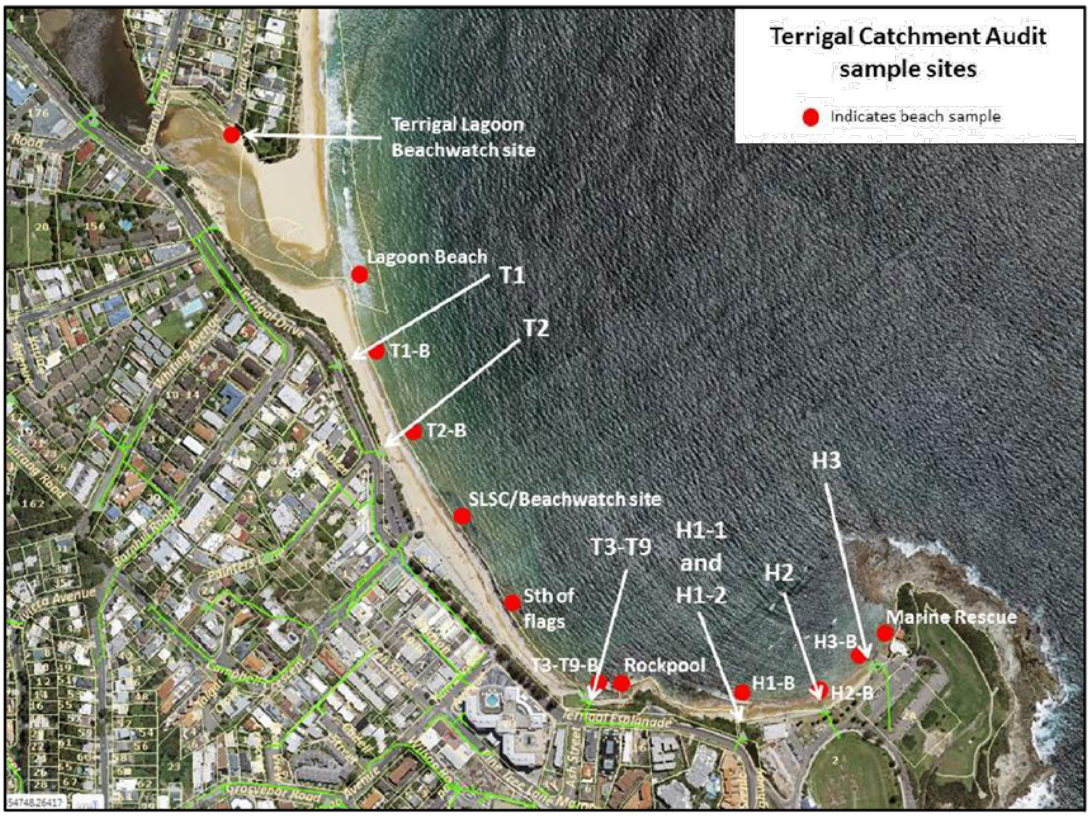


Figure 11: Sample locations for the Terrigal Catchment Audit.

In addition to sampling at Terrigal Beach, Council samples scientific controls (reference sites). These controls enable us to compare the variability in water quality in Terrigal to prevailing conditions experienced along the coastline, such as tide, rainfall and wave conditions. The Terrigal Catchment Audit's control sites have been balanced with north and south aspects, as well as sanitary inspection ratings which assess the potential sources of pollution (OEH 2018). For example, Terrigal Beach and Avoca Beach receive moderate sanitary inspections ratings and are both on the southern end of a beach (Figure 12: Appendix 1). Forresters Beach and North Avoca Beach receive low (good) ratings for sanitary inspections due to lower development pressures and are both on the northern end of the beach stretch (Figure 12: Appendix 1).

Both the Avoca Beach and north Avoca Beach controls are also situated closer to the nearest sewage outfall (Winney Bay) which is south of Avoca Beach. This allows Council to assess community concerns that the outfall is affecting adjacent beaches such as Terrigal. The discharge of sewage from Kincumber Sewage Treatment Plant at Winney Bay is covered by a licence from EPA and is accessible to the community: apps.epa.nsw.gov.au/prpoeoapp/ViewPOEOLicence.aspx?DOCID=76837&SYSUID=1&LICID=1802. The purpose of the licence is to sets limits on what and how much

pollution can be discharged to limit the environmental impact to nil, or if not nil, to limit it to a very small area around the discharge point.

