Pacific Highway Upgrade – Coopernook to Herons Creek

Operational Phase Fauna Crossing Structure Monitoring Program

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Cover Photo: Sugar glider (*Petaurus breviceps*) photographed at the east end of the John's River Rope Bridge (Sandpiper Ecological Surveys)

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1. Introduction

The upgrade of the Pacific Highway from Coopernook to Heron's Creek (C2HC) involved the construction of 33 kilometers of dual carriageway from Coopernook, just north of Taree, to Heron's Creek, just north of Kew. The project was completed in 2010.

As part of the upgrade a number of fauna mitigation measures were implemented, including the provision of fauna underpasses and overpasses (rope bridges) to address habitat fragmentation and possible barrier effects created by the highway. A Fauna Mitigation Monitoring Strategy (FMMS) (Parsons Brinckerhoff 2010) was developed to comply with the Conditions of Approval and to satisfy commitments made in the Environmental Impact Statement (EIS). An objective of the FMMS was to assess the effectiveness of the fauna mitigation measures.

Sandpiper Ecological Surveys (Sandpiper) was contracted by Roads and Maritime Services NSW (RMS) to monitor use of selected fauna crossings during two survey periods and to conduct baseline surveys within surrounding habitat up to 500m from each crossing structure. The aim of the monitoring and baseline surveys was to determine fauna usage of the selected structures in relation to species present in the surrounding habitat. The fauna crossings monitored were:

1. three fauna culverts each located at chainage 27760 (Moorland), 33450 (John's River) and 47270 (Kew);
2. two rope bridge fauna overpasses each located at chainage 33530 (John's River) and 49075 (Kew); and
3. twin pipes targeting frogs (frog pipes) at chainage 53160 (Heron's Creek).

The selected crossing structures were chosen for monitoring for a number of reasons. The culvert array at Moorland sits within a riparian corridor (i.e. Pipeclay Creek) which is located near an area undergoing rainforest restoration works. The culvert and rope bridge overpass at John's River are located within 100m of each other which provided the opportunity of monitoring combined overpass/underpass at the same location. Monitoring of the Kew underpass provided the opportunity to determine if built wooden post-and-rail furniture obstructed thoroughfare by larger fauna. The frog pipe monitoring was conducted to determine if frogs marked on the downstream side would move upstream through the pipes to cross the highway.

The following final report presents data collected during the two survey periods – year 1 (2011) and year 3 (2013). It builds upon an interim report submitted at the end of year 1 surveys (see Sandpiper 2012). A recommendation of the interim report was to abandon baseline surveys in year three and instead extend crossing structure camera monitoring for a full year. This was agreed to by RMS. Henceforth, the final report discusses the results of the two monitoring periods and the likely effectiveness of the monitored crossings and provides recommendations for enhancements to improve effectiveness. The work described was undertaken in accordance with Department of Industry and Investment Animal Care and Ethics Approval and OEH Scientific Licence.

2. Study Area

The study was located between the township of Moorland (chainage 27760) and Heron's Creek to the north of the township of Kew (chainage 53160) on the north coast of NSW. The study area included crossing structures at Moorland (culverts), John's River (culvert and rope bridge), Kew (culvert and rope bridge) and Heron's Creek (frog pipes) and habitat up to 500m surrounding each crossing. The study area and crossing locations are detailed in Figure 1.

The study area is situated within the north coast bioregion and experiences a largely sub-tropical climate (NSW NPWS 2003). Locally, average temperatures range between 18.5^{0}C and 29.1^{0}C and average annual rainfall is 1314mm (Bureau of Meteorology 2014). The north coast bioregion is one of the most diverse in NSW (NSW NPWS 2003).

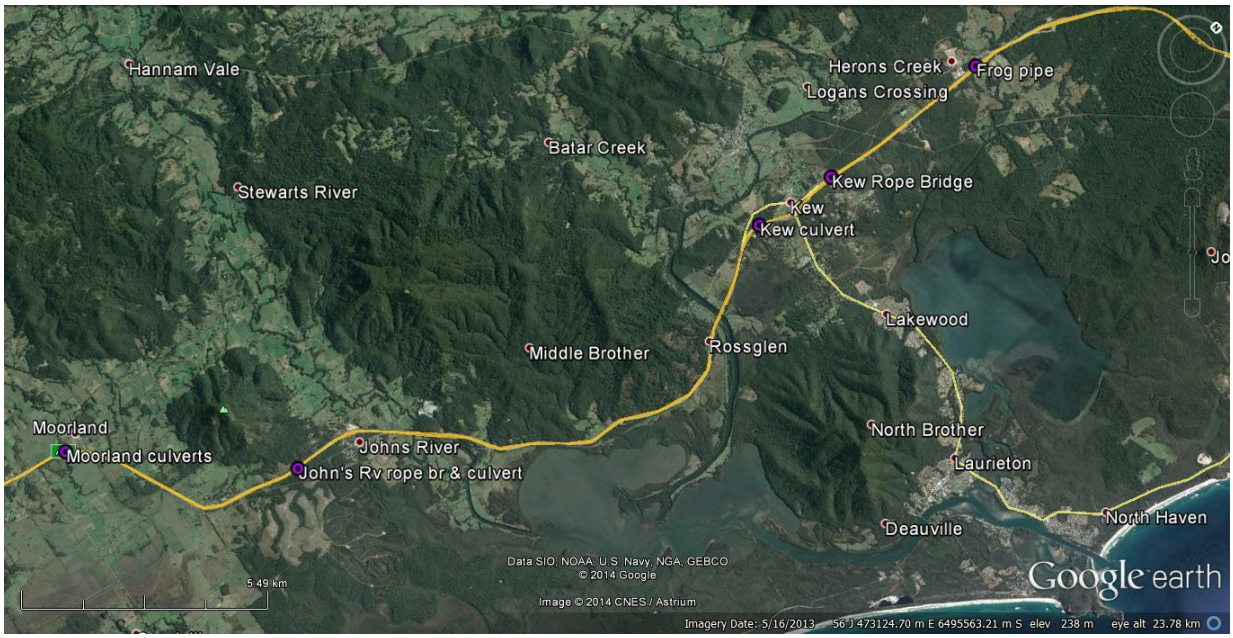

Figure 1: Location of monitored fauna crossing structures along the C2HC Pacific Highway upgrade (Source: Google Earth).

2.1 Rope Bridges

The rope bridge sites are located near large blocks of dry coastal forest. The forest is contiguous with the rope bridge on both sides of the highway at John's River and on the east side of the highway at Kew (Figure 1 & Plate 1). On the west side of the highway at Kew, the rope bridge terminates at a cluster of tall trees and is connected to the nearby forest block (~45m away) by a second rope bridge span over a service road and easement (Plate 1a).

(a)  (b) 

Plate 1: The rope bridge at Kew features two spans – one over the dual carriageway and a second over a service road to the west (a). The single-span John's River rope bridge connects directly to forest on the west (b) and east sides of the highway.

2.2 Fauna Culverts

The three fauna culvert sites are each located within drainage lines, although Moorland is the only site featuring permanently flowing water (Plate 2). Moorland culverts connect a riparian rainforest corridor. The John's River culvert links dry forest and heathland on either side of the highway. Vegetation surrounding the Kew culvert is largely dry open forest though it is highly fragmented on the east side of the highway.

Fauna culverts are reinforced concrete (RC) box design of varying dimensions (Plate 2). Kew and John's River culverts are single-cell design and each feature a timber rail running the entirety of their length. The Moorland culvert is triple-cell design featuring outer cells raised above creek low-flow level and central cell set into the creek bed. Moorland culverts do not feature timber rails. Culvert design and context features are detailed in Table 1.

(a)  (b)  (c) 

Plate 2: Monitored fauna culverts along the C2HC upgrade at Kew (a), John's River (b) and Moorland (c).

Table 1: Design and context features of three monitored fauna culverts located along the C2HC upgrade.

Culvert Location	Height x Width x Length (m)	Wooden Rail for Arboreals	Regular Inundation	Dominant Surrounding Habitat
Kew	1.5 x 1.5 x 53	Yes	No	Coastal dry forest with shrub & grass understory
John's River	1.2 x 2.4 x 48	Yes	Yes	Coastal dry forest with shrub understory & dry heathland
Moorland (x2)	2.1 x 2.4 x 58	No	After heavy rain	Riparian rainforest & dry forest surrounded by grassland

2.3 Frog Pipes

The pipes targeting frogs are located within the drainage line of a tributary of Heron's Creek (Figure 1). Pipes are RC twin-cell (900mm diam) and feature a ~130m^2 shallow drainage basin dominated by *Typha orientalis* on the eastern/downstream side and a narrow, disturbed creek line on the western/upstream side (Plate 3). The downstream basin is linked by a rubble spillway to a 1200m^2 sediment basin ~10m to the south and situated above the drainage basin. The sediment basin is dominated by *Typha* and would likely spill into the downstream basin during high rainfall events. A 400mm-high shade cloth drift fence is located between the edge of the highway and the pipe inlet/outlets to discourage frogs from accessing the road surface (Plate 3d & 3e). The drift fence extends 30-40m north and south from the pipe inlet/outlet.

(a)  (b) 

(c)  (d)  (e) 

Plate 3: Twin-cell pipes targeting frogs near Heron's Creek featured a shallow basin on the east/downstream side (a & b) and disturbed creek line on the west/upstream side (c & d). Frogs were discouraged from accessing the road surface above the pipes by a ~400mm high shade-cloth drift fence (e).

3. Methods

3.1 Survey Timing

The timing of surveys varied between different crossing structures and sampling methods (Table 2). Rope bridge baseline surveys in year 1 (2011) were timed to broadly coincide with small petaurid glider dispersal (Feb-Apr). As such, baseline surveys were conducted in March and targeted camera monitoring of the rope bridges continued from March until July. Year 3 (2013) camera monitoring of the rope bridges operated for the calendar year.

Monitoring of fauna culverts and baseline surveys of surrounding habitat were conducted during Spring (Nov) of year 1 (2011), broadly coinciding with breeding activity of a range of terrestrial fauna (Table 2). Baseline surveys were largely completed over a five day period (i.e. trapping, spotlighting, call playback) and extended up to three weeks for some methods (e.g. active searches). Year 1 targeted surveys of the culverts with sand pads, hair funnels and cameras extended for 26 days. Some sand pads were partially washed out on occasion during this period (i.e. John's River) and sand was washed out from two sites (i.e. John's River and Moorland) near the completion of the monitoring period. Year 3 (2013) targeted surveys included camera monitoring for a calendar year and sand pad monitoring during Spring. Sand pads were washed out part way through the Spring monitoring period on two consecutive occasions. They were not replaced after the second wash-out.

The Heron's Creek frog pipes study began with capture/mark/release of frogs on 29 & 30 January 2014. Subsequent recapture surveys were conducted 24 & 25 February; 4, 30 & 31 March; and 6 April 2014.

Table 2: Timing and duration of rope bridge and fauna culvert monitoring events during Year 1 (2011) and Year 3 (2013). A sample refers to a single search, spotlight survey, pit-line, Elliott trap, hair funnel, sand pad or camera. **extra camera installed on second rope bridge span at Kew was operational/sampling for 91 of 116 days.*

Method	Year 1 (sample days/samples)		Year 3 (sample days/samples)	
	Baseline	*Targeted*	*Baseline*	*Targeted*
Rope Bridges				
Spotlighting	16-18/3/11 (3/6)	na	na	na
Hair Funnels	17-30/3/11 (14/30)	17/3-7/4/11 (21/4)	na	na
Stag-watch	16-18/3/11 (3/2)	na	na	na
IR Cameras	na	17/3-21/7/11 (126/3;91/1)	na	23/1-29/12/13 (340/1; 311/1; 307/1;275/1; 91*/1)
Fauna Culverts				
Spotlighting	1-4/11/11 (3/12)	na	na	na
Hair Funnels	2-10/11/11 (9/52)	9-28/11/11 (19/24)	na	na
Sand Pads	na	3-28/11/11 (24/1,22/1,20/2)	na	31/10-21/11/13 (8/3)
Elliott Trapping	1-5/11/11 (4/120)	na	na	na
Pitfall Trapping	1-5/11/11 (4/6)	na	na	na
Predator Scats	3-28/11/11 (7/12)	na	na	na
Active Searches	3-28/11/11(8/18)	na	na	na
Call Playback	1-4/11/11(3/6)	na	na	na
IR Cameras	2-10/11/11 (9/6)	3-28/11/11 (26/2; 24/2)	na	24/1/13-10/1/14 (351/1; 329/1; 302/1; 280/1)

3.2 Rope Bridges

3.2.1 Baseline Surveys

Baseline surveys were conducted in year 1 within habitat up to 500m either side of each rope bridge using a combination of spotlighting and hair funnels to determine the species of arboreal mammal present. The east side of the Kew rope bridge was not surveyed because of access restrictions. A 250m-long transect was established in forest/woodland habitat within 150m of the end of each rope bridge (Figure 1). All baseline surveys were conducted on the sampling transect. Spotlighting was conducted on each transect during two non-consecutive nights by two experienced ecologists. Transects were traversed on foot at a speed of 1km/hr. A dusk census (stag-watch) was conducted on two occasions (16 & 18/3/11) focusing on suspected glider den trees identified along sampling transects. All arboreal mammals sighted were identified, their behaviour noted and location plotted using a GPS.

Ten hair funnels were installed along each sampling transect. Hair funnels were secured to a tree at 5-7m height and were baited with standard bait (peanut butter, honey and oats). A diluted mixture of water and honey was sprayed up the trunk of the tree above the funnel to act as an additional attractant. Hair funnels were spaced along each transect at 20-30m intervals. Funnels were retrieved after two weeks and wafers sent to a hair analysis expert (B. Triggs) for identification. Hair funnel sampling was concurrent with spotlight surveys.

