



Metropolitan Coal Longwalls 23-27

Spring/Summer 2018 Amphibian Survey

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1 INTRODUCTION

Metropolitan Coal is wholly owned by Peabody Energy Australia Pty Ltd. Metropolitan Coal was granted approval for the Metropolitan Coal Project (the Project) under Section 75J of the New South Wales (NSW) *Environmental Planning and Assessment Act, 1979* (EP&A Act) on 22 June 2009.

The Project comprises continuation, upgrade and extension of underground coal mining operations and surface facilities at the existing Metropolitan Coal mine. Longwalls 20-22 define the first secondary extraction mining sub-domain within the Approved Project underground mining area (Figure 1). Mining of Longwall 20 commenced in May 2010 and mining of Longwall 22 was completed in April 2014. Longwalls 23-27 defined the next series of longwall panels mined at Metropolitan Coal (Figure 1).

An amphibian monitoring program was developed to obtain data for Longwalls 23-27 as a component of the *Metropolitan Coal Longwalls 23-27 Biodiversity Management Plan* (Metropolitan Coal, 2015). Consistent with the amphibian monitoring program for 20-22, the Longwalls 23-27 monitoring program has been developed to monitor amphibian species, with a focus on habitats of the Giant Burrowing Frog (*Heleioporus australiacus*) and Red-crowned Toadlet (*Pseudophryne australis*) associated with tributaries.

Mining of Longwall 23 commenced in May 2014 and was completed in March 2015. Longwall 24 extraction commenced in April 2015 and was completed in September 2015. Longwall 25 extraction commenced in October 2015 and was completed in April 2016. Longwall 26 extraction commenced in May 2016 and was completed in August 2016. Longwall 27 extraction commenced in September 2016 and was completed in March 2017. Test sites 13 – 17 had been undermined at the time of this 2018 spring/survey. Hence, prior to undermining of test sites, there had been four years of baseline surveys carried out (See Appendix 1). The time elapsed since undermining of a particular site varies from 2-4 years.

The first baseline survey for Longwalls 23-27 was undertaken in spring/summer 2010 utilising 10 sites (five test sites above Longwalls 23-27 and five control sites). Sites monitored as a component of the Longwalls 20-22 amphibian monitoring program, continue to be monitored in conjunction with the Longwalls 23-27 monitoring program, using the same methodology, sampling parameters and at the same sampling frequency¹. Four baseline surveys have been undertaken for Longwalls 23-27 (2010-2013).

The spring–summer 2018 survey is the ninth amphibian survey, and the fifth survey carried out since the commencement of mining of Longwall 23 in May 2014.

Monitoring continues in accordance with the Metropolitan Coal Longwall 304 Biodiversity Management Plan (Metropolitan Coal, 2018).

¹ Note that the control sites established as a component of the Longwalls 20-22 amphibian monitoring program are being used to inform the assessment of potential impacts of Longwalls 23-27.



2 BACKGROUND - GIANT BURROWING FROG, RED-CROWNED TOADLET AND LITTLEJOHN'S TREE FROG

The Giant Burrowing Frog and Red-crowned Toadlet were recorded in the Project area and surrounds by Western Research Institute and Biosphere Environmental Consultants (2008). Both species are listed as Vulnerable under the NSW *Biodiversity Conservation Act, 2016* (BC Act). The Giant Burrowing Frog is also listed as Vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act, 1999* (EPBC Act). Littlejohn's Tree Frog is listed as Vulnerable under both the BC Act and EPBC Act. At the time of the Project Environmental Assessment, the Littlejohn's Tree Frog was reported to be common at Darkes Forest.

Giant Burrowing Frog

The northern populations of the Giant Burrowing Frog are largely confined to sandstone ridgetop habitat and broader upland valleys, where the species is associated with small headwater creek lines and slow flowing to intermittent creek lines in undisturbed areas (NPWS, 2001a). The vegetation in these areas is typically woodland, open woodland and heath, with riparian components in and along the sides of early order streams. The species may also utilise upland swamps as a component of the range of habitats it is able to exploit.

Much of the Giant Burrowing Frog's existence is spent burrowed underground sometimes beneath deep leaf-litter or in earth-filled rock crevices interspersed with brief periods of activity throughout the year during rainy weather (NPWS, 2001a). Burrows are excavated into the earth around, or associated with rocks fissures or boulders (NPWS, 2001a). It has also been reported that yabbie holes are utilised along the beds and banks of drying creeks (NPWS, 2001a). The Giant Burrowing Frog mainly breeds between mid-summer and autumn (Cogger, 2000). Males call from within or adjacent to the breeding burrows or amongst accumulated vegetation debris (NPWS, 2001a). Tadpoles develop in three to six months (NPWS, 2001a). The diet of the Giant Burrowing Frog mainly consists of invertebrates including ants, beetles, cockroaches, spiders, centipedes and scorpions (NPWS, 2001a). The Giant Burrowing Frog is thought to have a large home range; having been recorded at considerable distances from suitable moist habitat (Hoser, 1989; Gillespie, 1990). Individuals have been recorded moving up to 200-300 m in a night (NPWS, 2001a).

During targeted surveys within the Project area and surrounds, Western Research Institute and Biosphere Environmental Consultants (2008) recorded the Giant Burrowing Frog in areas where weeping joints in the upper sandstone areas had created damp sand banks and shallow ditches; sedges and plants typically associated with wet heath were prevalent at these sites.

Red-crowned Toadlet

The Red-crowned Toadlet is known only from Triassic sandstones of the Sydney Basin, being found in steep escarpment areas and plateaus, as well as low undulating ranges with benched outcroppings (NPWS, 2001b). Within these geological formations, this species mainly occupies the upper parts of ridges, usually being restricted to within about 100 m of the ridgetop (*ibid.*). The Red-crowned Toadlet may also occur on plateaus or more level rock platforms along the ridgetop, however this area is usually less preferred than the first talus slope areas below the upper escarpment or just below benched rock platforms (NPWS, 2001b).

The Red-crowned Toadlet has a unique terrestrial reproductive strategy: small nests are formed within decomposing accumulated leaf matter and clutch sizes are small, consisting of around 20-24 large eggs (NPWS, 2001b). The nests retain the eggs through the early stages of tadpole development; then rainfall events flush the embryos from the nest, and tadpoles complete development within transient pools (NPWS, 2001b). The timing of follow up rain events and duration of temporary pools is critical to reproductive success. Many clutches are lost to desiccation through evaporation of the shallow pools and therefore recruitment is usually in low numbers (NPWS, 2001b). To offset this loss, females can lay multiple clutches and breed opportunistically when appropriate conditions prevail (*ibid.*). The Red-crowned Toadlet has been recorded calling in all months of the year, including winter, and eggs have been found in all months (NPWS, 2001b).

Midwinter breeding is infrequent and likely to occur during milder weather conditions that may prevail in the coastal part of its range in some years (*ibid.*). The Red-crowned Toadlet can also be found breeding along eroded gutters or the verges of unsealed fire trails (NPWS, 2001b). In these locations, accumulations of leaf-litter in association with temporary pools mimics natural feeder creek breeding habitat (*ibid.*).

When not breeding, Red-crowned Toadlets are thought to disperse over wider areas of their sandstone habitat and many individuals have been observed sheltering under cover that would be unsuitable for egg-laying (NPWS, 2001b). However, it is likely that such 'dispersion' is only in the order of a few tens of metres from suitable breeding areas (*ibid.*). Red-crowned Toadlets forage on ants, termites, mites, pseudo-scorpions, collembolans and small cockroaches (Rose, 1974; Webb, 1983). Favoured microhabitats for shelter sites are under flat sandstone rocks ('bush-rock') either resting on bare rock or damp loamy soils (NPWS, 2001b). Red-crowned Toadlet's have also been found under logs on soil, beneath thick ground litter, particularly near large trees and in horizontal rock crevices near the ground (*ibid.*).