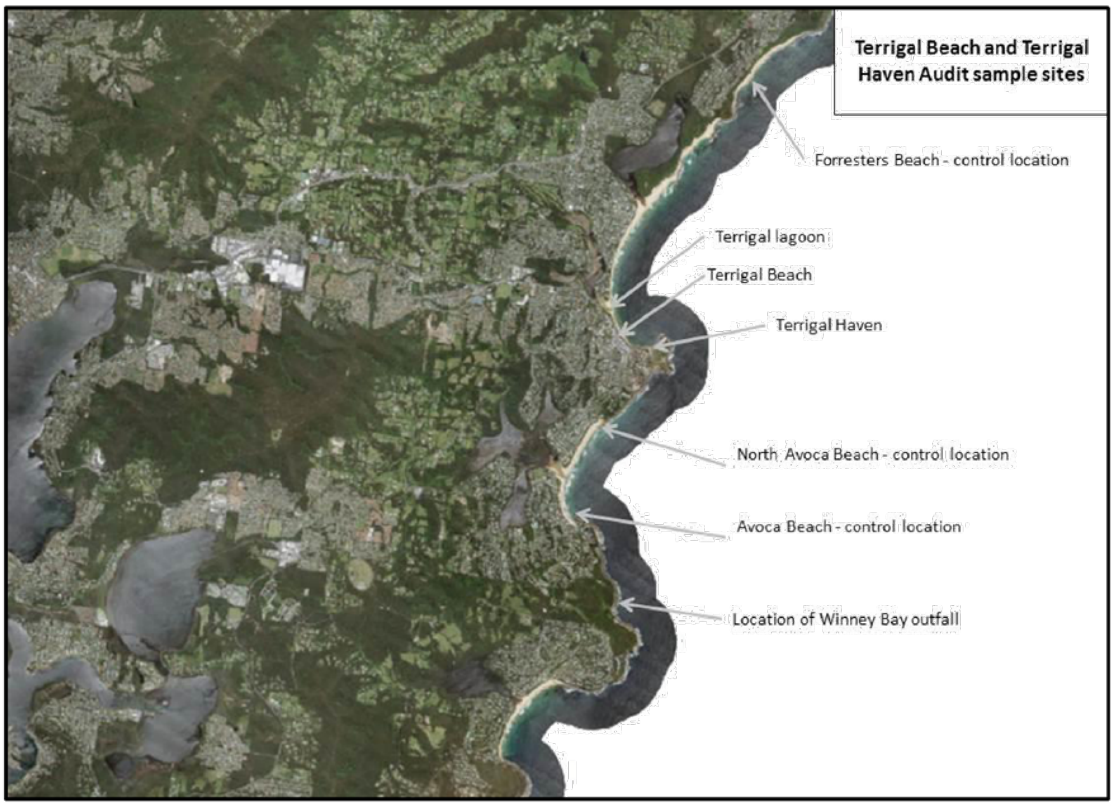


Figure 12: Location of control sites relative to the Terrigal Beach and Haven area.

Number of sampling days at the beach in the Terrigal Catchment Audit

The Terrigal Catchment Audit aims to undertake approximately 100 days of ocean sampling to assess how variable the water quality is at Terrigal Beach under different environmental conditions. The NHMRC guidelines indicate the analysis may be incomplete when using limited microbial data i.e. using less than 100 data points.

> *"The importance of using a sufficiently large sample size is illustrated when analysing less than 20 data points. Using the Hazen method, the corresponding value for the 95th percentile is the largest value of the data set (i.e. the 20th ranked value). Using the ranked method, the second largest value is used (i.e. the 19th ranked value). Due to the normally high variation in microbiological concentrations this can lead to large differences in the results obtained using the two methods." (NHMRC 2008, P. 71, Box 5.3. V)*

A. Initial audit: Under the *NHMRC (*2008) guidelines, 20 samples is considered an absolute minimum sample size for monitoring recreational waterways. With 20

samples, the initial audit is able to assess the preliminary suitability of each beach site for recreational swimming safety. Sampling is undertaken through a range of different weather conditions to establish dry, wet and first flush trends. The sampling program also aims to investigate conditions before and after lagoon openings to assess any impacts of this activity on the beach water quality. As sampling transitions into the catchment, the systematic sampling program aims to determine if individual pipe outlets are affecting beach swim safety. Pairing Enterococci, and ammonia comparable to guidelines. Lagoon openings.

B. Major audit: Under the *NHMRC (*2008) guidelines 100 days of samples is considered a robust enough data set to establish long-term trends for beach swim safety. This allows the establishment of baseline conditions, against which future conditions can be compared. All sampling programs must account for natural variability before true patterns and trends can be extracted. The major audit program will continue to expand on both the beach, bay, lagoon opening and catchment data sets to further examine the initial observations. This program will also review the claims that Winney Bay outfall is affecting Terrigal water quality and will work towards establishing a water quality improvement program. Pairing Enterococci, ammonia and trace pharmaceuticals.

Monitoring stormwater outlets

A. Initial Audit: To detect if microbial contamination is entering Terrigal Beach through stormwater, the audit also samples water from all stormwater drains entering the beach when water is flowing (T1-9 and H1-3). These samples are taken at the same time that beach samples are taken, to asses if the stormwater is causing microbial contamination in the ocean. The initial audit sets up a sampling regime to assess basic water quality contamination concentration. Assess the types of contaminants entering the system. Assess variability in contaminant concentrations under different weather events, for example dry and wet weather flows may vary in concentration due to dilution with rainfall. Locating key stormwater pipes to sample to identify priority pipes for further sampling. Provide priority map. Majorly on week days. Pairing Enterococci, ammonia and trace pharmaceuticals.
B. Major audit: Maintain sampling to assess variability. Extend sampling to weekends and public holidays. Extend the audit to Terrigal Lagoon. Pairing Enterococci, ammonia and trace pharmaceuticals.

Systematic catchment sampling

A. Initial Audit: Start investigating major stormwater drain lines to identify priority pipes for further sampling instigate CCTV infrastructure investigations. Provide priority map. Pairing Enterococci, ammonia and trace pharmaceuticals.
B. Major audit: Continue further into the catchment to refine the priority zones for sampling and continue CCTV infrastructure investigations. Extend sampling

to weekends and public holidays. Extend to Terrigal Lagoon. Pairing Enterococci, ammonia and trace pharmaceuticals.

Council is working closely with the NSW Government on the Terrigal Catchment Audit. The NSW Government has a team of scientists and funding dedicated to helping Council with a number of complex and difficult scientific questions, including but not limited to:

- determine if microbial contamination at Terrigal is from human or other animals
- assess off-shore microbial water quality where many community members swim, as beach samples are not adequate to assess the variability in water quality experienced by off-shore recreational swimmers at Terrigal Beach
- determine how the beach and lagoon systems respond to climatic/environmental conditions and lagoon openings, and assess how quickly the system recovers using hydrodynamic modelling
- undertake first flush catchment sampling to assess microbial loads entering the ocean and how this affects swim safety
- establish guidelines for stormwater quality to guide expectations
- assess broader concerns about environmental water quality in the embayment
- assess other possible microbial reservoirs such as seaweed and sediment.

This report focuses on the initial program undertaken by Central Coast Council. Results of the work of the NSW Government and Council will be presented in future joint reports.

Outcomes of the Initial Terrigal Catchment Audit

These values are derived from 20 sampling surveys from January to May 2019. This is a short period of time and may not reflect the full variability in weather or stormwater events seen in the stormwater or ocean. The audit is an ongoing investigation and the direction will change as more data is collected and the audit progresses. These outcomes give a snapshot of swim safety and the works being instigated to reduce contamination in stormwater pipes.

