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Strategic Advice on the Growling Grass Frog *Litoria raniformis*: Officer Structure Plan, Officer, Victoria

Report for Cardinia Shire Council

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Table of Contents

Tables

Figures

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SUMMARY

Introduction

Ecology Partners Pty. Ltd. was commissioned by Cardinia Shire Council to undertake ecological investigations on the Growling Grass Frog *Litoria raniformis* as part of the Officer Structure Plan, Officer, Victoria. The purpose of the study is to determine the distribution and abundance of the species within 428.1 hectares of residential and agricultural land, so that future land use planning is based on strategic ecological advice. A key aim is to provide information on how best to protect sites currently occupied by the Growling Grass Frog, to create habitat and maintain habitat connectivity for species in the Officer area.

The Officer Structure Plan (the "study area") consists of Area 1, Area 2 and Area 3 that occupy a mix of predominantly residential and agricultural land between Brown Road in the north, the proposed Pakenham Bypass in the south, Gum Scrub Creek to the east and Brunt and May Roads in the west, approximately 60 kilometres south-east of the Melbourne CBD. The study area is within the Gippsland Plain Bioregion.

Methods

Previous amphibian data recorded from the local area (i.e. approximately 10 kilometre radius) was obtained and reviewed from the Atlas of Victorian Wildlife, as well as previous reports and current studies being undertaken in the area. Documents reporting the establishment and progress of habitat creation projects for *L. raniformis* in Victoria and Green and Golden Bell Frog in New South Wales were reviewed.

Habitat assessments were conducted at 27 waterbodies to determine their suitability as habitat for *L. raniformis* and whether frog surveys were warranted. Waterbodies were selected from aerial photography. Information recorded included vegetation composition and structure, waterbody dimensions, presence of fish, presence of refuge or shelter sites and suitable dispersal habitat. Twenty-four waterbodies were surveyed on 6, 16, 21, 22, 24 and 29 November, and 7 December 2005 by one herpetologist during optimal climatic conditions when frog activity was likely to be highest. Surveys were conducted mainly at night and at a time when the species was calling in the local area. Nocturnal surveys comprised quiet listening, call playback and active searching for defined periods at waterbodies for which access was granted. All amphibian species detected during the surveys were recorded.

Results

Litoria raniformis was recorded from five waterbodies in Area 1. The species was not recorded in Area 2 or Area 3. Breeding was confirmed at one site, where a pair was observed in amplexus and metamorphosing froglets were observed. Calling was recorded at two sites

and juvenile dispersal was recorded between waterbodies. Six other frog species, locally common, were recorded during the study. Most of the sites surveyed were farm dams of varying size and vegetative structure dominated by several emergent, submerged and floating aquatic plant species. Habitat surrounding the sites is dominated by pasture. The predatory Mosquito Fish was recorded from five sites, while native fish species were recorded from a further four sites. The water quality was generally good, with approximately 50% of the waterbodies having clear water at the time of the surveys. Two of the occupied sites have a high proportion of submerged vegetation, but no emergent or floating vegetation; one has no vegetative structure; habitat is restricted to emergent vegetation at one; and one is dominated by floating vegetation and emergent vegetation. Therefore, vegetative structure varies among the occupied sites, although four of the five support aquatic vegetation.

Although the mean distance (± standard deviation) between waterbodies surveyed is 213±289 metres, the mean distance to the nearest waterbody occupied by *L. raniformis* is 1086±754 metres. All five occupied sites are within 200 metres of another occupied site, which suggest strong spatial clumping of the distribution of *L. raniformis* in the south-east corner of the study area. There is minimal connectivity among the unoccupied sites. However, the occupied sites are located close to potential dispersal corridors such as Gum Scrub Creek and drainage channels in the rail reserve. Therefore, the presence of suitable north-south (Gum Scrub Creek) and east-west (drainage channel along the railway) dispersal corridors appear to be restricted to the south-east corner of the study area, and this may strongly influence the presence of *L. raniformis*.

Discussion and Recommendations

The far south-east corner of the study area provides opportunities to create additional habitat and augment the population that currently exists there. The area that is recommended for habitat creation is bounded by the Princes Highway to the south, Gum Scrub Creek to the east and McMullen Road to the west. The riparian corridor through which Gum Scrub Creek flows should be protected and the corridor width increased where practicable. It is recommended to create habitat close (i.e. within 500 metres) of the existing population in the far south-east corner of the study area, to augment the current extent of habitat for *L. raniformis*. It is important that as many, if not all, waterbodies in the south-east corner of the study area (i.e. those that currently provide suitable habitat for *L. raniformis*) are protected and enhanced to ensure populations persist in the future.

If new roads are proposed for construction in priority areas for *L. raniformis* conservation or habitat creation/enhancement, suitable measures to mitigate the impact of the road structure and traffic on the movement of frogs should be included in the road design (i.e. underpass structures). The main direct impacts associated with road construction in the vicinity of populations of *L. raniformis* are traffic strike and habitat loss; indirect impacts include habitat

fragmentation and isolation, and pollution reducing water quality in adjacent and downstream waterbodies. It is essential that suitable wetlands (preferably permanent) are created either side of the underpasses to facilitate or encourage the movement of frogs under roads.

Future residential development in the study area has the potential to result in stormwater contamination and uncontrolled runoff into existing and created frog habitat. The following is therefore recommended:

- minimise vegetation removal throughout the Gum Scrub Creek catchment;
- prepare strict Erosion and Sediment Control Plans for all developments in the study area;
- establish revegetated open space and enhance the riparian zone of Gum Scrub Creek to protect the integrity of frog movement corridors in the priority area; and
- incorporate Water Sensitive Urban Design into all future developments in the study area.

It is recommended that a Feral Animal Control Plan be implemented in the study area to reduce the population size of foxes. Responsible pet ownership, particularly of cats, is recommended to reduce impacts to frog populations from predation.

Monitoring and management of created wetlands is essential over the first two years after establishment, during which time vegetation condition should be monitored every three months. Wetlands should be at full water level within at least six months to one year after construction and if they have not naturally reached this level, they should be artificially filled with water. Any enhancement works along Gum Scrub Creek should be monitored every three months to determine the progress of vegetation rehabilitation and to monitor water quality. Frog salvage and translocation measures should be undertaken prior to any disturbance of the creek. The status of *L. raniformis* at existing and created wetlands should be determined at least once a month over the activity period (i.e. September to March) and once during the non-breeding period. Waterbodies which the species is known to occupy, created wetlands and potential habitat should be surveyed using survey techniques similar to the methodology used in this study.

Conclusion

The presence of a series of waterbodies scattered across the study area, particularly those supporting key habitat determinants and located within 500 metres of each other are vital for the long-term persistence of populations in the Officer area. The study area is considered to be of national significance for *L. raniformis* as it supports a breeding population of the species, provides several high quality breeding sites in the form of farm dams, and the

provision of suitable dispersal habitat along Gum Scrub Creek. It is likely that Gum Scrub Creek is an important dispersal corridor for the species in the study area, and hence, the far south-east corner of the study area and the Gum Scrub Creek riparian corridor is considered a high conservation priority area. It is reasonable to conclude that the population in the study area is part of the far north-west corner of a metapopulation that extends throughout Pakenham, Nar Nar Goon and Bayles, south of the Princes Highway.

1 INTRODUCTION

1.1 Background

Ecology Partners Pty. Ltd. was commissioned by Cardinia Shire Council to undertake ecological investigations on the Growling Grass Frog *Litoria raniformis* as part of the Officer Structure Plan, Officer, Victoria. The purpose of the study is to determine the distribution and abundance of the species within approximately 905 hectares of residential and agricultural land, so that future land use planning is based on strategic ecological advice. A key aim is to provide information on how best to protect sites currently occupied by *L. raniformis*, to create habitat and maintain habitat connectivity for the species in the Officer area.

1.2 Objectives

Specifically, the objectives of this investigation are to:

- Review relevant data on the Atlas of Victorian Wildlife (AVW), and available literature in relation to the occurrence of *L. raniformis* within the study area and immediate surrounds (e.g. Organ 2004a, 2005d);
- Review the literature on the habitat requirements of *L. raniformis* including a review of known examples of sites which have been protected and where the species has persisted in an urban context;
- Review information on habitat creation projects conducted for *L. raniformis* in Victoria and the closely related Green and Golden Bell Frog *Litoria aurea* in New South Wales, including an analysis of the success or failure of these projects;
- Review similar a selection of projects that have been referred to the Commonwealth Environment Minister for determination under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), including a summary of conditions placed upon approval;
- Conduct targeted surveys (spotlighting, active searching and call play-back) during the core breeding period of the species to determine its status within and immediately adjacent to the study area;
- Obtain an estimate of the population size, current distribution and overall significance of populations and habitats;

- Provide information on construction design and mitigation measures which should be adopted prior to and during construction, and measures to enhance habitat values on the site;
- Provide requirements for future monitoring of populations and associated habitats; and
- Liaise with key stakeholders (e.g. DSE, landowners) where necessary.

1.3 Study Area

The Officer Structure Plan (herein referred to as "the Plan") consists of three areas. Area 1 comprises 428.1 hectares bounded by the Princes Highway to the north, the proposed Pakenham Bypass to the south, Brunt Road to the west and Gum Scrub Creek to the east (see Figure 1). Area 2 (194.5 hectares) occurs between Brown Road to the north, Princes Highway to the south, May Road to the west and the eastern boundary of Parklea's property to the east. Area 3 (282.9 hectares) is bound by Brown Road to the north, Princes Highway to the south, Area 2 to the west and Gum Scrub Creek to the east. Together, the three areas comprise the "study area".

The study area is located approximately 60 kilometres south-east of the Melbourne CBD, and currently comprised of a mix of predominantly residential and agricultural land, although some commercial plant nurseries and light industrial businesses are present.