Red-crowned Toadlets do not usually live along permanent flowing water courses occurring in gullies, instead preferring permanently moist soaks or areas of dense ground vegetation or litter along or near headwater stream beds (NPWS, 2001b). These are the non-perennial first or second order drainage systems that are adjacent to ridges, are ephemeral in nature, and commonly called 'feeder-creeks' (*ibid.*). These drainage systems channel water from the ridges, benches, cliffs and talus slopes to the perennial streams in the gullies below. Such watercourses are dry or reduced to scattered shallow pools or ponds for much of the year, and have sustained flow for only a few weeks following thunderstorms (NPWS, 2001b). Under natural conditions these feeder creeks have high water quality and low nutrient loads.

The main vegetation communities found in association with this species are open woodland and heath communities that are typical of Hawkesbury and Narrabeen geology (NPWS, 2001b). Tree cover, when present, is usually open and low (10-20 m) and with a xeromorphic understorey (*ibid.*).

During targeted surveys within the Project area and surrounds, Western Research Institute and Biosphere Environmental Consultants (2008) recorded the Red-crowned Toadlet at several locations in eucalypt woodland and heath, typically below sandstone ridges.

Littlejohn's Tree Frog (Description provided by the NSW Scientific Committee [2000])

Littlejohn's Tree Frog, *Litoria littlejohni* is distributed along the eastern slopes of the Great Dividing Range from Watagan State Forest near Wyong, south to Buchan in north-eastern Victoria. It appears to be restricted to sandstone woodland and heath communities at mid to high altitude. It forages both in the tree canopy and on the ground, and it has been observed sheltering under rocks on high exposed ridges during summer. It is not known from coastal habitats.

Breeding in Littlejohn's Tree Frog is unusual, being mostly in autumn, but the species will also breed after heavy rainfall in spring and summer. It appears to breed in wet forest margins, which may be wet heath or ephemeral wet areas. It lays relatively few eggs.

Littlejohn's Tree Frog is known from 13 locations in New South Wales. Of these locations, six occur in conservation areas: Blue Mountains National Park, Royal National Park, Barren Grounds Nature Reserve, Morton National Park, Budawang National Park and Wadbilliga National Park.

The range of Littlejohn's Tree Frog appears to have remained constant since 1976, although the species' prevalence and abundance within its range have declined significantly. Sightings of more than 10 frogs have been recorded from only three locations (Watagan State Forest, Ourimbah State Forest and Barren Grounds Nature Reserve) and most sightings are of no more than three frogs at one time.

Factors threatening the survival of Littlejohn's Tree Frog include: limited dispersal from small populations, which increases the risk of local extinction; clearing of native vegetation and reduced habitat availability; and inappropriate fire practices (including pre- and post-logging burns and control burning) that disturb breeding habitat.

The Scientific Committee is of the opinion that Littlejohn's Tree Frog, *Litoria littlejohni*, is likely to become endangered unless the circumstances and factors threatening its survival or evolutionary development cease to operate, and is therefore eligible for listing as a vulnerable species.

3 SITE SELECTION

The underground mining area is situated on the Woronora Plateau and within the Woronora Special Area. Much of the Woronora Plateau is dominated by underlying sandstone geologies, primarily derived from the Hawkesbury and Mittagong Formations (NPWS, 2003). The prevailing vegetation is a composite of dry sclerophyllous woodlands, forests and heaths. Quaternary Sand deposits are widespread across the catchments (NPWS, 2003). The Woronora Special Area is situated within the Woronora River catchment and drains to the Woronora Reservoir.

In accordance with the *Longwalls 23-27 Biodiversity Management Plan* (Metropolitan Coal, 2015), additional amphibian survey sites have been selected for monitoring over Longwalls 23-27 (test sites) and at locations outside of the potential impact area and previously mined areas (control sites). These include five sites overlying Longwalls 23-27 (test sites) and five control sites that will not be undermined. These sites will be surveyed annually in spring/summer (i.e. October to February) under suitable weather conditions. The surveys were initially conducted in two four day sessions chosen to optimise weather conditions for amphibian sampling, the first in the October – December period and the second in the following January to February period. On a few occasions the second sampling period has had to be delayed until early April to coincide with suitable weather conditions. The length of the survey period was increased to 2 x 5 days in 2015 to accommodate the collection of baseline data from six new test sites prior to the commencement of proposed mining in Longwalls 301-303. The length of the spring/summer 2018 survey was increased to six days and nights (Section 4.1). Control sites for Longwalls 301-303 are the 11 existing control sites associated with Longwalls 20-27.

The sites used in the surveys were selected on the following basis:

- Under expected rainfall conditions in spring/summer, there would likely be sufficient surface and free water to support various amphibian species' breeding events, and facilitate the successful surveying of adult amphibians, egg masses and tadpoles.
- The test and control sites, as far as possible, to be comparable based on key habitat attributes, and previous survey experience in this area.

The approximate locations of the Longwalls 23-27 amphibian monitoring sites are shown on Figure 1 (sites 13 to 22), as well as the approximate locations of the longwalls. The location of each survey site is briefly described in Table 1.

Each sampling site has been marked with a metal stake and a UV-resistant plastic tag, and its position determined using a Global Positioning System (GPS).

Table 1: Attributes of Monitoring Sites in March 2019

Site	C/T	Northings WGS84 Easting WGS84	Approx. Elevation (m AHD)	Site Description	Undermining Status Observed impacts
13	T	N6215108 E310084	265	Creek-line, Tributary B, upstream of confluence with Waratah Rivulet, with significant in-stream and riparian habitat. March 2019: Good flow of around 0.1 ML/day reappears immediately upstream of Site 13. Series of pools within stream. Valley side vegetation in good health. Water was murky.	Site 13 undermined by Longwall 23A. Permanent loss of stream continuity immediately upstream of Site 13 with upstream flows diverted to subterranean flows that re-emerge immediately upstream of Site 13. Relatively minor Fe staining associated with re-emerging flows. No evidence of changes in riparian or valley side vegetation based on visual cues between Site 5 (Longwall 22A) and Site 13.
14	T	N6214152 E311635	272	Downstream of Tributary C crossing. In most previous surveys this stream has been running with a well-defined riffle and pool system. Woodland/gully forest vegetation is located on either side of banks. Bed is sandstone with low to nil sediments. Bank width varies from 5-10 m. Overhanging bank vegetation with some sedges present but no ferns or rushes. March 2019: 1-2 ML/day flow, creating riffle-pool sequences. Pools along reach reinstated. Where breeding pools existed along reach, these have been swept away by fresh. Iron deposits in some pools.	Site 14 undermined by Longwall 23B. Surface flow under low flow conditions has been diverted to subterranean flow along an approximately 2km stream reach commencing near Site 6 (undermined by LW 20) and for a significant distance downstream of Site 14. Has resulted in large pools at Site 14 drying up under prolonged dry periods, and many other pools along this reach, loss of stream connectivity, with periods of recovery following rainfall induced freshes and floods. Evidence of significant Fe staining and precipitation under some circumstances. No evidence of changes in riparian or valley side vegetation based on visual cues between Site 6(Longwall 20) and immediately below Site 14.
15	T	N6214650 E311267	283	Ridge-top above Longwall 24 with roadside soak. Dense sandstone heath woodland with scattered trees with roadside verges cleared. Drops off on eastern side to form a first order stream. March 2019: Under survey conditions no free water was present but the soil profile was damp.	Site 15 undermined by Longwall 24. No evidence of surface cracking. No evidence of changes in terrestrial vegetation based on visual cues.
16	T	N6214800 E311400	275	Roadside soak-line fed from rock platform with intermittent woodland-heath vegetation. March 2019: No free water was present but the soil profile was dry to damp.	Site 16 undermined by Longwall 25. No evidence of surface cracking. No evidence of changes in terrestrial vegetation based on visual cues.