Beach water quality

Dry Weather

Throughout the first 20 sampling surveys 13 days were considered dry weather. Terrigal as a whole was considered good for swimming 94% of dry weather samples*.

If we assess Terrigal Beach separately from Terrigal Haven, Terrigal Beach was considered "Good" for swimming 96% of the time (using all seven ocean sample sites outliers included)*. During dry weather, Terrigal Haven was considered "Good" for swimming 88% of the time (using all four ocean sample sites outliers included)*.

Terrigal Lagoon was considered good to swim 84.6% of the time in dry weather*.

At the sample location on Terrigal Beach directly outside the T3-T9 drains (also known as the "7 drains"; Appendix 2), the drains were often flowing in dry weather, and 84.6% of the ocean samples directly outside the drains were considered "Good" for swimming (Figure 11: Appendix 2)*. The reduced percentage of good swimming days directly outside the drains was due to two days where Enterococci was elevated, however, during these increases in Enterococci all other locations at Terrigal Beach and Terrigal Haven were considered "Good" for swimming including the locations directly beside the drain. The low levels of Enterococci bacteria at these adjacent locations indicate that during dry weather, any minor elevated levels detected outside the drains were diluted and not affecting the swim safety of the beach. Further testing is underway in the off-shore zone where swimmers cross to Terrigal Haven to assess if water in the embayment is being affected by minor levels seen at T3-9B and will be included in subsequent reports.

The sample average shown in this image excludes one Enterococci outlier which occurred at the *Marine Rescue* boat ramp (Appendix 3 includes outliers). This was not associated with any overflows on Council records. Further monitoring is required to assess if this is a stand-alone event or a reoccurring event and the infrastructure in the location has been placed on a list for further investigation. For ease of viewing graphed raw data points, outliers were removed in Appendix 4 to show finer details in data points. With the *Marine Rescue* outlier removed (Appendix 4 excludes

outliers), the *Marine Rescue* site generally showed low Enterococci results, with a maximum of Fair (121mpn/100ml) in dry weather.

*These values are derived from 20 samples January to May 2019. This is a short period of time and may not reflect the full variability in weather or stormwater events. The audit is an ongoing investigation and values will change as the audit progresses.

Figure 11: Average water quality 20 sampling days 17 January – 31 May 2019 (average excludes a single outlier at the Marine rescue which is discussed in-text).

Wet Weather

Council does not recommend that people swim at Terrigal Beach within three days of rainfall. Throughout the first 20 sampling surveys, six surveys were considered wet weather, Terrigal as a whole was considered good for swimming 84% of the time*.

Assessing Terrigal Beach separate from Terrigal Haven, Terrigal Beach was considered "Good" for swimming 86% of the time, and Terrigal Haven was considered "Good" for swimming 83% of the time (Table 1 shows definitions for "Good", "Fair", "Poor" and "Bad")*.

Terrigal Lagoon was considered good to swim 50% of the time in wet weather*.

During rainfall, elevated levels of Enterococci bacteria occurred at three locations, outside Terrigal Beach drains T3-T9 ("7 drains") (Appendix 2) and at the beach directly north of the drains at Sth of Flags, and at the Marine Rescue. On Terrigal Beach directly outside the T3-T9 drains, 33% of the ocean samples were considered "Good" in wet weather, Sth of Flags was considered good to swim 83% of the time. During this period, the Rockpool was considered good to swim 100% of the time*. Visual comparison of Figure 11 and Figure 12 between dry and wet weather samples shows that during wet weather some microbial contamination enters Terrigal Beach at T3-9B, elevating Enterococci bacteria and affecting nearby Sth of Flags. However during wet weather the Rockpool, SLSC and all samples north of the SLSC were considered Good" to swim.

Marine Rescue boat ramp (Appendix 3 and 4). This was not associated with any overflows on Council records. These results are being further investigated.

*These values are derived from 20 samples January to May 2019. This is a short period of time and may not reflect the full variability in weather or stormwater events. The audit is an ongoing investigation and values will change as the audit progresses.

Figure 12: Average water quality 20 sampling days 17 January – 31 May 2019.

Lagoon opening

During the lagoon opening on the 2/4/2019, the Terrigal Catchment Audit took samples before (1/4/2019) and after (3/4/2019) the lagoon was manually opened. Rainfall over the day of and three days prior to lagoon opening was 44.5mm. Ocean conditions resulted in the lagoon water moving south, in front of the SLSC and evidence of turbid water was seen at the sample site known as Sth of Flags. Enterococci sampling indicated that beach sites were not suitable for swimming, and despite water being dark brown with large volumes of froth forming on the beach (Figure 13 and 14), a number of community members were swimming despite permanent warning signs about swimming after rainfall and despite the unappealing conditions at the beach. Water samples as of the 9/4/2019 showed that the beach was considered "Good" for swimming at 100% of Terrigal Beach and 75% of Terrigal haven Beach.

Figure 12: Water quality (single day sample 3/4/2019).

Figure 13 and 14: Poor conditions and unappealing appearance of Terrigal Beach after lagoon opening. Photos taken on the 3/4/2019.

Recent pollution event – June 2019

Between 24 June and 27 June 2019, a large storm event resulted in significant stormwater runoff from the catchment and the opening of Terrigal Lagoon. As a result of this event, high bacterial counts were recorded at multiple sampling points at Terrigal Lagoon, Terrigal Beach and Terrigal Haven. The control sites at Forresters, North Avoca and Avoca beaches did not see a significant rise in bacteria levels, indicating this event was associated with Terrigal only. As a result, Council closed Terrigal beach, Haven and lagoon on 25 June until bacterial levels returned to a safe level on 1 July 2019.

Analysis of results show the lagoon opening caused minimal impact on the beach water quality initially, indicated by the low levels of bacteria at the Lagoon Beach, T1-B and T2-B sites on the first sample day (24 June - Figure 15). This indicates that the lagoon water plume had not yet reached the SLSC or the south of the beach.