According to DSE's Biodiversity Interactive Map (www.dse.vic.gov.au) the study area is within the Gippsland Plain Bioregion, which extends from Port Phillip Bay in the west to Bairnsdale in the east, between the southern slopes of the Great Dividing Range and Wilsons Promontory, excluding the Strzelecki Ranges. Remnant indigenous vegetation in the study area has been mapped as Swampy Riparian Complex (Ecological Vegetation Class) during the Central Highlands Regional Forest Agreement (RFA) process (VicRFASC 1997). This habitat type occurs on wet flats and in drainage basins (which have mostly been drained and cleared for agriculture) and would once have been widespread over the flatter areas of the study area.

1.4 Nomenclature

Litoria raniformis can often cause confusion as it is known by at least five common names, including the Growling Grass Frog, Warty Bell Frog, Southern Bell Frog, Warty Swamp Frog and Green and Golden Frog. Within this report it is referred to as *L. raniformis*.

Common and scientific names of vascular plants follow the Flora Information System (FIS 2005 version of the Department of Sustainability and Environment (DSE) and the Census of

Vascular Plants of Victoria (Ross and Walsh 2003). Vegetation community names follow the DSE Ecological Vegetation Classes (EVC) Benchmarks (www.dse.vic.gov.au).

1.5 Conservation Status

Litoria raniformis is a species of national conservation significance and has declined markedly across much of its former range.

Table 1. Conservation status of L. raniformis.

Source	Status
Australia-wide	
Environment Protection and Biodiversity Conservation Act 1999	Vulnerable
Action Plan for Australian Frogs (Tyler 1997)	Vulnerable
IUCN Red List 2002	Endangered
Victoria-wide	
Advisory List of Threatened Vertebrate Fauna in Victoria 2002 (DSE 2003)	Endangered
Flora and Fauna Guarantee Act 1988	Listed

An 'Action Statement' under the *Flora and Fauna Guarantee Act 1988* has recently been developed for this species, which outlines the current threats to the species, and provides specific actions to protect and, where possible, increase populations in the future (DSE in prep).

1.6 Distribution

Although formally widely distributed across southern eastern Australia, including Tasmania (Littlejohn 1963, 1982; Hero *et al.* 1991), the species has declined markedly across much of its former range. Historically, *L. raniformis* has been recorded from most regions of Victoria, with the exception of Mallee and Alpine areas (Littlejohn 1963, 1982; Hero *et al.* 1991). The known range of this species has contracted dramatically over the past two decades and in many areas, particularly in south and central Victoria, populations have experienced serious declines and local extinctions (AVW; Organ pers. obs.). However, recent surveys of this species throughout the former Koo Wee Swamp and Pakenham area have revealed that the species is widely distributed throughout the area, with a number of relatively large populations present (principally in farm dams) (A. Organ pers. obs.).

Over recent years the species has received much attention, primarily due to its national significance rating, and several populations throughout the greater Melbourne region have

been extensively studied (Williams 2001, 2002; Organ 2002a, 2002b, 2003a, 2003b; Robertson *et al.* 2002; Heard *et al.* 2004a).

1.7 Habitat Requirements

Litoria raniformis is largely associated with permanent or semi-permanent still or slow flowing waterbodies (i.e. streams, lagoons, farm dams and old quarry sites) (Hero *et al.* 1991; Barker *et al.* 1995; Cogger 1996; Ashworth 1998). Frogs can also utilise temporarily inundated waterbodies (i.e. ephemeral waterbodies) for breeding purposes provided they contain water for at least three to four months over the breeding season (Organ 2003a). A detailed review of the current information on the biology and ecology of *L. raniformis* is provided by Pyke (2002).

1.7.1 Vegetation

Based on previous investigations there is a strong correlation between the presence of the species and key habitat attributes at a given waterbody. For example, the species is typically associated with waterbodies supporting extensive cover of emergent, submerged and floating vegetation (Robertson *et al.* 2002, Organ 2004a, 2005a). Occupied waterbodies are usually dominated by emergent vegetation including Water Ribbons *Triglochin procera*, Tall Spike Rush *Eleocharis sphacelata*, Common Reed *Phragmites australis* and Cumbungi *Typha* sp. Submerged vegetation is usually dominated by *Potamogeton* sp. and *Myriophyllum* sp., whereas fringing vegetation may include Common Spike Rush *Eleocharis acuta* and *Juncus* sp. Emergent vegetation provides basking sites for frogs and protection from predators, while floating vegetation provides suitable calling stages for adult males, and breeding and oviposition (egg deposition) sites. Terrestrial vegetation (grasses, sedges), rocks and other ground debris around a wetland perimeter also provide foraging, dispersal and over-wintering sites for frogs.

1.7.2 Spatial dynamics

Waterbodies supporting the above mentioned habitat characteristics and which are located within at least 500 metres of each other are more likely to support a population of *L. raniformis*, compared with isolated sites lacking important habitat features. Indeed, recent studies have revealed that the spatial orientation of waterbodies across the landscape is one of the most important habitat determinants influencing the presence of the species at a given site (Robertson *et al.* 2002; Heard *et al.* 2004a, 2004b). For example, studies have shown there is a positive correlation between the presence of the species and the distance of waterbodies to another occupied site. This is comparable to the spatial dynamics of many amphibian populations, including the closely related Green and Golden Bell Frog *Litoria aurea* (Hamer *et al.* 2002), in which a waterbody is more likely to be occupied if it is in close proximity to an

occupied waterbody. This observation, and the highly mobile nature of *L. raniformis*, suggests that dispersal among waterbodies is likely to be an important activity in the life history of the species.

It appears that populations are invariably structured as metapopulations (i.e. local populations form a series of discrete sub-populations), whereby movement between waterbodies would occur as habitat conditions change over time (e.g. when waterbodies dry out). Unhindered movement between and within waterbodies is also likely to be important for *L. raniformis* on a spatial and temporal scale, and would be important for the long-term viability of (meta-) populations throughout the Pakenham area (Organ 2005a). The loss of waterbodies of high habitat quality from the landscape not only reduces the number of potential breeding sites (i.e. sources), but may also increase the distance between occupied sites. This potentially places the remaining occupied sites at greater risk of extinction from stochastic processes (e.g. drought, disease) because such sites cannot be easily recolonised, as frogs have to move further.

Regardless of proximity to other known occupied sites, habitat characteristics at a particular waterbody need to be suitable for the species to occupy the area. Submerged and floating vegetation are considered two important habitat features for *L. raniformis* (Robertson *et al.* 2002; Pyke 2002). Similarly, emergent vegetation is considered important as they provide suitable sites where frogs can bask or seek refuge during the day. Nevertheless, the key habitat attribute influencing the species at a given site throughout the Pakenham area is the presence of extensive areas of floating vegetation, primarily Blunt Pondweed *Potamogeton ochreatus* and Sago Pondweed *Potamogeton pectinatus*. Habitat complexity such as variation in hydrological processes (water depth, flooding frequency, ephemerality/permanency) and the type and location of refuge sites are also important for this species.

1.7.3 Water quality

Water quality is likely to be an important factor for successful breeding and larval development. Many of the sites occupied by the species in Tasmania have low nitrate and phosphate levels (Ashworth 1998). In laboratory experiments conducted by Hamer *et al.* (2004), the tadpoles of *L. aurea* had significantly higher levels of mortality in high concentrations of nitrate and phosphate than did the Common Eastern Froglet *Crinia signifera* and Striped Marsh Frog *Limnodynastes peronii*. From this result, it was suggested that fertilizer application may be responsible for the decline in Bell Frog species in agricultural areas. Although water quality is likely to be important for larval development, the adult frogs appear to have wide tolerances for variation in water quality (Organ 2004b). For example, pH, salinity, conductivity, dissolved oxygen and turbidity did not influence the occupancy of waterbodies by *L. aurea* in an agricultural and estuarine area (Hamer *et al.* 2002), and other recent studies on the physico-chemical properties waterbodies inhabited by Bell Frog species

indicate wide tolerances (Ashworth 1998; Patmore 2001; Pyke *et al.* 2002). Organ (2003) documented an apparent preference for waterbodies at the Western Treatement Plant, Werribee that had a lower nutrient content. Robertson *et al.* (2002) suggested that poor water quality may be implicated in the decline of *L. raniformis* in the south of the Merri Creek catchment.

1.7.4 Breeding habitat

Litoria raniformis is an opportunist in its choice of breeding sites and may use waterbodies of varying permanency (i.e. ephemeral, semi-permanent) to breed, although permanent waterbodies are usually required for successful breeding due to the relatively long larval development times, which may be several months or some tadpoles may over-winter and metamorphose in the following season. However, waterbodies need to contain suitable vegetative structure for the species to breed, including sufficient areas of emergent and submerged vegetation. *L. raniformis* has been recorded breeding in a variety of ephemeral waterbodies around metropolitan Melbourne, southern N.S.W and Tasmania (AMBS 2000; Organ 2001, 2002a, 2003a; Williams 2001).

2 METHODS

2.1 Literature Review

Previous reports pertaining to the occurrence of *L. raniformis* and its habitats within the study area and immediate surrounds were obtained. The results of a regional and mark-recapture study (Hamer & Organ 2006a) recently completed in Cardinia Shire were also considered in the context of the Plan.

Documents reporting the establishment and progress of habitat creation projects for *L. raniformis* in Victoria and Green and Golden Bell Frog in New South Wales were also obtained. An appraisal of the success or failure of these projects was undertaken.

2.2 Database Searches

Previous occurrences of *L. raniformis* recorded from the local area (i.e. approximately a 10 kilometre radius surrounding the study area) was obtained and reviewed from the Atlas of Victorian Wildlife (AVW), a biological database maintained by Department of Sustainability and Environment.

2.3 Site Selection

Waterbodies were selected from an aerial photograph of the study area (scale 1:13130, 4 October 2005), and all waterbodies were targeted for survey, irrespective of size or location in the study area. Some waterbodies had been previously surveyed during studies conducted for the regional survey for Cardinia Shire Council or as part of the detailed monitoring program being undertaken for the Pakenham Bypass. Thirteen waterbodies were surveyed in Area 1, two in Area 2, and 12 in Area 3 (see Figure 2). Six waterbodies (1a-1f) were included in a mark-recapture study of *L. raniformis* and therefore had greater survey effort (Hamer & Organ 2006a).

