Appendix 3*

Abel Underground Coal Mine Dam Monitoring and Management Plan: 2011 Monitoring Report

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2011 Monitoring Report.

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Executive Summary

Donaldson Coal Pty Ltd commenced operating Abel Underground Coalmine at Beresfield in the lower Hunter Valley, New South Wales, during 2008. To comply with part of the conditions of consent a Flora and Fauna Management Plan was prepared (**ecobiological** 2007). This identified the need to establish a Surface Ecological Monitoring Plan (SEMP), comprising several different monitoring programs. This Dam Monitoring and Management Plan (DMMP) is one of the monitoring programs.

In 2008, baseline ecological data was recorded at 156 dams in the Abel underground mine area (**ecobiological** 2008). As well, assessment of the habitat value of dam sites for threatened fauna and flora was undertaken so that future monitoring could target dams which exhibited habitat that may potentially support target threatened species. This report builds on the baseline information collected in previous surveys regarding the occurrence of threatened and non-threatened species at the targeted dams.

Species diversity and composition data for frogs and species diversity, abundance and composition data for water-dependent bird species at each of the targeted dams were recorded for the 2011 survey. This data is then used to provide a means of measurement and evaluation of potential subsidence impacts at each of the dams over time. While mining is not currently underneath any of the dams, it is likely that within the next 12 months the operations will extend underneath some of the dams. This will provide at least five years of baseline data before potential impacts from subsidence; this is a suitable dataset by which data collected after this period can be compared against.

Frog species diversity was similar across the dams between the 2011 and 2010 surveys. In 2009, a much lower overall diversity of frog species was noted across the dams. Only a few dams recorded more species in 2009 than what was recorded in 2008. However, in 2010 and 2011 there has been an increase in frog diversity across a number of dams to levels comparable or greater than the 2008 survey results. Bird diversity increased slightly in 2011 in comparison to the 2010 results. There was a considerable decline in 2010 in comparison to the 2008 and 2009 results; however, bird diversity has rebounded slightly to a total of 13 species in 2011. The greatest increase in bird species diversity and abundance compared with the 2010 results was observed at Dam 14.

No threatened frogs or birds were identified. No individuals of the threatened plant *Maundia triglochinoides* were identified.

Monitoring will continue until one year after mining has passed the Long Gully and Blue Gum Creek catchments. The information and management recommendations from these and other surface monitoring studies will then be available to inform best practice measures to be incorporated into the Subsidence Management Plan (SMP).

In order to differentiate between possible effects of the mine from other environmental impacts on changes in the composition and abundance of frog and water bird species at the target dams, it is recommended that future surveys include a water quality, water level and condition assessment at each dam. It would be beneficial to have these water indices prior to any subsidence occurring.

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1. Introduction

Donaldson Coal Pty Ltd (Donaldson) has commenced operations at an underground mine (Abel), approximately 23 kilometres north-west of Newcastle. The mine will extract up to 4.5 million tonnes per year over 21 years using high productivity continuous miner based bord and pillar systems, and pillar extraction techniques. The seams to be mined are located under the Black Hill rural and adjoining forested areas. Mine access and associated surface infrastructure will be located within the existing Donaldson Coal mine open cut void at Beresfield, with transfer of coal to the existing Bloomfield Coal Handling and Preparation Plant (CHPP) immediately to the north for coal washing and rail transport to the Port of Newcastle.

Underground coal mining is often associated with adverse environmental impacts because of subsidence (Bell *et al.* 2000, Sidle *et al.* 2000). Subsidence can cause loss of productive land, damage to underground pipelines and above-ground structures, decreased stability of slopes and escarpments, contamination of groundwater by acid drainage and dewatering of streams and groundwater supplies (Sidle *et al.* 2000). Of these, one of the major environmental concerns arising from the Abel mine is the effect of subsidence on local and regional hydrology. Surface and sub-surface cracking associated with mining subsidence can alter and create preferential flow paths, thus causing dewatering and rerouting of surface water and groundwater (Sidle *et al.* 2000). Alterations in channel and drainage morphology may also affect channel erosion, sediment delivery, and routing in streams and riparian habitat.

Associated with development approval for the Abel coalmine were a number of conditions of consent. These conditions included a requirement for the preparation of a Flora and Fauna Management Plan (F & FMP) which was prepared by **ecobiological** (2007). The F & FMP, which forms part of a comprehensive Environmental Management System for the Abel mine, sets out a strategy to monitor the effectiveness of the conservation measures proposed in the Environmental Assessment (EA) Statement of Commitments for the overall operation of the mine.

Part of this strategy was to establish a Surface Ecological Monitoring Plan (SEMP) to monitor the effectiveness of the conservation measures proposed in the EA to mitigate against subsidence impacts on three distinct habitat areas; farm dams that form a belt across the mine site; subtropical

rainforest areas of Long Gully Creek; and Pambalong Nature Reserve. The SEMP outlines a monitoring program for each of these areas by which baseline and subsequent monitoring data are to be gathered to inform future management. This report builds upon the baseline report for the Dam Monitoring and Management Program (DMMP) which forms part of the overall SEMP.

The Dam Monitoring and Management Plan (DMMP) gathered data for 156 dams in 2008, all of which are located above the Abel underground mining area. In 2009, the number of dams identified for longer-term monitoring was reduced to 84, following assessment of their habitat suitability for the Green and Golden Bell Frog *Litoria aurea,* the Green-thighed Frog *Litoria brevipalmata,* the Blue-billed Duck *Oxyura australis* and the aquatic plant *Maundia triglochinoides.* Preferred habitat of each is detailed in **Appendix 1**.

Species diversity and composition data for frogs and species diversity, abundance and composition data for water-dependent bird species at each of the dams containing preferred habitat were recorded for the 2011 survey. This data is then used to provide a means of measurement and evaluation of potential subsidence impacts at each of the dams over time to later be incorporated into the SMP.

2. Location

The Abel Underground Mine is located within Newcastle, Cessnock and Maitland local government areas (LGAs). The majority of the underground mine and surface infrastructure area is within the Cessnock LGA.

The location of the underground mine area and surface facilities is shown in **Figure 1**; the current extent of the underground mine is also shown. The underground mine area is bounded on the eastern side by the F3 Freeway; the western and southern sides by a tract of forest that extends south to the Central Coast and beyond to Hornsby, and the northern side by existing open cut coal mining activities within the Donaldson and Bloomfield mine leases.

The Abel underground mine area is approximately 2750 ha and consists of low undulating forested hills with patches of cleared land for 110 rural/residential properties. Approximately 175 farm dams are located above the underground mining area, scattered across these various properties. Large areas of land are owned by Donaldson, Coal and Allied and the Catholic Diocese of Maitland and Newcastle. Black Hill School, various local roads and other infrastructure are located in the area.