At the same time the bacterial counts at the stormwater pipes known as the "7 drains" (T3-T9) were extremely high. The sites directly outside the drain at the rockpool and T3-9B and further up the beach showed high concentrations of bacteria (Figure 15). This indicates that the major source of pollution at the southern end of the beach on the first day was microbial contaminant in the stormwater. Samples from Terrigal Haven also showed high concentrations at the beach and stormwater pipes.

Results after the initial rainfall event from the 25, 26, 27 and 28 show a decrease in Enterococci over time for all ocean sites and stormwater pipes and a return to safe swimming conditions at all ocean locations by the 28 June 2019.

Terrigal Beach, Terrigal Haven were not opened until 1 July as the testing takes 24-48 hours to complete.

Investigation of the impacts of large wet weather events is ongoing. With more information, it may become clearer that the triggers for elevated bacterial loads under high rainfall conditions are different from those experienced under dry weather and light-moderate rain events. Council, in partnership with the NSW Government, with continue to investigate the impacts of large events and lagoon openings and report back to Council and the community in future reports.

Figure 15: Water quality after large rainfall event and lagoon opening (single day sample 24 June 2019).

Priority Sub-catchment Sampling and Investigation Works Program

The direction of the Terrigal Catchment Audit is being driven by scientifically accurate water quality results. Based on the water quality results obtained from the catchment, there is no indication of direct sewage sources in dry weather throughout the current dataset (20 survey days). Results have shown that the Terrigal catchment does have dispersed sources of microbial contamination, and that on the 24/6/2019 there was a large pollution event, and bacteria counts suggest a sewage overflow occurred. Using the concentrations of dispersed contamination, the following catchment priority list in Figure 15 has been developed to direct CCTV investigations for both stormwater and sewer networks (Figure 16). Later stages of the audit with the NSW Government will reassess the priority sub-catchment map based on microbial load.

Figure 16: Priority sub-catchment zones scheduled for works in the 2018-2019 and 2019-2020 financial year based on stormwater quality. Later stages of the audit with the NSW Government will reassess the priority sub-catchment map based on microbial load.

In Terrigal Haven and Terrigal Beach CCTV investigations have started (Zone 1 Figure 16) and zone 2 (A) ("7 drains" T6-T9) (Table 4). The details in the work schedules will change, adapting to water quality results. Currently the works schedule extends until

the end of September, however, it is expected that the scheduled works will instigate a number of other investigations and new schedules for these extra investigations will be shown in later reports.

Table 4: Priority pipe CCTV investigation and pipe relining schedule. The schedule is responsive to changes in water quality results and priority zones may be brought forward or pushed back dependent on water quality results found in the catchment (Refer to Figure 1 for details for adaptive management processes). Throughout this process water quality sampling continues every week at the beach and within the catchment.

Priority zone	Location/ pipe	Approximate timeframe (month)	Activity in stormwater	Activity in sewer network
1	Terrigal Haven	April 2019	Preliminary assessment of stormwater pipes and sewer network	Preliminary CCTV assessment of sewer mains in Terrigal Haven Catchment 95% complete
1	Terrigal Haven	May 2019		Sewer CCTV investigation of Terrigal Haven
1	Terrigal Haven	June 2019	Further mapping stormwater pipes, looking for other sources of water, assessing asset condition for potential groundwater and sewer infiltration	Relining of 1 pipe recommended to commence as soon as realistically possible. Contractor engaged and works to commence in the first quarter of the 2019-2020 financial year.
2 (A and B)	Terrigal Beach	June 2019	2 (A) Assessing stormwater asset condition and looking for illegal connections at "7 drains" T6-9.	Recommendation - 2 (A and B) - Relining of 13 pipes recommended to commence as soon as realistically possible. Contractor engaged and works to be undertaken during the first and second quarters of 2019-2020 financial year.
1	Terrigal Haven	July-Sept 2019	Relining of stormwater drain H2	Relining of sewer pipe in Terrigal Haven.
2 (B)	Terrigal Beach "7 drains" T3-5	July 2019	Assessing stormwater asset condition and looking for illegal connections	Reviewing choke history for relevant sewer sub-catchments and conducting additional CCTV surveys. Assessing sewer network condition.
2 (C)	Terrigal Beach "7 drains" T6-9	August 2019	Assessing stormwater asset condition and looking for illegal connections	Reviewing choke history for relevant sewer sub-catchments and conducting additional CCTV surveys. Assessing sewer network condition.
2 (D) and 3	Terrigal Beach "7 drains" T6-9 and the Scenic Highway	September 2019	Assessing stormwater asset condition and looking for illegal connections	Reviewing choke history for relevant sewer sub-catchments and conducting additional CCTV surveys. Assessing sewer network condition.

Infrastructure outcomes

Private infrastructure investigations and outcomes

Currently Council is not releasing data due to the sensitive nature of the project. The data may directly or indirectly identify houses or businesses with known or unknown breaks in sewer pipes or illegal connections. If private property is implicated throughout the audit, Council is looking to help people do the right thing. It is hoped that bringing these issues to light with the landowners will instigate fixes through information and education. If private landowners do not fix illegal connections or cracks affecting stormwater, Council will commence regulatory actions. These actions will be reported as number of investigations undertaken, number of issues detected and number of issues rectified.

Number of investigations undertaken on private infrastructure	Three
Number of issues detected	No private infrastructure issues currently detected
Number of issues rectified	No private infrastructure issues currently in need of rectification

Summary of Council infrastructure investigations

Where Council infrastructure is identified as a source of pollution, these locations will be immediately scheduled for infrastructure refurbishment, and outcomes of this process will be officially reported and made public.