2.4 Habitat Assessments

Diurnal habitat assessments were conducted at 27 waterbodies on 6, 22 and 24 November 2005 to determine their suitability as habitat for *L. raniformis*, and hence if nocturnal surveys were warranted. Suitable refuge sites such as logs, rocks and other ground debris were lifted opportunistically to locate inactive frogs. Habitat variables recorded included:

- Size and type of waterbody (e.g. farm dam, drain);
- Percentage of open water;

- Approximate distance from other waterbodies surveyed in this study and nearest known waterbodies occupied by *L. raniformis*;
- Percentage cover of emergent, fringing, submerged and floating vegetation;
- Presence of terrestrial refuge sites (e.g. rocks, logs, debris);
- Water quality based on turbidity (i.e. poor = turbid, moderate = slightly turbid, good = clear);
- Type of surrounding habitat within 30 metres of each site; and
- Presence/absence of fish through incidental sightings.

The size of a waterbody was estimated in the field or measured from a scaled aerial photograph. Distance between waterbodies was measured from an aerial photograph.

2.5 Field Surveys

2.5.1 Nocturnal surveys

Surveys for *L. raniformis* were conducted at 21 waterbodies which contained potential habitat, on properties for which access had been granted by the landowner. A further three waterbodies were surveyed from nearby roads and other public areas on properties for which access was not granted (sites 3c, 3d, 3e). Three waterbodies assessed during the day were considered to be unsuitable habitat for *L. raniformis* (sites 1g, 1j, 3i).

Personnel experienced in surveying *L. raniformis* conducted the nocturnal surveys in the study area on the 6, 21, 22, 24 and 29 November, and 7 December 2005. Surveys were conducted at a time when *L. raniformis* was calling in the local area, and during optimal survey conditions when frog activity was likely to be highest (i.e. calm evenings, above 16^{o}C, recent rain).

Nocturnal surveys comprised quiet listening at each waterbody for approximately five minutes. This exercise was conducted from nearby roads or other public areas at waterbodies for which access was not granted. The advertisement call of male *L. raniformis* was imitated for several minutes to elicit a response from any adult males residing within the waterbody. This was followed by quiet listening for several minutes. At waterbodies where access was granted, the banks, open water and areas of emergent vegetation were searched for frogs using 50 watt 12 volt hand-held spotlights. The surrounding terrestrial habitat within 10 metres of the waterbody was also searched. All frog species detected during the surveys were recorded. The time spent surveying each site varied depending on size and habitat complexity, but was between 10 – 40 minutes.

2.5.2 Survey hygiene

To reduce the risk of infection and spread of amphibian disease, particularly chytrid fungus, the NSW National Parks and Wildlife Service (NPWS) hygiene protocol for surveying frogs was followed (NSW NPWS 2001). The herpetologist washed hands between sites and after frogs had been handled, and field equipment was cleaned with a diluted bleach solution prior to field surveys.

2.5.3 Limitations

The greatest limitation in surveying waterbodies in the study area was the denial of access to some properties that contained potential habitat for *L. raniformis*. This was the case for sites 3d and 3e, and for a large waterbody adjacent to Berwick Potteries. However, most waterbodies (i.e. potential *L. raniformis* habitat) that were identified from the aerial photograph were surveyed.

Most waterbodies were visited on two occasions during ideal climatic conditions (i.e. rain, calm, mild ~ 17.0°C). This survey effort is considered sufficient to maximise the probability of detecting adult *L. raniformis* (Heard *et al.* 2004). However, the surveys represent a snap-shot of the distribution and abundance of the *L. raniformis* population in the study area. Consequently, information on the relative importance of various sites to the species on a spatial and temporal scale was not determined over the survey period. This would require more detailed investigations such as mark-recapture and radio-telemetry.

The presence of predatory fish, both native and introduced, at a site was determined from a visual assessment. It is therefore possible that some fish species that are not conspicuous may have not been detected. A more rigorous assessment of fish presence at a waterbody is only possible through use of baited traps and nets. Nonetheless, fish species that are active during the day, such as Plague Minnow *Gambusia holbrooki*, are easily observed in waterbodies as they school in large numbers close to the water surface.

3 RESULTS

3.1 Literature Review

3.1.1 Population and habitats in the Pakenham area

The following documents were consulted to provide information on the occurrence of *L. raniformis* and its habitats in the study area and immediate surrounds:

- Costello, C., Timewell, C. & Organ, A. 2003. Flora and Fauna Assessment of the proposed Pakenham Bypass, Victoria.
- Timewell, C. 2003. Pakenham Bypass: Survey for the Warty Bell Frog *Litoria raniformis*, Pakenham and surrounds, Victoria.
- Hamer, A.J., Organ, A. 2006a. Population Ecology of the Growling Grass Frog *Litoria raniformis* in the Pakenham area, Victoria.
- Heard, G.W., Robertson, P. & Moysey, E.D. 2004a. Management Plan for the Growling Grass Frog *Litoria raniformis* within the Fairway Waters development, Pakenham, Victoria.
- Mueck, S. & Smales, I. 2004. Flora and Fauna of the VicUrban Development, Officer, Victoria.
- Organ, A. 2004a. Pakenham Bypass: Growling Grass Frog *Litoria raniformis* 2003/04 survey, Pakenham and surrounds Victoria.
- Organ, A. 2005a. Pakenham Bypass: Conservation Management Plan for the Growling Grass Frog *Litoria raniformis*, Pakenham, Victoria.
- Organ, A. 2005b. Targeted Growling Grass Frog *Litoria raniformis* survey and management recommendations for the proposed Fairway Waters, Pakenham, Victoria.
- Organ, A. 2005c. Growling Grass Frog *Litoria raniformis* revised Conservation Management Plan for the proposed 'Fairway Waters' development, Pakenham, Victoria.
- Organ, A. 2005e. Targeted Growling Grass Frog *Litoria raniformis* survey Koo Wee Rup Road, Pakenham, Victoria.
- Organ, A., & Hamer, A.J. in prep. Targeted survey and Conservation Management Plan for the Growling Grass Frog *Litoria raniformis*: Pakenham Urban Growth Corridor, Pakenham, Victoria.

These recent surveys for *L. raniformis* throughout the local area have revealed that several breeding sites and important populations exist on, or in close proximity to the study area. Most records are concentrated in Area 1 between Station Street and Gum Scrub Creek. There are no documented records of the species from Area 2 and Area 3 (AVW 2005).

Litoria raniformis has recently been recorded from several waterbodies on the VicUrban land (Mueck & Smales 2004; Organ pers. obs.), and in the vicinity of the proposed Pakenham Bypass during November – March 2002/03 and 2003/04 (see Figure 3; Costello *et al.* 2003; Timewell 2003; Organ 2004a).

As stated in Mueck and Smales (2004), *L. raniformis* was recorded inhabiting several farm dams and drains throughout the VicUrban site. Several males were heard calling and a juvenile was located in a drain in the Novaso property in February 2004, indicating that the species successfully bred in the vicinity of the current study area during the 2003/04 breeding period (Organ pers. obs.). The existing network of known and potential breeding ponds and the associated drainage lines provide important habitat and movement corridors for this breeding population (Figure 3, Organ 2004a).

The species was recorded from 43 sites (primarily farm dams) of 91 surveyed during the 2003/04 breeding season, which represented an occupancy rate of nearly 50% of all farm dams surveyed (Organ 2004a). There was no distribution pattern and occupied sites were scattered sporadically throughout the area. Organ (2004) recorded a total of 317 adult frogs of which 97% were males. Frog abundance varied greatly across the sites surveyed, with the highest population recorded (4 adult males, 3 adult females and 39 metamorphs) from a waterbody located immediately east of Toomuc Creek. Organ (2004) recorded tadpoles at only three waterbodies. A large population (one of the largest in the local area) remains at this site and it is considered one of the most important 'source' populations crucial for population maintenance in the local area (i.e. continual emigration/dispersal from this site to other peripheral sites).

Despite the distribution of *L. raniformis* being scattered sporadically across the Pakenham area, Organ (2004) reported four potentially discrete areas of sub-populations. The western end of one of these sub-populations is within the study area, that is, between Cardinia Road and Officer South Road. The species was not recorded during recent surveys conducted within the proposed Fairway Waters development (Organ 2005b).

Furthermore, recent targeted surveys have revealed that *L. raniformis* is widely distributed throughout the Pakenham, Nar Nar Goon and Bayles area (Quin *et al.* 2005; Hamer & Organ 2006a; Organ & Hamer in prep). Again, the majority of these occupied sites are in the vicinity of permanent or semi-permanent creeks and channels that were created some time ago to drain the former Koo Wee Rup Swamp.