3.2.2 Rope Bridge Surveys

Targeted surveys of rope bridges involved the use of hair funnels (year 1 only) and infra-red (IR) cameras (years 1 & 3). A single hair funnel containing standard bait was secured to the bulkhead at each end of both rope bridges. Funnels were retrieved after 3 weeks and sent to a hair analysis expert (B. Triggs) for identification. Camera monitoring involved installation of a Reconyx HC500 (Reconyx, WI, USA) IR camera at each end of both rope bridges. Cameras were initially mounted to the end post ~100mm above the attachment point of the rope bridge and orientated along the top of the rope bridge (Plate 4). In an effort to reduce the frequency of false triggers caused by traffic, an alternative mounting method was adopted in year 3. Reconyx cameras were each mounted to a timber paling which was then clasped to the rope bridge via a second paling (Plate 4). The 'sandwich' board mount was positioned approximately 3m from the end of the bulkhead and directed to it. A third camera was later (5/9/13) mounted at the west end of the Kew double-span rope bridge in an effort to detect crossings of the combined highway/service road expanse. Cameras and hair funnels were installed and retrieved by a qualified tree climber.

(a)  (b) 

Plate 4: Reconyx cameras were mounted to the bulkhead at each end of both rope bridges during year 1 monitoring (a). For year 3 monitoring, cameras were mounted on 'sandwich' boards and directed back at the bulkhead in an effort to reduce the frequency of false-triggers caused by passing traffic (b).

During periodic site visits, images saved onto 4GB SD memory cards were downloaded and batteries replaced. Pictures were later viewed on a laptop computer and interrogated for evidence of fauna. Fauna species were identified using standard field guides (e.g. Menkhorst & Knight 2004).The following information was collected for active pictures: date, time, species, whether the animal was the same as the previous picture, direction of movement (east/west), location on the rope bridge. Types of movement include: moved east, moved west, moved away but returned, and unsure. Full crossings were assessed by studying the species present, time and date of crossing between the two cameras.

Monitoring continued from 17/3-21/7/2011 (126 days) during year 1 and from 23/1-29/12/13 (340 days) during year 3. All cameras were active for the entire year 1 monitoring period except the east camera at John's River which was active up to 16/6/2011 (91 days). During year 3, Johns' River cameras were active for 340 days (west cam) and 275 days (east cam: 23/1-25/10/13). Kew cameras were active for 307 days (east cam: 23/1-16/2, 21/2-1/12/13) and 311 days (mid cam: 23/1-9/8, 5/9-27/12/13). The west cam installed on 5/9/13 was active for 91 of 116 days (5/9-4/12/13). Excessive false triggering, largely attributed to either vehicles (during year 1) or moving vegetation and persistent visitation by Torresian crows (*Corvus orru*) (year 3), was the main cause of premature filling of memory cards and subsequently reduced sampling days. Overall, 35 camera days

were lost during year 1 and 152 during year 3. Lost camera days were spread amongst the five cameras and each rope bridge featured at least one active camera throughout the two survey years. Importantly, only five camera days were lost (Kew east cam) during the Feb-Apr focal period for the two survey years.

3.3 Fauna Culverts

3.3.1 Baseline Surveys

Baseline surveys were conducted in year 1 within habitat up to 500m either side of each fauna culvert entrance to determine the surrounding fauna community and to assist in identifying species using the monitored culverts (see Figure 1). A combination of Elliott and pitfall trapping, spotlighting, call playback, hair funnels, active searches, predator scat searches and IR cameras were utilised (Table 2). A 500m-long sampling transect was established within adjoining habitat. Transects were located in an effort to sample variations in adjoining habitats. Basic habitat assessments were conducted within each transect to ascertain habitat quality.

Twenty Elliott traps were distributed along the length of each sampling transect at 20-25m intervals. Traps were baited with peanut butter, honey and oats. A single pitfall line incorporating five pits each at 5m intervals and associated drift fencing was established in close proximity to the sampling transect. Pits and Elliott traps were checked early each morning and pits were checked again in the afternoon. Any captures were identified, sexed and breeding condition recorded. All animals were released at their point of capture. Elliott and pitfall traps were active for four nights (Table 2). During the trapping period, spotlight surveys were conducted along each transect and nearby tracks within 500m of a culvert. Each spotlight transect was sampled on two non-consecutive nights by two experienced ecologists following the methods described above (refer Section 3.2.1). At the beginning of some spotlight sessions (6 samples), large owl and/or petaurid glider calls were broadcast for periods of up to one minute each followed by one minute of listening. This was repeated for 3-4 cycles to elicit call responses.

Ten hair funnels containing standard bait were distributed along each sampling transect at 40-50m intervals. Funnels were fixed to the ground with tent pegs and remained active for nine days (Plate 5a). Retrieved hair samples were sent to B.Triggs for identification. A Reconyx IR camera was positioned along each sampling transect. Cameras were strapped to a tree at approximately 1m height and directed at a bait station ~3m away (Plate 5b). Bait stations were constructed from ~300mm-long PVC pipe elbows (100mm diam) with a bait chamber in the centre and grated covers on each end. Bait stations were baited with chicken necks and secured to the ground with a tent peg. Fish sauce was dripped around the secured bait chamber as an additional attractant.

(a)  (b) 

Plate 5: Hair funnels (a) and IR cameras aimed at bait stations (b) were used during baseline surveys of habitat surrounding the three monitored fauna culverts.

Active searches (2 hours/side) and predator scat searches (1 hour/side) were conducted in a variety of appropriate habitats within 500m of the end of each culvert (Table 2). Active searches were generally conducted during the late morning/early afternoon and focused on large rocks and logs, decorticating bark and ground hollows to uncover resting herpetofauna. Any animals observed or captured were identified to species level (if possible) and released at point of capture. Searches for predator scats focused largely on tracks and rock piles and open areas favoured by canids and large dasyurids. All scats collected were individually deposited in a press-seal bag marked with collection location and date. Samples were sent to B.Triggs for analysis.

3.3.2 Fauna Culvert Monitoring

Targeted surveys of fauna utilising the subject culverts involved a combination of hair funnels (year 1 only), IR cameras and sand pads. Four hair funnels with standard bait were placed within each culvert (2 in each culvert at Moorland). Funnels were placed on the floor of each culvert and secured with a large rock. At John's River and Kew where wooden arboreal rails were present, two of the hair funnels were secured to the arboreal rail. Wafers and bait were replaced after two weeks and hair samples were sent to B.Triggs for identification. Sampling occurred between 9-28/11/11 (19 days).

A Reconyx IR camera was installed within each culvert at the beginning of each monitoring period as close as practicably possible to the centre. At John's River and Moorland (2 culverts), a wooden wedge was bolted to the culvert wall and the camera attached to the wedge. At Kew, the camera was attached to the wooden arboreal rail for Year 1 and re-positioned on a wall-wedge for Year 3. At Johns River and Kew cameras were set at between 900 and 1200mm height and tilted to capture the view of both the culvert floor and arboreal rail. Memory cards and batteries (if necessary) were replaced regularly and images later downloaded onto a laptop. Year 1 monitoring was conducted from 3-28/11/11 (26 days) and cameras were active for the entire period except Moorland cameras were active for 24 days. Monitoring in year 3 operated from 24/1/13-10/1/14 (351 days) and cameras were active at Kew for 351 days, John's River 280 days, Moorland north 302 days and Moorland south 329 days. Reduced camera sampling time was due to either inundation or camera malfunction.

Sand pads to detect the tracks of fauna were installed in the three fauna culverts at the beginning of each Spring monitoring period. A sand pad was placed near each end and in the middle of the John's River and Kew culverts. At Moorland, two sand pads were placed in each of the two dry culverts (one pad each end). Pads were ~100cm wide and 5cm deep and spread across the width of the culvert. Sand pads consisted of a 1:1 mix of washed river sand and 'brickies' loam to create a medium that would retain moisture and not develop a hard crust as it dried out. Sand pads were installed by filling 20kg grain bags with sand, dropping the bags over the sides of culvert fencing and then depositing the sand on the pad site. Pads were spread using a nail rake and smoothed using a trowel at the commencement of monitoring and at completion of each monitoring period. Pads were inspected and re-set every 5-7 days during the month-long survey.

During each inspection the following information was recorded: sand pad condition; species or taxa group ('definite' or 'probable') assigned to each track; total number of crossings by each species; and, direction of movement. Tracks were identified using Triggs (1996). At the completion of inspection, sand was moistened with water using a 4L garden sprayer if it were too dry to capture good quality prints and the pad was re-smoothed ready for the next session. Year 1 monitoring was conducted from 3-28/11/11 (26 days) and sand pads were active at Kew for 24 days, John's River for 22 days and at Moorland for 20 days. Monitoring in year 3 operated from 31/10/13-21/11/13 (22 days) yet sand pads were only active at all three sites for 7 days due to two instances of inundation.

3.4 Frog Pipes

The drainage pond and adjoining sediment pond on the eastern/downstream side of the frog pipes was searched for frogs for 3-4 hours by two ecologists on each evening of 29 and 30/1/14 (Plate 6). Captured frogs were toe-tipped according to which pond they were captured at. Frogs captured on the first night were retained in an aquarium until the following night. All frogs were subsequently released at point of capture on completion of the second nights' search. No rain occurred during the two survey nights though 25.8mm of rain had fallen during the previous seven days (BOM, Laurieton weather station). Below average rainfall in December 2013 and January 2014 meant the frog survey was delayed until late January. Sampling during a wet period when frog activity, particularly movement, is greatest was preferable.

Recapture surveys on the upstream/western side of the highway were conducted on 24 and 25 February; 4, 30 and 31 March; and 6 April 2014. The upstream riparian zone within 50m of the pipe inlet was searched for frogs for 2-4 hours on each night by two ecologists. Captured frogs were inspected and scored as either new captures or recaptures. All captured frogs were released at point of capture. Rainfall occurred during the 24 hours prior to four of the six recapture surveys and light rain fell during the survey on 31 March and 6 April 2014. Weather details during surveys are provided in Table F1, Appendix F.

Plate 6: An ecologist searches for frogs to capture/mark/release on the downstream/eastern side of the frog pipes. The drainage pond is dominated by *Typha orientalis.*

4. Results

4.1 Weather Conditions

Weather conditions during years 1 (2011) and 3 (Jan 2013 – Jan 2014) featured average temperatures and above average rainfall, with the exception of late spring and summer 2013/14. During year 1, weather conditions for spotlighting were generally favourable for the autumn and spring survey with calm to light winds, >70% cloud cover and no rainfall. Some light overnight rainfall occurred on one occasion during the spring 2011 trapping survey otherwise fine conditions prevailed (Table A1 & A2, Appendix A). Weather

conditions during the remainder of the spring culvert monitoring period were variable. High rainfall events on two occasions caused both partial and complete washout of sand pads at John's River and Moorland and camera inundation at Moorland. A similar scenario played out during culvert monitoring in spring of year 3 with high rainfall events causing complete washout of sand pads at all three sites on two occasions and camera inundation at Moorland on two occasions. Despite the rainfall event in mid-November 2013 dry conditions prevailed at the time.

4.2 Rope Bridges

4.2.1 Fauna Recorded in Habitat Surrounding Rope Bridges

A number of arboreal mammals were recorded in habitat surrounding rope bridges at Kew (west side only surveyed) and John's River during autumn spotlight and hair funnel surveys (Table 3). A koala (probable female) was spotlighted on one occasion ~250m to the west of the John's River rope bridge sitting in the upper canopy of a Tallowwood (*Eucalyptus microcorys*). A koala was also spotted ~150m east of the John's rope bridge during culvert baseline surveys in spring (refer section 4.3.1). Two sugar gliders were observed in forest ~200m to the north-east of the John's River rope bridge. One individual was heard as it landed on a tree trunk having glided from a nearby tree. The second individual was observed sitting on an installed nest box. Full details of spotlight surveys are provided in Table B1, Appendix B.

Hair funnels placed on trees in surrounding bushland detected three taxa (Table 3). Sugar or squirrel glider hair was detected on the west side and within 200m of both rope bridges. Brushtail possum sp. hair was detected in forest either side of the John's River rope bridge and *Antechinus* sp. hair was detected in bushland to the west of the Kew rope bridge.

Table 3: Fauna recorded in habitat surrounding Kew (west side) and John's River rope bridges during Autumn spotlight and hair funnel surveys. S= Spotlight; HF = Hair Funnel; ? = Probable identification

Species	John's River (east)	John's River (west)	Kew (west)
Koala		1 (S)	
Sugar Glider	2 (S)		
Sugar or Squirrel Glider		(HF)	(HF)
Brushtail possum sp	(HF)?	(HF)	
Antechinus sp.			(HF)
Southern boobook	1 (S)		

4.2.2 Arboreal Fauna Recorded Using Rope Bridges

Three, probably four, species of arboreal mammal were detected accessing rope bridges during the two monitoring periods (Table 4). Sugar gliders were detected at both ends of the John's River rope bridge, including on at least eight occasions by the east camera (Plate 7a). A sugar glider was also detected on one occasion (26/7/13 at 8:49pm) by the Kew-mid camera which requires crossing of either the service road to the west or the highway to the east to access. The east camera did not register any concurrent detections and the west cam was not deployed at that time. It is likely the individual came across the service road.