Number of investigations undertaken on public infrastructure	**Terrigal Beach catchment:** two minor issues detected **Terrigal Haven catchment:** two major issues detected
Number of issues detected in public infrastructure	**Terrigal Beach catchment:** Infrastructure integrity investigation of entire sewer network in Terrigal CBD undertaken A) One issue detected which has the potential to affect water quality at T9, however water quality here is considered a low priority as the pipe is predominantly dry and there is no current indication of stormwater infiltration. Investigations are ongoing. B) One minor issue has been detected in a sewer pipe which may be causing a smell in Pine Tree Lane. **Terrigal Haven catchment** A) H2 stormwater pipe integrity poor B) Sewer pipe integrity poor (crossing under H2)
Number of issues rectified in public infrastructure	**Terrigal Beach catchment:** Investigations are ongoing and methods to fix issues are being investigated. **Terrigal Haven catchment:** Investigations are ongoing and works are scheduled to rectify infrastructure.

Detailed assessment of Council infrastructure

Terrigal Haven

Stormwater Pipe H2	
Audit information	Investigations at the drain H2 have direct indictors of sewage input. A possible source includes infiltration from the underground sewage network which may infiltrate into the stormwater system. To cover other possible sources of discolouration further analysis was undertaken.  
Response to audit data	A) Once water quality was confirmed as poor, the audit program assessed the beach water quality directly outside the pipe. Water quality at the beach did not have elevated levels of Enterococci, and swim safety was not affected by poor stormwater quality. The pipe H2 has minimal water flow during dry weather, and is intermittent, having very low flow at the time that the audit was undertaken. These low volumes of poor water quality were not affecting swim safety, however, the infrastructure required investigation and works to prevent sewage from entering stormwater. Organic fertiliser is not used on the oval and therefore cannot be a source of Enterococci. B) CCTV works were immediately undertaken assessing infrastructure condition stormwater pipe H2 and the sewer main directly crossing underneath the stormwater pipe. Both stormwater and sewer were determined to be in poor condition and in need of immediate works (See photographs below). It is

	uncertain if the poor condition of the pipes is causing poor water quality at the exit if H2, other inputs in the catchment may also contribute to the poor water quality such as cracks in pipes further up the system or presence of minor and intermittent overflows. Follow-up CCTV works were undertaken to map all possible sources of contamination in Terrigal Haven. Water samples were taken at the same time where water was available to assess if the pollution source could be fully or partially caused from upstream (further up the catchment).
Works scheduled	Relining of both stormwater and sewer to be undertaken in first quarter of the 2019-2020 financial year. Instant recommendation for rehabilitation of the sewer (relining) by Asset Management. Neighbouring sewer lines are to be assessed as well and recommend immediate rehabilitation if their condition is sub-standard.
Remaining investigations	A) Continuing to assess if other sources of microbial contamination are present in the catchment. B) Further investigation is required to assess the environmental implications of high nutrient input from H2 (Council and NSW Government ongoing program).
Issues and limitations	The audit monitoring program is designed to both detect issues and monitor changes in water quality after rectifications to infrastructure have been made. Pipe H2 has been blocked with seaweed which acts as a reservoir for Enterococci bacteria, as such the pipe is currently contaminated and samples cannot be taken. Due to the weed presence, the audit is unable to thoroughly assess before and after effect of infrastructure improvements. To fix this issue the installation of a metal grate to prevent weed from entering the pipe is being investigated.