Based on the results of these surveys (Timewell 2003; Organ 2004a), several key habitat attributes have been identified as important for *L. raniformis* in the Pakenham area:

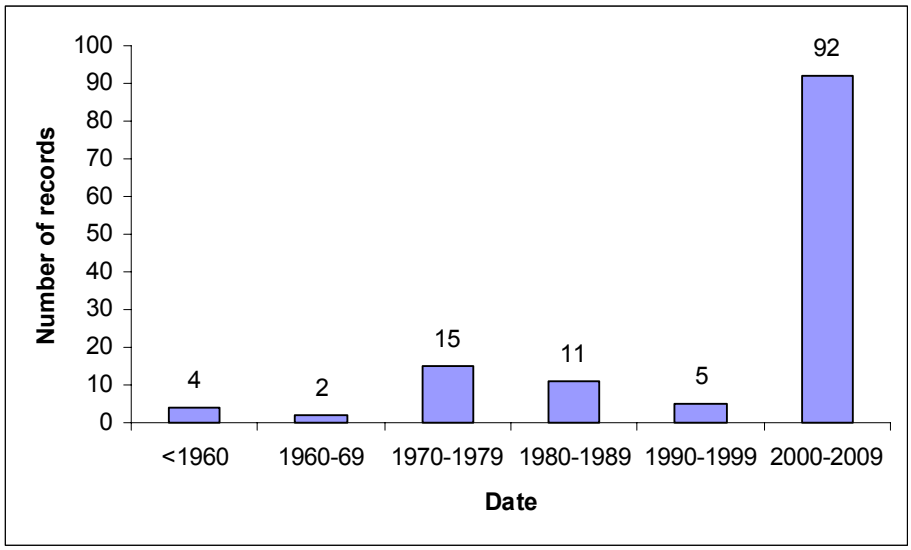
- Several large permanent waterbodies supporting a complexity of habitat features important for breeding and recruitment, particularly extensive areas of fringing, emergent and submerged vegetation;
- Relatively low water turbidity and presence of suitable refuge sites adjacent to occupied sites;
- High density of suitable waterbodies and terrestrial habitats in close proximity to each other (i.e. <500 metres);
- Presence of suitable wetlands located adjacent to drainage lines, creeks, drains and water channels which are suitable for dispersal between sites;
- No apparent barriers to dispersal. For example, the majority of roads throughout the study area are unsealed and would experience low traffic volumes, particularly at night; and
- Absence or relatively low numbers of predatory fish (e.g. Plague Minnow *Gambusia holbrooki*).

Organ (2004a) recorded a correlation between the presence of *L. raniformis* and the distance of waterbodies to main drainage channels. From these investigations it appears that frogs may move from drains to farm dams to breed when habitat (e.g. water levels, vegetation) and climatic conditions (e.g. prolonged rain) become favourable, and conversely, frogs may move from farm dams to the drains when conditions become unfavourable. Indeed, this phenomenon has been documented at a number of other sites occupied by the species such as at the Western Treatment Plant where frogs are known to move between treatment lagoons and drainage channels when habitat conditions become suitable or unsuitable (Organ 2003a, 2003b, Organ 2005d).

3.2 Database Searches

The AVW contains 129 individual records of *L. raniformis* in the local area (i.e. 10 kilometres surrounding the study area) (see Figure 3, Graph 1). The majority of records (n = 92) are from 2002-04 due to the increased search effort devoted to the species in the Pakenham district for the proposed Pakenham Bypass and other developments (e.g. Timewell 2003; Organ 2004a) (see Section 3.1). The recent emphasis on survey for *L. raniformis* can largely be attributed to the species' national threatened status, and the increase in the species' profile. Prior to 2000, the majority of records were from 1970 – 1989, with the nearest documented recorded from Cranbourne Botanic Gardens, Cranbourne.

Graph 1. Records of *L. raniformis* from the Atlas of Victorian Wildlife.



3.3 Field Surveys

Litoria raniformis was recorded from five waterbodies in Area 1 (sites 1a, 1b, 1c, 1e and 1f; see Figure 3). The species was not recorded in Areas 2 and 3. The five waterbodies were included in a mark-recapture study recently completed (Hamer & Organ 2006a). The total number of frogs marked at site 1a as of the 17/1/06 is 11 males and 1 female; site 1b is 0 males and 6 females; site 1c is 1 juvenile, site 1e is 1 female, and site 1f is 3 males and 1 female. Breeding has been confirmed at site 1a, where a pair was observed in amplexus on 29 November 2005 (see front cover). Subsequent surveys at site 1a during the mark-recapture study confirmed successful recruitment, with metamorphosing *L. raniformis* observed in December 2005, January 2006 and February 2006. Sites 1a and 1f had choruses of calling males. No calling was recorded at site 1b and, given that only females were recorded, it appears that during the 2005/06 breeding season this site functioned as habitat for females to forage and shelter prior to moving to site 1a to breed. Although no breeding was observed at site 1b three metamorphs were observed around the banks of the waterbody. These individuals most likely moved from site 1a into site 1b. A juvenile was recorded at site 1c in February 2006 and this individual most likely dispersed from site 1a.

Other frog species recorded during the field surveys included the Common Froglet *Crinia signifera*, Southern Bullfrog *Limnodynastes dumerilii*, Striped Marsh Frog *L. peronii*, Spotted Marsh Frog *L. tasmaniensis*, Southern Brown Tree Frog *Litoria ewingii* and Whistling Tree Frog *L. verreauxii verreauxii*. These species are common in the local area.

3.4 Habitat Assessment

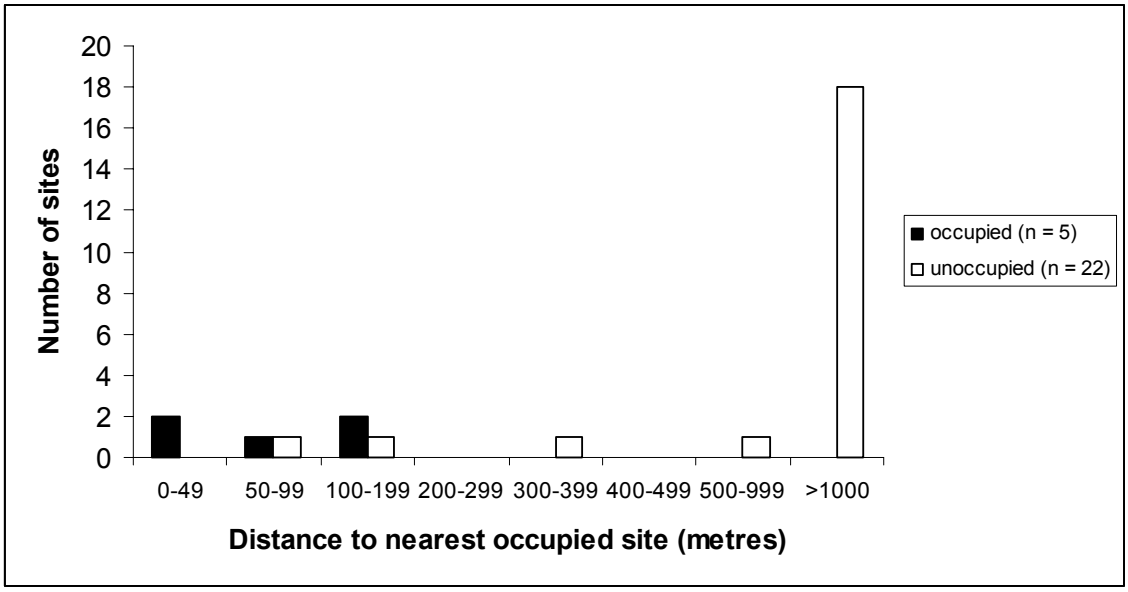
3.4.1 All sites

Habitat assessments were conducted at 27 waterbodies. Most were farm dams, with a range of size and vegetative structure, although the floristic composition is dominated by several species, including Common Spike Rush *Eleocharis acuta*, Tall Spike Rush *Eleocharis sphacelata*, *Juncus* sp. and Cumbungi *Typha* sp. as the dominant emergent and fringing species, and Blunt Pondweed *Potamogeton ochreatus* and Swamp Lily *Ottelia ovalifolia* as the dominant submerged and floating species. The surrounding habitat is dominated by pasture, although several waterbodies occur on the property of commercial plant nurseries. Refuge sites within 30 metres of waterbodies include low levels of rocks, logs, vegetation debris and leaf litter, farm debris and cracked clay. The water quality was generally good, with approximately 50% of the waterbodies having clear water. However, the water quality at site 1a deteriorated over the course of the season, and by February the water was highly turbid due to the increased use during hotter weather by cattle. Water quality at the remaining waterbodies was moderate to poor. Fish are generally absent, with Plague Minnow recorded from five waterbodies (sites 1c, 1d, 1l, 1m and 3b), Common Jolly-tail *Galaxias maculatus* from site 1b, and Short-finned Eel *Anguilla australis* from sites 1b, 1c, 1e, 1m and 2b. Given that trapping or netting was not undertaken during the surveys, it is probable that more sites support fish populations, particularly native species including Short-finned Eel, Common Jolly-tail and Flat-headed Gudgeon *Philypnodon grandiceps*.

The mean distance (± standard deviation) between waterbodies surveyed is 213±289 metres. The mean distance to the nearest waterbody occupied by *L. raniformis* is 1086±754 metres. Approximately half of the waterbodies surveyed are within 50 metres of each other. All five occupied sites are within 200 metres of another occupied site (see Graph 2). However, 82% of the unoccupied sites are greater than one kilometre from an occupied site. This result suggests there is spatial clumping of the distribution of *L. raniformis* toward the south-east corner of the study area. There is minimal connectivity between sites throughout the majority of the study area, particularly outside the south-east corner. The exception is for those sites in close proximity (i.e. within 50 metres) of potential dispersal corridors such as Gum Scrub Creek (sites 1a, 1b, 1c, 1m and 3k) and the drainage channel in the Melbourne – Bairnsdale railway line reserve (sites 1c, 1d, 1e, 1f and 1m). Therefore, the presence of suitable north-

south (Gum Scrub Creek) and east-west (drainage channel along the railway) dispersal corridors appear to be restricted to the south-east corner of the study area, and this may strongly influence the presence of *L. raniformis*.

Graph 2. Distance to nearest occupied site.



3.4.2 Occupied sites

Four of the waterbodies where *L. raniformis* was recorded have good water quality. However, site 1c has poor water quality, although it is speculated that the juvenile recorded at this site was using the waterbody on a temporary basis as a stepping stone during dispersal. Sites 1a and 1b are relatively large waterbodies (0.28 and 0.25 hectares, respectively) with a high percentage cover (40%) of submerged vegetation (*Chara* sp.), although only site 1a has a moderate to high cover of fringing vegetation. Male frogs were recorded calling from fringing Common Spike Rush. Both site 1a and 1b have over 90% open water, and neither site has a distinct emergent layer, although site 1a has a small percentage cover (i.e. 5%) of Tall Spike Rush. Site 1c has no emergent, submerged or floating vegetation, and a low cover (20%) of Common Spike Rush on the bank. Site 1e has a moderate cover (i.e. 40%) of Common Reed *Phragmites australis*, but no submerged or floating vegetation. Site 1f has a moderate cover of Common and Tall Spike Rush, but is dominated by a high percentage cover (i.e. 60%) of floating aquatic vegetation such as *Azolla* sp. and *Lemna* sp. The high cover of floating vegetation at site 1f may be related to the predominantly shallow water depth, with

the emergent layer occurring in a small area of deeper water. Contrary to many occupied sites in the local area, floating vegetation such as *Potamogeton* sp. is largely absent at the remaining occupied sites including sites 1a and 1b where the largest aggregation of frogs was recorded. No fish were recorded at sites 1a, 1e and 1f, although Common Jolly-tail is present in 1b and Mosquito Fish in 1c.