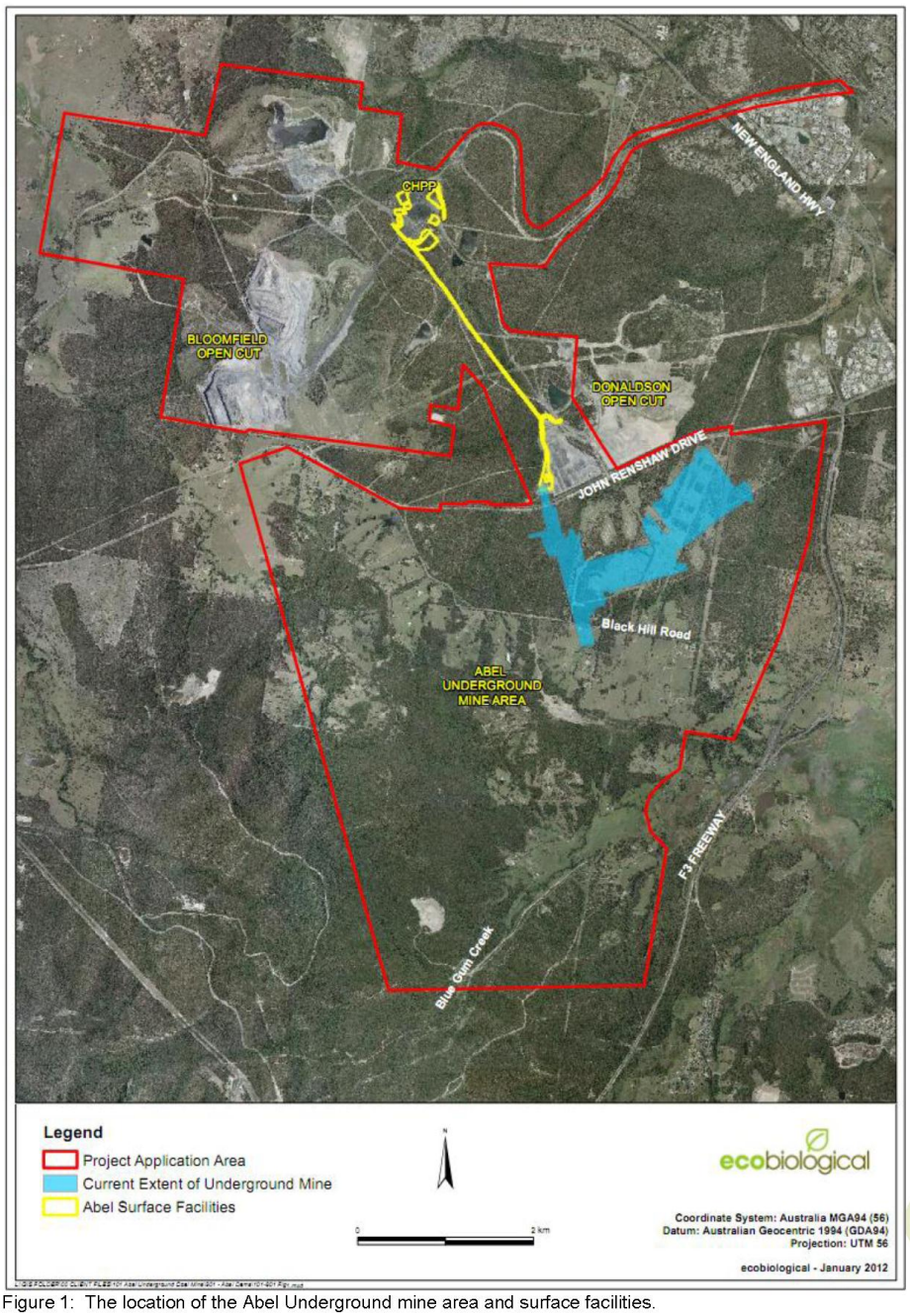

Figure 1: The location of the Abel Underground mine area and surface facilities.

3. Objectives

The Abel EA submission notes that the 175 dams located above the underground mining area are vulnerable to subsidence impacts such as cracking or tilting with significant water loss as a result. The DMMP aims to develop a set of data for 84 of these dams (**Appendix 2**) focusing on sensitive flora and fauna (targeting threatened species), species diversity, composition and abundance to inform the SMP. **Figure 2** shows the location of the targeted dams across the mine area as well as other significant surface features.

Table 1 sets out the target threatened species, appropriate methods and monitoring times as outlined in the F & FMP.

Table 1: Species to be targeted by the DMMP.

Scientific name	Common Name	Method	No. of Dams	Monitoring Period
Litoria aurea	Green and Golden Bell Frog	Call playback and targeted search	64	Warm nights during or after rain (October – February)
Litoria brevipalmata	Green-thighed Frog	Targeted search	2	Warm nights during or after rain (October – February)
Oxyura australis	Blue-billed Duck	Targeted search	4	Summer
Maundia triglochinoides		Targeted search	63	Late spring to early autumn

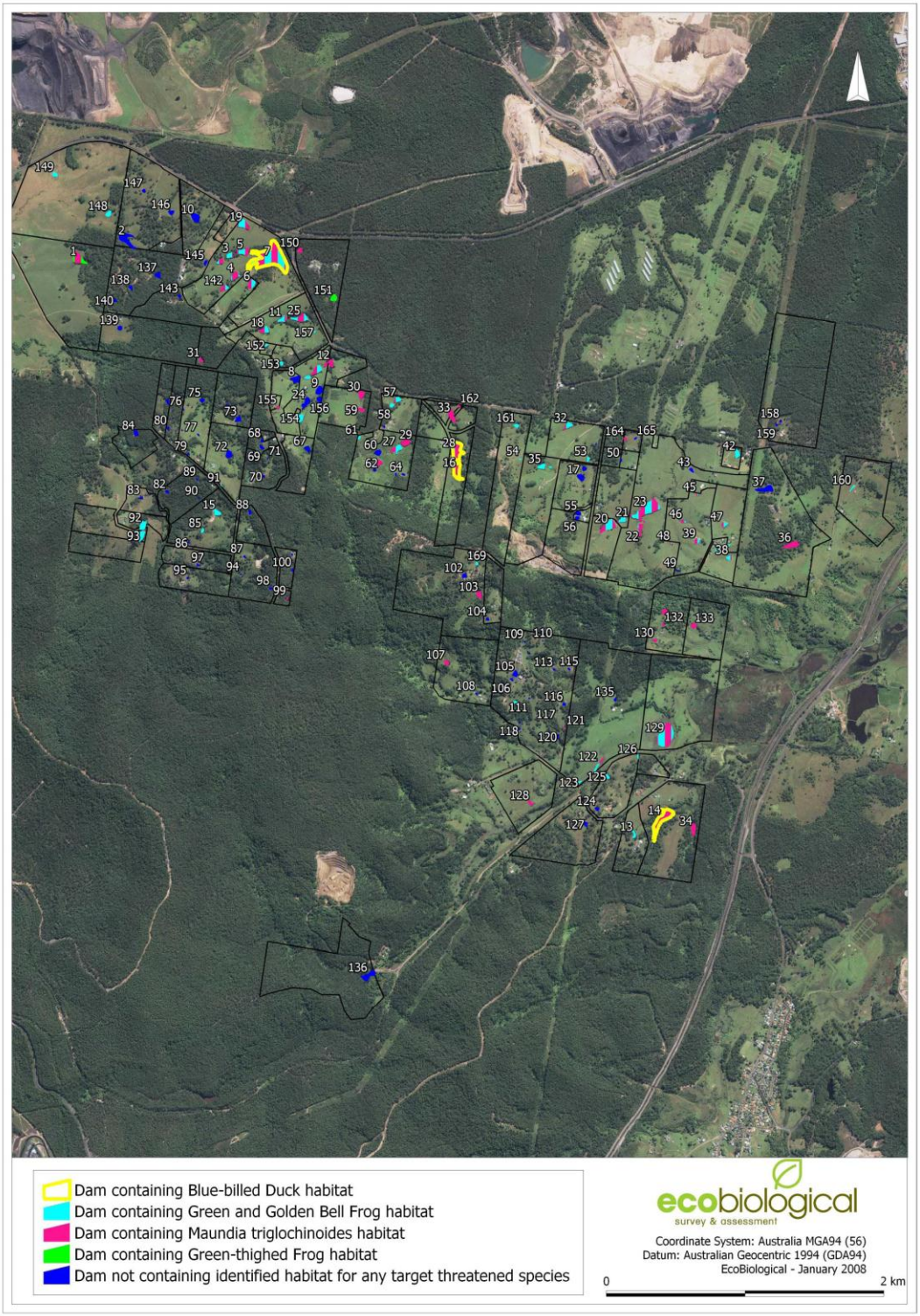

Figure 2: Aerial photograph of the Abel Mine area showing the layout of dams surveyed and the location of dams containing habitat suitable for each targeted threatened species.