Table 1: Attributes of Monitoring Sites in March 2019 (Continued)

Site	C/T	Northings WGS84 Easting WGS84	Approx. Elevation (m AHD)	Site Description	Undermining Status Observed impacts
17	T	N6215031 E311593	263	Part of an upland swamp surrounded by mallee heath. Part of this site was substantially damaged by infrastructure works clearing heath vegetation in late 2012 but significant recovery has occurred along roadside. March 2019: The site was characterised by damp soil and litter beds with no free water present.	Site 17 undermined by Longwall 26. No evidence of surface cracking. No evidence of changes in terrestrial vegetation based on visual cues.
18	C	N6214721 E306653	281	Roadside drainage associated with road gutter, crosses road to potentially form a series of small pools with significant litter. Roadside maintenance since 2016 survey but minor impact on site. March 2019: No pools were present and the surrounding ground was mostly dry.	Control No evidence of changes in terrestrial vegetation based on visual cues.
19	C	N6213105 E306937	359	Soak area feeding into first order stream along a disused track 150 m in from Darkes Forest Road. March 2019: No free water present and the ground damp. Track entrance pool dry. Evidence of some bulldozer work at this site.	Control No evidence of changes in terrestrial vegetation based on visual cues.
20	C	N6218565 E308980	227	Potential extensive roadside soak on Fire Trail 9 extending along and across track a distance of 75 m, parallel with Bee Creek. Cleared roadside verge edged by extensive mallee heath. Significant site recovery in habitat quality from 2012 roadside maintenance. March 2019: No free water and slightly soil damp and drying out.	Control No evidence of changes in terrestrial vegetation based on visual cues.
21	C	6219407	239	Potential roadside soak extending approximately 100 m along road with clumps of <i>Juncus</i> sp. present. Significant site recovery in habitat quality from 2012 roadside maintenance. March 2019: No free water and soil damp and drying out.	Control No evidence of changes in terrestrial vegetation based on visual cues.
22	C	6219927	222	Source reach of a first order stream. Cleared roadside verge edged by extensive mallee heath. Significant site recovery in habitat quality from 2012 roadside maintenance. March 2019: No free water, soil damp but drying out.	Control No evidence of changes in terrestrial vegetation based on visual cues.

4 METHODS

Each sampling site consists of an area of approximately 200 x 50 m or 1 hectare. Searches concentrate on free water areas when targeting some species and for assessing the presence or absence of tadpoles. Each survey site enables a surveyor to clearly hear frog calls across its area, when present.

Each site is surveyed once during a standard one hour general area day search (early morning and late afternoon) supplemented by an evening 60 minute search/play-back session, using hand held spotlights and head lamps.

Adults are identified by sight and call characteristics, tadpoles are identified by sight and where necessary keyed out using Anstis (2013). Handling of frogs is minimised and usually unnecessary, but when required, conducted consistent with the hygiene protocols outlined in the *Hygiene Protocols for the Control of Disease in Frogs* (NPWS, 2008). Tadpoles that cannot be immediately identified are captured using a small hand-held net and transferred to a small white enamel tray and identified.

An estimate of relative abundance of each species is recorded at each site. Species are assigned to the following categories for tadpole and adult stages. The relative abundance of tadpoles and adults is determined independently for each species otherwise large numbers of tadpoles at individual sites could skew an observation where low numbers of adults are present, which is often the case.

0 – No sightings;

1 – One sighting of adult or tadpole stage;

UC – Uncommon, 2 to 10 individuals (adult/tadpole stage);

MC – Moderately common, 11 to 20 individuals (adult/tadpole stage);

C – Common, 21 to 40 individuals (adult/tadpole stage); and

A – Abundant, >40 individuals (adult/tadpole stage).

When tadpoles were present an estimation of numbers to the nearest 'ten', 'fifty', 'hundred' or '1000' etc was determined. Adult frogs were counted by direct observation and/or by the number of calls of a particular species that could be heard across a site coming from distinct locations. Minor under-estimations of frog numbers can occur under these circumstances but this was not an issue in this survey where low numbers of adults or zero returns were recorded at all sites.

The location of threatened species was recorded using a Magellan Explorist 710 GPS. The habitat of each sample site was also photographed and described during the survey.

4.1 SURVEY TIMING AND WEATHER CONDITIONS

The 2018 spring/summer survey was carried out over six days and six nights in March 2019 (25th – 30th March). No second survey period was possible due to a lack of suitable survey conditions being unavailable as a result of the ongoing drought. The weather conditions, sunrise and sunset times and moon phases during the two survey periods are described in Table 2.

Table 2: Weather Conditions during the March 2019 Survey

Date	Temperature (°C) ¹		Rainfall (mm) Darkes Forest BOM	Moonrise Moonset	Sunrise Sunset	Comments on Day-time Conditions	Comments on Evening Conditions
	Maximum	Minimum					
25/3/2019	24.4	18.2	1.0	10.04 pm 11.09 am waning	7.01 am 7.00 pm	95% cloud cover. No rain, light intermittent breeze, warm humid	85% cloud cover, no rain, intermittent light breeze, mild
26/3/2019	25.2	14.3	1.0	10.47 pm 11.12 am waning	7.02 am 6.59 pm	Warm, cloud-free, moderate breeze, no rain	Cloud free, mild, no breeze, no rain,
27/3/2019	22.1	10.7	0	11.32 pm 1.10 pm Last quarter	7.03 am 6.57 pm	Warm, humid, cloudy, no breeze, no rain	50% cloud, no breeze, no rain, cool to mild
28/3/2019	26.7	14.4	0	1.22 am 2.04 pm Last quarter	7.03 am 6.56 pm	Warm, humid, no rain, cloudy, no rain, intermittent light breeze	10% cloud cover, no rain, light breeze, mild
29/3/2019	28.3	13.2	0	12.21am 2.54 pm Last quarter	7.04 am 6.55 pm	30-80% cloud cover, no rain, no breeze, mild	55% cloud cover, no rain, no wind, cool to mild
30/3/2019	24.0	17.4	13.6	2.06 am 4.19 pm Last quarter	7.07 am 6.53 pm	90% cloud cover, no wind, light rain, mild	Cloud free, gusting wind, no rain, cold

¹Holsworthy Defence

The mean yearly rainfall at Darkes Forest (Table 3) indicates that yearly rainfall was relatively stable, in the period 2008 - 2015, mostly within the range of $\pm 20\%$ of the mean. Years 2016-2018 have been the driest years since the commencement of this study in 2008, with mean rainfall decreasing throughout that period. However monthly rainfall can vary markedly from monthly means. The red highlighted monthly rainfalls are significantly below monthly long-term means. The period 2016 - March 2019 has experienced 20 out of 27 months with significantly less rainfall than long term means.