Sites 1a and 1b are in close proximity to each other (i.e. approximately 20 metres). They are also within 30 metres of Gum Scrub Creek, which provides a potential dispersal corridor to the rail reserve. This rail reserve contains a drainage channel and culverts that link to site 1f and eastwards to occupied farm dams immediately south of Harold Street. It also provides a dispersal corridor to other drainage channels in the far south-east corner of the study area. Frogs are likely to be dispersing between site 1f to sites 1a and 1b using sites 1c, 1d and 1e as 'stepping stones', and the drainage channel in the rail reserve as a movement corridor. Indeed, the use of habitats by *L. raniformis* is expected to change on a temporal and spatial scale as demonstrated by the occurrence of 15 adult males at site 1d during a previous survey on the 4/12/2003 (Organ 2004a), and where, despite visiting the site on 10 occasions during the mark-recapture study, no frogs were detected over the current surveys.

In summary, the presence of a series of waterbodies scattered across the study area, particularly those supporting key habitat determinants and located within 500 metres of each other are vital for the long-term persistence of populations in the area. As mentioned, there appears to be a positive correlation between the occurrence of *L. raniformis* and the proximity to permanent drainage channels and streams throughout Pakenham, Nar Nar Goon and Bayles, south of the Princes Highway, including Gum Scrub Creek and Toomuc Creek (Organ pers. obs.).

3.4.3 Significance of *L. raniformis* population in the study area

The study area is considered to be of national significance for *L. raniformis* as it supports a breeding population of the species, provides several high quality breeding sites in the form of farm dams, and the provision of suitable dispersal habitat along Gum Scrub Creek. The conservation significance of the Pakenham population has previously been documented as part of the proposed Pakenham Bypass (Organ 2004a).

The significance of the study area to *L. raniformis* extends beyond the confines of the immediate study area and habitats are important for the maintenance of a significant population over a broader area of the Pakenham region (Organ 2004a).

4 DISCUSSION

4.1 Habitat Creation Projects for *L. raniformis* in Victoria

The purpose of the following section is to provide a summary of a selected number of habitat replacement and/or creation projects which have been completed, currently in progress or are proposed to ensure that *L. raniformis* populations in the Greater Melbourne metropolitan area persist. Information on the success or failure of these projects will be discussed with the primary intent to guide future land management decisions in the Officer area in order to ensure that *L. raniformis* populations persist in an urban context over the long term.

4.1.1 'Fairway Waters' – Pakenham

This is a 17 hectare site located on the eastern side of Racecourse Road directly north of Gippsland railway line, Pakenham (Melways Ref 317 G9 – H9). A series of wetlands will be constructed in 2006 in the southern portion of a site known as 'Fairway Waters'. These wetlands have been designed and will be constructed specifically to provide suitable habitat for *L. raniformis*. A conservation management plan for the species, which includes detailed design and habitat management actions to cater for *L. raniformis* has also been prepared (Organ 2005c). For example, waterbodies will contain a range of habitat characteristics such as extensive cover of aquatic and semi-aquatic macrophytes, and the presence of suitable cover and overwintering sites. Additionally, management will have the ability to drain individual ponds in the event that undesirable fish species such as Plague Minnow or pollutants are present.

Although *L. raniformis* is not currently present at this site (Organ 2005b), the nearest population has been recorded on the Pakenham District Golf Course, approximately 500 metres north east of the site (Timewell 2003; Organ 2004a; Brett Lane & Associates 2004, 2005; author pers. obs.). Up to five specimens were detected from waterbodies (dams) supporting emergent and submerged vegetation during a targeted survey conducted over the 2002/03 and 2003/04 breeding periods (AVW, Timewell 2003; Organ 2004a).

It is possible, indeed probable, that owing to the proximity of the 'Fairway Waters' site to a known population, and the current absence of any apparent barriers to dispersal, frogs may naturally colonise the site in the future. The success or failure of created habitat, and long term persistence of the species on the site (if assuming the species is able to colonise the site) will depend upon the suitability of wetlands after construction and the implementation of the *L. raniformis* Conservation Management Plan (Organ 2005c).

4.1.2 Pakenham Bypass

The proposed Pakenham Bypass covers a distance of approximately 20 kilometres and commences on the western end of the Princes Highway (between Beaconsfield and Officer), continuing eastwards on the southern side of Pakenham, then returning to the existing highway to the north of Nar Nar Goon.

Most of the study area has been wholly or substantially modified since European settlement, and largely consists of agricultural land, primarily used for cattle grazing. However, many areas in the vicinity of the road are currently been developed for residential and industrial use.

Litoria raniformis currently occupies several waterbodies in the vicinity (both north and south) of the proposed Bypass. Subsequent to the detailed monitoring of *L. raniformis* populations which was undertaken between November and March 2002/03 and 2003/04 (Costello *et al.* 2003; Timewell 2003; Organ 2004a) a detailed Conservation Management Plan for the species was developed to mitigate against potential adverse impacts of the road on local populations (Organ 2005a). Specifically, the following measures will be implemented as part of the proposed development:

- Provision of frog underpasses and culvert crossings to allow for ongoing exchange of frogs north and south of the Bypass and to allow frog dispersal between and within breeding, foraging and over-wintering sites;
- The provision of at least 29 separate wetlands to mitigate against potential habitat fragmentation associated with the road development and to provide additional dispersal opportunities under the road. These wetlands will contain key habitat features required by the species;
- Installation of 'drift fencing' or frog fencing. This serves two main purposes; firstly to prevent frogs from entering the road pavement, thus reducing the risk of road mortality, and secondly to guide frogs into crossing structures and under the road; and
- Ongoing population and habitat monitoring to determine the likely impact of the road on local frog populations.

Proposed waterbodies along the length of the Pakenham Bypass have not been created at this stage, but will occur during 2006.

4.1.3 Craigieburn Bypass

Similar to the Pakenham Bypass, the Craigieburn Bypass is a major road development that may potentially cause adverse impacts to known *L. raniformis* populations surrounding the road (Williams 2001, 2002). Several waterbodies either side of the Bypass have been created to treat water runoff from the road pavement. The vegetation in these large waterbodies are in varying stages of establishment with wetlands further south of the Bypass (i.e. Stage 2 of the development) more advanced than those created in the north (Organ pers. obs.). Small ponds

have also been created at the entrances of crossing structures to attract frogs to these areas and to facilitate movement under the road.

Although several of the larger waterbodies currently provide suitable breeding habitat for *L. raniformis*, as of January 2006 the species has yet to be detected at these sites. However, at this stage it is too early to ascertain whether wetlands and underpass structures are functioning as intended, and therefore ongoing monitoring will continue.

4.1.4 Cairnlea Estate

Cairnlea Estate is a newly developed site located approximately 13 kilometres north west of Melbourne CBD (Melways Map 25 F6 and G6). A series of artificial stormwater treatment wetlands have been created as part of the residential development, with several now supporting a population of *L. raniformis* (Organ 2005f). Populations exist in recently created wetlands at Cairnlea Estate and Serpentine Wetlands, Caroline Springs. These artificial ponds have been colonised by frogs dispersing from Kororoit Creek prior to development on the site. However, the majority of these waterbodies are now surrounded by houses, roads and other development, and consequently there is little connection between habitats. While several waterbodies have been created and have been successfully colonised by *L. raniformis*, the long-term viability of these populations in an urban context is unknown.

4.1.5 Botanica Park – Thomastown

Botanica Park is located approximately 15 kilometres from Melbourne CBD, directly north of the Western Metropolitan Ring Road (Melways Map 9 G9 and H9). At this site waterbodies have been created to compensate for the loss of *L. raniformis* habitat located approximately 400 metres to the north, and immediately east of the G. B. Landfill site. The wetlands comprise one large sediment wetland (~30 metres x 20 metres) which receives stormwater runoff from the surrounding residential development, and a long linear (~200 metres long x 10 metres wide) waterbody which varies in depth. This linear waterbody contains extensive areas of varying sized rocks lining the wetland edge. A diversity of emergent, submerged and floating vegetation has also been planted and is now established throughout the entire waterbody. Unfortunately there are now few areas of open water, which is generally required by the species for breeding, as the majority of the waterbody is choked with Cumbungi *Typha* sp. An outlet valve has also been installed at the eastern end of the wetland in the event that it needs to be drained to remove undesirable fish species or pollutants. Treated water eventually discharges into Darebin Creek.

Several *L. raniformis* frogs were translocated into these artificial sites and have successfully bred over the past three seasons (Organ 2006). This site is currently managed by the City of Whittlesea and a detailed management plan which will include detailed actions to ensure that habitats remain suitable for the species will be developed.

4.1.6 Western Treatment Plant – Werribee

The Western Treatment Plant is located approximately 35 kilometres south-west of Melbourne. Melbourne Water manages the Western Treatment Plant primarily for the treatment of approximately 54% of Melbourne's domestic and industrial wastewater. A series of sewage treatment lagoons, drainage channels, and large ponds managed primarily for conservation purposes (e.g. shorebirds, crakes, rails, and the Growling Grass Frog) are present.