4. Methods

4.1. Amphibians

4.1.1. Green and Golden Bell Frog (*Litoria aurea*)

Sixty-four (64) dams with suitable Green and Golden Bell Frog habitat were surveyed for this species in 2008 and 2009; however only 61 dams were surveyed in 2010 and 2011 as a result of private landholders preventing access to their land. Surveys were conducted on 28-30 November 2011 and 1 December 2011. The dams that were surveyed spanned across the area where underground mining will occur. It is considered that the dams surveyed were suitably representative of the total dams present and that the surveys provided a reasonable chance of detecting the Green and Golden Bell Frog.

Both targeted habitat surveys and call playback surveys were conducted throughout the survey period. At each dam an initial 2 minute quiet listening period was carried out to see if any Green and Golden Bell Frogs were calling and to record any other common species that were calling. This was followed by 10 minutes of call playback and 10 minutes of habitat searching. During call playback, pre-recorded calls of the Green and Golden Bell Frog were broadcast over a megaphone to attempt to illicit a response from any males that may have been present.

The call playback period generally consisted of around 1 minute of playing the calls followed by 20 seconds of quiet listening, repeated until the 10 minute period was complete. The habitat searches consisted of searching suitable habitat with the aid of a head-torch to locate any adults or juveniles by eye-shine or by physical sightings. All other amphibian species observed were also recorded.

4.1.2. Green-thighed Frog (*Litoria brevipalmata*)

Two (2) dams were deemed potentially suitable for the Green-thighed Frog. Both Dam 1 and Dam 151 were surveyed for this species on 28 November 2011.

Quiet listening and a habitat search were carried out for the Green-thighed Frog at each dam. The species only calls on a small number of nights (usually <5) in any given season. It does not readily respond to call playback. The habitat search consisted of searching suitable habitat with the aid of a head-torch to locate any adults or juveniles by eye-shine or by physical sightings.

4.2. Birds

4.2.1. Blue-billed Duck (*Oxyura australis*)

Four (4) dams were surveyed for the Blue-billed Duck on 30 November 2011; Dams 7, 14, 16 and 28. The remaining dams were not surveyed because an initial assessment determined that they did not contain suitable habitat for the targeted species. The surveyed dams spanned across the mine site and were chosen based on their size (with only large dams usually being inhabited by the species), the amount of deep, open water and the amount of fringing aquatic vegetation present.

Targeted surveys for the Blue-billed Duck involved a 20-minute walking transect along the edge of each of the selected dams. This time period enabled the inspection of the entire surface area of each dam for the target species. The surveys were carried out during clear and warm conditions. All other waterbird species observed utilising the surface of the water body or foraging either within the vegetated margins or aerially foraging over each dam was also recorded.

Each dam surveyed was assessed as to its suitability to provide habitat for the Blue-billed Duck and other threatened waterbird species based on habitat attributes such as the amount of fringing aquatic vegetation present, the amount of deep, open water present and the proximity to other suitable dams or areas of habitat.

4.3. Flora

4.3.1. Maundia triglochinoides

Sixty-three (63) dams were assessed as containing suitable habitat for the aquatic plant *M. triglochinoides*. Searches were conducted on 28 - 30 November 2011 using a random meander methodology ensuring that all water edge environments were searched. The surveys were performed in November to coincide with the flowering time of *M. triglochinoides* as it is difficult to detect and distinguish from closely related species during the non-flowering period.

5. Results

5.1. Amphibians

No Green and Golden Bell Frogs were detected at any of the 61 dams surveyed. No Green-thighed Frogs were detected at either of the two dams surveyed that contained habitat for this species. No frogs listed under State or Commonwealth legislation were recorded during field surveys.

Twelve (12) non-threatened species of frog were detected at the dams during 2011 surveys (**Appendix 3**). All are considered to be common dam or pond breeding species. Eleven (11) frog species were detected at the dams during 2008 and 2009 surveys, and 10 frog species were detected during the 2010 survey. All species detected were the same as previous years except for the addition of the Tusked Frog *Adelotus brevis* which was recorded for the first time in 2011 at Dam 125. At most dams (47) there was a decline in frog diversity between 2008 and 2009. However, 38 dams experienced an increase in frog diversity between the 2009 and 2010 surveys. This trend has continued with 20 dams recording an increase in frog species diversity between 2010 and 2011, and 13 dams having the same diversity as 2010. This increase in frog species diversity of the last two years is most likely a result of changing weather patterns across the region as abnormally hot conditions prevailed through much of November 2009 and average temperatures were above normal (National Climate Centre 2009). Also Donaldson Coal rainfall statistics for the region show an increased level of rainfall during the 2011 monitoring period. Rainfall data shows that between September to December, 334 millimetres of rain fell in 2010 and 479 millimetres in 2011, in comparison to 202.4 millimetres from September to December 2009.

The 2011 survey results are comparable to the 2008 survey results as frog diversity at most dam sites is similar or greater than 2008. Twenty five (25) dams show an increase in frog diversity (in comparison to 2008), 22 dams show a decrease in diversity (in comparison to 2008) while 18 dams have the same number of species diversity in 2008 and in 2011.

The list of frog species identified from each dam is displayed and the total tallied and charted in a bar graph in **Appendix 3**. Nine (9) dams recorded the highest diversity over the four years with 11 species at Dam 125, and 9 species at Dams 1, 7, 25, 40, 112, 153, 154, and 162. At none of these dam sites were all of these species recorded in the same year.

5.2. Birds

The Blue-billed Duck was not detected at any of the four targeted dams surveyed. No bird species listed as threatened under State or Commonwealth legislation were recorded during field surveys.

A total of 24 bird species have been recorded between 2008 and 2011 across all of the dams surveyed. The 2011 surveys identified 13 bird species using the surveyed dams with between 5 and 6 species detected at any one individual dam. The 2008 surveys identified 17 species with between 3 and 10 species at any one individual dam; the 2009 surveys identified 17 species with between 6 and 11 species at any one individual dam; and the 2010 surveys identified 10 species with between 1 and 7 species at any one individual dam.

In 2011, species diversity was highest at Dam 7 with six species recorded. An increase in species diversity from the preceding year was noted at Dams 14 and 16, with a rise from one species in 2010 to five species in 2011 for both dams. A slight decrease in diversity was recorded at Dams 7 and 28, compared with the 2010 results. Between 2009 and 2011, Dams 7 and 28 show an overall declining trend in diversity, whereas Dams 14 and 16 fluctuate considerably in the number of species recorded each year. Dam 14 demonstrated the largest increase in species richness and abundance in 2011 with total species richness increasing from 1 to 5 and total number of individuals increasing from 1 to 14 since 2010.

In 2011, total abundance was highest at Dam 28 with 17 individuals recorded. An increase in abundance from the preceding year was noted at Dams 14, 16 and 28. A slight decrease in abundance was recorded at Dam 7, compared with the 2010 results. Dams 7 and 28 show an overall declining trend in abundance, however, abundance has levelled off at Dam 28 with 16 and 17 species recorded in 2010 and 2011 respectively. Similar fluctuating trends in abundance are noticeable at Dams 14 and 16; however, abundance data from 2011 is well below that recorded in 2009.

Two duck species (Grey and Chestnut Teal) were not recorded in 2011 or 2010, despite occurring in large numbers at Dam 14 in 2009. Similarly, the counts of Pacific Black Duck in 2011 of between 1 and 10 individuals are considerably less than the count of 72 individuals from Dam 14 in 2009.

One new bird species (Cattle Egret) was recorded at Dam 16 in 2011. The list of bird species identified from each dam across the years is displayed and the total tallied and charted in a bar graph in **Appendix 4**.