Table 4 provides the rainfall data available from three Metropolitan Coal gauges, comparing rainfall at those locations with data available from the Darkes Forest BOM rain gauge over the same period. Metropolitan Coal rain gauges for PV5 and PV6 for the period 2011- 2017 were generally less than the BOM Darkes Forest rainfall, but as great or greater in 2018. PV7 's recorded rainfall was less than the BOM Darkes Forest gauge from 2011 – 2013 but higher for the period 2015 – 2018. In 2019 the rainfall recorded at PV5 – PV7 in January and February, was significantly lower than recorded at the Darkes Forest BOM. Rainfall across the Woronora Plateau appears to be relatively evenly spread over the catchment. The data indicate that in the period 2016 – February 2019 the Woronora Plateau was experiencing drought conditions even though some outlier months with above-average rainfall pushed up annual means

Table 3: Monthly Rainfall (mm) Recorded at Darkes Forest 2008- March 2019

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2008	114.8	279.2	61.6	165.0	5.6	204.8	83.2	47.4	117.4	69.8	64.0	85.8	1298.6
2009	57.6	271.4	62.4	264.0	180.8	96.6	72.8	5.4	30.6	174.2	69.6	80.2	1365.6
2010	41.6	253.4	162.0	30.6	173.4	181.8	73.6	46.8	183.2	143.2	156.2	137.8	1583.6
2011	48.6	26.2	312.4	182.0	133.6	199.4	252.4	89.8	85.6	116.0	183.8	81.2	1711.0
2012	242.2	272.4	285.8	111.0	14.6	165.8	62.2	10.6	24.6	71.4	67.4	32.6	1360.6
2013	187.0	241.0	79.4	137.6	167.4	363.2	16.0	9.0	12.6	16.2	329.4	69.4	1747.8
2014	52.4	NA	NA	NA	NA	NA	12.8	NA	NA	NA	NA	NA	NA
2015	133.2	116.4	34.8	436	122.6	72.2	58.8	95.6	51.6	33.6	110.2	70.6	1335.6
2016	220.6	47.4	79.2	52.2	14.0	410.4	106.0	104.8	54.6	11.6	33.2	52.0	1186.0
2017	72.2	171.8	406.4	69.2	18.8	157.2	0.4	27.4	0.8	39.4	61.2	51.6	1076.4
2018 ³	12.0	16.6	45.0	21.6	8.0	91.8	0.4	15.8	41.8	200.8	127.8	91.0	688.4
2019	55.4	54.2	201.2										-
Long Term Mean ²	131.8	158.7	154.3	126.1	128.1	145.8	96.0	88.9	77.2	91.9	105.4	103.8	1423.3

¹ Bureau of Meteorology Station Number 68024 established in 1894. The red highlighted monthly rainfall data is for months where rainfall received is significantly lower than the long-term monthly means.

² Each monthly long-term mean is calculated using all data obtained since the commencement of monitoring at Station 68024.

NA = data not available

Table 4: Yearly Rainfall (mm) at Metropolitan Coal Gauges 2010 – March 2019
(brackets contain percent of Darkes Forest BOM Gauge in same period where available)

Site No.	Year									
	2010 (1/7 - 31/12)	2011	2012	2013	2014 ²	2015	2016	2017	2018	2019 (30/3)
PV5	460	1130 (66.0%)	945 (69.5%)	1210 (69.3%)	951	1225 (84.2%)	1098 (92.6%)	860 (79.9%)	700 (101.7%)	140 (45.0%)
PV6	610	1120 (65.5%)	990 (72.8%)	1300 (74.4%)	952	1160 (86.9%)	1200 (101.2%)	975 (90.6%)	808 (117.4%)	228 (73.3%)
PV7	595	1575 (92.1%)	1175 (86.4%)	1670 (95.6%)	1137	1490 (111.6%)	1385 (116.8%)	1163 (108.1%)	966 (140.3%)	150 (48.2)

¹ 2010 was the year rainfall gauges were installed at Metropolitan Coal Sites.

² Rainfall data were not available from the Darkes Forest BOM (Table 3) for most months in 2014.

5 SURVEY SITES AND HABITAT DESCRIPTIONS

Survey sites are briefly described in Table 1 and their locations shown on Figure 1. Habitat descriptions are provided below.

Site disturbance

The track component of three control sites were significantly disturbed by fire trail works conducted by the Sydney Catchment Authority sometime prior to the spring/summer 2012 survey (Sites 20, 21 and 22). A fourth site (17), a test site, was damaged by clearing of half of the survey site associated with infrastructure works conducted on behalf of Metropolitan Coal prior to the spring/summer 2012 survey. The nature of the disturbance events at each impacted site are described in the Spring/Summer 2012 Amphibian Survey Report. Significant habitat recovery of damaged sites has occurred in the intervening years.

Test Sites

Five test sites (13-17) are located above Longwalls 23-27. (See Figure 1)

Site 13

This site is situated in the lower reach of Tributary B with significant in-stream and riparian habitat. Boulders of varying sizes are located along the stream. The rocky platform formations are not continuous but common features of this stream and where visible, are 2 – 5 m wide. It is a bedrock stream with a series of pools and riffles with a slope of around 5 degrees. The bedrock is overlain by unstable sand deposits in sections up to 50 cm deep that is the likely result of both stream erosion and deposition processes. Habitat is further enhanced with numerous boulders and smaller rocks as well as many rock fissures. A significant amount of vegetation debris is present throughout the stream. The stream is contained within a valley dominated by Woodland/Gully Forest vegetation.

Fallen trees provide additional habitat spaces both on valley sides and within the creek line. All phases of the life cycle of various frog species could potentially be supported within this habitat under appropriate conditions.

In the 2014 survey it was observed that water flow upstream of this site had changed, appearing to flow underground, reappearing about 50 m upstream of Site 13.

In March 2019, a flow of around 0.1 M/day was recorded at Site 13, re-emerging immediately upstream of Site 13. There were a series of pools within the stream. Pools were milky in colour. The bankside soil was dry. Valley side vegetation was observed to be in good health.

Site 14

This site is situated in the mid reaches of the Eastern Tributary and downstream of site 6 and the river crossing. It is a 'riffle and pool' system. Woodland/Gully Forest vegetation is located on either side of banks. The stream bed is sandstone. Bank width varies from 5-15 m. Overhanging bank vegetation is present with some sedges present but no ferns or rushes. The bedrock is overlain by unstable sand deposits in some locations up to 50 cm deep that is the likely result of stream erosion and deposition processes. Habitat is further enhanced with numerous boulders and smaller rocks as well as many rock fissures. In the period 2008 to 2014 under low flow conditions pools were usually less than 10 m² in area and 20-50 cm deep, often with their beds covered with vegetation debris over sand. Fringing vegetation overhung a shallow undercut bank. No stream bed cracking was observed, nor was there any evidence of poor water quality. The stream is contained within a valley dominated by Woodland/Gully Forest vegetation. Fallen trees provide additional habitat spaces on the valley sides. All phases of the life cycle of frog species could potentially be supported within this habitat under the survey conditions.

In March 2019 a 1-2 ML/day flow was observed with a riffle pool sequence present. Most pools hosting breeding events prior to this survey period, would have likely been swept away by the fresh event.

Site 15

This site is situated along a ridge-top on Fire Trail 9G above Longwall 24. This site is a roadside soak within a 5-10 m wide roadside verge. On either side of the road verge the vegetation is dense Sandstone Heath Woodland with scattered emergent trees present. The site drops off on the eastern side of the fire trail to eventually form a first order stream. All phases of the life cycle of frog species could potentially be supported within this habitat under some conditions.