Feathertail gliders were photographed exploring each end of the John's River rope bridge on numerous occasions (Plate 7b) and were detected on at least one occasion by the Kew-west camera. What is probably a squirrel glider (Plate 7c) was detected exploring the east end of the Johns River rope bridge on one occasion (30/3/13 at 10:36pm). A common brushtail possum was photographed at the east end of the Kew rope bridge

moving west (Plate 7d) and on another occasion moving west and returning. Full details of fauna detections are provided in Table C1, Appendix C.

No crossings of the highway were confirmed during either monitoring period. On one occasion (11/9/13) a feathertail glider was photographed at 11:13pm at the west end of the rope bridge and a feathertail glider was later photographed (11:39pm) at the east end. It is possible that the photographs were of the same individual and a crossing had occurred though this could not be determined by movement direction.

Table 4: Species and number of detections at John's River and Kew rope bridges during Year 1 & Year 3. Probable detections are in parenthesis. All detections were made during Year 3 monitoring apart from two detections of a sugar glider at John's River (east) during May, 2011 (Year 1). *Kew (west) camera was deployed 5/9/13 during Year 3 monitoring.

Species	John's River (east)	John's River (west)	Kew (east)	Kew (mid)	Kew (west)*
Sugar Glider	8 (1)	1	-	1	-
Squirrel Glider	(1)				
Feathertail Glider	7 (1)	11 (2)	-	-	1 (1)
Common Brushtail Possum	-	-	2	-	-
Brushtail Possum sp.	-	(1)	-	-	-
Unidentified mammal	-	1	-	-	-

Plate 7: Sugar gliders (a) and feathertail gliders (b) were detected at each end of the John's River rope bridge. What is probably a squirrel glider was photographed exploring the east end of the John's River rope bridge (Plate 7c). A common brushtail possum was detected on two occasions at the east end of Kew rope bridge. No crossings of the highway were confirmed during the monitoring period.

4.3 Fauna Culverts

4.3.1 Fauna Recorded in Habitat Surrounding Culverts

Forty five species/groups of vertebrate were recorded in habitat surrounding the three subject fauna culverts (Table 5). A similar number of species/groups were recorded at each site with Moorland the most diverse (24 spp.) followed by John's River (21 spp.) and Kew (20 spp.).The number of species either side of each culvert was generally similar although almost twice the number of species was recorded on the west side of the Kew culvert compared to the east side (17 spp. versus 10 spp.; Table 5). Few species/groups were recorded on both sides of each culvert (4-8 spp.) and only four species were detected at all three sites: northern brown bandicoot, black rat, swamp rat and garden sun-skink.

Most species detected in surrounding habitat are recognised as being widespread and relatively common in north-east NSW (Plate 8a-c). A number of less common species were also detected during surveys. The dusky antechinus (*Antechinus swainsonii*) was captured in dry forest on the west side of John's River ~300m from the culvert (Plate 9a). The eastern water skink (*Eulamprus quoyii*) was captured in riparian rainforest ~100m to the west of the Moorland fauna culvert (Plate 9b). Two threatened species were detected during surveys. Both records occurred on the east side of John's River. A koala was detected ~150m east of the culvert and a powerful owl, which responded to call playback, was detected ~200m east of the culvert.

(a)  (b)  (c) 

Plate 8: Remote cameras within habitat surrounding fauna culverts detected a range of species, including echidna (John's River east) (a), northern brown bandicoot (Kew west) (b) and short-eared brushtail possum (Moorland west) (c).

(a)  (b) 

Plate 9: A male dusky antechinus (*Antechinus swainsonii*) (a) was captured in an Elliott trap ~300m east of the John's River culvert and an eastern water skink (*Eulamprus quoyii*) (b) was detected during active searches to the west of the Moorland culverts. Photos: B.Taylor.

Table 5: Vertebrate fauna species/group recorded during baseline surveys within 500m of fauna culverts at Kew, John's River and Moorland. ET=Elliott trap; PT=Pitfall trap; AS=Active Search; PS=Predator Scats; HF=Hair Funnel; S=Spotlight; C=Camera; HC=Heard Call; CP=Call Playback; IN=Incidental; ?=Probable. * = Listed as Vulnerable under the *NSW Threatened Species Conservation Act* 1995.

Species/Group	Kew		John's River		Moorland	
	West	East	West	East	West	East
Tusked Frog				HC		
Common Eastern Froglet	HC	S				HC
Striped Marsh Frog	HC					HC
Spotted Grass Frog			HC			
Red-backed Toadlet	HC		HC			
Smooth Toadlet		PT				
Bleating Tree Frog						HC
Eastern Dwarf Tree Frog			HC			HC
Peron's Tree Frog			HC			
Tyler's Tree Frog				HC		HC
Land mullet	C					
Robust Ctenotus					AS	
Eastern Water Skink					AS	
Medium Skink					AS	
Garden Sun-skink	AS	AS	PT; AS	PT	PT	PT
Sun-skink	AS		AS	AS		
Three-toed Skink					AS	
Eastern Water Dragon					C; AS; IN	
Lace Monitor			C	C		
Diamond Python						IN
Red-bellied Black Snake						IN
Yellow-face Whip Snake	IN					
Bar-shouldered Dove					C	
Southern Boobook		HC				
Tawny Frogmouth		S				
Powerful Owl*				CP		
Eastern Whipbird	C					
Eastern Yellow Robin	C					
Short-beaked Echidna				C		
Brown Antechinus			ET	?HF	ET	
Dusky Antechinus			ET			
Northern Brown Bandicoot	C;HF	HF	HF	PS;HF		?C;?HF
Long-nose Bandicoot	ET	C				
Koala*				S		
Common Ringtail Possum	S				S	
Short-eared Brushtail Possum					C; S	C; S
Common Brushtail Possum					S	
Brushtail Possum sp.						HF
Sugar Glider			S			
Bush Rat	?C; ET	ET	?C	ET; ?C		
Black Rat	C; ET	ET	?C		C;ET;HF	C;ET;HF
Swamp Rat	ET;HF		ET;HF	ET;HF		ET;HF
Rat sp.	?HF		?HF	?HF	C;?HF	?HF
Dog	C	PS				
Fox				PS		
Cat					C	
Spp/grps recorded each side	**17**	**10**	**15**	**14**	**14**	**14**
Spp/grps recorded for site	**20**		**21**		**24**	
Spp/grps recorded both sides	**7**		**8**		**4**	

4.3.2 Fauna Recorded in Culverts

Species Diversity

Twenty two species/groups of vertebrate were recorded using the three monitored fauna culverts. John's River and Moorland were the most diverse (17 spp.) and Kew the least diverse (10 spp.). The combination of sand pads and cameras enabled a relatively high level of confidence in identifying culvert users. For example, a brown antechinus was photographed at John's River (Plate 10a) concurrent with sand pad tracks attributed to a small dasyurid (Plate 11a). Other species identified with a high level of confidence included: long-nosed potoroo (Plate 10b), lace monitor (Plate 10c), northern brown and long-nosed bandicoot, pacific black duck (plate 10d), fox, black rat, bush rat, water dragon, echidna, water rat, cat and dog. The only species/groups not confidently determined to species level were brushtail possum (probably short-eared possum), wallaby (probably swamp wallaby or red-neck wallaby), heron/egret (probably white faced heron or egret sp.) and small lizard/skink (probably *Eulamprus* sp.). Full details of camera and sand detections are provided in Table D1, Appendix D and Table E1 & E2, Appendix E.

Plate 10: A variety of fauna were detected using C2HC culverts, including brown antechinus (a), long-nosed potoroo (b) and lace monitor (c). A procession of pacific black ducks were photographed moving through one of the twin-cells at Moorland (d).

(a)  (b)  (c) 

Plate 11: Moist, loamy sand provided a useful medium for registering animal tracks including those of brown antechinus (a), fox and rodent (b) and bandicoot sp. (c).

Year one monitoring yielded marginally greater species diversity than year three for Kew and John's River (Table 6, 7) despite the greater camera survey effort. Loss of sand pads during year three monitoring caused by repeated flooding events contributed to this because track registration is a particularly effective method for detecting small species (e.g. lizards, rodents) that may evade camera detection. At Kew, the between year differences are largely explained by the absence of reptile, antechinus, rodent and dog detections during year three. Conversely, fox was only detected during year three. Similarly, year three monitoring at John's River failed to detect water dragon or small lizard use and recorded lower rodent use. However, long-nosed potoroo, swamp wallaby and cat were only detected during year three. At Moorland species diversity was equivalent between the monitoring periods though the assemblage differed. Bandicoots, dogs and foxes were only detected during year three monitoring whereas eastern water dragon and rodents were only detected during year one. For all culverts, the diversity of introduced predators was greater during year three compared to year one. In particular, fox was only detected at John's River during year one but was recorded in all culverts during year three, especially at Moorland.

Most frequent users

The species most frequently making complete culvert crossings at Kew were bandicoots (northern brown and long-nosed), followed by cats and dogs (Figure 2). Bandicoots were also the most frequently recorded species crossing at John's River followed by short-beaked echidna and rodents (Figure 3). At Moorland, foxes made the most complete crossings followed by bandicoots, rodents and brushtail possum sp. (probably short-eared brushtail possum) (Figure 4). The only bird taxa to have made complete crossings were pacific black ducks and an egret/heron sp. They were detected at the Moorland culvert complex which includes a wet culvert positioned at low flow level. All species and/or species group were detected making crossings of culverts in both directions apart from Pacific black duck at Moorland (east only), fox at Kew (east only), brushtail possum sp. at John's River (east only), small skink/lizard at Kew and John's River (east only), swamp wallaby at Moorland (west only) and long-nosed potoroo at John's River (west only).

Species in surrounding habitat and those using culverts

Fewer species were detected within culverts than recorded in surrounding habitat (Table 6, 7, 8). No records of culvert use by frogs or snakes and little use by small reptiles largely accounted for the disparity. Most terrestrial mammals and large lizards detected in surrounding habitat were detected using respective culverts. Exceptions to this include: sugar glider (Johns River JR), common ringtail possum (Kew K & Moorland M), koala (JR), brown antechinus (M) and cat (M). Some species detected in surrounding habitat could only be identified

to genus/group from culvert tracks and photos, including: bush rat (K), black rat (K), swamp rat (K & M), dusky antechinus (JR), short-eared brushtail possum (M) and common brushtail possum (M). Conversely, a number of species not detected in surrounding habitat were identified using culverts, including: lace monitor (K & M), eastern water dragon (JR), *Antechinus* sp. (K), brushtail possum sp. (K & JR), long-nosed bandicoot (JR & M), the threatened long-nosed potoroo (JR), swamp wallaby (JR & M), water rat (M), fox (K & M) and cat (K & JR).

Kew

Table 6: Species/groups of vertebrate fauna detected in surrounding habitat (excluding passerine birds) (refer to codes in Table 4) &/or within Kew culvert during Year 1 and Year 3 monitoring. Detection accuracy is 'definite' unless stated ? = probable. Detection Method: T = Track; P = Photographed; HF = Hair Funnel (Yr 1 only). Confirmed crossing: Yes = tracks of the same species/group moving in the same direction across all three sand pads (2 pads/culverts during year 3) or photographed in centre of culvert moving in one direction & not photographed again for >30 minutes; No. of passes/tracks: passes (photo series of thoroughfare) and tracks (sum of tracks from all sand pads) are aggregated for each species/group within culvert for entire monitoring period.

Species/Group	Surrounding habitat		Year 1			Year 3		
	West	East	Detection Method	Confirmed Crossing	No. Passes or Tracks	Detection Method	Confirmed Crossing	No. Passes or Tracks
Common Eastern Froglet	HC	S						
Striped Marsh Frog	HC							
Red-backed Toadlet	HC							
Smooth Toadlet		PT						
Land mullet	C							
Garden Sun-skink	AS	AS						
Sun-skink	AS							
Small lizard/skink			T	Yes	3			
Lace Monitor			T	Yes	1			
Yellow-face Whip Snake	IN							
Antechinus sp.			T	Yes	5			
Bandicoot sp.			T	Yes	37	P,T	Yes	26P,32T
Nthnn Brown Bandicoot	C;HF	HF	HF,P	Yes	1	P	Yes	3
Long-nose Bandicoot	ET	C	P	Yes	4	P	Yes	6
Common Ringtail Possum	S							
Brushtail Possum sp.			HF					
Bush Rat	C; ET	ET						
Black Rat	C; ET	ET						
Swamp Rat	ET;HF							
Rat sp.	HF		T	Yes	10			
Dog	C	PS	P,T	Yes	3P,14T			
Fox						P	Yes	2
Cat			T	No	3	P,T	Yes	18P,8T
Human						P	Yes	6
Total Species/Groups (Total spp. for both years)	**16**		**9 (10)**			**5 (10)** *(Human not inc)*		

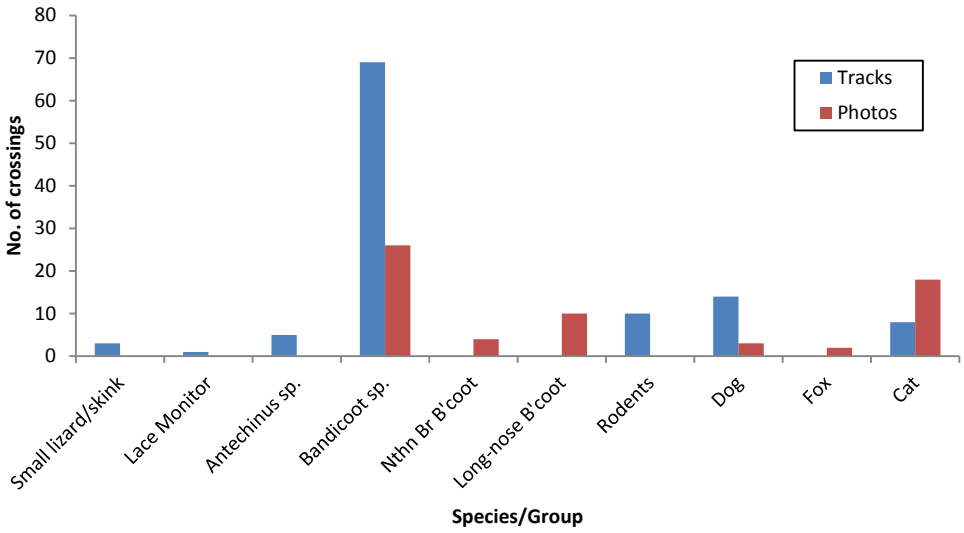

Figure 2: Complete crossings of the Kew culvert (1.5m H x 1.5m W x 53m L) pooled for the two monitoring periods.