5.3. Flora

Maundia triglochinoides was not detected at any of the 63 dams surveyed. No other flora species listed as threatened under State or Commonwealth legislation or under the ROTAP (Rare or Threatened Australian Plant) scheme were recorded during field surveys.

6. Discussion

6.1. Amphibians

6.1.1. Green and Golden Bell Frog

While a third of all the dams identified and surveyed in 2008 were considered to contain habitat suitable for the Green and Golden Bell Frog, this species were not detected in 2008, 2009, 2010 or 2011.

Regardless of the current status of occupancy of the dams by the targeted threatened species, the presence of a large number of dams with habitat suitable for these species (particularly those that interconnect and form habitat complexes) may be an important factor for their future recovery. This may be particularly true for the Green and Golden Bell Frog, a relatively mobile species that is known to be able to travel considerable distances and traverse hostile habitats to reach suitable ones (Daly 1995).

Currently there are 2 recognised key populations of Green and Golden Bell Frog at opposite ends of Hexham Swamp (known as the Sandgate and Kooragang Island populations). The species was also once known to be widespread right through the Hexham Swamp and adjoining areas. Old records of this species are known from within a 10 kilometre radius of the Black Hill area; however these are thought to be now extinct (M. Mahoney pers. comm.). Nevertheless, should this species recover in the near future it is highly conceivable that it may migrate back through this area towards Pambalong Nature Reserve and onto the adjoining belt of farm dams.

6.1.2. Green-thighed Frog

Only 2 dams were considered to contain habitat suitable for the Green-thighed Frog. While the surveys carried out were considered robust, it always remains a possibility that a threatened species may have been overlooked, particularly after only four seasons of survey activity. This is particularly true of the more cryptic species such as the Green-thighed Frog, which may only call on one or two nights of the year (Lemckert *et al.* 2006) and remains very difficult to detect on other nights.

The Green-thighed Frog is only known from 2 records some 13 km from the Black Hill area and is not known for its high mobility. However, it is considered that as the annual surveys progress, the likelihood of detecting this threatened species will increase.

6.1.3. Common Frogs

The detection of numerous species of non-threatened frogs throughout the survey period is a promising sign of overall ecosystem health within the dams surveyed. Amphibian calling activity observed throughout the survey period was high, resulting in a high level of confidence that the majority of species present were likely to be detected.

Nine (9) dams recorded the highest diversity over the four years with 11 species at Dam 125, and 9 species at Dams 1, 7, 25, 40, 112, 153, 154, and 162. At none of these dam sites were all of these species recorded in the same year. The total number of known frog species identified from each dam is displayed and the total tallied and charted in a bar graph (**Appendix 3**). Overall species diversity has increased over the past four years and species composition has remained relatively stable.

Some species of frog with a possible occurrence in the study area have not been detected in the four years of surveys so far, particularly, the Green Tree Frog *Litoria caerulea,* Bleating Tree Frog *Litoria dentata,* Ornate Burrowing Frog *Platyplectrum ornatum,* Pobblebonk *Limnodynastes dumerilli*, Haswell's Frog *Paracrinia haswelli,* Bibron's Toadlet *Pseudophryne bibroni* and Tyler's Toadlet *Uperoleia tyleri.* One (1) species, the Red-backed Toadlet, *Pseudophryne coriacea,* was detected in 2008 at one dam site that was not selected for further monitoring. Future surveys in following years may detect some of these species or confirm their absence.

The absence of the above species and the difference in the diversity and species composition at the dams over four years may be due to a variety of factors, such as the health of the dam ecosystems (cattle disturbance is widespread), or the Chytrid virus (a pathogenic fungus that is considered largely responsible for the recent global amphibian decline (Berger *et al.,* 1998)), but may also be due to unsuitability of local habitat, changing weather conditions or just chance.

It must be noted that no matter how much expertise or effort is employed, species that may use a site may go unrecorded during ecological survey. This is due to their mobility, unpredictable movement through their habitat and cryptic nature; as well as environmental factors such as rainfall, drought and bushfire which may impact on the type and number of species which are recorded at any one time or site.

6.2. Birds

Only four dams were considered to contain habitat potentially suitable for the Blue-billed Duck. This species is considered to be an uncommon visitor

to the Hunter region, and has been irregularly recorded from key sites including Walka Water Works, Oakhampton Heights (approximately 8 km north of the study area) and Deep Pond, Kooragang Island (approximately 13 km east of the study area). The Blue-billed Duck is a mobile species that may re-appear at suitable deep dams at any time provided conditions are suitable. This species is also known from the Bloomfield Dam (NSW Wildlife Atlas 2010), to the north of the Abel mine area.

There was a considerable increase in species richness and abundance at Dams 14 and 16 compared with 2010. Dam 14 demonstrated the largest increase in species richness and abundance with total species richness increasing from 1 to 6 and total number of individuals increasing from 1 to 14 since 2010. This increase follows a substantial decline in bird diversity and abundance in 2010 in comparison to the 2008 and 2009 surveys.

The substantial decline in diversity and abundance in 2010 and moderate recovery in 2011 is most likely a result of changing weather patterns across both the region and the state. Many regions of NSW were experiencing abnormally dry conditions in 2009 due to an El Nino event that affected much of NSW from May to October 2009 (National Climate Centre 2009; Bureau of Meteorology 2011). Dry inland conditions are likely to have forced many waterbirds to move to coastal areas in search of permanent water bodies in which to forage and breed. This drying trend began to reverse in November 2009 through March 2010, with many areas inland of the Great Dividing Range experiencing above average to very high rainfall during this period. The increase in rainfall across NSW in late 2009 / early 2010 is likely to have caused many of the water-dependent bird species to return inland to wetlands and lakes which had previously been unable to provide quality habitat for these species during past years of poor rainfall and drought (Bureau of Meteorology 2011).

The collection of data on non-threatened bird species observed during the standardised surveys will be used to make comment on the ongoing health of the dam ecosystems into the future. While mining is not currently underneath any of the dams (Figure 1), it is likely that within the next 12 months the operations will extend underneath some of the dams. This will provide at least five years of baseline data before potential impacts from subsidence; this is a suitable dataset by which data collected after this period can be compared against. This will provide an indication of the health of the dams after potential impacts may have started to occur.

6.3. Flora

While a third of all the dams identified and surveyed in 2008 were considered to contain habitat suitable for *Maundia triglochinoides*, this species was not detected in 2008, 2009, 2010 or 2011.

Only 3 records of *Maundia triglochinoides* in close proximity to the study area exist, one from Kooragang Wetlands (pers. obs., D. Pedersen), Irrawang Wetlands (pers. obs., Dan Pedersen) and the Medowie area, some 25 km from the Abel Mine site (NSW Wildlife Atlas, 2010). However, a close inspection of suitable dams over the four year period has not recorded this species. As this species mainly disperses via stream flow, it is unlikely that it will appear at any of the dam sites which are not generally connected to natural streams. It may also be dispersed by duck faeces; this however is a relatively unlikely occurrence.

7. Recommendations

It is recommended that in future amphibian surveys, water quality and aquatic habitat assessments of the relevant dams be made because any future changes in frog diversity or species composition at the dams may be explained by local environmental factors. Indices of water quality that can be collected with minimal cost and effort include temperature, pH and salinity (EC) as well as visual observations of water and aquatic vegetation health.

This will assist in the future to identify factors, such as eutrophication of dams from stock, recent fertiliser applications, or nutrient runoff from farming practices and local surface runoff which may contribute to local frog and bird decline other than effects from mining.

8. Conclusion

While suitable habitat exists at 84 dams in the Abel mine area for targeted threatened species, none have been detected in four years of surveys (**ecobiological** 2008, **ecobiological** 2009, **ecobiological** 2010, and this report). Species diversity and composition data has been collected for 12 frog species and abundance data, species diversity and composition data has been collected for 24 bird species.