In March 2019 under the survey conditions no free water was present but the soil profile was dry to damp.

Site 16

This site is accessed by Fire Trail 9G and is more-or-less halfway between sites 15 and 17. The site is a roadside soak that under wet conditions overflows to an adjacent fire-cracked rock platform with intermittent woodland heath vegetation. All phases of the life cycle of frog species could potentially be supported within this habitat under some conditions.

In March 2019 no free water was present and the soil profile was dry to damp.

Site 17

This site is located about 200 m west of site 16 along Fire Trail 9G above Longwall 26 and is surrounded by mallee heath. The site is in the uppermost reach of a first order stream that flows into a southern arm of the Woronora Reservoir. This section of the mallee heath is dominated by a dense shrub understorey with some emergent trees present. All phases of the life cycle of frog species could potentially be supported within this habitat under some conditions. Part of this site was substantially damaged by infrastructure works clearing heath vegetation in late 2012, as described in the spring/summer 2012 survey report.

In March 2019, the site was characterised by dry to damp soil and litter beds with no free water present.

Control Sites

Five control sites (18-22) are located in areas that have not been undermined and are described below.

Site 18

This site is accessed along Darkes Forest Road and is about 350 m south-east of the Woronora River crossing. Roadside drainage is via a road gutter that crosses the road that under some conditions enables a series of small pools to form. Significant litter is present. All phases of the life cycle of frog species could potentially be supported within this habitat under a range of conditions.

In March 2019, there were no pools present or ground flow, and the surrounding ground was dry to damp. Some recent bulldozer damage was observed in the centre of track.

Site 19

This site is located off Darkes Forest Road along a disused track 150 m in from Darkes Forest Road. It is a soak area feeding into a first order stream in the headwaters of a swamp area. The disused track is badly eroding in parts and surrounded by dense upland swamp vegetation with a few emergent trees. All phases of the life cycle of frog species could potentially be supported within this habitat under a range of conditions.

In March 2019, no free water was present and the ground dry to damp. The track entrance pool was dry.

Site 20

This site is accessed along the northern section of Fire Trail 9. It is located east of Bee Creek swamp that runs parallel with the fire trail. This site consists of an extensive roadside soak along and across Fire Trail 9 about 75 m in length. Clumps of *Juncus* sp. are present indicating that the site remains damp after pools dry out. The roadside is a cleared verge, edged by extensive mallee heath vegetation. All phases of the life cycle of frog species could potentially be supported within this habitat under a range of conditions. The track component only of this site was damaged by track work in late 2012 and judged to be 60% degraded, and less likely to sustain a breeding event under appropriate condition. However, the habitat of the site has now significantly recovered to near pre-impact values.

In March 2019 there was no free-standing water and the soil was damp and/or drying out.

Site 21

This site is accessed along the northern section of Fire Trail 9. It is located east of Bee Creek swamp that runs parallel with the fire trail. This site under appropriate conditions consists of an extensive roadside soak extending along and across the fire trail for a distance of 100 m. Clumps of *Juncus* sp. are present indicating that the site remains damp after pools dry out. The roadside is a cleared verge, edged by extensive mallee heath vegetation. All phases of the life cycle of frog species could potentially be supported within this habitat under a range of conditions.

The track component only of this site was damaged by track work in 2012 judged to be 25% degraded, and therefore less likely to sustain a breeding event under appropriate condition. However by 2015 the site had recovered substantially to near pre-impact habitat values.

In March 2019, there was no free-standing water and the soil was dry to damp.

Site 22

This site is accessed along the northern section of Fire Trail 9. It is located east of Bee Creek swamp that runs parallel with the fire trail. This site is the source reach of a first order stream that feeds into Bee Creek. The roadside is a cleared verge edged by extensive mallee heath vegetation. All phases of the life cycle of frog species could potentially be supported within this habitat under a range of conditions.

The track component only of this Site was damaged by track work in 2012 and judged to be 60% degraded, and therefore less likely to sustain a breeding event under appropriate condition. However, the site had substantially recovered in 2015 to near pre-impact conditions.

In March 2019 there were no free-standing water and the soil damp but drying out.

6 RESULTS AND DISCUSSION

The results of the nine surveys to date are summarised in Tables 5 and 6. Table 7 summarises the frequency of amphibian breeding events observed in the period 2010 to 2018.

A total of six species were located in the 2018 survey, five in test and three in control sites, being representatives from the two families Myobatrachidae and Hylidae. For each species at each site, the estimated number of adult and tadpoles located are presented together with the relative abundance category for both tadpole and adult observations. Species diversity at each site is also presented in Table 5.

One species predicted to be present and located in baseline studies (Biosphere Environmental Consultants, 2007; Cenwest Environmental Services, 2009; and Western Research Institute and Biosphere Environmental Consultants, 2008), but not located in the nine spring/summer surveys to date (2010 – 2018), was the Stony Creek Frog. The Green Stream Frog not located in the previous eight surveys was located for the first time in 2018 - one adult at Site 13 and one breeding event at Site 14. Both the Brown-striped Frog (2 tadpoles at site 14) and the Broad-palmed Frog (1 adult at site 13) were located for the first time during the 2015 surveys.

Littlejohn's Tree Frog was observed for the first time in 2017 as an adult at site 18 and again in 2018 at Site 21.

Six species have only been located in one of the seven survey years: The threatened Giant Burrowing Frog (2010), the Spotted Grass Frog (2012), the Bleating Tree Frog (2010), Smooth Toadlet (2011), and the Broad-palmed Frog (2015). Only one species has been located in each of the survey years: the Common Eastern Froglet.

Species diversity across individual sites varied from 0 to 4 (Table 5). No frog species was located at every site in 2018, as an adult, sub-adult or tadpole. Four species, the Common Eastern Froglet (site 14), the Southern Rocket Frog (site 14), Peron's Tree Frog (site 14) and Green Stream Frog (site 14) were observed breeding in 2018. The most species-diverse sites with four species present was site 14, followed by sites 13, 16, 21 and 22 each with two species present, and sites 15, 17, 18 and 20, with zero species observed.

The species diversity recorded across the survey area has varied over the nine survey years between three to eight species. Species diversity across test sites in the same period has varied from two to seven species, and in control sites from two to six species.

Species recorded at test sites but not located at control sites during the nine surveys included Spotted Grass Frog, Broad-palmed Frog, Lesueur's Frog and the Green Stream Frog. Species absent in test sites but recorded in control sites were the Smooth Toadlet, the Bleating Tree Frog and Littlejohn's Tree Frog. Frogs that have been recorded in both test and control sites included the Common Eastern Froglet, the Red-crowned Toadlet, the Blue Mountains Tree Frog, the Southern Rocket Frog and Peron's Tree Frog

Frogs not observed in this survey year (2018) but present in one or more of the preceding years 2010 - 2016, included the Giant Burrowing Frog, the Spotted Grass Frog, the Smooth Toadlet, the Bleating Tree Frog, the Blue Mountains Tree Frog, the Broad-palmed Frog and Lesueur's Frog.

The most widespread frog was the Common Eastern Froglet recorded at three test and three control sites in 2018. All other frogs located in this survey were patchily distributed. The number of sites used by each species from 2010 to 2018 is presented in Table 6.

Of the three threatened species known to be present in this domain, the Giant Burrowing Frog was absent in 2018. The Red-crowned Toadlet and Littlejohn's Tree Frog were both present in 2018.

Four species (Common Eastern Froglet, the Southern Rocket Frog, Peron's Tree Frog and the Green Stream Frog), were found breeding in 2018, all at Test site 14.