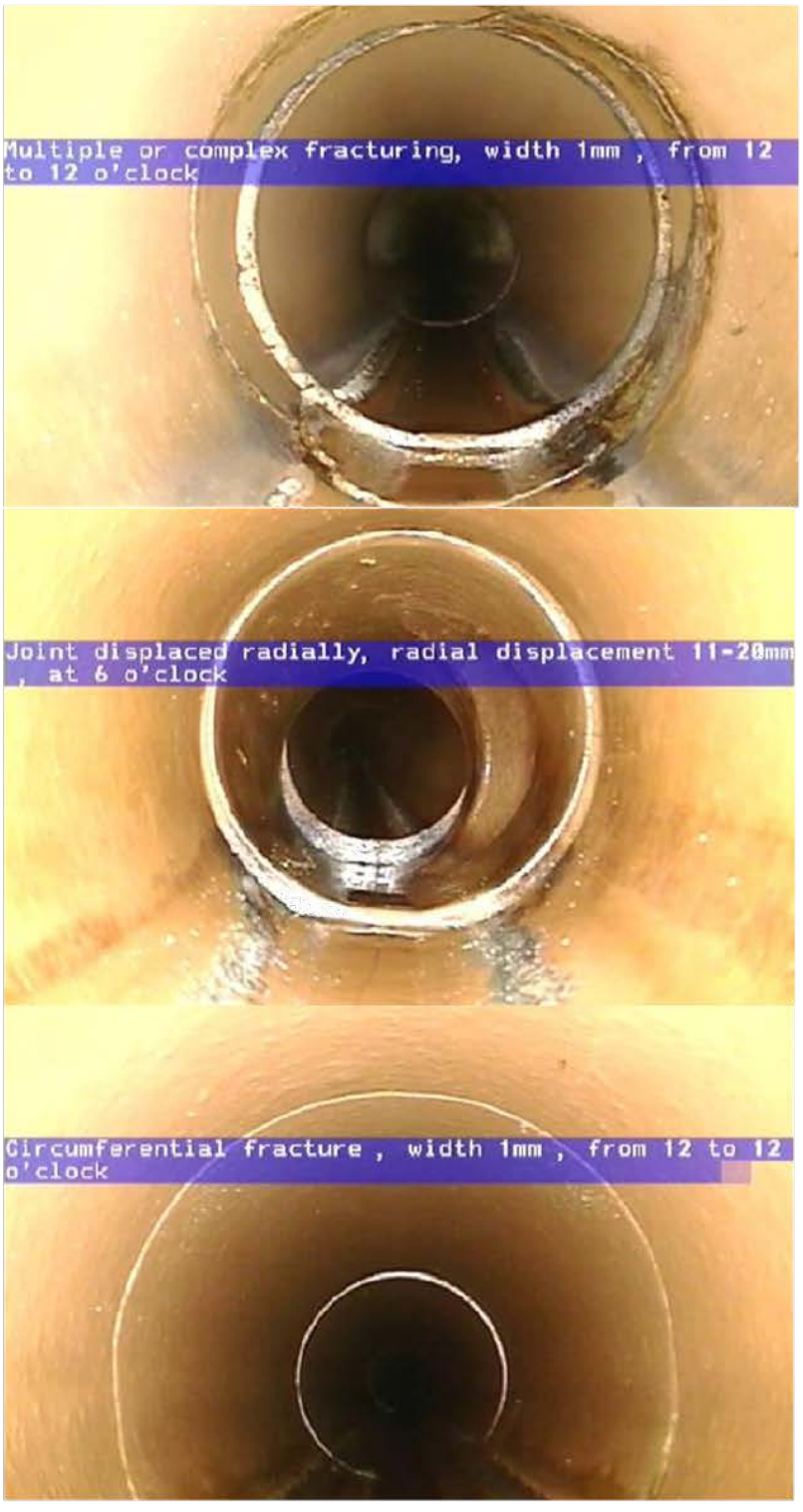
Photographs

Examples of stormwater pipe issues at H2


Deposit is Hard or compacted material in the invert, at joint , Obstruction: 5-20% , from 4 to 6 o'clock
1.35m
Breaking, some pieces are missing, at joint, length of break 100 , from 9 to 10 o'clock
10.79m

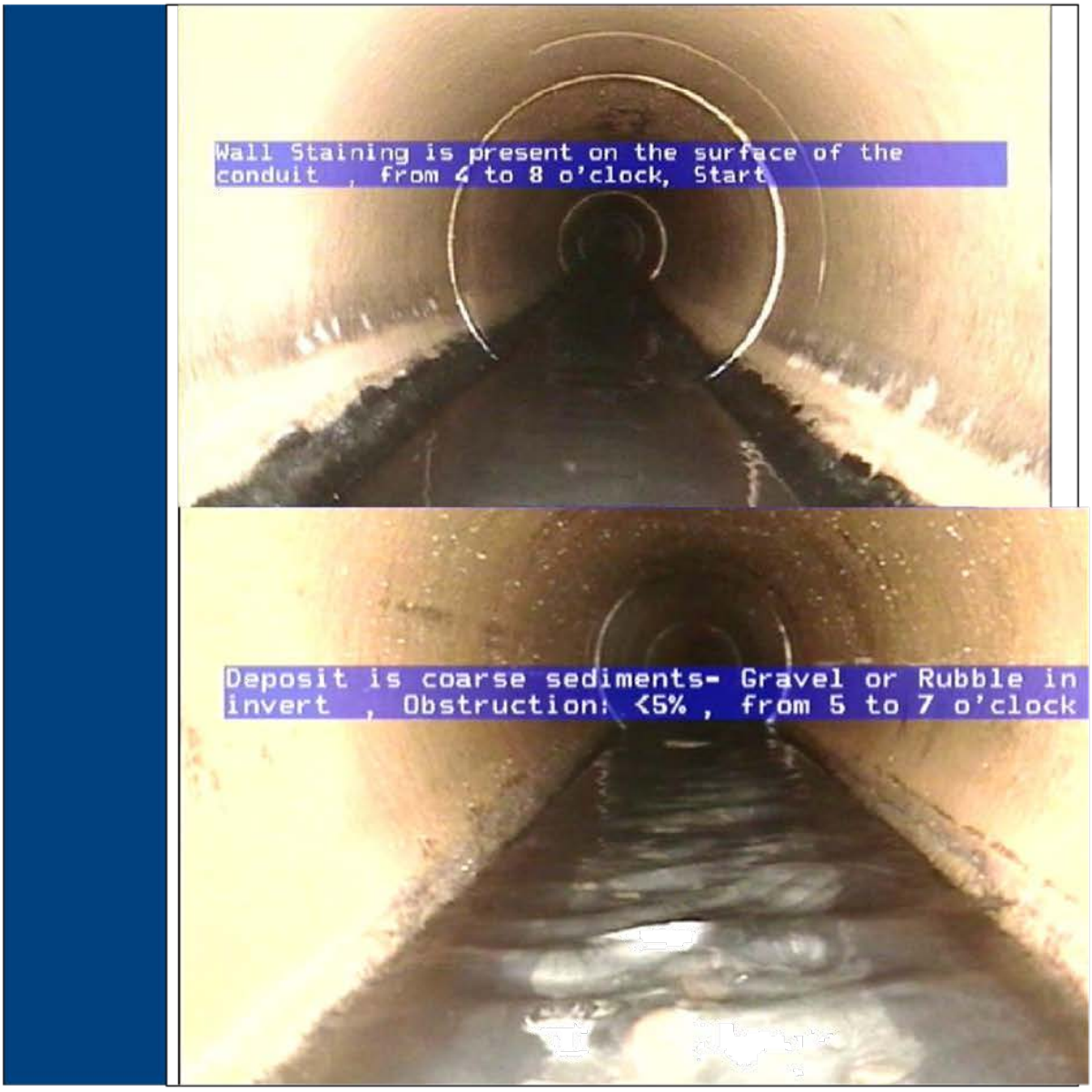
47

Examples of sewer pipe issues



Sewer pipes leading to stormwater Pipe T9	
Audit information	General sewer CCTV work throughout the catchment detected minor structural issues in a sewer pipe. There is currently no evidence to suggest that the sewer pipe is affecting stormwater quality. The stormwater pipe in close proximity (T9) does not have dry weather flows suggesting there is little to no cross-contamination. T9 is a small catchment unlikely to receive regular catchment water in dry weather e.g. car washing/sprinklers, as other pipes in the "7 drains" do.
Response to audit data	Not applicable - There is currently no evidence to suggest the sewer pipe is affecting stormwater quality.
Works scheduled	Relining of sewer mains identified as being in poor condition due to commence in the first quarter of the 2019-2020 financial year and completed at the end of second quarter of the 2019-2020 financial year.
Remaining investigations	A more detailed investigation into possible infiltration from the sewer pipe to the stormwater pipe is advised. The audit program will continue monitoring the water quality from T9 when available. Further CCTV survey work to be performed in the upstream sewer sub-catchments that relate to sections 2A and 2C in Figure 15 to assess sewer network condition. Whist T9 does not experience regular dry weather flow, T8 does. It is currently not known if T8 and T9 are connected underground. Works are scheduled to determine if these stormwater pipes are connected and assess their current condition.
Issues and limitations	The stormwater pipe network is large and may not always be mapped clearly. Where these issues are identified, Council is working to accurately map the infrastructure.
Photographs	***Example of sewer pipe issue***