Frog species diversity was largely similar across the dams between the 2011 and 2010 surveys. In 2009, a much lower overall diversity of frog species was noted across the dams, only a few dams recorded more species in 2009 than what was recorded in 2008. However in 2010 and 2011 there has been an increase in frog diversity across a number of dams to levels comparable or greater than the 2008 survey results.

Total bird diversity increased in 2011 to 13 species in comparison to the 2010 results whereby 10 species were recorded. However, bird diversity remains lower than in 2008 and 2009 when 17 species were recorded. The greatest increase in bird species diversity and abundance was observed at Dam 14. Abnormally dry conditions in 2009 followed by above average rainfall in early 2010 are likely to be the main cause of the sizeable fluctuations in bird abundance during these years.

No threatened frogs or birds were identified. No individuals of the threatened plant, *Maundia triglochinoides*, were identified.

The data collected over the four years are beginning to provide a means of measurement and evaluation of potential subsidence impacts. While mining is not currently underneath any of the dams, it is likely that within the next 12 months the operations will extend underneath some of the dams. This will provide at least five years of baseline data before potential impacts from subsidence; this is a suitable dataset by which data collected after this period can be compared against. Therefore, a more detailed statistical analysis will be conceivable in the next few years to provide an indication of the health of the dams after potential impacts may have started to occur. An accompanying water quality and condition assessment at the target dams is recommended to identify factors, such as eutrophication, recent fertiliser applications or nutrient runoff and local surface runoff. Any of these factors may impact abundance and diversity numbers at each of the targeted dams.

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Appendix 1: Target species profiles

Green and Golden Bell Frog (Litoria aurea)

The Green and Golden Bell Frog is a large frog with a robust body form ranging from 45-110mm in size. Diagnostic features include a gold or creamish white stripe running along the side, extending from the upper eyelids to groin, with a narrow dark stripe beneath it which runs from the nostril to the eye (DEC 2005). The body colour varies; it is usually a vivid pea green with splotches of metallic brown or green and a bluish green colour on the inside of the thighs. Some individuals may have an entirely green back, whereas, others backs be primarily covered in the metallic markings.

This species was once one of the most common frog species on the east coast of Australia. It inhabited many lentic freshwater habitats throughout its distribution which occurred predominately along the coast but also extending as far inland as Bathurst and along the highlands in the north and south of the state (White and Pyke 1996). The Green and Golden Bell Frog has undergone a widespread and unexplained range contraction since the mid 1970's and the species is now listed as endangered under the NSW *Threatened Species Conservation (*TSC*) Act* 1995, and as vulnerable under the federal *Environmental Protection and Biodiversity Conservation Act* 2000. Its distribution today is restricted to isolated pockets along the coast at various scattered locations throughout its former range with only one known remaining highland population at Queanbeyan.

The habitat preference and requirements of the Green and Golden Bell Frog are not well understood and difficult to define (Mahony 1999) resulting in some disagreement and confusion between biologists studying the species. Some of the differing views on Green and Golden Bell Frog ecology between biologists may be due to a failure to take into account the role of disease (a pathogenic fungus) that is probably primarily responsible for changes in its distribution and abundance in the last two decades (Berger *et al*. 1998).

The species uses different habitat components throughout the various stages of its life cycle including different breeding, foraging and refuge habitats and has been known to disperse distances of up to several kilometres between these various habitats. Generally large, permanent water bodies containing high levels of emergent vegetation such as *Typha*, *Baumea* and the introduced *Juncus acutus* are favourable for the detection of the Green and Golden Bell Frog, however it has been observed using a wide range of natural and man-made water bodies including; coastal swamps, marshes, dune swales, lagoons, lakes, estuary wetlands, riverine floodplain wetlands, billabongs, storm water retention basins, farm dams, bounded areas, storage tanks, water troughs, drains, ditches and other excavation areas capable of capturing water such as quarries and brick pits (DEC 2005).

Terrestrial habitat attributes that appear to favour the species include large grassy areas associated with adjacent cover from logs, rocks or tussock forming vegetation that provide shelter. There also appears to be a preference shown to habitat containing a complexity of terrestrial and aquatic vegetation structure (Hamer *et al.* 2002). The introduced mosquito fish, *Gambusia holbrooki*, is believed to feed on small tadpoles; habitat which is free of these fish is preferred (White & Pike 1996)

The Green and Golden Bell Frog is frequently active at day and night in the warmer months and can often be observed sitting in emergent vegetation well above the water level (0.5-1m). It has also been observed well away from water altogether. The breeding period generally occurs between September and March although reproductive behaviour has been noted to occur between late winter and early autumn (DEC 2005a). Breeding events occur most often during, and just after, heavy rain events with a peak around January/February when summer storms are common. Males call while floating in the water or from pond-side vegetation mostly at night but will occasionally call during the day. Individuals or small groups of males often respond to call play back or call imitation.

Green-thighed Frog (Litoria brevipalmata)

The Green-thighed Frog was only discovered in 1970, originally at Wauchope, NSW and later in the Gosford area (Barker & Grigg 1977). It reaches around 40mm in length and is chocolate brown on the dorsum with yellowish lower flanks. A dark stripe runs from the snout, through the eye and tympanum and ends in the flank. The groin and backs of thighs are a distinct bright blue-green with black flecks throughout and the belly is pale cream (Robinson 1998). The Green-thighed Frog is listed as vulnerable under the NSW TSC Act.

It is distributed in forests and swamps of the coast and adjacent ranges from central New South Wales to south east Queensland (Cogger, 2000; Hines *et al,* 1999). Its habitat requirements have remained highly cryptic for a long time with breeding noted to take place after heavy summer rains in rainforest and wet sclerophyll forest but also around temporary and semi-permanent ponds, flooded ditches and swamps including areas such as roadsides and power easements.

More recent research however has shed some light on the biology of this highly cryptic species, particularly in relation to its breeding habitat requirements and calling behaviour. In a study by Lemckert *et al* (2006) it was found that over 90% of breeding sites consisted of ephemeral pools, partly or wholly within rainforest or wet sclerophyll forest (84% of the time). There are however some records from around permanent, artificial ponds within dry sclerophyll forest, and a small number from coastal forests and swamps. Natural depressions adjacent to streams (e.g. old billabongs) are the most commonly used calling sites, although breeding also occurs in artificial water bodies such as human excavated hollows and flooded road verges (around half of sites recorded). These pools are usually either leaf or shrub filled depressions, or have significant amounts of grass in and around them (Lemckert *et al*, 2006).

The duration of calling events for the species is brief, with calling lasting for a median of only 1 night and a mean of 1.4 nights (Lemckert *et al,* 2006). Calling occurs between September and May, although greater than 90% of all calling activity occurs between November and February, with between 1 and >100 males calling (most commonly 2-10 individuals) (Lemckert *et al,* 2006). The species in the southern part of its range often displays only one calling event in a season, with two calling events observed on only four occasions in a study by Lemckert *et al* (2006), and three calling events in a season observed only once. The maximum total recorded number of nights of calling activity at any site in a season in the 2006 study was five, with only one day or less per season recorded 80% of the time, indicating that the Green-thighed Frog has the lowest number of calling days of any temperate Australian anuran species (Lemckert *et al,* 2006). Calling is likely to occur only after rainfall events that are significantly above the mean daily or three daily levels for the given time of year (when it is more likely that flooding

will occur in breeding ponds), and it is believed that the flooding of the breeding pools is the significant factor in calling behaviour, rather than the intensity of the rain itself.