The number of sites used by species in the period 2010 - 2018 is provided in Table 6. Amphibians were located at 88 Test sites over nine years (11/15 spp) and 71 Control sites (9/15 spp).

At Test sites, 24 breeding events have been observed between 2009 – 2018 (9/15 species) and 18 breeding events in Control sites (6/15 species) (Table 7).

Table 5: Amphibian Species Diversity and Abundance for Longwalls 23-27, Spring/Summer 2010 – 2018

Scientific Name	Common Name	Survey	Sites Above Longwalls 23-27 (Test)					Control Sites					Total		Relative Abundance ²	
			13	14	15	16	17	18	19	20	21	22	Test	Control	Test	Control
Myobatrachidae																
Crinia signifera	Common Eastern Froglet	2010	2 ¹ 0	3 0	0 6	0 0	1 0	9 c100	2 0	2 0	1 c100	3 75	6 6	17 c275	UC 0	MC A
		2011	0 0	11 4	0 0	3 0	6 0	1 0	21 0	1 0	0 2	2 15	21 4	25 17	MC UC	MC MC
		2012	5 0	2 0	2 0	0 0	1 0	10 0	0 0	5 0	11 10	5 0	10 0	31 10	UC 0	C UC
		2013	13 0	1 10	1 0	0 0	0 0	3 0	1 0	0 0	3 0	1 0	15 10	5 0	C UC	UC 0
		2014	5 0	3 135	10 0	14 0	10 0	19 0	2 0	20 0	10 0	25 0	42 135	76 0	A A	A 0
		2015	6 0	11 0	4 3	1 0	1 0	2 0	1 0	5 0	2 0	2 0	23 3	12 0	C UC	MC 0
		2016	17 0	12 0	5 0	1 0	2 0	6 150	0 0	2 1050	7 200	3 300	37 0	18 1700	A 0	MC A
		2017	3 0	2 40	0 0	0 0	0 0	2 0	0 0	1 0	0 0	0 0	5 40	3 0	UC A	UC 0
		2018	1 0	1 10	0 0	2 0	0 0	0 0	1 0	0 0	4 0	4 0	4 10	9 0	UC UC	UC 0
Heleioporus australiacus	Giant Burrowing Frog ^{v,v}	2010	1 0	0 0	1 0	0 0	0 0	1 0	0 0	0 0	0 0	1 0	2 0	2 0	UC 0	UC 0
		2011	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2012	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2013	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2014	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2015	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2016	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2017	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2018	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0

Table 5: Amphibian Species Diversity and Abundance for Longwalls 23-27, Spring/Summer 2010 – 2018 (continued)

Scientific Name	Common Name	Survey	Sites Above Longwalls 23-27 (Test)					Control Sites					Total		Relative Abundance ²		
			13	14	15	16	17	18	19	20	21	22	Test	Control	Test	Control	
Myobatrachidae																	
Limnodynastes peronii	Brown-striped Frog	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	2	0	0	0	0	0	0	0	0	0	2	0	UC	0		
2016	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Limnodynastes tasmaniensis	Spotted Grass Frog	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	1	0	0	0	0	0	0	1	0	1	0	0
		2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Table 5: Amphibian Species Diversity and Abundance for Longwalls 23-27, Spring/Summer 2010 – 2018 (continued)

Scientific Name	Common Name	Survey	Sites Above Longwalls 23-27 (Test)					Control Sites					Total		Relative Abundance ²	
			13	14	15	16	17	18	19	20	21	22	Test	Control	Test	Control
Myobatrachidae																
<i>Pseudophryne australis</i>	Red-crowned Toadlet ^v	2010	2 3	2 0	1 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	5 3	0 0	UC UC	0 0
		2011	2 0	3 0	0 0	0 0	1 0	0 0	0 0	0 0	0 0	2 7	6 0	2 7	UC 0	UC UC
		2012	0 0	0 0	0 0	0 0	0 0	1 0	0 0	1 0	1 0	4 0	0 0	7 0	0 0	UC 0
		2013	1 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	2 0	1 0	2 0	1 0	UC 0
		2014	1 0	0 0	2 0	0 0	0 0	6 0	0 0	1 0	5 0	5 0	3 0	17 0	UC 0	MC 0
		2015	1 0	0 0	0 0	0 0	0 0	3 0	0 0	1 0	0 0	6 0	1 0	10 0	1 0	UC 0
		2016	0 0	1 0	0 0	0 0	0 0	0 0	0 0	5 0	3 0	3 0	1 0	11 0	1 0	MC 0
		2017	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2018	0 0	0 0	0 0	1 0	0 0	0 0	0 0	0 0	0 0	3 0	1 0	3 0	1 0	UC 0
<i>Uperoleia laevis</i>	Smooth Toadlet	2010	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2011	0 0	0 0	0 0	0 0	0 0	0 0	2 8	0 0	0 0	0 1	0 0	2 9	0 0	UC UC
		2012	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2013	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2014	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2015	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2016	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2017	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2018	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0

Table 5: Amphibian Species Diversity and Abundance for Longwalls 23-27, Spring/Summer 2010 – 2018 (continued)

Scientific Name	Common Name	Survey	Sites Above Longwalls 23-27 (Test)					Control Sites					Total		Relative Abundance ²	
			13	14	15	16	17	18	19	20	21	22	Test	Control	Test	Control
Hylidae																
Litoria citropa	Blue Mountains Tree Frog	2010	0 0	0 0	2 0	0 0	0 0	2 0	0 0	0 0	0 0	0 0	2 0	2 0	UC 0	UC 0
		2011	3 0	0 0	0 0	0 0	0 0	0 0	2 8	0 0	0 0	0 5	3 0	0 5	UC 0	0 UC
		2012	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2013	2 0	0 43	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	2 43	0 0	UC C	0 0
		2014	6 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	6 0	0 0	UC 0	0 0
		2015	5 0	1 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	6 0	0 0	UC 0	0 0
		2016	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2017	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2018	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		Litoria dentata	Bleating Tree Frog	2010	0 0	0 0	0 0	0 0	0 0	1 24	0 0	0 0	0 0	0 0	0 0	1 24
2011	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2012	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2013	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2014	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2015	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2916	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2017	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2018	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0

Table 5: Amphibian Species Diversity and Abundance for Longwalls 23-27, Spring/Summer 2010 – 2018 (continued)

Scientific Name	Common Name	Survey	Sites Above Longwalls 23-27 (Test)					Control Sites					Total		Relative Abundance ²	
			13	14	15	16	17	18	19	20	21	22	Test	Control	Test	Control
Hylidae																
<i>Litoria freycineti</i>	Southern Rocket Frog	2010	2 4	1 3	1 6	0 0	0 0	0 0	0 0	3 7	2 50	2 0	4 13	7 57	UC MC	UC A
		2011	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2012	0 0	0 7	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 7	0 0	0 UC	0 0
		2013	2 0	0 0	0 0	0 0	1 0	0 0	0 0	0 0	0 0	0 0	3 0	0 0	UC 0	0 0
		2014	9 0	2 c100	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	11 100	0 0	MC A	0 0
		2015	1 0	2 8	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	3 8	0 0	UC UC	0 0
		2016	5 0	0 0	0 0	1 0	0 0	0 20	0 0	0 0	0 0	0 20	6 0	0 60	U 0	0 A
		2017	0 0	1 3	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	1 3	0 0	1 UC	0 0
		2018	0 0	0 10	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 10	0 0	0 UC	0 0
		<i>Litoria latopalmata</i>	Broad-palmed Frog	2010	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2011	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2012	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2013	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2014	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2015	1 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	1 0	0 0	1 0	0 0
2016	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2017	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2018	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0