The site contains large areas of water which support a diversity of water quality, vegetation cover and other habitat characteristics, and currently supports one of the largest known populations of *L. raniformis* close to Melbourne. With the exception of a few of the natural streams (e.g. Cherry Tree Creek, Little River) dissecting the site, all waterbodies currently occupied by the species are artificial and were created several years ago. It appears that relatively large populations of the species have persisted at the site for over the past 20 years. Indeed, Schulz (1987) recorded large numbers of individuals in treatment ponds and irrigation channels across the southern sections of the plant.

There is currently ongoing management, in accordance with a detailed conservation management plan for the species, of numerous sites to ensure that the *L. raniformis* population on the site is viable in the future (Organ 2003b).

4.1.7 Caroline Springs

Caroline Springs is a relatively recently (post 2000) residential development located approximately 22 kilometres north west of Melbourne CBD (Melways Map 358 F2). A series of artificial wetlands have been created as part of the residential development, with several now supporting a population of *L. raniformis* (Organ 2004c, 2005f). A large number of frogs of mixed age classes were recorded during a targeted survey of the species on 19/11/2005 along Kororoit Creek and in artificial waterbodies south of the creek (Organ 2005f). However, fewer frogs were recorded during a recent inspection (February 2006) of the site, which may be a result of the lack of successful recruitment due to habitat changes and the presence of large numbers of Plague Minnow.

Wetlands at Caroline Springs, between Kororoit Creek and the Western Highway, are now completed surrounded by houses and roads, with no connection to Kororoit Creek. While several waterbodies have been created and have been successfully colonised by *L. raniformis*, the long-term viability of these populations in an urban context is unknown, and somewhat questionable without active management.

4.2 Habitat Creation Projects for *L. aurea* in New South Wales

Several projects have been undertaken in New South Wales to create habitat for *L. aurea*, primarily to augment existing populations. The best known example is at Homebush Bay, the site of the Summer 2000 Olympic Games. This site has received considerable attention since the discovery of *L. aurea* in the early 1990s and has been the subject of a PhD research project (Christy 2000), a variety of management plans and development appraisals (e.g. Greer 1994; AMBS 1999a, 1999b), and publications (White 1995; Pyke and White 1996). Other projects have aimed to translocate populations for which habitat was to be destroyed for residential development or road construction (White and Pyke in press).

4.2.1 Homebush Bay

4.2.1.1 Background

One of the largest known populations of *L. aurea* in New South Wales resides in the Homebush Bay area, within two discrete areas: a disused brickpit and areas external to the brickpit that once supported extensive wetlands. The 15.4 hectare brickpit was formerly a quarry for the NSW State Brickworks, and comprises four levels of relatively flat land enclosed within steep cliffs or slopes (AMBS 1999a). Since quarrying activities ceased in 1992, the site developed naturally into a mosaic of permanent and ephemeral freshwater wetlands and ponds (Greer 1994). *Litoria aurea* successfully colonised the brickpit and much of the brickpit is regarded as core breeding habitat for the species in the Homebush Bay area, containing over 30 potential breeding sites (AMBS 1999a). The brickpit also contains ponds that were specifically created as breeding habitat for *L. aurea*. These ponds were created to offset the loss of breeding ponds in a low section of the brickpit that was flooded as part of a water reclamation project associated with the Olympic Games infrastructure. The majority of habitat for *L. aurea* in the brickpit includes a variety of broad, shallow ponds and watercourses on rock or shallow soil, extensive rock and rubble piles, and areas of low, sparse, weedy vegetation typical of disturbed sites (AMBS 1999a).

To comply with the New South Wales Threatened Species Conservation Act 1995, a Species Impact Statement was prepared that assessed the impacts of the proposal on the population of *L. aurea* at Homebush Bay, and detailed habitat works necessary to replace lost habitat and progressively enhance habitat in the brickpit for the species (AMBS 1999b). Outside the brickpit, habitat for *L. aurea* has been constructed (30 discrete ponds/wetlands) in different stages since 1994 around a former landfill site at Haslams Creek and, more recently, on an extensive floodplain at Newington (AMBS 1999a). The species has naturally colonised, or been relocated to, many of these new ponds. Since the Olympic Games, these areas have been incorporated into the Millennium Parklands, an area dedicated to passive recreation and conservation.

4.2.1.2 Key design features

A habitat strategy has been developed at Homebush Bay that aims to provide habitat areas to maintain a viable population of *L. aurea*, in an effort to minimise the impact of habitat removal required by proposed developments (AMBS 1999a). This strategy included provision for habitat creation to offset habitat loss. Pond designs included five habitat types:

- Deep ponds (to 1 metre) to replicate breeding habitat in the brickpit;
- Shallow ponds between 50mm and 250mm deep with gravel base and a fluctuating water level;
- Scree slopes including rock shelter piles to provide foraging habitat with protection for frogs;
- Drainage swales and ponds of varying length and depth to link ponds; and
- Shallow ponds and macrophyte trenches including broad shallow ephemeral ponds 50mm to 250mm deep with permanent macrophyte trenches to provide refuge.

Habitat specifications for pond design at Homebush Bay generally follow the recommendations of Pyke and White (1996):

- Pond substrate must retain water and crushed or broken sandstone over clay is recommended;
- The pond should be shallow at one end (100 – 150mm at a distance of 1 or 2 metres from the edge) and deeper at the other (500 – 1000mm);
- There must be provision to alter the water level of the pond and to completely drain the pond if required;
- A range of pond sizes between 10 – 70 metres long and 5 – 15 metres wide;
- Piles of sandstone rocks should be placed at intervals along the edge of the ponds (e.g. one pile every 5 – 10 metres);
- Clumps of aquatic plants should be established along the edges of the pond;
- Areas surrounding the ponds should be maintained as grassland for a minimum of 20 metres, with no trees planted as they may overshadow the ponds. Mowing or slashing should not occur in this area; and
- Use of fertilizers, pesticides and other chemical treatments which will affect water quality of the ponds should not be used within the catchment area.

In addition to habitat creation, habitat enhancement aims to improve habitat in the brickpit and elsewhere at Homebush Bay, to increase the population size of *L. aurea*. Habitat components that can be added to an enhancement area include (AMBS 1999a):

- A freshwater body;

- Surrounding foraging area of low grassy vegetation;
- Shelter sites;
- Basking sites and aquatic vegetation;
- Over-wintering sites;
- Removal of aquatic predators (if necessary); and
- Capacity to manage the site to maintain its suitability for *L. aurea*.

Similar to *L. raniformis*, *L. aurea* is known to colonise and persist in man-made or disturbed habitats, and it has been suggested that a level of disturbance that prevents habitat succession or creates new areas to colonise is important to the species (Pyke and White 1999). With respect to the latter recommendation, vegetation succession may result in the habitat becoming progressively less suitable for *L. aurea* (AMBS 1999a). Management actions to counter succession may include periodic removal of dense emergent vegetation by mechanical means or by altering water levels in ponds (e.g. draining ponds). The latter method also removes unwanted tadpole predators, such as Plague Minnow or *Gambusia*.

Buffer zones around ponds provide potential foraging, shelter and dispersal habitat. It has been recommended that an area of approximately 20 metres (or greater) around ponds and pond complexes at Homebush Bay remain undisturbed by development or unauthorised access (AMBS 1999a). Movement corridors recommended at Homebush Bay include (Pyke 1995):

- minimum 20 metres width, preferably 50 metres or greater;
- corridors should follow drainage lines;
- corridors should provide continuous vegetation and rock piles should be placed in and adjacent to each corridor at intervals of about 50 metres;
- ponds should be constructed at regular intervals along the corridor; and
- the number and width of roads and other linear barriers to dispersal that intercept the corridor should be minimised and include underpasses in the construction.

If underpasses are required, the specifications of Pyke (1995) should be adopted:

- Underpasses should be 0.5 to 1.0 metres high and 2 to 3 metres wide, or larger, and as short as possible;
- The base of each underpass should have several levels so there will always be a passageway that is not flooded;
- Underpasses should be positioned within drainage lines with the same specifications as movement corridors (see above); and

- Small ponds at least 15 metres in diameter and 100 to 150mm deep should be located adjacent to each underpass on both sides, and vegetated with macrophytes

Certainly, the design recommendations above have been used for several projects for *L. raniformis* in Victoria.

4.2.2 Shortland Wetlands Centre

A proposal by the Shortland Wetlands Centre (SWC) to reintroduce *L. aurea* into three artificial wetlands created specifically for the species aimed to establish a permanent breeding population within the confines of SWC (Shortland Wetlands Centre 2001). *Litoria aurea* once occurred throughout wetlands in the SWC but disappeared during the 1970s and 1980s. The pond design specifications followed those recommended by Pyke and White (1996), with some input of the local habitat requirements of *L. aurea* provided in Hamer (1998). The wetlands were constructed and planted with locally-occurring native vegetation, and the wetland area was situated on an 'island' to protect frogs from terrestrial predators such as cats and foxes. Tadpoles were introduced into the wetlands from eggs collected from a nearby wetland at Sandgate. It is not known at this stage how successful or otherwise this reintroduction project has been.

4.2.3 Translocation Projects

Several translocation projects conducted in the Greater Sydney metropolitan area have aimed to conserve populations of *L. aurea* at risk of impending destruction by "rescuing" frogs and moving them to another location where suitable habitat has been created, or moving them into captive breeding facilities for later release of their offspring, usually tadpoles. Attempted translocations of *L. aurea* have taken place in relation to two source populations (i.e. Rosebery, Arncliffe) and four recipient sites (i.e. Botany, Marrickville, Long Reef and Arncliffe). Recipient sites were stocked with the offspring from Roseberry (Dalmeny Avenue) and Arncliffe (Marsh Street Wetland) frogs that had been collected and maintained in captive-breeding facilities at Taronga Zoo, Sydney. A summary of the translocations is provided in Table 2. White and Pyke (in press) provide a review of translocation projects undertaken in the Greater Sydney metropolitan area since 1996. Most releases were of captive-bred tadpoles, with the exception of Long Reef Golf Course, where some immature and adult frogs were released.