The majority of Green-thighed Frogs are found within 100m of a tract of natural vegetation >20ha in size and none were found in the 2006 study (Lemckert *et al* 2006) to occur in largely cleared (>50%) grazing lands or within entirely urban areas. While habitat on a broad scale is a clear threat for this frog, it appears that partial clearing of vegetation within an area does not prevent Green-thighed Frogs from calling at a site and that they may have some tolerance for disturbance (Lemckert *et al,* 2006). Fire, particularly high-intensity fire, is also listed as a potential threat to the Green-thighed Frog, particularly when associated with multiple disturbance events in rapid succession (Lemckert *et al,* 2006).

Blue-billed Duck (Oxyura australis)

The adult male Blue-billed Duck has a slate blue bill with a glossy black head and neck. The back and wings are a rich chestnut and the tail coverts are a black-brown. During the summer breeding season the males bill turns bright blue (DEC 2005b). The adult female has a grey-brown bill with plumage darker than the male with each feather barred with narrow bands of light brown. Juveniles are similar to the adult female but paler with a grey-green bill (Marchant & Higgins 1990).

Preferred habitat is in large, deep, well-vegetated swamps where they spend almost all of their time in the water often in large flocks. Occasionally the species can be found using creeks, rivers and farm dams for foraging and breeding (Frith 1982). The Blue-billed Duck feeds on the surface of the water or by diving, for aquatic insects such as chironomid larvae, caddis flies, dragonflies, damselflies, flies and water beetle larvae (Schodde and Tidemann 1986).

The Blue-billed Duck is endemic to Australia occurring mainly within temperate wetlands of the south-eastern and south-western parts of the continent (Marchant & Higgins 1990). The Blue-billed Duck has also been reported from central Australia and Tasmania with little change in reporting rate over the last 20 years (Barrett *et al.* 2003). The Blue-billed Duck is listed as vulnerable under the NSW TSC Act. Nationally the Blue-billed Duck is classed as of 'least concern' because of the very large flocks that inhabit large artificial wetlands (Garnett & Crowley 2000) although threats are noted as being the destruction or modification of habitat, particularly by drainage works, clearing, cropping or burning (Marchant & Higgins 1990).

Maundia triglochinoides

Maundia triglochinoides is a perennial plant with rhizomes about 5mm thick and emergent tufts of leaves arising along their length. Leaves are triangular in cross section, to 80 cm long, 5 - 10mm wide. Inflorescence is up to 10cm long and 2.5 cm wide. Carpels (female parts of flower) are 6 - 8mm long, sessile, each with a spreading beak (Harden, 1993). This species is found along the NSW coast and southern Queensland. There are old records of this species occurring as far south as Sydney, however it is presumed extinct from these sites, and Wyong in now thought to be the southern limit of its range (DECC 2005). *Maundia triglochinoides* is listed as vulnerable under the NSW TSC Act.

Maundia triglochinoides grows in swamps, creeks or shallow freshwater 30 - 60 cm deep on heavy clay and low nutrients and it is often associated with wetland species e.g. *Triglochin procerum*. The flowering occurs during warmer months

(November to January). The plant is likely to be wind pollinated. The long distance dispersal is the seed and root tubers, which are probably dispersed by water. The plant spreads vegetatively, with tufts of leaves arising along the rhizomes (DECC, 2005b). The main threats to this species are further loss and fragmentation of habitat, changes in hydrology and water quality, and weed invasion (DECC 2008).

Appendix 2: Suitability of habitat at target dams

M. triglochin = *Maundia triglochinoides*; **GGBF** = Green and Golden Bell Frog (*Litoria aurea*); **GTF** = Green-thighed Frog (*Litoria brevipalmata*); **BBD** = Blue-billed Duck (*Oxyura australis*).

Dam Number	*M. triglochin*	GGBF	GTF	BBD
1	✓	✓	✓	
3	✓	✓		
4	✓	✓		
5	✓	✓		
6	✓	✓		
7	✓	✓		✓
11	✓	✓		
12	✓			
13	✓	✓		
14	✓			✓
15		✓		
16	✓	✓		✓
18	✓	✓		
19	✓	✓		
20	✓	✓		
21	✓	✓		
22	✓	✓		
23	✓	✓		
25	✓	✓		
26	✓	✓		
27	✓	✓		
28	✓	✓		✓
29	✓			
31	✓			
32	✓	✓		
33	✓			
34	✓			
35		✓		
36	✓			
38	✓	✓		
39	✓	✓		
40	✓	✓		
41	✓	✓		
42		✓		
45	✓	✓		
46	✓	✓		
47	✓	✓		
48	✓	✓		
51	✓	✓		
53		✓		

Dam Number	*M. triglochin*	GGBF	GTF	BBD
54		✓		
57	✓	✓		
58		✓		
59	✓			
61		✓		
62	✓	✓		
85		✓		
91		✓		
92		✓		
99	✓			
103	✓			
107	✓			
112		✓		
121	✓			
122	✓	✓		
123		✓		
125	✓	✓		
126	✓	✓		
128	✓			
129	✓	✓		
130	✓	✓		
131	✓			
132	✓			
133	✓			
134	✓			
142	✓	✓		
144	✓	✓		
148		✓		
149		✓		
150	✓			
151	✓		✓	
152		✓		
153	✓	✓		
154		✓		
155	✓			
157		✓		
160		✓		
161		✓		
162	✓	✓		
163		✓		
164	✓			
167	✓	✓		
168	✓	✓		
169		✓		
Total	63	64	2	4

Appendix 3: Amphibian species recorded in each dam surveyed

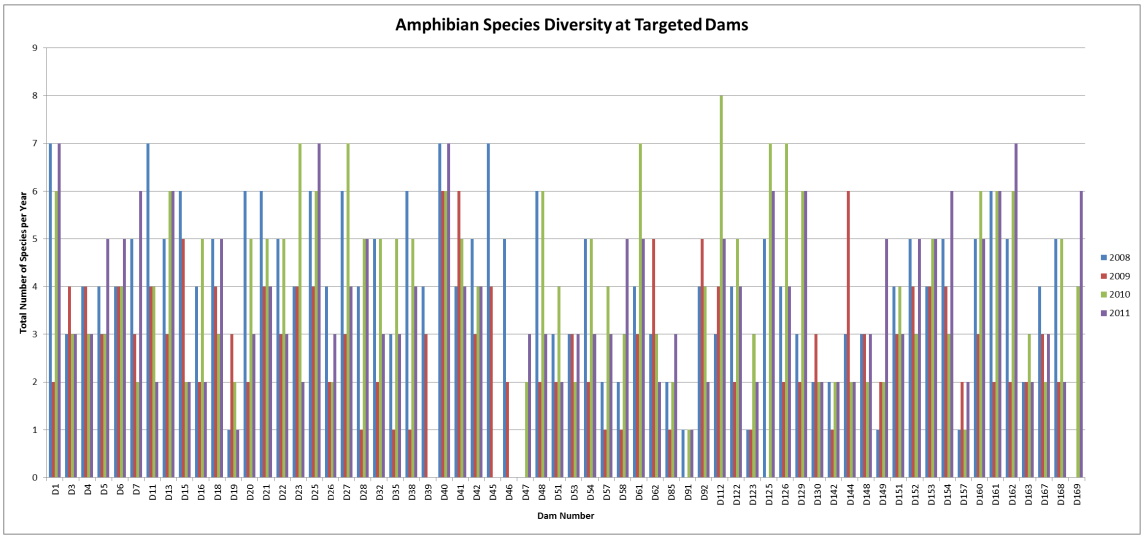
L. fallax = Dwarf Green Tree Frog (*Litoria fallax*); **L. peronii** = Emerald-spotted Tree Frog (*Litoria peronii*); **L. tyleri** = Southern Laughing Frog (*Litoria tyleri*); **L. lato.** = Broad-palmed Frog (*Litoria latopalmata*); **L. nasuta** = Rocket Frog *(Litoria nasuta);* **L. verr.** = Whistling Tree Frog (*Litoria verreauxii*); **Lim. per.** = Striped Marsh Frog (*Limnodynastes peronii*); **Lim. tas.** = Spotted Grass Frog (*Limnodynastes tasmaniensis*); **U. fusca** = Dusky Toadlet (*Uperoleia fusca*); **U. laev.** = Smooth Toadlet (*Uperoleia laevigata*); **C. sig.** = Common Eastern Froglet (*Crinia signifera*); **A. brevis** = Tusked Frog (*Adelotus brevis*);