Sewer smell Pine Tree Lane	
Audit information	During the Terrigal Catchment Audit a sewer smell was noted on Pine Tree Lane. Samples taken from stormwater close by did not indicate direct influence of sewer to stormwater.
Response to audit data	Persistent sewage odour on the corner of Kurrawbya Ave and Pine Tree Lane can now be attributed to changes in the grade of the sewer as well as rubble in the sewer line. The combined effect holds sewage and the pipe is approximately 40% full even under dry weather flow conditions.
Works scheduled	Repairs yet to be scheduled. Discussions continuing to co-ordinate Council resources to clear sewer main.
Remaining investigations	Not applicable
Issues and limitations	The pipe is particularly difficult to access.
Photographs	***Sewer pipe issues***


Wall Staining is present on the surface of the conduit , from 4 to 8 o'clock, Start
Deposit is coarse sediments- Gravel or Rubble in invert , Obstruction: <5% , from 5 to 7 o'clock

Indicates 40% full. Rubble and slumping possible cause of smell.

Grease traps and sewer/stormwater infrastructure	
Audit information	Assessing possible sources of overflows. Grease traps are a pumping device used to separate fats oils and greases (FOG's) and from private infrastructure such as food businesses, before the wastewater goes to sewer. Sewer exposed to high levels of FOG's can become blocked and can then cause sewer overflows.
Response to audit data	Assessment of the inspection program for grease trap maintenance of restaurants/ cafes in Terrigal CBD. The maintenance of the grease traps in the CBD has improved considerably in the last 2 years.
Works scheduled	Ongoing monitoring to be performed by Council's Trade Waste Compliance Team.
Remaining investigations	Ongoing monitoring to be performed by Council's Trade Waste Compliance Team.
Issues and limitations	Not applicable
Photographs	Not applicable

Limitations to the study and next stages of the audit

The Terrigal Catchment Audit is an adaptively managed program, where audit direction is dictated by water quality results. The catchment size and the number of developments in Terrigal along with the age of the suburb pose challenges when investigating infrastructure, however investigations have been scheduled. Furthermore, identifying and accessing private infrastructure will be challenging, however this will be comprehensively assessed as the audit progresses.

Based on the Australian Government's National Health and Medical Research Council's *Guidelines for Managing Risks in Recreational Waters 2008* (NHMRC 2008), 100 samples is recommended to assess swim safety. When the sample size (number of sampling days) in the Terrigal Catchment Audit has increased, the data from the audit will more adequately represent varying water quality such as varying weather, ocean and stormwater conditions. Further sampling on weekends and long weekends will be undertaken to increase sample size and to sample stormwater when the population of Terrigal increases due to visitors. This will include more sampling on weekends, long weekends and school holidays. Adequately sampling these varying conditions takes time.

Catchment sampling will continue to be undertaken and new sewer and stormwater infrastructure investigated with CCTV until the catchment has been thoroughly assessed.

The current report does not assess content which forms a part of the major audit, such as testing the off-shore zone where swimmers cross to Terrigal Haven, hydrological mechanisms driving microbial movement, reservoirs for bacteria and their response to environmental conditions, volume and microbial load or broader environmental impacts from other pollution sources in the catchment. It is evident that further sampling of ocean conditions is needed to understand the hydrodynamics of Terrigal Beach and Terrigal Haven in response to lagoon openings. The movement of lagoon discharge is likely affected by wind speed, wind direction, swell direction, long-shore drift and the discharge interaction with tide. Further testing is needed to assess how long water quality declines after lagoon opening under different environmental conditions and how this may it affect swimming safety. It is also evident that Terrigal Haven water quality at the Marine Rescue requires more investigation and shows the need to assess how water quality responds to a lack of water flushing due to the adjacent rock platform. The effect of reduced flushing at Terrigal Haven will be assessed as a part of the major audit and may be assisted by hydrodynamic modelling. Sampling at Terrigal Lagoon both in the receiving waters and the catchment will be addressed as a part of the major audit. Central Coast Council alongside the NSW Government are addressing these issues, and these will be reported on as a part of the major audit. These data are complex and will take time to collect and scientifically analyse.

Conclusions

The Terrigal Catchment Audit is a complex monitoring, investigation and research program, which combines work undertaken by the Central Coast Council and the NSW Government. Programs investigating catchment pollution input take time to ensure funding is spent based on robust data and intelligent, not rushed decisions.

The *Initial Water Quality Investigation Report* for the Terrigal Beach Catchment Audit is designed to provide background information on water quality issues, provide an update on ocean water quality and the outcomes of infrastructure investigations.

The program establishes a robust monitoring program at 12 ocean locations over 20 separate days, assessing the impact of stormwater on ocean microbial contamination. Terrigal was often considered good for swimming, being safe for swimming 94% of the time in dry weather. Haven and Terrigal beach have similar water quality being considered "Good" for swimming at Terrigal Beach 96% and Terrigal Haven 88% of the time. Sampling is continuing.

Dry weather stormwater flows have been associated with microbial contamination at all stormwater pipes discharging to the beach at varying concentrations, which is a common occurrence in catchments in Australia and globally. Some impact is seen on water quality directly outside the stormwater pipes at the "7 drains", however directly adjacent to the drains at the rockpool and south of the SLSC flags were considered good for swimming, indicating dilution of microbial contamination and minimal risk to swim safety. Sampling is continuing.