John's River

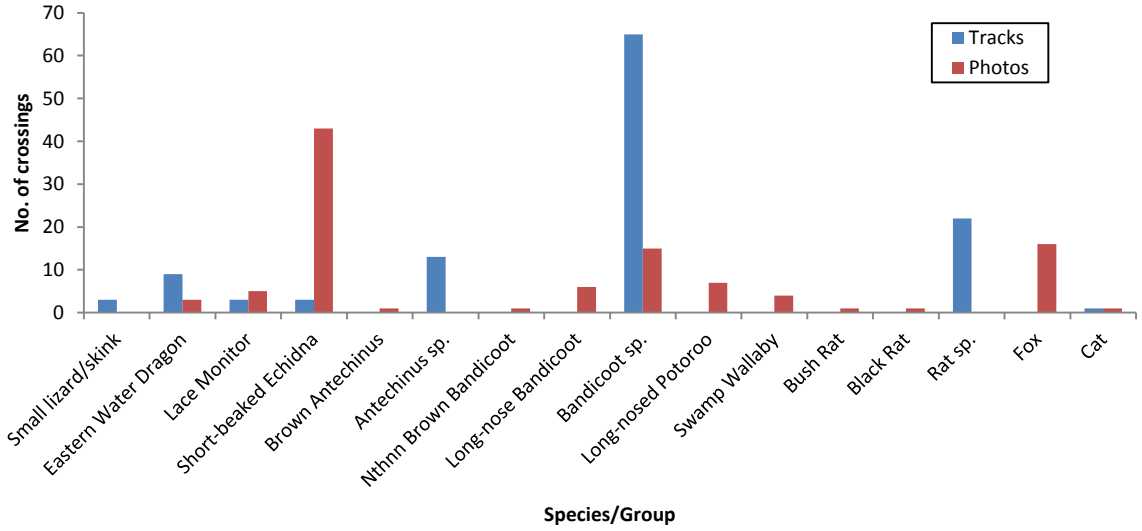

Figure 3: Complete crossings of the John's River culvert (1.2m H x 2.4m W x 48m L) pooled for the two monitoring periods.

Table 7: Species/groups of vertebrate fauna detected in surrounding habitat (excluding passerine birds) (refer to codes in Table 4) &/or within John's River culvert during Year 1 and Year 3 monitoring. Detection accuracy is 'definite' unless stated ? = probable. Detection Method: T = Track; P = Photographed; HF = Hair Funnel (Yr 1 only). Confirmed crossing: Yes = tracks of the same species/group moving in the same direction across all three sand pads (2 pads/culverts during year 3) or photographed in centre of culvert moving in one direction & not photographed again for >30 minutes; No. of passes/tracks: passes (photo series of thoroughfare) and tracks (sum of tracks from all sand pads) are aggregated for each species/group within culvert for entire monitoring period.

Species/Group	Surrounding habitat		Year 1			Year 3		
	West	East	Detection Method	Confirmed Crossing	No. Passes or Tracks	Detection Method	Confirmed Crossing	No. Passes or Tracks
Tusked Frog		HC						
Spotted Grass Frog	HC							
Red-backed Toadlet	HC							
Eastern Dwarf Tree Frog	HC							
Peron's Tree Frog	HC							
Tyler's Tree Frog		HC						
Garden Sun-skink	PT; AS	PT						
Sun-skink	AS	AS						
Small lizard/skink			T	Yes	3			
Eastern Water Dragon			P,T	Yes	3P,9T			
Lace Monitor	C	C	P,T	Yes	1P,3T	P	Yes	4
Short-beaked Echidna		C	P,T	Yes	1P,3T	P	Yes	42
Brown Antechinus	ET	?HF	HF,P	Yes	1			
Dusky Antechinus	ET							
Antechinus sp.			?HF,T	Yes	6	T	?	7
Nthnn Brown Bandicoot	HF	PS;HF	HF,P	Yes	1			
Long-nose Bandicoot						P	Yes	6
Bandicoot sp.			P,T	Yes	7P,58T	P,T	Yes	8P,7T
Koala*		S						
Brushtail Possum sp.						T	?	1
Sugar Glider	S							
Long-nosed Potoroo						P	Yes	7
Swamp Wallaby						?P	Yes	4
Bush Rat	?C	ET; ?C	P	Yes	1			
Black Rat	?C		P	Yes	1			
Swamp Rat	ET;HF	ET;HF	HF?	-	-			
Rat sp.	?HF	?HF	HF,T	Yes	22	T	?	7
Fox		PS	T	No	2	P	Yes	16
Cat						P,T	Yes	1P,1T
Total Species/Groups (Total spp. for both years)	**20**		**13 (17)**			**11 (17)**		

Moorland

Table 8: Species/groups of vertebrate fauna detected in surrounding habitat (excluding passerine birds) (refer to codes in Table 4) &/or within Moorland culvert during Year 1 and Year 3 monitoring. Detection accuracy is 'definite' unless stated ? = probable. Detection Method: T = Track; P = Photographed; HF = Hair Funnel (Yr 1 only). Confirmed crossing: Yes = tracks of the same species/group moving in the same direction across sand pads at each end or photographed in centre of culvert moving in one direction & not photographed again for >30 minutes; No. of passes/tracks: passes (photo series of thoroughfare) and tracks (sum of tracks from sand pads in both culverts) are aggregated for each species/group within culvert for entire monitoring period.

Species/Group	Surrounding habitat		Year 1			Year 3		
	West	East	Detection Method	Confirmed Crossing	No. Passes or Tracks	Detection Method	Confirmed Crossing	No. Passes or Tracks
Common Eastern Froglet		HC						
Striped Marsh Frog		HC						
Bleating Tree Frog		HC						
Eastern Dwarf Tree Frog		HC						
Tyler's Tree Frog		HC						
Robust Ctenotus	AS							
Eastern Water Skink	AS							
Medium Skink	AS							
Garden Sun-skink	PT	PT						
Three-toed Skink	AS							
Small skink/lizard			T	Yes	6			
Eastern Water Dragon	C; AS		P,T	Yes	1P,5T			
Lace Monitor			T	Yes	2	P	Yes	3
Diamond Python		IN						
Red-bellied Black Snake		IN						
Pacific Black Duck		IN	P	Yes	1			
Egret/heron		IN	T	No	3	P	Yes	1
Brown Antechinus	ET							
Nthnn Brown Bandicoot		?C;?HF				P	Yes	2
Long-nose Bandicoot						P	Yes	2
Bandicooot sp.						P,T	Yes	11P,7T
Common Ringtail Possum	S							
Short-eared B'tail Possum	C; S	C; S						
Cmn B'tail Possum	S							
Brushtail Possum sp.		HF	T	Yes	5	P	Yes	8
Wallaby sp.			T	Yes	2	P	Yes	1
Black Rat	C;ET;HF	C;ET;HF	P	Yes	2			
Swamp Rat		ET;HF						
Water rat			T	No	6			
Rat sp.	C;?HF	?HF	T	Yes	9			
Microbat						P	Yes	6
Dog	IN					P	Yes	5
Fox						P,T	Yes	112P,7T
Cat	C							
Human						P	Yes	3
Total Species/Groups (Total spp. for both years)	**23**		**10 (15)**			**10 (15)** *(Human not inc)*		

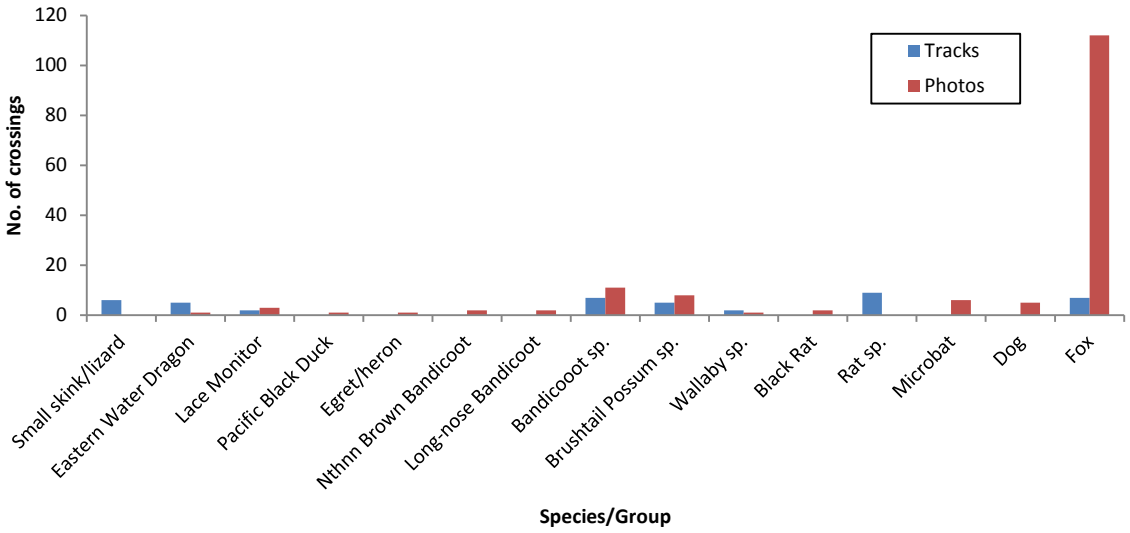

Figure 4: Complete crossings of the Moorland culverts (2.1m H x 2.4m W x 58m L) pooled for the two monitoring periods (2 culverts pooled).

4.4 Frog Pipes

Thirty four eastern sedge frogs (*Litoria fallax*) were captured, toe-tipped and released during two survey nights of the drainage pond and adjoining sediment pond on the eastern/downstream side of the frog pipes (Plate 12). Subsequent recapture surveys of the western/upstream side of the highway conducted one and two months later yielded six and eight eastern sedge frogs, respectively. No marked downstream frogs were identified in recaptures.

(a)  (b)  (c) 

Plate 12: Different colour morphs of the eastern sedge frog perched on *Typha* (a & b). A toe-tipped individual is released at point of capture (c).

5. Discussion

5.1 Rope Bridges

Rope bridges are becoming a common feature of road upgrades in eastern Australia and are reportedly used by a range of arboreal fauna. The three, probably four, species detected accessing the C2HC rope bridges have been recorded at other locations (Goldingay & Taylor 2014; Sandpiper 2009a; Sandpiper unpub. data; Soanes & van der Ree 2009). All but one of the detections (a sugar glider at John's River east) was made during year 3. The John's River rope bridge proved the most active and included detections of sugar and feathertail gliders at both ends. Whereas highway crossing could not be confirmed, there was a possible feathertail glider crossing at John's River. Unfortunately, in that instance, it was difficult to determine the direction of movement and whether it was the same individual. Feathertail glider movement is typically frenetic and exploratory making interpretation of movement direction difficult. This is further compounded by limited vision along the rope bridge because of the necessity to direct cameras towards the bulkhead.

Sugar and feathertail gliders were also detected at the Kew rope bridge albeit at a single side only. Although the feathertail glider detection occurred at the west camera, the sugar glider detection occurred at the mid camera which requires either a highway or service road crossing to access. The photos suggest that the individual reached the mid camera via the service road rope bridge rather than the highway rope bridge. The other probable glider detection was that of the vulnerable squirrel glider (Schedule 2 *Threatened Species Conservation Act 1995*) at the east end of the John's River rope bridge. The individual was seen to move out to the camera and return to the bulkhead. Squirrel gliders were not detected during EIS or baseline surveys but sugar/squirrel glider hair (species cannot be confidently separated) was detected within west side habitat at both John's River and Kew. The closest Atlas record of a squirrel glider is ~9km to the north (BioNet 2014).

Possums were infrequently recorded accessing the C2HC rope bridges. The only possum detections were of a common brushtail possum on two occasions at Kew east and a probable brushtail possum sp. at the John's River west camera. One of the Kew records show the individual heading west beyond the camera with no detection of return. A full road crossing may have occurred though this could not be confirmed as the mid cam was inoperable at that time. Common ringtail possums were not detected during baseline rope bridge surveys or accessing rope bridges though an individual was observed near the Kew fauna culvert ~1200m to the south of the rope bridge albeit well outside the average home range for this species.

Two other arboreal mammal species were recorded in adjoining forest but not detected accessing the rope bridge – the koala and Antechinus. A koala was detected on either side of the highway at John's River. In each instance, individuals were between ~100-250m from the rope bridge. Koalas have not been reported using rope bridges to cross major roads but are known to use culverts and bridge underpasses (e.g. Taylor & Goldingay 2003). Despite this, they were not recorded using the John's River fauna culvert which is located ~80m to the south. Brown and dusky Antechinus were captured to the west of the fauna culvert/rope bridge and Antechinus hair was detected on a tree in forest to the west of Kew rope bridge. Antechinus are a largely terrestrial species but are scansorial foragers and highly adept climbers. They have not been reported accessing rope bridges. Possums are the only taxa group recorded using both arboreal and terrestrial crossing structures.