Table 5: Amphibian Species Diversity and Abundance for Longwalls 23-27, Spring/Summer 2010 – 2018 (continued)

Scientific Name	Common Name	Survey	Sites Above Longwalls 23-27 (Test)					Control Sites					Total		Relative Abundance ²	
			13	14	15	16	17	18	19	20	21	22	Test	Control	Test	Control
Hylidae																
<i>Litoria lesueurii</i>	Lesueur's Frog	2010	1 0	0 0	2 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	3 0	0 0	UC 0	0 0
		2011	1 0	6 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	7 0	0 0	UC 0	0 0	
		2012	0 0	0 26	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 26	0 0	0 A	0 0	
		2013	0 0	0 5	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 5	0 0	0 UC	0 0	
		2014	0 0	1 29	0 0	0 0	0 0	0 0	0 0	0 0	0 0	1 29	0 0	1 C	0 0	
		2015	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	
		2016	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	
		2017	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	
		2018	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	
<i>Litoria wilcoxii</i>	Stony Creek Frog*	2010	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2011	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2012	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2013	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2014	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2015	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2016	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2017	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2018	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0

Table 5: Amphibian Species Diversity and Abundance for Longwalls 23-27, Spring/Summer 2010 – 2018 (continued)

Scientific Name	Common Name	Survey	Sites Above Longwalls 23-27 (Test)					Control Sites					Total		Relative Abundance ²	
			13	14	15	16	17	18	19	20	21	22	Test	Control	Test	Control
Hylidae																
<i>Litoria peronii</i>	Peron's Tree Frog	2010	0 0	0 0	0 0	0 0	1 0	0 0	2 0	0 0	0 0	0 0	1 0	2 0	UC 0	UC 0
		2011	0 0	0 0	0 0	1 0	0 0	0 0	0 0	0 0	0 0	0 0	1 0	0 0	UC 0	0 0
		2012	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2013	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2014	1 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	1 0	0 0	1 0	0 0
		2015	2 0	0 2	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	2 2	0 0	UC UC	0 0
		2016	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2017	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
		2018	0 0	0 11	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 11	0 0	0 MC	0 0
		<i>Litoria phyllochroa</i>	Green Stream Frog*	2010	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2011	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2012	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2013	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2014	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2015	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2016	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2017	0 0			0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2018	1 0			0 10	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	1 10	0 0	1 UC	0 0

Table 5: Amphibian Species Diversity and Abundance for Longwalls 23-27, Spring/Summer 2010 – 2018 (continued)

Scientific Name	Common Name	Survey	Sites Above Longwalls 23-27 (Test)					Control Sites					Total		Relative Abundance ²		
			13	14	15	16	17	18	19	20	21	22	Test	Control	Test	Control	
Hylidae																	
<i>Litoria littlejohni</i>	Littlejohn's Tree Frog ^{v,v}	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
2017	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
2018	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Table 5: Amphibian Species Diversity and Abundance for Longwalls 23-27, Spring/Summer 2010 – 2017 (continued)

	Survey	Sites Above Longwalls 23-27 (Test)					Control Sites					Total		Relative Abundance ²	
		13	14	15	16	17	18	19	20	21	22	Test	Control	Test	Control
Species Diversity at Each Site	2010	5	3	6	0	2	4	2	2	2	3				
	2011	5	4	0	2	2	2	2	2	1	5				
	2012	1	3	1	1	1	2	0	2	2	2				
	2013	4	3	1	0	1	1	1	0	1	2				
	2014	5	3	2	1	1	2	1	2	2	2				
	2015	6	5	1	1	1	2	1	2	1	2				
	2016	2	2	1	2	1	3	0	2	2	3				
	2017	1	2	0	0	0	2	0	1	0	0				
	2018 ³	2	4	0	2	0	0	1	0	2	2				
Species Diversity in all Control and all Test sites	2010											7	6		
	2011											6	5		
	2012											4	3		
	2013											5	2		
	2014											6	2		
	2015											7	2		
	2016											3	4		
	2017											2	2		
	2018 ³											5	3		
Species Diversity across the survey site	2010											8			
	2011											7			
	2012											5			
	2013											5			
	2014											6			
	2015											7			
	2016											4			
	2017											3			
	2018 ³											6			

* Species not recorded at the Longwalls 23-27 monitoring sites, but included for ease of future comparison to the Longwalls 20-22 monitoring results.

¹ First line of data refers to the presence or absence of adults, while the second line of data refers to absence or presence of tadpoles.

² Relative Abundance of adult and tadpole stage assessed independently: 0 – no sightings, 1 – One sighting, UC – Uncommon, 2 to 10 individuals, MC – Moderately common, 11 to 20 individuals, C – Common, 21 to 40 individuals, A – Abundant, >40 individuals, c1000 = approximately 1,000 animals estimated.

³ Only one survey of 5 days was carried out in 2018 rather than the normal 2 x 5 days due to lack of rain.

^{v, v} Listed as vulnerable under the BC Act and EPBC Act.

^v Listed as vulnerable under the BC Act.

Table 6: Longwalls 23-27 Number of sites used per Amphibian Species in 2010 – 2018

Species	Test Sites									Control								
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2010	2011	2012	2013	2014	2015	2016	2017	2018
Common Eastern Froglet	4	3	4	3	5	5	5	2	3	5	5	4	4	5	5	5	2	3
Giant Burrowing Frog ^v	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Brown Striped Frog	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
Spotted Grass Frog	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red-crowned Toadlet ^v	3	3	0	1	2	1	1	0	1	0	1	4	1	4	3	3	0	1
Smooth Toadlet	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Blue Mountains Tree Frog	1	1	0	2	1	2	0	0	0	1	1	0	0	0	0	0	0	0
Bleating Tree Frog	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Southern Rocket Frog	3	0	1	2	2	2	2	1	1	3	0	0	0	0	0	2	0	0
Broad-palmed Frog	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Lesueur's Frog	2	2	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Stony Creek Frog	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peron's Tree Frog	1	1	0	0	1	2	0	0	1	1	0	0	0	0	0	0	0	0
Green Stream Frog	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Littlejohn's Tree Frog	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Total sites used by all species/year	16	10	7	10	12	14	8	3	8	14	9	8	5	9	8	11	2	5
Total test and control sites	Test = 88									Control = 71								

Note: Test sites include 13 to 17 and control sites include 18 to 22 (i.e. a total of 5 test sites and 5 control sites).

^{v,v} Listed as vulnerable under the BC Act and EPBC Act. ^v Listed as vulnerable under the BC Act.