Investigations have begun to assess possible sources of microbial contamination in order to schedule improvements to infrastructure. A clear *Priority Sub-catchment Sampling and Investigation Works Program* provides the systematic sampling and infrastructure inspection regime, and the *Infrastructure outcomes* section indicates that infrastructure improvements can be made on 14 sewer pipes and one stormwater pipe which may or may not contribute to microbial presence, however further investigations are required to detect other sources within the Terrigal Catchment. No compliance issues have currently been detected in private infrastructure. Investigations are continuing.

Investigation of the impacts of large wet weather events is ongoing and may prove to be the major source of microbial pollution in Terrigal.

Sampling for the Terrigal Catchment Audit is ongoing and the current report comments on initial outcomes only. Initial outcomes are based on a small sample size of 20 sampling days and continuing investigations may find new and unpredicted results, which may change the outcomes of the audit. Consequently, although minimal to no risk to swim safety from stormwater pipes has been detected in the initial audit, further data may prove this outcome to be incorrect. Council is continuing to sample and assess the water quality at Terrigal Beach and Terrigal

Haven to build a detailed understanding of water quality under different conditions, particularly large wet weather events, and is working alongside the NSW Government to build a larger monitoring and water quality improvement program.

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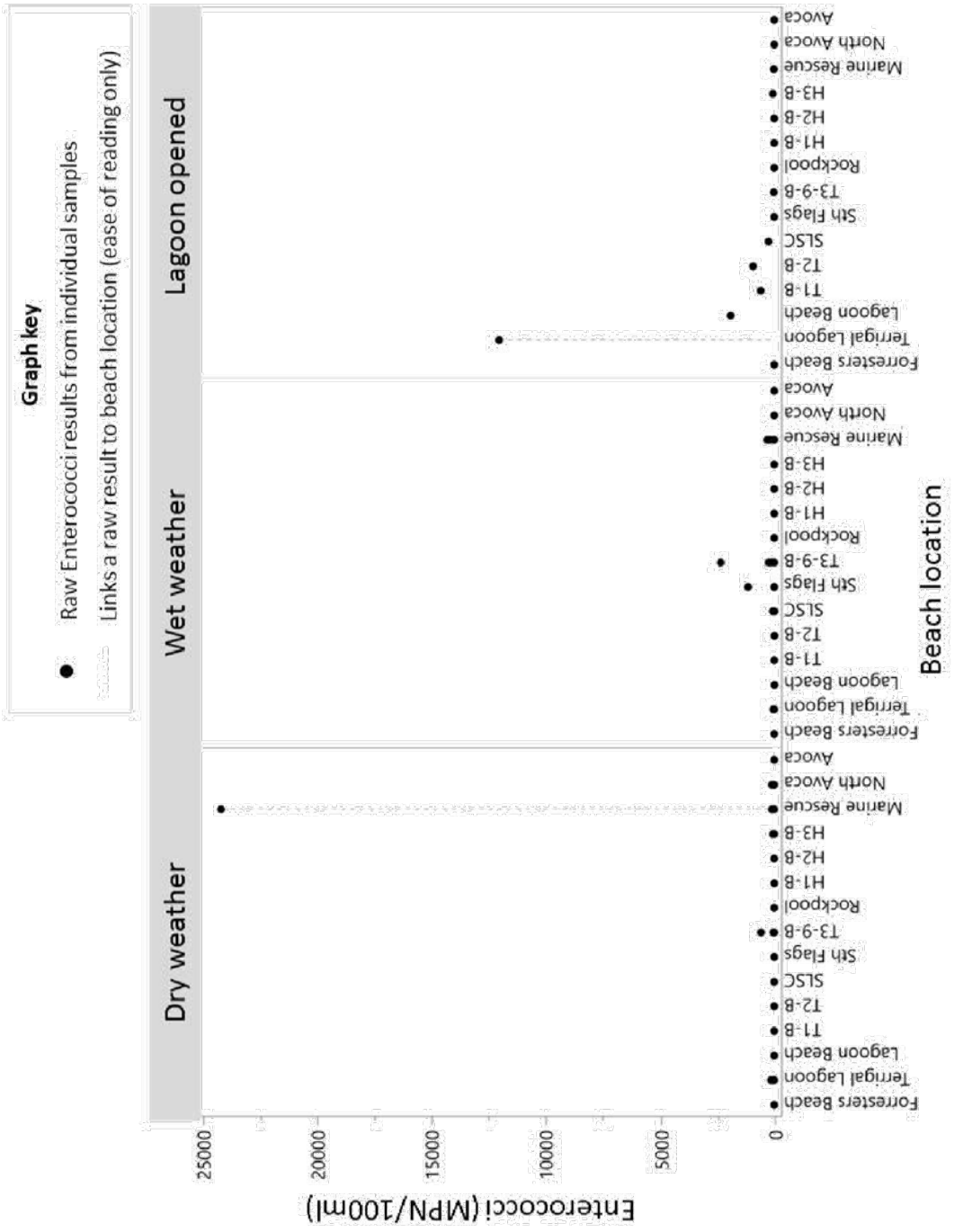
APPENDIX

Appendix 1: List of controls and the possible pollution and environmental conditions (aspect) experienced by control sites.

Location	Pollution potential based on sanitary inspections	Ocean aspect
Foresters Beach	Low	North
Terrigal Beach	Moderate	South
Terrigal Haven	Moderate	South
North Avoca Beach	Low	North
Avoca Beach	Moderate	South

Appendix 2: Photograph of ocean sample location T3-9B which received two days of elevated Enterococci in 23 days of sampling. Photograph shows dry weather flow from drain T8.

Appendix 3: Outliers included. Raw Enterococci data for beach samples from 17 January – 31 May 2019 with outliers included to see data more easily.



Appendix 4: Outliers excluded. Raw Enterococci data for beach samples from 17 January – 31 May 2019 with outliers excluded to see data more easily.