A further two arboreal species known from the study area but not detected accessing rope bridges or during EIS or baseline surveys are the greater glider and yellow-bellied glider. Greater gliders were recorded in nest boxes ~2.4km to the north of the Kew rope bridge (see Sandpiper 2009b), at Johns River during clearing and from Atlas records show them to the east and west of Kew and to the west of John's River rope bridge (Bionet 2014). Yellow-bellied gliders have been recorded either side of the Kew rope bridge and 4km to the west of the

John's River rope bridge (Bionet 2014). Neither species have been reported using rope bridges though a yellow-bellied glider was recently photographed on a glide pole along the Oxley Highway (Goldingay & Taylor 2014).

It is apparent from the above discussion that the C2HC rope bridge monitoring has produced results that are largely inconclusive. Despite confirming the willingness of feathertail gliders, sugar gliders, squirrel gliders (probable identification) and common brushtail possums to access rope bridges, the lack of confirmed crossings is somewhat vexing. It is possible that highway crossings took place and were not detected which may occur due to camera malfunction at one end; animals failing to trigger a camera; or, an animal departs/glides off before reaching the second camera. Notwithstanding such scenarios, we do know from other locations in eastern Australia that common brushtail possums, common ringtail possums, sugar gliders and squirrel gliders have made complete highway crossings using similarly designed rope bridges (Thiess 2006; Goldingay et al. 2013; Sandpiper unpub. data; Soanes & van der Ree 2009). Full road crossing by feathertail gliders remains equivocal (see Goldingay et al. 2013; Goldingay & Taylor 2014; Sandpiper unpub. data) and use of rope bridges by either yellow-bellied gliders or greater gliders remains undetermined.

Can the efficacy of the C2HC rope bridges be improved? The extent of records gathered from varied locations in eastern Australia of similarly designed rope bridges suggests that the ladder-style is an appropriate generic design. Future monitoring records and/or behavioural trials are required to confirm if this is the case for yellow-bellied gliders and greater gliders. The C2HC rope bridges are positioned lower over the highway than more recent Pacific Highway upgrade rope bridges (e.g. Glenugie, Devil's Pulpit) which may constrain use by arboreal fauna. Ideally, the rope bridge should sit at the height of mid-upper canopy of adjoining forest and cross the road alignment well above traffic, preferably above 12m. For koalas, trials of various rope bridge designs, including ladder-style, have so far failed to detect use (Taylor & Goldingay unpub. data). Hardened aerial structures (e.g. poles/gantry), land bridges and underpasses may prove the most appropriate road crossing design for koalas.

Site factors are another feature that may influence the efficacy of the C2HC rope bridges. The John's River rope bridge is well located in relation to surrounding forest and glider records and features relatively high quality forest. By contrast, habitat on the west side of Kew is of moderate-high quality and that on the east side is of low-moderate quality. The Kew site also features a service road to the west of the highway requiring a 90m-long, 2-span rope bridge to link east and west forest patches, with a small stand of 3 mature trees at the middle pole. Little is known about the influence of forest gap size on crossing structure use and whether there are distance thresholds for different species (e.g. van der Ree et al. 2010). As such, some arboreal mammals may be averse to breaching such distances, albeit a sugar glider was detected in the middle of the two spans requiring crossing of at least one span. Furthermore, trees surrounding the centre camera have become senescent (possibly due to compaction caused by the road construction) and will require pruning to avoid branch-fall onto the rope bridge. Additional planting is required at the centre pole to ensure continued tree cover. Loss of tree canopy around the central pole of the rope bridge reduces refuge options for arboreal fauna using the crossing and may discourage use. Installing a predator shield above the bulkhead of the central pole may be advisable.

5.2 Fauna Culverts

The range of vertebrate fauna recorded using culverts at C2HC is similar to that reported at other Pacific Highway upgrade locations (e.g. AMBS 2002; Taylor & Goldingay 2003; Hayes & Goldingay 2009; Sandpiper 2009c, 2010). This is to be expected as all these upgrade sites reside within the north coast bioregion and feature similar coastal forest landscapes (NSW NPWS 2003). Amongst the three C2HC culvert sites, John's River and Moorland feature habitat of similar quality and type either side of the culvert resulting in an equivalent number of species either side of the road. Conversely, habitat to the west of the Kew culvert comprised a

relatively large, high quality coastal forest block whereas the east side featured largely disturbed (e.g. under-scrubbed) and fragmented rural landholdings with domestic dogs. This pronounced difference in habitat quality probably accounts for the 40% difference in species diversity between the two sides.

Twenty four of the 39 (non-wetland birds excluded) vertebrate species/groups recorded within surrounding habitat were detected within one or more of the three monitored fauna culverts. The apparent disparity was largely accounted for by a lack of use by frogs and snakes. Ten species of amphibian were detected in culvert surrounds (6 spp. of ground frog; 4 spp. of tree frogs) yet none were detected within culverts. Notwithstanding their low camera detectability due to size and low thermal signature, limited use of RC culverts by amphibians has been reported in other monitoring studies (e.g. AMBS 2002; Fitzgerald 2005; Taylor & Goldingay 2003). This is discussed further in section 5.3.

A diverse reptile fauna was detected in surrounding habitat but less within fauna culverts. Lace monitors were recorded making full crossings at all culvert sites and eastern water dragons detected crossing at John's River and Moorland. Small to medium-sized lizards, accounting for six species recorded in adjoining habitat, were detected making full crossings of all culverts. It was not possible to ascribe a species to tracks for this group and cameras did not detect them within culverts, probably due to their small size and low thermal signature. Snakes were not detected within culverts but were recorded in surrounds at two sites, including a diamond python and a red-bellied black snake within 5m of the west entrance to the Moorland culverts. Snakes have been reported as infrequent RC culvert users in other monitoring studies (e.g. Fitzgerald 2005; Taylor & Goldingay 2003; AMBS 2002) so it is reasonable to expect they may use the C2HC culverts.

With the exception of gliders (not known to access fauna culverts), koala and common ringtail possum, all mammal species/groups recorded in surrounding habitat were detected making complete crossings in at least one culvert. This includes echidna (JR), northern brown and long-nosed bandicoot (K, JR, M), brown antechinus (JR), brushtail possum (probably short-eared), long-nosed potoroo (JR), swamp wallaby (JR), bush rat and black rat (JR) and microbat (M). A water rat was recorded making a partial crossing of a Moorland culvert though they have been reported making complete crossings of fauna culverts at other locations (e.g. AMBS 2002; Taylor & Goldingay unpub. data). The crossing records of the threatened long-nosed potoroo at John's River are noteworthy as they were not detected during baseline surveys. Potoroos have also been recorded using a variety of RC box culverts located in forest habitat near Bulahdelah (see AMBS 2002).

The long-nosed potoroo is one of a number of species/species group only detected making crossings of culverts in one direction (west only). Others included Pacific black duck at Moorland (east only), fox at Kew (east only), brushtail possum at John's River (east only), small skink/lizard at Kew and John's River (east only) and swamp wallaby at Moorland (west only). It is possible that individuals made crossings in the other direction but were not detected, particularly during the period of camera-only monitoring. Single-direction crossing may also indicate dispersal events or seasonal movements rather than back and forth movements associated with foraging activities within an individual's home range. It is also plausible that individuals used a monitored culvert to cross in one direction and returned via another crossing structure (e.g. drainage pipe/culvert). Little is known on the type of movements that culvert crossings represent for different species (see Taylor & Goldingay 2014a).

Common ringtail possums were not detected using culverts despite being recorded within 300m of the Kew and Moorland culverts. This has been reported in other culvert studies (e.g. AMBS 2002) and may indicate a preference for using aerial structures such as rope and land bridges to cross road gaps (see Soanes et al. 2009; Taylor & Goldingay in press). Koalas were observed on both sides and within 250m of the John's River culvert but were not detected using the culvert. Despite this, koalas have been reported using a similar sized box culvert under the Pacific Highway at Brunswick Heads on one occasion (Taylor & Goldingay 2003) and larger RC box culverts and bridge underpasses at other locations on more frequent occasions (e.g. Sandpiper 2010;

AMBS 2002; Goldingay & Taylor 2014). It may be the case that the John's River culvert (i.e. 1200H x 2400W) is at the lower end of the suitable size class for koalas.

The John's River culvert (and Kew) also feature an arboreal timber rail (refer Plate 2). In each case, the rail is mounted ~400mm from the culvert ceiling which may constrain use by an arboreal mammal the size of a koala. The apparent attractiveness of timber rails in culverts for arboreal mammals is largely unknown although a koala was photographed using a timber rail within a 2400mm^2 RC box culvert at Bonville (AMBS 2011). No fauna were detected using either of the C2HC culvert rail systems during our monitoring. It does raise the question, however, whether timber rails installed in small dimension culverts such as at Kew and John's River inhibit use by arboreal mammals. That is, the timber rail system in the John's River and Kew culvert may not physically restrict access or thoroughfare by larger fauna. Indeed, a large canid (likely an Alsatian) was photographed travelling through the relatively narrow Kew culvert (1500mm wide) on a number of occasions. However, the combination of small dimension culvert and large post and rail system may obstruct vision through the culvert and thereby inhibit use. More recent upgrades of the Pacific Highway feature larger dimension dedicated culverts, commonly in the order of 3000mm x 3000mm (e.g. NH2U, OH2Ku). The effect of culvert dimension and length on use is a vexed question (see Taylor and Goldingay 2014a). Moreover, teasing out possible effects of differences in design of the three monitored culverts at C2HC on fauna use is confounded by many factors, particularly type, configuration and quality of surrounding habitat.

Introduced predators were especially prevalent during year three monitoring with complete crossings recorded by fox (K, JR, M), dog (K, M) and cat (K, JR). Varied use of culverts by introduced predators has also been reported at other sites (e.g. Fitzgerald 2005; AMBS 2002). No evidence of predation within culverts was recorded during either monitoring period although the impact of these species on local native fauna is well documented. Despite the proposition that culverts may function as prey traps being largely unsubstantiated (see Chambers & Bencini 2014; Taylor & Goldingay 2014a), the frequency of use by fox(s) at Moorland and John's River (the site featuring long-nosed potoroo) is of concern. In particular, it is likely that at least two individual foxes used the John's River culvert. Targeted fox/canid control at these two sites should be undertaken.

Another feature of the current study was to consider the efficacy and value of complementing sand pads with cameras to more accurately describe culvert users. Sand pads provide a cost-effective method of recording taxa groups but are largely confined to the genera-level of identification. When combined with cameras, however, the level of precision is enhanced. This was clearly demonstrated in the current study whereby small dasyurid, rodent and bandicoot tracks could be positively identified as brown antechinus, bush rat, black rat, northern brown bandicoot and long-nosed bandicoot respectively through the aid of photographs. Conversely, a small number of species were detected by tracks only (e.g. small lizards). Sand pads may prove particularly valuable on occasions of camera malfunction, camera response too slow for fast moving individuals (e.g. wallabies), or when individuals only access the entrance area beyond detection range of a centrally-positioned camera. However, an unfortunate feature of sand pads is they're vulnerability to inundation. Almost the entire second monitoring period was lost due to repeated inundation. In future, it may be more plausible to only use cameras in culverts that are prone to flooding.

A number of site enhancements may improve the attractiveness of C2HC fauna culverts to potential users. These include: habitat restoration around culvert entrances at Kew and John's River west; installation of 'furniture' such as hollow logs, rocks, mulch, gravel to encourage use by amphibians, rodents and small reptiles; and, installation of raised concrete ledges (i.e. 300mmH x 900mmW) along the outer wall of the outer two cells at Moorland to provide relatively continuous dry access.

5.3 Frog Pipes

Roadside frog populations may be susceptible to unsustainably high levels of road mortality, particularly in areas of high quality habitat (see Goldingay & Taylor 2006; Richard 2008). However, the scale of frog road mortality largely goes unreported or underestimated because their small size and rapidly deteriorating carcass makes them difficult to detect during daytime road-kill surveys (Taylor & Goldingay 2004). Mitigating the potential mortality and fragmentation impacts roads may impose on frogs has proven somewhat challenging particularly as frogs do not seem to take readily to RC box fauna culverts (e.g. AMBS 2002; Fitzgerald 2005). Indeed, during a wet evening along the Brunswick Heads bypass frogs were observed moving in large numbers past a RC fauna culvert, up a roadside batter, through chainmesh exclusion fencing and on to the road surface (Taylor & Goldingay 2003). A 60-minute walking observation of a 1.4km section of the roadway revealed 55 frog carcasses.

At C2HC, no frogs were observed moving or killed on the road surface and no breaches of the drift fence were observed during survey nights. Our recapture surveys failed to detect any upstream movement of frogs. The lack of dispersal movement evident during recapture surveys may have been an artefact of the poorer quality habitat on the upstream side and/or insufficient rainfall to trigger such movement. Summer rainfall was well below average and no substantial rain fell until early March (BOM 2014). The only substantial rainfall event (i.e. >50mm) prior to a recapture survey occurred on 2 March, 48 hours before survey. On this occasion, light rain fell during survey but frogs were not observed moving and calling by males was infrequent.

Notwithstanding the inconclusive result at the C2HC, recent mitigation efforts under a major road in Victoria have yielded promising outcomes for the threatened growling grass frog (*Litoria raniformis*) (see Gilmore & Koehler 2014). A series of four RC box culverts (~2400mm^2) were installed with three of the culverts set below low water level to link constructed wetland habitat under the road. Frogs reportedly moved in both directions between the wetlands and the authors suggest that submerging the culvert floors was crucial to their success. The frog pipes at C2HC were submerged at the downstream end but not the upstream end. Also, the pipes were only 900mm diameter which may not be of sufficient size to encourage use. For future projects, use of larger sized pipes/culverts and permanently submerging at least one cell may improve their effectiveness.