Table 7: Longwalls 23-27: Frequency of amphibian breeding events at Sites 13 - 22 observed 2010 – 2018

Species	Test Sites					Test. Events / sp	Control Sites					Control. Event / sp
	13	14	15	16	17		18	19	20	21	22	
Common Eastern Froglet	0	5	2	0	0	7	2	0	1	4	3	10
Giant Burrowing Frog	0	0	0	0	0	0	0	0	0	0	0	0
Brown-striped Frog	0	1	0	0	0	1	0	0	0	0	0	0
Spotted Grass Frog	0	0	0	1	0	1	0	0	0	0	0	0
Red-crowned Toadlet	1	0	0	0	0	1	0	0	0	0	1	1
Smooth Toadlet	0	0	0	0	0	0	0	0	0	0	1	1
Blue Mountains Tree Frog	0	1	0	0	0	1	0	1	0	0	1	2
Bleating Tree Frog	0	0	0	0	0	0	1	0	0	0	0	1
Southern Rocket Frog	1	6	1	0	0	8	1	0	0	1	1	3
Broad-palmed Frog	0	0	0	0	0	0	0	0	0	0	0	0
Lesueur's Frog	0	2	0	0	0	2	0	0	0	0	0	0
Stony Creek Frog	0	0	0	0	0	0	0	0	0	0	0	0
Peron's Tree Frog	0	2	0	0	0	2	0	0	0	0	0	0
Green Stream Frog	0	1	0	0	0	1	0	0	0	0	0	0
Littlejohn's Tree Frog	0	0	0	0	0	0	0	0	0	0	0	0
Total breeding events at each site Independent of species	2	18	3	1	0	24	4	1	1	5	7	18
Total breeding events for Test vs Control sites	24						18					
Species with no breeding event recorded in Test vs Control sites	6/15						9/15					

Asymmetric Analysis of the Amphibian Data Set 2009 – 2018, Including Longwalls 20-22, Longwalls 23-27 and Longwalls 301-307

This section of the report summarises the statistical analysis of the combined data for Longwalls 20-27 and Longwalls 301 – 303, and the additional sites 29-30 (for Longwalls 305-307) carried out post the 2018 survey by Dr Bernard Ellem for Cenwest Environmental Services, the three data sets being analysed together to increase the resolution of the analyses.

A feature of the combined data for the 2009-2018 surveys is the high numbers of zero records that dominate the data, indicating a non-normal distribution, i.e. a skewed distribution of data. This means that the results of these studies over ten years cannot be analysed by simple parametric statistics such as Chi² or analysis of variance (ANOVA).

The statistical analysis of skewed data to assess any impact of longwall mining on the amphibian population can be determined by the use of Poisson Regression, that is using a generalised linear model with Poisson errors and default logarithmic link function.

The purpose of the Poisson Regression analysis is to detect an adverse impact from mining on the amphibian assemblage at the 95% confidence level. The results are assessed against the following Biodiversity Management Plan Performance Indicator:

The amphibian assemblage at mined sites is not expected to experience changes significantly different to the amphibian assemblage at control sites.

The exceptionally dry period under which the one survey was undertaken in 2018 has greatly suppressed the number of adult frogs calling/observed as well as significantly suppressing breeding events. At the commencement of the spring-summer 2018 survey, test sites 1-6, 13-17 and 23-28 had been undermined. It is very unlikely for there to be any adverse impacts on test sites 29-30 that have not yet been undermined, and likely too early to detect such impacts on Sites 27-28 that have been only recently undermined.

Poisson regression is a generalised linear model form of regression analysis used to model count data and contingency tables. Poisson regression assumes the response variable Y has a Poisson distribution and assumes the logarithm of its expected value can be modeled by a linear combination of unknown parameters. A Poisson regression model is sometimes known as a log-linear model, especially when used to model contingency tables. Negative binomial regression is a popular generalisation of Poisson regression because it loosens the highly restrictive assumption that the variance is equal to the mean made by the Poisson model. The traditional negative binomial regression model, commonly known as NB2, is based on the Poisson-gamma mixture distribution. This model is popular because it models the Poisson heterogeneity with a gamma distribution.

Poisson regression models are generalised linear models with the logarithm as the (canonical) link function and the Poisson distribution function as the assumed probability distribution of the response.

The combined data gathered since 2009 demonstrate:

- Low numbers of adult frogs patchily distributed, including the three threatened species.
- Patchy breeding events.
- Significant variation between sites and between years in regard to the presence and absence of adult frogs and breeding events.
- A very high number of zero counts.

The following data sets have been established, and analyses carried out since 2014:

1. An excel database has been established that is updated each year, and data transformation carried out as necessary.
2. The 'power' of the experimental design has been determined (that is the ability of the experimental design to detect potential impacts of longwall mining on amphibian species, including the three threatened species).
3. Using Poisson regression, various analyses have been carried out and models tested to determine for Longwalls 20-27 and 301-307 whether or not the Performance Indicator has been met based on:
 - Yearly data and all years to date;
 - Individual species including threatened species; and
 - Tadpoles versus adult data.

4. Spatial methods (variograms and kriging²) have been used to assess the data for the presence of spatial variability over the experimental area.

The data have been demonstrated to be sparse, with zero counts at 90% (adults 85%, tadpoles 95%). Tadpoles are more variable (dispersed) than adults. Due to differences in (over) dispersion, tadpole and frog data have been modelled separately. Multi-collinearity within the dataset required that an additive (main effects) model be used for the majority of analyses.

For Longwalls 20-27 and 301-303, the experimental design has been demonstrated to be very robust at the 95% confidence level, that is the experimental design can detect whether mining could adversely impact frog species or not if mining does indeed have an effect.

The tadpole data up until and including the 2018 analysis could not be used to determine if the indicator has been exceeded due to the level of overdispersion of the tadpole data. Overdispersion in time data occurs when greater variability occurs in a data set than expected in the assumed distribution. It is very likely that at some future point in the survey program that both adult and tadpole data will be able to be used in the Poisson analysis.

The reduction of survey effort in 2018 from two to one survey period has required an offset factor to be included in the modelling process for analysis of the spring/summer 2018 data.

To date, no adverse impact from mining can be detected for Longwalls 20-27 and 301 - 303 on the amphibian assemblage of 15 amphibian species, including the Giant Burrowing Frog, the Red-crowned Toadlet and Littlejohn's Tree Frog, at the 95% confidence level. However, it cannot be discounted that a delayed adverse impact might be detected at some future date. Such potential future impacts might be due to either a lag phase in the expression of any potential impact or a more immediate future adverse impact.

The full analysis is described in Ellem (2019).

7 CONCLUSIONS

This report presents the results of the Longwalls 23-27 amphibian spring/summer 2018 survey.

Five test sites above Longwalls 23-27 had been undermined for periods ranging from two to four years at the time of the spring/summer 2018 survey (survey completed March 2019). Test sites 13 and 14 have demonstrated varying degrees of physical impact due to longwall mining including limited stream flow diversion to subterranean flows under low flow conditions, some instream rock cracking, loss of pool numbers and/or persistence under low flow conditions, and Iron – Manganese pollution.

The amphibian species distribution, diversity and abundance data appear to be consistent with expected population variations and cycles in response to seasonal variations. There are no significant differences between the test and control sites at the 95% confidence level. Thus, the Performance Indicator (*The amphibian assemblage is not expected to experience changes significantly different to the amphibian assemblage at control sites*), has not been exceeded for Longwalls 23-27.

² Kriging or Gaussian Process Regression, is a method of interpolation giving the best linear unbiased prediction of intermediate values in spatial data.

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David Goldney wrote the report.

Appendix 1: Longwalls 23-27: History of undermining at sites 13 – 17, 2010 - 2018

	Test Sites					Control Sites				
Year	13	14	15	16	17	18	19	29	21	22
2010	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline
2011	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline
2012	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline
2013	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline
2014	Undermined	Undermined	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline
2015	Undermined	Undermined	Undermined	Undermined	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline
2016	Undermined	Undermined	Undermined	Undermined	Undermined	Baseline	Baseline	Baseline	Baseline	Baseline
2017	Undermined	Undermined	Undermined	Undermined	Undermined	Baseline	Baseline	Baseline	Baseline	Baseline
2018	Undermined	Undermined	Undermined	Undermined	Undermined	Baseline	Baseline	Baseline	Baseline	Baseline