Abundance ratings: (1=1) (2=2-5) (3=6-10) (4=11-20) (5=21-50) (6=51-100) (7=>100)

'x' - indicates presence only NA - No available access Dam = Dam Number

DAM	L. fallax				L. peronii				L. tyleri				L. lato.				L. nasuta				L. verr.				Lim. per.				Lim. tas.				U.fusa				U. laev.				C. signif.				A.brevis				Total No. of Species				
Survey Year	8	9	10	11	8	9	10	11	8	9	10	11	8	9	10	11	8	9	10	11	8	9	10	11	8	9	10	11	8	9	10	11	8	9	10	11	8	9	10	11	8	9	10	11	8	9	10	11	2008	2009	2010	2011	TOTAL
1	x	4	x	x	x		x	x	x		x	x								x	x	1		x	x		x								x		x		x				x								7	2	6	7	9
3	x	6		x		1										x								x	x										x				x	4	x			4	x							3	4	3	3	8
4	x	6	x					x					x	2		x																		x	x	x	4	x			x	4							4	4	3	3	6
5	x	6	x	x		1		x	x							x							x	x											x	x					x	4	x						4	3	3	5	8
6	x	4	x	x												x					x	2		x		3	x	x							x		x					x	3	x	x					4	4	4	5	7
7	x	6	x	x				x	x							x					x	4			x			x								x						x	6	x						5	3	2	6	9
11	x	6	x	x	x	1			x												x					2			x		x						x	3	x	x	x		x							7	4	4	2	8
13	x	6	x	x	x	2	x	x	x	2	x	x			x	x											x	x						x	x	x					x								5	3	6	6	8
15	x	6	x	x	x	2							x	1											x	3	x										x			x									6	5	2	2	6
16	x		x	x			x					x	x		x							2	x		x																x	2	x						4	2	5	2	7
18	x	6	x	x	x	1	x	x	x			x										3		x												x			x	x	4	x							5	4	3	5	6
19	x	6	x	x																		2																				2	x							1	3	2	1	3
20	x	5	x	x	x		x	x	x		x					x									x		x										x		x		x	2							6	2	5	3	7
21	x	6	x	x	x	1	x	x	x	2	x	x			x	x							x		x																x	2							6	4	5	4	8
22	x	5	x	x							x		x	2	x	x							x		x	2	x	x													x								5	3	5	3	7
23	x	6	x	x		3					x		x	2	x								x		x		x	x			x											x	5	x						4	4	7	2	8
25	x	6	x	x	x			x								x					x	4	x	x	x	2		x			x	x			x	x		x			x	4	x						6	4	6	7	9
26	x		x	x	x			x				x																														x	2			x	5	x						4	2	2	3	5
27	x	4	x	x	x		x	x	x		x				x	x					x	2	x		x	3	x	x													x				x				6	3	7	4	8
28	x		x	x			x					x	x		x	x							x		x		x	x																x	x	2					4	1	5	5	8
32	x	1	x	x	x		x	x	x		x		x		x	x							x		x	1																							5	2	5	3	6
35	x		x	x							x	x	x		x								x				x	x															2							3	1	5	3	7
38	x	6	x	x	x		x	x					x		x	x												x	x		x						x		x		x								6	1	5	4	7
39	x	5	NA	NA	x	3	NA	NA	x		NA	NA	x		NA	NA		NA	NA				NA	NA			NA	NA			NA	NA			NA	NA			NA	NA		4	NA	NA			NA	NA	4	3	-	-	5
40	x	4	x	x	x		x	x				x	x	2	x	x								x	x	2	x		x	5	x	x					x	3	x	x	x	4							7	6	6	7	9
41	x	5	x	x		1	x	x				x	x	1	x								x			2												x	5		x	x	4	x						4	6	5	4	7
42	x		x	x	x		x	x	x				x	1	x	x						1							x		x	x											2							5	3	4	4	7
45	x	2	NA	NA	x		NA		x	2	NA	NA	x	2	NA	NA			NA	NA			NA	NA	x		NA	NA	x	1	NA	NA			NA	NA	x		NA	NA			NA	NA			NA	NA	7	4	-	-	7
46	x	2	NA	NA	x		NA	NA	x		NA	NA	x	1	NA	NA			NA	NA			NA	NA	x		NA	NA			NA	NA			NA	NA			NA	NA			NA	NA			NA	NA	5	2	-	-	5
47			x	x								x																														x							0	0	2	3	4
48	x	6	x	x	x		x	x	x		x	x	x		x								x						x		x						x	1											6	2	6	3	7
51	x	3	x	x							x		x		x								x				x																x	2							3	2	4	2	6

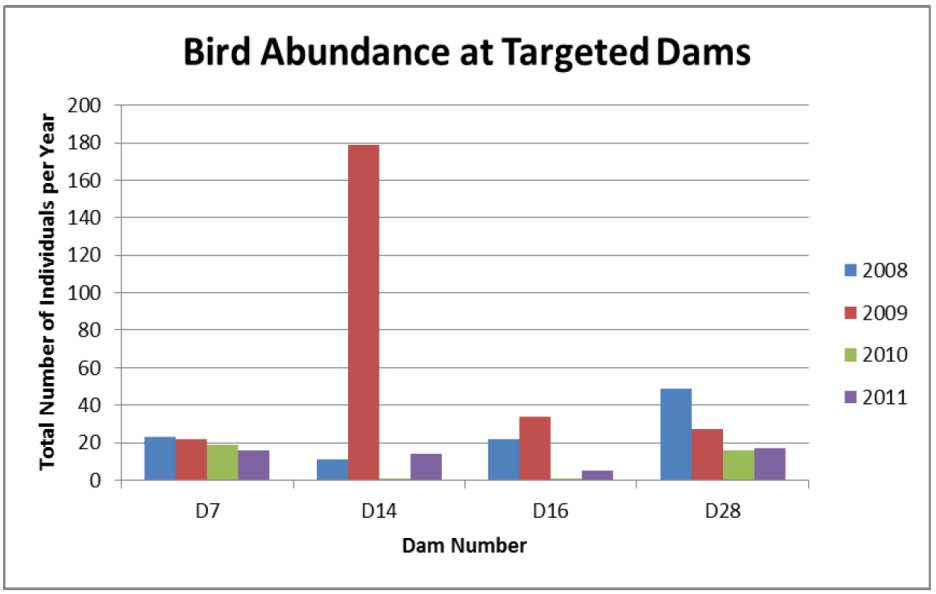
DAM	L. fallax				L. peronii				L. tyleri				L. lato.				L. nasuta				L. verr.				Lim. per.				Lim. tas.				U.fusa				U. laev.				C. signif.				A.brevis				Total No. of Species				
Survey Year	8	9	10	11	8	9	10	11	8	9	10	11	8	9	10	11	8	9	10	11	8	9	10	11	8	9	10	11	8	9	10	11	8	9	10	11	8	9	10	11	8	9	10	11	8	9	10	11	2008	2009	2010	2011	TOTAL
53	x	1	x	x								x													x	1	x	x									x						1							3	3	2	3	5
54	x			x	x		x						x		x	x							x												x				x	1	x	x		2							5	2	5	3	7
57	x		x	x			x	x							x	x																	x		x							2							2	1	4	3	5
58			x	x			x	x				x			x	x																	x								x	x	2						2	1	3	5	7
61	x	4	x	x			x		x		x	x			x	x											x												x	3	x	x	x	4	x						4	3	7	5	8
62	x	5	x	x		1	x	x		4					x											2												x					x	3							3	5	3	2	7
85	x	3	x	x	x			x				x															x																								2	1	2	3	4
91																									x		x	x																						1	0	1	1	1
92	x	6	x	x	x	2	x		x		x	x										1				1												x			x		2	x							4	5	4	2	7
112	x	6	x	x		2	x	x	x	2	x	x			x								x				x	x			x				x				x	4								3	4	8	5	9
122	x	5	x	x																					x		x	x	x		x	x							x		x			2	x	x				4	2	5	4	5
123	x	6	x	x							x	x																	x																						1	1	3	2	3
125	x		x	x			x				x	x			x								x		x		x	x	x						x				x				x							5	0	7	6	11
126	x	2	x	x					x		x	x													x		x	x			x				x				x		x	x		2	x					4	2	7	4	7
129	x	6	x	x					x		x	x															x				x				x	x			x		x	x		3	x	x				3	2	6	6	7
130	x	5	x	x		1																																	x		x	x		2	x						2	3	2	2	4
142	x	5	x	x				x																														x		x										2	1	2	2	3
144	x	6		x		1		x		2											x	2	x														x	4				3	x						3	6	2	2	6
148	x	6	x	x							x	x	x	1											x																x		3						3	3	2	3	6
149	x	6	x	x											x	x													x														x		2						1	2	2	5	6
151	x	6	x	x		4					x							5			x				x		x	x															x	x		x					4	3	4	3	8
152	x	5		x	x	3	x	x	x			x	x			x																	4	x	x	x	3	x										5	4	3	5	6
153	x			x	x		x	x			x	x	x			x											x			1				4	x			5	x	x	x	2							4	4	5	5	9
154	x	6	x	x				x				x				x	x	1			x						x	x												x	3			x	3	x	x					5	4	3	6	9
157													x	1		x												x																						1	2	1	2	4
160	x	2	x	x	x		x	x			x	x	x	1	x	x													x	2	x								x		x	x								5	3	6	5	6
161	x		x	x	x		x	x	x		x	x	x		x	x							x		x		x	x												x	7		x		3						6	2	6	6	8
162			x	x			x		x		x	x			x	x					x		x		x		x	x											x	1		x	x	3		x				5	2	6	7	9
163	x		x	x		1					x					x													x																	2						2	2	3	2	6
167	x			x	x							x														1	x	x												x	2			x	3	x						4	3	2	3	6
168	x		x	x																			x		x		x	x	x												x	2	x		x	3	x						5	2	5	2	7
169			x	x								x			x	x														x	x													x	x						0	0	4	6	6