6. Recommendations

6.1 C2HC Project

- Install ‘furniture’ (i.e. fixed, clay tiles,) within the John’s River culvert to encourage use by amphibians, small reptiles and rodents;
- Encourage further vegetation restoration near culvert entrances at Kew and John’s River (west);
- Install raised concrete ledges (i.e. 300mmH x 900mmW) along the outer wall of the outer two cells at Moorland to provide relatively continuous dry access;
- Prune upper branches of the senescent tree adjacent the central pole of the Kew rope bridge;
- Install a predator shield above the bulkhead of the central pole of the Kew rope bridge to compensate for the loss of canopy cover/refuge;
- Plant seedling trees and shrubs around the centre pole of the Kew rope bridge to provide cover in the long-term.
- Conduct targeted fox/canid control around John’s River (site featuring long-nosed potoroo) and Moorland culverts.

6.2 Future Projects

- The benefit of post and rail structures within culverts targeting koalas is questionable and their inclusion probably unnecessary;
- For monitoring use cameras only in fauna culverts prone to flooding and ensure they are positioned above high water level;
- Culverts/pipes targeting frogs should be >1500mm^2 and positioned in series such that one or more of the cells is permanently submerged.
- Rope bridges should be installed at mid-upper canopy level to improve accessibility to arboreal fauna;
- Rope bridges should be a minimum of 12m above road level at their lowest point.
- Disturbance should be minimised around the entrance to dedicated fauna culverts during the construction phase and effective revegetation (understorey plants, logs and rocks) implemented before completion to provide cover.
- A strategy for introduced predator control should be developed for dedicated culverts that target high risk (i.e. critical weight range <5000g) species.

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Appendix A – Year 1 (2011) Baseline Survey Weather Conditions

Table A1: Weather data recorded during Autumn 2011 spotlight surveys of habitat adjoining Kew and John's River rope bridges along the C2HC upgrade of the Pacific Highway.

Date	Cloud Cover %		Temperature		Rel Humidity %		Wind		Rainfall		Dew Point	
	Dawn	Dusk	Dawn	Dusk	Dawn	Dusk	Dawn	Dusk	Dawn	Dusk	Dawn	Dusk
16/03/2011		100		26.4		84		1		1		25.8
17/03/2011	90	100	23.5	25.3	78.4	81.4	1	2	3	3	19.1	21.2
18/03/2011	100	70	21.6	27.1	78.8	70.6	1	3	3	4	17.2	20.9

Table A2: Weather data recorded during Spring 2011 spotlight and trapping surveys of habitat adjoining fauna culverts at Kew, John's River and Moorland along the C2HC upgrade of the Pacific Highway.

Date	Cloud Cover %		Temperature		Rel Humidity %		Wind		Rainfall		Dew Point	
	Dawn	Dusk	Dawn	Dusk	Dawn	Dusk	Dawn	Dusk	Dawn	Dusk	Dawn	Dusk
1/11/2011		25		18.4		67.3		1		4		13.4
2/11/2011	0	75	15.5	22.1	76.2	68.3	1	1	4	4	11.8	16.5
3/11/2011	50	100	19.9	22.4	70.2	66.4	1	2	4	3	15.1	16.5
4/11/2011	75	90	18.2	24.3	73.5	77.2	1	1	3	4	18.2	19.9
5/11/2011	50		17.4		74.3		1		4		17.1	

Appendix B – Year 1 (2011) Baseline Spotlight Surveys

Table B1: Results of spotlight surveys conducted in forest habitat within 500m of Kew (K) and John's River (JR) rope bridges along the C2HC upgrade of the Pacific Highway. Due to access restrictions, habitat on the east side of the Kew rope bridge was not surveyed.

Date	Transect	Start	End	Results	Number	Notes
16/03/2011	JR_east	1855	1935	Sugar Glider	1	stagwatch; SG ~200m NE of rope bridge (470840-6488350)
16/03/2011	JR_east	1940	2013	Sugar Glider	1	SG ~230m NE of rope bridge (470837-6488375)
18/03/2011	JR_east	2014	2046	Southern Boobook	1	
16/03/2011	JR_west	2028	2102	koala	1	High in Tallowwood; fem?; ~250m W of rope bridge (470493-6488211)
18/03/2011	JR_west	1900	1934	nil		stagwatch
18/03/2011	JR_west	1935	2006	nil		
17/03/2011	K_west	1939	2013	nil		
18/03/2011	K_west	2104	2136	nil		

Appendix C – Year 1 (2011) and Year 3 (2013) Rope Bridge Camera Monitoring

Table C1: Fauna detected by remote cameras positioned at each end of Kew (K) and John's River (JR) rope bridges along the C2HC upgrade of the Pacific Highway. Year 1 monitoring operated from 17/3-21/7/11 (126 days) with all cameras active for the duration of the monitoring period except Kew_mid was active for 91 days. Year 3 camera monitoring operated from 23/1/13-29/12/13 (340 days). Cameras were active for 275 days (JR_east), 340 days (JR_west), 307 days (Kew_east), 311 days (Kew_mid) and 91/116 days (Kew_west). Movement codes: E = move east; W = move west; NDM = no directional movement; X = exploring; TA = turned around.

Site & side of Hwy	Date	Time	Species	Accuracy	Movement & Direction	No. Active Images	Image No.'s	Comments
JR_East	3.5.11	11.14.28	sugar glider	Pr	at end	4	1060-1063	Year 1
	30.5.11	4.34.05	sugar glider	D	W,TA,E	13	2936-2950	Year 1
	30.3.13	10.36pm	Squirrel glider	Pr	W,TA,E	15	506-520	[male]
	13.5.13	9.36pm	Sugar glider	D	W	15	656-671	[m;white tail tip]
	21.5.13	3.43am	Sugar glider	D	W	15	746-60	[M,white tail tip]
	26.6.13	3.13pm	Grey Goshawk	D	NDM	10	426-435	
	2.8.13	8.26am	Grey shrike thrush	D	X	15	501-15	
	5.8.13	2.27am	Feathertail Glider	D	W,TA,E	10	516-25	
	7.8.13	1.08am	Feathertail Glider	D	E?X?	5	181-85	
	17.8.13	5.08am	Sugar Glider	D	W,TA,E	15	551-565	[m; white tail tip]
	1.9.13	1.34am	Feathertail Glider	D	W	5	616-620	
	5.9.13	7.47am	Grey shrike thrush	D	X	5	621-625	
	9.9.13	1.51am	Feathertail Glider	D	W,TA,E	8	101-110	wire and rope
	9.9.13	2.01am	Feathertail Glider	D	W	5	111-115	wire and rope
	11.9.13	11.39pm	Feathertail Glider	Pr	at pole	5	116-120	
	15.9.13	2.31am	Sugar Glider	D	W & at cam	13	121-145	edge rope and rope
	5.10.13	11.23pm	Feathertail Glider	D	E?X?	5	241-245	wire and rope
	6.10.13	1.39am	Feathertail Glider	D	W	13	246-260	wire and rope
	21.10.13	7.47am	Grey shrike thrush	D	NDM	10	716-725	
	25.10.13	2.02am	Sugar glider	D	W,TA,E	20	720-750	wire and rope

Site & side of Hwy	Date	Time	Species	Accuracy	Movement & Direction	No. Active Images	Image No.'s	Comments
JR_west	7.3.13	11.28pm	Feathertail Glider	Pr	X	6	001-006	
	11.3.13	2.01am	Brushtail Possum sp	Pr	X	6	007-012	
	8.6.13	11.14pm	Feathertail Glider	D	E	10	106-20	
	13.6.13	9.18PM	Feathertail Glider	Pr	E? X?	1	122	
	14.6.13	1.37am	Feathertail Glider	D	X	10	126-35	
	19.6.13	3.51am	Feathertail Glider	D	W	5	141-45	
	7.7.13	11.14am	Feathertail Glider	D	X	15	146-160	
	8.7.13	1.15am	Feathertail Glider	D	E? X?	5	161-65	
	10.8.13	8.30pm	Feathertail Glider	D	X?	5	311-15	
	11.8.13	1.58am	Feathertail Glider	D	X?	5	316-20	
	16.8.13	4.23am	Feathertail Glider	D	X?	5	336-340	
	11.9.13	11.13pm	Feathertail Glider	D	W	10	161-170	wire and rope
	7.10.13	12.55am	Feathertail Glider	D	W	5	171-175	rope
	10.10.13	1.26am	Sugar Glider	D	E	32	176-220	wire and rope
	28.12.13	3.09am	Feathertail Glider	D	E	6	816-830	wire and rope
	29.12.13	1.04am	Unid mammal		at cam	2	936-937	
KEW_east	21.2.13	11.02pm	Common Brushtail Possum	D	W	9	btp1-9	
	3.9.13	10.53pm	Common Brushtail Possum	D	W,TA,E	20	76-95	
KEW_mid	26.7.13	8.49pm	Sugar glider	D	X	10	4606-15	(M;no white tip)
Kew_west	29.9.13	9.44pm	Feathertail glider	D	NDM	9	1206-1219	
	6.10.13	1254am	Feathertail glider	Pr	NDM	3	1441-43	near cam

Appendix D – Year 1 (2011) Culvert Surveys

Table D1: Results of culvert sand pad, camera and hair funnel surveys conducted in fauna culverts at Kew, John's River and Moorland along the C2HC upgrade of the Pacific Highway. Confidence level: D=Definite, Pr=Probable, Po=Possible.

Session: 2-10 Nov 2011								
Site	**Spp/Taxa Gp**	**Camera**			**Sand Pad Tracks&Direction ('Definite' unless stated)**			**Pad condition**
		Confid	**Direction**	**Pic No's**	**East**	**Mid**	**West**	
Kew	Bandicoot sp		NO PICS		1E	1E	2E*1W	all 3 moist
	Rat sp				1E	1E	1E	& undisturbed
	Cat				1E*1W	from E & turned		
John's	Bandicoot sp				1W	1E*1W	1E*1W	E=mod crust
Rv	R rattus	D	W?; W?	91-100; 216-20				undisturbed
	Rattus sp				1E[Pr]	1E[Pr]	1E*2W	Mid=light crust
	Fox						1E*1W	undisturbed
	Echidna	D	W	211-15	1W[Pr]	1W[Pr]	1W	W=moist;
								undisturbed
	Estn Water Dragon	D	W; W; E	186-90; 201-10; 221-25				
	Lg Dragon sp					1W[Pr]		
	Goanna	D	E	191-99	1E	1E	1E	
	Sm lizard/skink				1E[Pr]	1E[Pr]	1E[Pr]	
Moor-			NO PICS		no pad			Mid&West
land						no tracks in session		pads dry;
(North)								mod crust;
								undisturbed
Moor-			NO PICS		no pad			
land						no tracks in session		Mid&West
(South)								pads dry;

		Session: 11-14 Nov 2011						
Site	**Spp/Taxa Gp**	**Camera**			**Sand Pad Tracks&Direction ('Definite' unless stated)**			**Pad condition**
		Confid	**Direction**	**Pic No's**	**East**	**Mid**	**West**	
Kew	Bandicoot sp				2E*1W	1E	1E	all 3 moist
	Rat sp						2E*2W	& undisturbed
	Dog	D	E	41-45	2E*2W	1E*1W	1E*1W	
	Sm dasyurid				1E[Pr]	1E[Pr]	1E[Pr]	
	Sm lizard/skink				1E[Pr]	1E[Pr]	1E[Pr]	
John's	Bandicoot sp	D	4xW	21-35;41-45	3E*2W	4E*3W	5E*3W	E=20% washed out
Rv	Nthn Br B'coot	D	E	36-40				rest moist
	R fuscipes	D	E	11-20				Mid=20% washed out
	Rattus sp				2E*1W	1E*1W	2E	rest moist
	Lg Dragon sp				2E*1W[Pr]	1E*1W[Pr]	1E*1W[Pr]	W=50% washed out
								rest moist
Moor-			NO PICS		no pad			Mid&West
land						no tracks in session		pads dry;
(North)								mod crust;
								undisturbed
Moor-	Rattus sp		NO PICS		no pad	3E*2W	2E*1W	Mid=damp
land								W=dry, mod
(South)	Wallaby sp					1W	1W	crust
								both
								undisturbed

Session: 15-21 Nov 2011								
Site	**Spp/Taxa Gp**	**Camera**			**Sand Pad Tracks&Direction ('Definite' unless stated)**			**Pad condition**
		Confid	**Direction**	**Pic No's**	**East**	**Mid**	**West**	
Kew	Bandicoot sp				4E*3W	3E*3W	4E*3W	all 3 moist
	Lng-nose B'coot	D	W	21-24				& undisturbed
John's Rv	Bandicoot sp	D	W & E	35a-e;36-40	3E*2W	2E*2W	3E*2W	all 3 moist
	R rattus	Pr	E	21-25				& undisturbed
	Rattus sp				3E*2W	1E*2W	1E*1W	E=20% washed away
	A stuartii	Pr	E	31-35				Mid=100%
	Sm dasyurid				2E*2W[Pr]	1W[Pr]	1W[Pr]	washed away
	Lg Dragon sp				1E[Pr]			W=80% washed away
Moorland	Br-tail possum		NO PICS		no pad	2E*2W[Pr]	1W[Pr]	Both pads
(A-North)	Rattus sp					2E	3E*2W	moist;
	Water rat						1E*1W[Pr]	undisturbed
	Bird_egret?						1W[Pr]	
	Lg dragon					2E*1W		
	Sm lizard/skink					2E*2W[Pr]		
Moorland	Rattus sp				no pad	1W	2E*1W	Both v moist
(C-South)	R rattus	Pr	E	6-10				some tracks diffused
	Water rat						2E*2W	undisturbed
	Bird_egret?						1E*1W	
	Estn Water dragon	D	sit	11-15				
	Lg dragon					1E*1W		
	Sm lizard/skink					2x[Pr]		
	Goanna					1E*1W		