Several translocation projects failed due to invasion by Mosquito Fish, competition from other frogs especially the Striped Marsh Frog (*Limnodynastes peronii*) and bird predation on tadpoles. In general, translocations that were most successful appeared to succeed because of the attention given to the provision of sufficient foraging, shelter and breeding habitat, the active management of these recreated habitats and the control of competing frog species and native (such as water birds) and exotic predators (especially fish and foxes). The various case

studies highlight the need to cater for all habitat requirements, not just those habitat components that are most easily provided. The passive translocation of Bell Frogs to new sites within the immediate vicinity of the parent (source) population was found to be more successful than forced translocations of frogs.

Each translocation was routinely monitored and insights into the further refinement of Bell Frog habitats were gained resulting in improved translocation success. Despite the improvement in outcome, translocations still remain a costly undertaking and one that requires a long-term commitment to monitoring and habitat management.

The species is also the focus of other habitat modification/enhancement programs that may involve the passive relocation of *L. aurea* from close by sites to newly created habitat areas (e.g. Greenacre, White 1999; Port Kembla, White 2001a; Woonona, White 2002; Kooragang Island, AMBS 2004).

Table 2. Appraisal of translocation projects for *L. aurea* undertaken in the Sydney metropolitan area.

Source site	Recipient site	Reason for translocation	Habitat features at recipient sites (i.e. created habitat)	Date of habitat creation (subsequent enhancements)	Arrival of non-translocated frogs	Date of release (captive-bred stock)	Tadpole metamorphosis successful?	Date of first unassisted breeding (subsequent spawning)	Frogs present in subsequent seasons?	Success of translocation and management issues
Arncliffe (Marsh Street wetlands)	Arncliffe (adjacent to Kogarah Golf Course)	Development consent for the M5 East Motorway in southern Sydney.	Two ponds 25 x 20 metres (0 – 1 metre deep) Extensive boulder fields Emergent vegetation planted Fencing to exclude foxes Ponds designed to exclude Striped Marsh Frogs *Limnodynastes peronii*	November 1999	January 2000	March 2000, February 2001	Yes	January 2000 (November 2000, January 2001)	Yes	Successful. No further tadpole releases planned.
Roseberry (Dalmeny Avenue)	Botany (Sir Joseph Banks Park)	Section 120 licence for proposed residential development.	Two large (permanent) and two small (ephemeral) ponds Native grasses planted around ponds Ponds naturally colonised by Cumbungi Bushes and trees removed within 20 metre radius of ponds Fish poisons used to eradicate Mosquito Fish and erection of frog exclusion fencing in June 1999 Large sandstone boulders placed around banks of largest pond in late 1999	Early 1996 (June 1999, late 1999)	No	1. March 1996 2. February 1997 3. November 1999 4. January 2000	Yes No Yes Yes	None	No No No Yes	1. Unsuccessful due to inappropriate timing of tadpole release. 2. Unsuccessful due to invasion of ponds by Mosquito fish and competing frog species such as Striped Marsh Frogs. 3. Unsuccessful due to lack of overwintering shelter habitat. 4. Successful.
Roseberry (Dalmeny Avenue)	Long Reef Golf Course	No legislative requirement. Opportunistic use of created habitat.	Breeding habitat inadvertently created through the creation of 12 new ponds through the golf course. Removal of aquatic vegetation to keep ponds open. Addition of rock piles.	Not specified. Additional two ponds created late 1997.	No	January 1998 – September 2002	Yes	None	Yes	Partly successful. No metamorphosis observed in ponds containing Mosquito fish. Few frogs surviving over winter. Further releases planned.

Source site	Recipient site	Reason for translocation	Habitat features at recipient sites (i.e. created habitat)	Date of habitat creation (subsequent enhancements)	Arrival of non-translocated frogs	Date of release (captive-bred stock)	Tadpole metamorphosis successful?	Date of first unassisted breeding (subsequent spawning)	Frogs present in subsequent seasons?	Success of translocation and management issues
Roseberry (Dalmeny Avenue)	Marrickville Community Nursery	No legislative requirement. Not aimed at creating a long-term habitat area for the species.	4.5 metre diameter pond, maximum depth of 0.5 metres. Sandstone blocks around pond. Pots containing the emergent rushes *Typha* sp. and *Eleocharis* sp. were submerged in the pond. Frog-exclusion fencing was set up around the outer perimeter of the nursery to exclude other frog species from entering the site and to prevent Bell Frogs from escaping the site Site was vegetated and consisted of a mixture of native plants and exotic grasses Salt added to pond (3% seawater) in spring 2000 to eradicate Chytrid fungus	1997 (spring 2000)	No	February 1998, February 1999, December 2000	Yes	November 1999	Yes	Partly successful. Predation by birds reduced tadpole population. Predation by Black Rats *Rattus rattus* on adult frogs. Adult mortality due to Chytrid fungus. Predation of juvenile *L. aurea* by Striped Marsh Frogs

4.3 Priority Areas for *L. raniformis* Conservation in Officer

It is imperative that areas supporting breeding habitat for *L. raniformis* are conserved within the study area. The results from this study and the mark-recapture study (Hamer & Organ 2006a) have revealed that successful recruitment is occurring in site 1a and the species has been recorded in surrounding waterbodies (1b, 1c, 1e and 1f). The results of the mark-recapture surveys also demonstrates that frogs are moving between sites over the course of the active period, including juvenile dispersal from site 1b to other waterbodies such as 1c. Movement of female *L. raniformis* has also been recorded from site 1b to 1a during the mark-recapture study. Because of the positive correlation between the occurrence of *L. raniformis* and the proximity to permanent drainage channels and streams throughout Pakenham, it is likely that Gum Scrub Creek is an important dispersal corridor for the species in the study area. Given these results, the far south-east corner of the study area and the Gum Scrub Creek riparian corridor is considered a high conservation priority area (see Figure 4).

The population in this high priority conservation area is linked to additional waterbodies to the south-east that are currently occupied by *L. raniformis* (Hamer & Organ 2006a; Organ & Hamer in prep). It is reasonable to conclude that the population in the study area is part of the far north-west corner of a metapopulation that extends throughout Pakenham, Nar Nar Goon and Bayles, south of the Princes Highway. Results from the mark-recapture study have yet to confirm that movement of frogs is occurring from the study area to waterbodies to the south-east, south of the railway. The nearest known occupied waterbody outside the study area is a farm dam, approximately 450 metres south-east of site 1b, in which up to eight calling males have been recorded, as well as females, but recruitment has not been observed at this stage.

4.4 Priority Areas for Habitat Creation and Enhancement in Officer

Aside from being a primary conservation area, the far south-east corner of the study area provides opportunities to create additional habitat and augment the population that currently exists there. Waterbodies created within several hundred metres of sites 1a, 1b, 1c, 1e and 1f are likely to be colonised by *L. raniformis*, providing they contain the necessary habitat components such as large size, permanent water, patches of emergent and submerged vegetation, are fish-free and have good water quality (see Section 4.6). Given that the species is likely to use Gum Scrub Creek as a dispersal corridor, there is the possibility that habitat created north of the Princes Highway within the vicinity of the creek will be colonised. Indeed, anecdotal evidence at another site along the Hume Highway directly south of Donnybrook Road in Mickleham, suggests that juvenile *L. raniformis* may potentially be using a culvert under the Hume Highway to move to suitable breeding habitat on the other site of the road (G. Heard pers. comm.).

The area that is recommended for habitat creation is bounded by the Princes Highway to the south, Gum Scrub Creek to the east and McMullen Road to the west (see Figure 4).

The riparian corridor through which Gum Scrub Creek flows should be protected and the corridor width increased where practicable. Pyke (1995) recommends a minimum movement corridor width of 20 metres, and preferably greater (e.g. 50 metres) for populations of *L. aurea* in New South Wales. A similar approach should be adopted in designing corridors for *L. raniformis* in Victoria. Increasing the width of the Gum Scrub Creek corridor reserve would also allow opportunities to rehabilitate degraded swamp scrub vegetation and improve the quality of instream aquatic habitat for frogs, fish and other biota. There are also opportunities to create a series of small ponds interconnected to one another along either one, or both sides of the creek.

4.5 Wetland Design and Habitat Enhancement

Previous research on *L. raniformis* and *L. aurea* has shown that a landscape-based approach to habitat creation and management is required (Robertson *et al.* 2002; Hamer *et al.* 2002). For example, the likelihood of the species occupying a waterbody is largely dependent on the distance to a nearby occupied site. Therefore, it is recommended to create habitat close (i.e. within 500 metres) of the existing population in the far south-east corner of the study area, to augment the current extent of habitat for *L. raniformis*. Key design requirements to be incorporated into wetland creation should follow the recommendations of Organ (2005a, 2005c), which outlined design features for created wetlands to mitigate the impact of the proposed Pakenham Bypass. The 'Constructed Wetland Systems Design Guidelines for Developers' (Melbourne Water 2002) should be referred to during all phases of wetland design and construction. A summary of key design requirements for created wetlands for *L. raniformis* in the study area includes:

- Wetlands should be located within 500 metres of currently occupied sites and at any underpass and culvert entrances where roads are proposed to be constructed;
- Wetlands should be greater than 40 x 10 metres;
- There should be provision of a range of edge habitats;
- Wetlands should have low water turbidity, be still, have low nitrate and phosphate, and salinity levels;
- Wetlands should be surrounded by a terrestrial buffer of no less than 20 metres width, in which there is no development, mowing, slashing or use of herbicides and pesticides, but which may be landscaped with indigenous grasses, herbaceous species and low shrubby vegetation (but no trees);
- Wetlands should have permanent water levels between 0.5 and 2.0 metres in depth;

- There should be inclusion of rock piles, rock matrixes and large woody debris around wetlands;
- Wetlands should be planted with a dense cover and diversity of emergent, submerged and floating vegetation;
- Access tracks, roads, houses and other infrastructure should not be located near created wetlands, and there should be no apparent barriers to dispersal;
- Wetlands should be kept free of predatory fish such as Plague Minnow and non-native fish such as Trout;
- Cattle grazing should be discouraged around existing and created wetlands, and movement corridors, particularly within the riparian zone of Gum Scrub Creek and any areas conserved adjacent to the creek;
- Several smaller ephemeral wetlands should be created around the larger permanent wetland that provide additional habitat that is more likely to remain fish-free, because it will dry out during periods of extended dry; and
- Small ponds and depressions should be constructed between created wetlands, and between created wetlands and potential dispersal corridors such as Gum Scrub Creek, preferably along drainage lines, to act as smaller movement corridors in the study area.