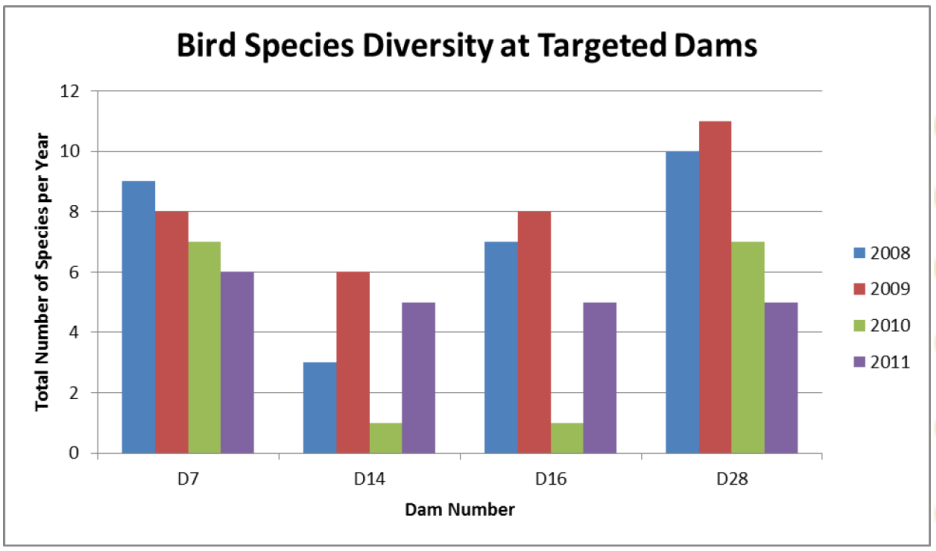


Appendix 4: Bird species and abundance at target dams

h=heard

Scientific Name	Common Name	Dam No. 7				Dam No. 14				Dam No. 16				Dam No. 28			
		2008	2009	2010	2011	2008	2009	2010	2011	2008	2009	2010	2011	2008	2009	2010	2011
Tachybaptus novaehollandiae	Australasian Grebe				1		2		1		4		1	2	3		
Pelecanus conspicillatus	Australian Pelican														1		
Acrocephalus australis	Australian Reed Warbler				h										h		
Chenonetta jubata	Australian Wood Duck	6				6	4		10	10	4			26	3	5	
Cygnus atratus	Black Swan	1											1			5	1
Ardea ibis	Cattle Egret												1				
Anas castanea	Chestnut Teal					4	40				10			2			
Anhinga melanogaster	Darter									1							1
Gallinula tenebrosa	Dusky Moorhen		2	2					2	2	2		1	3	2	1	2
Fulica atra	Eurasian Coot	4	1	2	8						2			2	1		
Phalacrocorax carbo	Great Cormorant			1													
Anas gracilis	Grey Teal						60				6			5			
Aythya australis	Hardhead										1			3			
Phalacrocorax sulcirostris	Little Black Cormorant	4	2	2	3									2	3	2	3
Phalacrocorax melanoleucos	Little Pied Cormorant		1		2										1		
Vanellus miles	Masked Lapwing		1							2							
Nycticorax caledonicus	Nankeen Night Heron														1		
Anas superciliosa	Pacific Black Duck	1	4			1	72		1	5	5			2	10		10
Phalacrocorax varius	Pied Cormorant									1							
Porphyrio porphyrio	Purple Swamphen	2	10	10	2								1	2	2	2	
Todiramphus sanctus	Sacred Kingfisher	1		1			1	1	h			1				h	
Circus approximans	Swamp Harrier	2								1							
Haliastur sphenurus	Whistling Kite			1													
Egretta novaehollandiae	White-faced Heron	2	1													1	
Total individuals recorded on each dam		**23**	**22**	**19**	**16**	**11**	**179**	**1**	**14**	**22**	**34**	**1**	**5**	**49**	**27**	**16**	**17**
No. of species recorded on each dam		**9**	**8**	**7**	**6**	**3**	**6**	**1**	**5**	**7**	**8**	**1**	**5**	**10**	**11**	**7**	**5**


Bird Abundance at Targeted Dams
Total Number of Individuals per Year
200
180
160
140
120
100
80
60
40
20
0
D7
D14
D16
D28
Dam Number
2008
2009
2010
2011


Bird Species Diversity at Targeted Dams
Total Number of Species per Year
12
10
8
6
4
2
0
D7
D14
D16
D28
Dam Number
2008
2009
2010
2011

Appendix 5: Contributions and qualifications of ecobiological staff

Name	Qualification	Title	Contribution
Kristy Peters	B. ParkMgt. (Hons)	Senior Ecologist (Ornithologist)	Blue-billed Duck surveys and report review
Aaron Mulcahy	B. Env Sc.	Botanist	*M. triglochinoides* survey and report writing
Gilbert Whyte	B. Biol Sc (Hons). PhD (candidate)	Ecologist	*M. triglochinoides* survey
Daniel O'Brien	B. Env. Sc. & Mgt. (*Biol.*). (Hons)	Ecologist	Amphibian survey
Glenn Jeffs	B.App.Sc.	GIS Manager	GIS Mapping

ecobiological
survey & assessment

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