Session: 22-28 Nov 2011

Site	Spp/Taxa Gp	Camera			Sand Pad Tracks&Direction ('Definite' unless stated)			Pad condition
		Confid	Direction	Pic No's	East	Mid	West	
Kew	Bandicoot sp				2E*1W	4E*2W	5E*2W	East-70% washed away
	Lng-nose B'coot	3D*3Pr	4E*1W*1?	21-25;51-90				Mid-50% gone
	Nthn Br B'coot	Pr	W	26-35				West-50% gone
	Rat sp				1E	1W	1W	AREA received
	Dog	D	1E*1W	91-100	1E*1W	1E	2E*1W	~210mm rain
	Sm dasyurid				1x[Pr]		1x[Pr]	b/t Nov24-27
	Goanna					1x[Pr]		
John's Rv	Bandicoot sp	D	E	21-25	5E*5W	washed away track counts for 2 nights	5E*4W	22-Nov checked E&W pads 23-Nov reinstalled mid pad & checked E&W 28 Nov all washed away
Moor-land (North)			NO PICS		no pad	washed away	washed away	both culv's washed out 80-100mm still running through culvert evidence level up to 1400mm
Moor-land (South)	R rattus	D	E?	15-25	no pad	washed away	washed away	Both cameras mounted at 120cm inundated
	Pac Black Duck	D	E [7 ind's]	1-10				

Appendix E – Year 3 (2013) Culvert Surveys

Table E1: Results of culvert sand pad surveys conducted in fauna culverts at Kew, John's River and Moorland during Spring 2013. Confidence level: D=Definite, Pr=Probable, Po=Possible.

Site	Time Period	Inspection Date	Pad No.	Species	Accuracy	No. Passes	Direction	Picture Sequence
Kew	31/10-7/11	07-11-13	east	Bandicoot spp	pr	6-10	both	
			east	Cat	d	1	east	332-342
			west	Bandicoot spp	pr	6-10	both	323-331
			west	Cat	d	2-5	both	343-346
Moorland	31/10-7/11	07-11-13	west	Red fox	d	2-5	both	347-370
			west	Bandicoot spp	po	2-5	both	
			east	Bandicoot spp	pr	2-5	both	371-384
			east	Red fox	d	2-5	both	
Johns River	31/10-7/11	07-11-13	west	Cat	d	1	west	385-429
				Bandicoot spp	d	2-5	both	
				Brushtail Possum	pr	1	east	
				Antechinus spp.	po	2-5	both	
				Rodent spp.	po	2-5	both	
Kew	7/11-14/11	14-11-13	Pads washed out	Pad replaced				
Moorland	7/11-14/11	14-11-13	Pads washed out	Pad replaced				
Johns River	7/11-14/11	14-11-13	Pads washed out	Pad replaced				
Kew	14/11-21/11	21-11-13	Pads washed out					
Moorland	14/11-21/11	21-11-13	Pads washed out					
Johns River	14/11-21/11	21-11-13	Pads washed out					

Table E2: Results of camera surveys within fauna culverts at Kew, John's River and Moorland during January 2013 to January 2014. Confidence level: D=Definite, Pr=Probable, Po=Possible. Movement codes: E = move east; W = move west; NDM = no directional movement; TA = turned around; ?

Culvert Location	Date	Time 24h	Species	Accuracy	Movement & Direction	No. Active Images	Image No.'s
Kew	2.2.13	2108	Bandicoot sp	D	E	3	025-027
	26.1.13	1747	Human x 2	D	W	6	016-21
		1754	Human x 2	D	E	3	022-24
	24.2.13	2228	Red Fox	D	E	5	036-40
	22.3.13	2043	Red Fox	D	E	5	011-015
	12.5.13	2248	Long-nosed Bandicoot	D	E&TA	10	016-025
	10.6.13	1713	Cat	D	W	5	o11-15
	16.7.13	1652	Cat	D	W	8	o16-24
	7.8.13	0416	Bandicoot sp	D	E	5	016-020
	7.8.13	0744	Human	D	E	25	021-045
	17.8.13	0205	Long-nosed Bandicoot	Pr	W	5	046-050
	17.8.13	0344	Long-nosed Bandicoot	Pr	E&stop	5	051-055
	24.8.13	1720	cat	D	E	5	056-060
	29.8.13	1808	Bandicoot sp	D	E	5	061-065
	2.9.13	2053	Long-nosed Bandicoot	Pr	E	5	066-070
	5.9.13	0022	Cat	D	W	3	26-28
	5.9.13	1752	NB Bandicoot	Pr	E	5	31-35
	6.9.13	1739	NB Bandicoot	Pr	W	5	36-40
	15.9.13	0856	Cat	D	W	8	41-48
	19.9.13	0809	Human	D	E	8	51-58
	22.9.13	0816	Cat	D	W	3	61-63
	22.9.13	0854	Cat	D	E	10	66-75
	26.9.13	1734	Cat	D	E	5	76-80
	26.9.13	2003	Bandicoot sp	D	W	1	81

Culvert Location	Date	Time 24h	Species	Accuracy	Movement & Direction	No. Active Images	Image No.'s
Kew	30.9.13	1833	Bandicoot sp	D	E	5	86-90
	30.9.13	1836	Bandicoot sp	D	E	5	91-95
	30.9.13	2106	Bandicoot sp	D	W	3	96-98
	9.10.13	0943	Cat	D	W	10	101-110
	9.10.13	1827	Cat	D	E	5	111-115
	11.10.13	2044	Bandicoot sp	D	E	5	116-120
	14.10.13	0056	Long-nosed Bandicoot	D	E	5	121-125
	16.10.13	0904	Cat	D	W	8	126-133
	16.10.13	1654	Cat	D	E	5	136-140
	21.10.13	1000	Cat	D	W	8	141-148
	21.10.13	1409	Cat	D	E	20	151-170
	23.10.13	2023	Bandicoot sp	D	E	5	171-175
	26.10.13	1513	Bandicoot sp	D	E	3	176-178
	27.10.13	1924	Bandicoot sp	Pr	E	5	181-185
	28.10.13	0822	Cat	D	W	7	186-192
	28.10.13	1446	Cat	D	E	5	196-200
	31.10.13	2004	Bandicoot sp	D	W	5	256-260
	31.10.13	2008	Bandicoot sp	D	W	5	261-265
	1.11.13	0004	Bandicoot sp	D	E	5	266-270
	1.11.13	0038	Cat	D	W	7	271-277
	2.11.13	1901	Bandicoot sp	D	W	4	281-284
	2.11.13	1904	Bandicoot sp	D	E then W	14	286-301
	3.11.13	0013	Bandicoot sp	D	E	5	306-310
	3.11.13	1932	Bandicoot sp	D	W	10	311-320
	3.11.13	1945	Bandicoot sp	D	E	8	321-328
	3.11.13	2205	Bandicoot sp	D	E	5	331-335
	22.11.13	2157	Long-nosed Bandicoot	D	W	3	21-23

Culvert Location	Date	Time 24h	Species	Accuracy	Movement & Direction	No. Active Images	Image No.'s
Kew	26.11.13	1935	Bandicoot sp	D	E	5	26-30
	27.11.13	1901	Bandicoot sp	D	E	5	31-35
	28.11.13	1932	Bandicoot sp	D	E	5	36-40
	4.12.13	2105	Northern-Brown Bandicoot	D	W	5	41-45
	24.12.13	2151	Bandicoot sp	D	E	5	46-50
	28.12.13	2142	Bandicoot sp	D	E	5	51-55
	1.1.14	2022	Bandicoot sp	D	E	5	56-60
	10.1.14	0847	Cat	D	E	20	61-80
John's Rv	30.1.13	2144	Long-nosed B'coot	D	E	6	010-015
	8.2.13	2109	Swamp Wallaby	Pr	W	3	016-18
	17.2.13	1629	Short-beaked Echidna	D	W	3	019-021
	25.2.13	0022	Short-beaked Echidna	D	E	5	026-030
	27.2.13	2030	Short-beaked Echidna	D	E	5	031-035
	16.3.13	1017	Lace Monitor	D	W	5	011-015
	19.3.13	1155	Lace Monitor	D	E	10	016-025
	25.3.13	0944	Lace Monitor	D	E&TA	20	026-045
	25.3.13	1749	Cat	D	E	5	046-050
	2.4.13	1155	Lace Monitor	D	E	10	051-060
	18.4.13	1520	Short-beaked Echidna	D	E	5	061-065
	19.4.13	0544	Microbat	Po	ND	1	o66
	26.4.13	1440	Short-beaked Echidna	D	E	5	071-075
	27.4.13	0517	Red Fox	D	E	3	076-078
	5.5.13	0325	Red Fox	D	E&TA	20	081-100
	10.5.13	2244	Red Fox	D	W	10	101-110
	13.5.13	1915	Red Fox	D	E&TA	6	111-116

Culvert Location	Date	Time 24h	Species	Accuracy	Movement & Direction	No. Active Images	Image No.'s
John's Rv	13.5.13	2310	Red Fox	D	E	5	121-125
	17.5.13	2345	Swamp Wallaby	Pr	E	5	131-135
	20.5.13	2036	Red Fox	Pr	W`	1	136
	31.5.13	1931	Short-beaked Echidna	D	E	5	o6-10
	20.6.13	0242	Long-nosed Potoroo	D	W	5	o11-15
	20.6.13	2017	Red Fox	D	W	5	o16-20
	21.6.13	0225	Long-nosed Potoroo	D	W	4	o21-25
	21.6.13	0637	Red Fox	D	W	1	o26
	23.6.13	0159	Red Fox	D	E,TA,W	5	o31-36
	23.6.13	0252	Short-beaked Echidna	D	E	5	o41-45
	23.6.13	1816	Long-nosed Potoroo	D	W	5	o46-50
	3.7.13	1855	Long-nosed Bandicoot	D	W,TA,E	10	o51-60
	8.7.13	1519	Short-beaked Echidna	D	E	5	o61-65
	10.7.13	2340	Long-nosed Potoroo	D	W,stop	5	o66-70
	11.7.13	1958	Short-beaked Echidna	D	W	5	o71-75
	12.7.13	1629	Short-beaked Echidna	D	E	5	o76-80
	15.7.13	2256	Short-beaked Echidna	D	E	5	o81-85
	17.7.13	1928	Short-beaked Echidna	D	W	5	o86-91
	18.7.13	1843	Red Fox	D	W	5	o96-100
	18.7.13	2045	Short-beaked Echidna	D	E	10	101-110
	19.7.13	0218	Long-nosed Potoroo	D	W	5	111-115
	23.7.13	0003	Short-beaked Echidna	D	E	5	116-120
	24.7.13	0513	Long-nosed Potoroo	D	W	5	121-125
	24.7.13	1605	Short-beaked Echidna	D	E	5	126-130
	24.7.13	1836	Long-nosed Potoroo	D	W	5	131-135

Culvert Location	Date	Time 24h	Species	Accuracy	Movement & Direction	No. Active Images	Image No.'s
John's Rv	28.7.13	2040	Short-beaked Echidna	D	W	5	141-45
	29.7.13	1526	Short-beaked Echidna	D	E	10	146-155
	1.8.13	2022	Short-beaked Echidna	D	W	3	156-159
	3.8.13	1024	Short-beaked Echidna	D	E	10	161-170
	5.8.13	1423	Short-beaked Echidna	D	W,TA,E	15	171-85
	7.8.13	1938	Bandicoot sp	D	E	5	011-015
	7.8.13	1953	Long-nosed Bandicoot	D	E,stop	5	016-20
	9.8.13	1329	Short-beaked Echidna	D	W	6	021-26
	9.8.13	1428	Short-beaked Echidna	D	E	5	31-35
	11.8.13	1929	Short-beaked Echidna	D	E	5	36-40
	17.8.13	1838	Short-beaked Echidna	D	E	5	41-45
	18.8.13	1309	Short-beaked Echidna	D	W	10	46-55
	19.8.13	1847	Short-beaked Echidna	D	E	5	56-60
	20.8.13	0010	Short-beaked Echidna	D	W	5	61-65
	23.8.13	0952	Short-beaked Echidna	D	E	10	66-75
	23.8.13	0039	Short-beaked Echidna	D	W,TA,W	40	76-115
	25.8.13	0459	Swamp Wallaby	Pr	W	5	116-120
	25.8.13	0845	Swamp Wallaby	Pr	E	5	121-125
	26.8.13	1511	Short-beaked Echidna	D	W	10	126-135
	27.8.13	1526	Short-beaked Echidna	D	E	5	136-140
	29.8.13	1903	Long-nosed Bandicoot	D	W,stop	5	141-145
	29.8.13	2047	Long-nosed Bandicoot	D	W	10	146-155
	30.8.13	0052	Bandicoot sp	D	E	5	156-160
	30.8.13	1555	Short-beaked Echidna	D	W	5	161-165
	30.8.13	1900	Long-nosed Bandicoot	D	W	5	166-170

Culvert Location	Date	Time 24h	Species	Accuracy	Movement & Direction	No. Active Images	Image No.'s
John's Rv	30.8.13	2155	Short-beaked Echidna	D	E	5	176-180
	1.9.13	1955	Short-beaked Echidna	D	E	5	181-185
	1.9.13	2019	Bandicoot sp	D	E,TA,W	5	186-195
	3.9.13	1800	Bandicoot sp	D	E	5	196-200
	3.9.13	2046	Bandicoot sp	D	W	5	206-210
			Data lost				
	15.11.13	1846	Red Fox	D	W	2	6-7
	16.11.13	2027	Red Fox	D	W	3	11-13
	17.11.13	1635	Short-beaked Echidna	D	E	5	16-20
	21.11.13	538	Red Fox	Pr	E	5	21-25
	26.11.13	1735	Red Fox	Pr	W	1	26
	27.11.13	0213	Short-beaked Echidna	D	E	5	36-40
	4.12.13	0355	Short-beaked Echidna	D	E	5	41-45
	4.12.13	2024	Bandicoot sp	D	E	5	46-50
	8.12.13	2119	Short-beaked Echidna	D	W	5	51-55
	11.12.13	0615	Red Fox	D	E	5	56-60
	13.12.13	2118	Bandicoot sp	D	E	4	61-64
	15.12.13	1907	Short-beaked Echidna	D	E	5	66-70
	20.12.13	1930	Bandicoot sp	D	E	4	71-74
	22.12.13	0305	Bandicoot sp	D	E	5	76-80
	23.12.13	2119	Bandicoot sp	D	E	5	81-85
	25.12.13	0427	Short-beaked Echidna	D	E	5	86-90
	29.12.13	1848	Red Fox	D	E	5	91-95
	31.12.13	1344	Short-beaked Echidna	D	E	10	96-105
	5.1.14	217	Short-beaked Echidna	D	E	5	106-110

Culvert Location	Date	Time 24h	Species	Accuracy	Movement & Direction	No. Active Images	Image No.'s
Moor_Nth	21.3.13	2044	Brushtail Possum sp	D	E	3	011-013
	22.3.13	2109	Brushtail Possum sp	D	W	1	o16
	22.3.13	2117	Brushtail Possum sp	D	E	2	021-022
	23.3.13	2137	Brushtail Possum sp	D	E	4	026-029
	24.3.13	0019	Red Fox	D	W&TA	5	031-035
	9.4.13	0830	Microbats	D	Roost	610	036-545
	9.4.13	1733	Microbats	D	Roost	55	546-600
	12.4.13	1958	Microbats	D	Roost	55	601-655
	13.4.13	0609	Microbats	D	Roost	1690	656-2345
	4.5.13	0142	Red Fox	D	E	2	2346-47
	5.5.13	0447	Red Fox	D	W&TA	5	2351-55
	10.5.13	0534	Red Fox	D	W&TA	5	2356-60
	1.6.13	0219	Microbats	D	FLY	1	27
	9.6.13	2200	Microbats	D	FLY	1	O34
	15.7.13	0033	Red Fox	D	W	1	O36
	21.7.13	0423	Red Fox	D	W	1	O41
	21.7.13	0602	Dog	D	W	5	O46-52
	21.7.13	0615	Dog	D	E	3	056-58
	20.8.13	0629	Dog	D	W,TA,E	10	16-25
	3.9.13	1321	Red Fox	D	ndm	5	31-35
	5.9.13	0327	Red Fox	D	E	2	36-37
	5.9.13	0607	Red Fox	D	W	2	41-42
	8.9.13	0241	Red Fox	Po	E	1	46
	9.9.13	0458	Red Fox	D	E	5	51-55
	10.9.13	1831	Red Fox	D	W	3	56-58

Culvert Location	Date	Time 24h	Species	Accuracy	Movement & Direction	No. Active Images	Image No.'s
Moor_Nth	11.9.13	0216	Red Fox	D	W	3	61-63
	11.9.13	2148	Red Fox	D	W	2	66-67
	12.9.13	0450	Red Fox	D	E	1	71
	13.9.13	0428	Red Fox	D	E	2	76-77
	13.9.13	1815	Red Fox	D	W	2	81-82
	14.9.13	1959	Red Fox	D	W	3	86-88
	14.9.13	2246	Red Fox	D	E	2	91-92
	14.9.13	2313	Red Fox	D	W	2	96-97
	15.9.13	1805	Red Fox	D	W	2	101-102
	16.9.13	2246	Red Fox	D	W	1	106
	16.9.13	2329	Red Fox	D	E	2	111-112
	20.9.13	0054	Red Fox	D	E	1	121
	20.9.13	2115	Red Fox	D	E	2	126-127
	22.9.13	1841	Red Fox	D	W	2	136-137
	25.9.13	0029	Red Fox	D	E	2	141-142
	25.9.13	1829	Red Fox	D	W	2	146-147
	26.9.13	0236	Red Fox	D	E	2	151-152
	26.9.13	0443	Red Fox	D	E	2	156-157
	26.9.13	1844	Red Fox	D	W	2	161-162
	27.9.13	0503	Red Fox	D	E	1	166
	29.9.13	0503	Red Fox	D	E	1	171
	30.9.13	1911	Red Fox	D	W	2	176-177
	2.10.13	2052	Red Fox	D	W	1	181
	3.10.13	1839	Red Fox	D	W	1	186
	5.10.13	1917	Red Fox	D	W	1	191

Culvert Location	Date	Time 24h	Species	Accuracy	Movement & Direction	No. Active Images	Image No.'s
Moor_Nth	5.10.13	1917	Red Fox	D	W	1	196
	8.10.13	1523	Red Fox	D	E	1	201
	6.10.13	1834	Red Fox	D	W	1	206
	6.10.13	2017	Red Fox	D	W	2	211-212
	10.10.13	1917	Red Fox	D	W	3	221-223
	11.10.13	0426	Red Fox	D	E	3	226-28
	11.10.13	0631	Red Fox	D	W	1	231
	11.10.13	2316	Red Fox	D	E	2	236-37
	13.10.13	1903	Red Fox	D	W	1	241
	16.10.13	0155	Red Fox	D	E	1	246
	17.10.13	1902	Red Fox	D	W	2	261-62
	17.10.13	1933	Red Fox	D	W	2	266-67
	20.10.13	1953	Bandicoot spp	D	W	1	271
	22.10.13	0457	Red Fox	D	E	3	276-78
	23.10.13	0306	Red Fox	D	E	1	281
	23.10.13	2119	Red Fox	D	W	3	286-88
	26.10.13	0749	Dog	D	W	2	291-92
	28.10.13	0315	Red Fox	D	E	4	296-99
	28.10.13	2134	Red Fox	D	W	2	301-02
	28.10.13	2306	Red Fox	D	E	1	306
	2.11.13	1854	Red Fox	D	W	1	311
	8.11.13	1856	Red Fox	D	W	1	316
	14.11.13	0140	Hare	Pr	W	2	326-27
	3.12.13	2047	Red Fox	D	E	1	11
	4.12.13	1313	White-faced Heron	Pr	W then E	3	16-20

Culvert Location	Date	Time 24h	Species	Accuracy	Movement & Direction	No. Active Images	Image No.'s
Moor_Nth	4.12.13	1951	Red Fox	D	W	2	21
	4.12.13	1952	Red Fox	D	E	4	26-29
	4.12.13	1954	Red Fox	D	W	2	31-32
	5.12.13	1633	Water Dragon	D	W	3	36-38
	8.12.13	1931	Red Fox	D	W	1	41
	9.12.13	2026	Red Fox	D	W	3	46-48
	10.12.13	0259	Red Fox	D	E	1	51
	21.12.13	1936	Red Fox	D	W	1	56
	22.12.13	1932	Red Fox	D	W	1	61
	22.12.13	2250	Red Fox	D	E	1	66
	3.1.14	2006	Red Fox	D	W	2	71-72
Moor_Sth	4.2.13	921	Human	D	E	3	016-18
	4.2.13	0924	Human	D	W	3	019-21
	21.3.13	2227	Brushtail Possum sp	D	E	5	051-055
	13.4.13	2054	Brushtail Possum sp	D	E	5	056-60
	14.4.13	0955	Lace Monitor	D	E	5	061-65
	14.4.13	2205	Brushtail Possum sp	D	E	5	066-70
	9.6.13	2133	Brushtail Possum sp	D	E	5	O36-40
	6.8.13	1923	Bandicoot sp	D	E	3	37-39
	7.8.13	1759	Bandicoot sp	D	W	3	40-42
	9.8.13	2007	Red Fox	D	W	3	43-45
	11.8.13	2003	Red Fox	D	E,ta,W	6	46-51
	12.8.13	2350	Red Fox	D	W,TA,E	6	52-57
	20.8.13	0701	Dog	D	W	6	58-63
	22.8.13	0033	Red Fox	D	W,TA,E	6	64-69

Culvert Location	Date	Time 24h	Species	Accuracy	Movement & Direction	No. Active Images	Image No.'s
Moor_Sth	24.8.13	0248	Red Fox	D	E,ta,W	6	70-75
	24.8.13	1847	Red Fox	D	W	3	76-78
	25.8.13	1921	Bandicoot sp	D	E	3	79-81
	27.8.13	0417	Red Fox	D	E,ta,W	6	82-87
	28.8.13	1937	Bandicoot sp	D	E	3	88-90
	1.9.13	0104	Red Fox	D	W	3	91-93
	5.9.13	0303	Bandicoot sp	Pr	W	3	41-43
	5.9.13	0337	Red Fox	D	E	5	46-50
	5.9.13	1808	Long-nosed Bandicoot	D	E	2	51-52
	5.9.13	2011	Bandicoot sp	Pr	W	2	56-57
	8.9.13	0524	Red Fox	D	W	3	61-63
	8.9.13	0634	Red Fox	D	E	5	66-70
	11.9.13	0157	Red Fox	D	W	4	71-74
	11.9.13	1400	Lace Monitor	D	E	5	76-80
	11.9.13	2133	Red Fox	D	W	5	81-85
	13.9.13	2357	Red Fox	D	W	3	86-88
	14.9.13	0009	Red Fox	D	W	4	91-94
	14.9.13	0012	Red Fox	D	E	2	96-97
	14.9.13	0013	Red Fox	D	W then E	8	101-108
	14.9.13	0029	Red Fox	D	E	4	111-115
	14.9.13	0401	Red Fox	D	W	5	116-120
	14.9.13	0504	Red Fox	D	W	5	121-125
	15.9.13	0606	Red Fox	D	W	4	126-129
	15.9.13	2338	Red Fox	D	W	4	131-134
	15.9.13	2351	Red Fox	D	E	5	136-140

Culvert Location	Date	Time 24h	Species	Accuracy	Movement & Direction	No. Active Images	Image No.'s
Moor_Sth	16.9.13	2239	Red Fox	D	W	4	141-144
	16.9.13	2333	Red Fox	D	E	3	146-149
	17.9.13	1936	Red Fox	D	W	4	151-154
	20.9.13	0824	Red Fox	D	W	3	156-158
	20.9.13	1816	Red Fox	D	E	5	161-165
	21.9.13	0533	Red Fox	D	W	2	166-167
	21.9.13	1811	Red Fox	D	E	4	171-174
	21.9.13	1857	Red Fox	D	W	4	176-179
	22.9.13	1833	Red Fox	D	W	3	181-183
	23.9.13	0035	Human	D	W	30	186-215
	25.9.13	0110	Red Fox	D	E	1	216
	7.10.13	1906	Red Fox	D	E	2	221-222
	12.10.13	0022	Bandicoot sp	Pr	W	3	226-228
	19.10.13	1838	Red Fox	D	E	2	231-232
	20.10.13	2111	Bandicoot sp	D	W	2	236-237
	21.10.13	1304	Red Fox	D	W	3	246-248
	22.10.13	1900	Red Fox	D	E	2	251-252
	23.10.13	1847	Red Fox	Pr	E	1	256
	27.10.13	0506	Red Fox	D	W	3	261-263
	30.10.13	2131	Red Fox	D	W	3	266-268
	31.10.13	0556	Red Fox	D	W	2	271-272
	3.11.13	1925	Bandicoot sp	Pr	W	2	346-347
	20.11.13	2029	Long-nosed Bandicoot	D	E then W	8	6-14
	22.11.13	0152	Bandicoot sp	D	W	1	16
	28.11.13	2031	Northern-brown Bandicoot	D	E then W	6	21-30

Culvert Location	Date	Time 24h	Species	Accuracy	Movement & Direction	No. Active Images	Image No.'s
Moor_Sth	28.11.13	2032	Northern-brown Bandicoot	D	W	4	31-34
	8.12.13	1658	Red Fox	D	W	2	36-37
	13.12.13	2157	Red Fox	D	E	2	41-42
	17.12.13	2126	Red Fox	D	E	1	46
	20.12.13	1423	Lace Monitor	D	E	5	51-55
	10.1.14	2133	Red-necked Wallaby	Pr	W	10	56-65

Appendix F – Frog Pipe Survey Weather Conditions

Table F1: Weather data recorded during capture/recapture surveys at the Heron's Creek frog pipes (chainage 53160) along the C2HC upgrade of the Pacific Highway.

Date	Start	Finish	Temp	Humidity	Rainfall	
					Last 24 hrs	During Survey
29/1/2014	2015	2310	24	70	no	no
30/1/2014	2015	2245	23.4	69.3	no	no
24/2/2014	2020	2225	23	72	yes	no
25/2/2014	2012	2222	23	72	yes	no
4/3/2014	1930	2130	20.2	87	no	no
30/3/2014	1930	2130	21.1	92	yes	no
31/3/2014	1930	2130	22.2	75	no	yes
6/4/2014	1845	2015	20	88	yes	yes