Created wetlands should be not used for recreational purposes and should not be stocked with fish for sporting or other purposes. The suitability of vegetation for *L. raniformis* should be determined and supplementary plantings undertaken by a qualified wetland practitioner. Undesirable weeds or aquatic vegetation that is choking the wetland (e.g. *Typha* sp.) should be removed preferably by physical removal, although frog-sensitive herbicides such as Roundup Bi-active may be used where this is not possible or not feasible. Damage to aquatic vegetation immediately after planting in newly created wetlands by waterfowl may be prevented by protective netting. Wetlands should be pumped dry if predatory fish invade, although the implications of draining on tadpoles and frogs in the wetland needs to be considered prior to any drainage activities.

4.6 Mitigation Measures

4.6.1 Habitat protection

The majority of the study area and immediate surrounds are within the designated Pakenham Urban Growth Corridor and, as such, will be developed primarily for residential purposes over the next 5 – 10 years. It is important that as many, if not all, waterbodies in the south-east corner of the study area (i.e. those that currently provide suitable habitat for *L. raniformis*) are protected and enhanced to ensure populations persist in the future. Where possible, waterbodies could be retained in areas of open space or in reserves; however, connection between these sites needs to be maintained for population viability.

4.6.2 Road construction

If new roads are proposed for construction in priority areas for *L. raniformis* conservation or habitat creation/enhancement (see Figure 4), suitable measures to mitigate the impact of the road structure and traffic on the movement of frogs should be included in the road design. The most important design feature is the incorporation of underpasses that are strategically positioned in areas where frogs are known or considered likely to move between habitats. Underpasses allow dispersing frogs to move through them and avoid having to cross roads where the risk of mortality may be high, depending on traffic volumes. Underpasses have been included in several large-scale road projects throughout metropolitan Melbourne, including the recently completed Craigieburn Bypass (10 fauna underpasses, Williams 2001) and proposed Pakenham Bypass (nine underpasses proposed, Organ 2005a). Although frogs are likely to use underpasses if these structures are constructed appropriately, there has been no documented evidence to show that these structures alone would mitigate against isolation effects caused by roads, and therefore, the efficacy of frog underpasses for *L. raniformis* must be viewed with caution (Organ 2005a).

The main direct impacts associated with road construction in the vicinity of populations of *L. raniformis* are traffic strike and habitat loss; indirect impacts include habitat fragmentation and isolation, and pollution reducing water quality in adjacent and downstream waterbodies. For example, fragmentation may result in the isolation of sites occupied by *L. raniformis* because of the increase in the required dispersal distance between waterbodies, which may be beyond the distance typically travelled by dispersing frogs, and hence exchange of frogs between sites may not occur (Organ 2005a).

The key design requirements for frog underpasses proposed to mitigate the effects of the Pakenham Bypass on *L. raniformis* are outlined in Organ (2005a). It is essential that suitable wetlands (preferably permanent) are created either side of the underpasses to facilitate or encourage the movement of frogs under roads. Culverts proposed for construction in priority areas may also be designed to function as crossings for *L. raniformis* (see Organ 2005a). Drift fences are also required to be installed at both ends of underpasses and culverts because they assist frogs in locating underpasses by guiding their movement, and prevent frogs from entering the road surface. Recommendations for drift fence design are outlined in Organ (2005a). However, in summary the following design aspects should be considered:

- Underpasses should be as straight as possible, and be rectangular in cross section with minimum dimensions of 1.0 metres high x 1.5 metres wide at ground level;
- Underpasses should have a smooth surface, have a flat bottom and have no obstructions (e.g. rocks or logs). Depending upon the size of the underpass benching should be provided along one or both sides of the underpass so that the underpass remains dry in 1 in 5 year flood events, thus allowing frogs to move under roads;

- Light or air slots in the top of underpasses should be considered for aeration and temperature equilibrium;
- Constructed wetlands at underpass entrances should be at least 20 metres x 10 metres in diameter, up to one metre in depth, and contain sufficient vegetation cover and refuge sites;
- Lockable, movable gates should be provided at each end of the underpass to exclude rabbits, foxes and cats; and
- Underpasses should be monitored to determine their effectiveness and to ensure that they area functioning as intended.

4.6.3 Water Quality

Future residential development in the study area has the potential to result in stormwater contamination and uncontrolled runoff into existing and created frog habitat. Increases in the area of hard surfacing may in increased runoff, nutrient levels and sediment entering Gum Scrub Creek, and development upstream of the creek has the potential to alter its hydrology. It is therefore recommended that vegetation removal be minimised throughout the Gum Scrub Creek catchment and that strict Erosion and Sediment Control Plans be required for all developments in the study area. The establishment of revegetated open space and enhancement of the riparian zone of Gum Scrub Creek is recommended to protect the integrity of frog movement corridors in the priority area. Water Sensitive Urban Design should be incorporated into the design of all future developments in the study area.

4.6.4 Feral and domestic animal control

There is currently a high density of red foxes in the priority area for *L. raniformis* conservation in the study area (Organ & Hamer pers. obs.). For example, during the detailed mark-recapture study several foxes and fox cubs were observed in the vicinity of Gum Scrub Creek and sites 1a and 1b. Over the course of the monitoring period there was a significant reduction in the number of frogs detected at sites 1a and 1b, and indeed on one night, one of the females previously marked had sustained a serious injury (loss of one of its legs). It is reasonable to assume that this was the result of predation from a fox, which coincidently was observed within 30 metres of the site on the same night. It is possible that foxes may be following the tracks of field personnel, which unfortunately has lead to an increase in predation.

Foxes are known to hunt and kill bell frogs and therefore pose a risk to the population of *L. raniformis* in the study area. It is recommended that a Feral Animal Control Plan be implemented in the study area to reduce the population size of foxes.

Future residential development close to the priority area is likely to introduce unrestrained cats that may also hunt and kill *L. raniformis*. Therefore, implementation of a night-time

curfew on cats is an option, or alternatively a cat covenant may be considered as part of future developments in the area. Responsible pet ownership should also be encouraged, particularly regarding the proper confinement and restraint of cats.

4.7 Monitoring of *L. raniformis* Habitats and Populations

4.7.1 Created wetlands

Monitoring and management of created wetlands is essential over the first two years after establishment, during which time vegetation condition should be monitored every three months. Monitoring of water quality at created wetlands is considered essential to ensure that wetlands are suitable for reproduction, tadpole development and recruitment. Water monitoring should occur at least every three months for the first two years after wetland construction and the requirement for water quality monitoring should be reviewed after two years. Sampling methods should be consistent with EPA guidelines for water quality. Water sampling should also be conducted at existing wetlands so that comparisons can be made between created versus existing wetland water chemistry. Wetlands should be at full water level within at least six months to one year after construction and if they have not naturally reached this level, they should be artificially filled with water. Dense aquatic vegetation may reduce the area of open water in a wetland and reduce its suitability as breeding habitat for *L. raniformis*. If the removal of aquatic vegetation is deemed a necessary action by a qualified wetland ecologist or zoologist, then manual removal should be undertaken.

4.7.2 Movement Corridors

Any enhancement works along Gum Scrub Creek should be monitored every three months to determine the progress of vegetation rehabilitation. Water quality in the creek should be monitored at these times, paying particular attention to turbidity, total dissolved solids, salinity, and nutrient levels, which are potential gauges of the impact of residential and other development in the catchment. Habitat features along movement corridors, such as rock piles, and vegetation condition should be inspected to determine their suitability for *L. raniformis*. Furthermore, prior to any disturbance of the creek, frog salvage and translocation measures should be undertaken, only after all the necessary permits and approvals are obtained. Frog salvage and translocation measures should follow an appropriate Frog Salvage and Translocation Protocol.

4.7.3 Population Monitoring

The status of *L. raniformis* at existing and created wetlands should be determined at least once a month over the activity period (i.e. September to March) and once during the non-breeding period. Waterbodies which the species is known to occupy, created wetlands and potential habitat (where the species was not recorded during the present study) should be surveyed

using diurnal and nocturnal survey techniques, similar to the methodology used in this study. Diurnal searches would also include active searching beneath rocks and debris (e.g. fallen timber, corrugated iron, fence posts) for inactive frogs during a prescribed search period. Site-specific habitat variables that should be recorded during the day include those recorded during this study (see Section 2.4). A photo (at the same location) of each survey site, at both created and existing wetlands, should be taken so that changes in habitat conditions over time can be recorded. All surveys will follow the hygiene protocols described in Section 2.5.2 to reduce the risk of transmission of chytrid fungus between frogs and between sites.

There is the possibility of swabbing frogs caught during the surveys to obtain samples for analysis to determine the presence of chytrid in the population. There is also potential to include created wetlands within the network of waterbodies currently being surveyed in the mark-recapture study to determine the colonisation and movement patterns, and population size, of *L. raniformis* in the south-east corner of the study area.

Waterbodies where calling males are recorded should be surveyed for tadpoles using fish traps containing glow sticks that are deployed for several nights at each site. Active searching for metamorphs should be conducted during diurnal or nocturnal surveys at sites where calling and/or tadpoles are recorded. Other frog species recorded during monitoring should be noted to determine species turnover at existing and created wetlands.

5 CONCLUSION

During the targeted surveys 11 waterbodies were surveyed in Area 1, two in Area 2, and 12 in Area 3, while six waterbodies (1a-1f) were included in a mark-recapture study of *L. raniformis*. Diurnal habitat assessments were conducted at 25 waterbodies on 22 and 24 November 2005 to determine their suitability as habitat for *L. raniformis*. Following the habitat assessments, nocturnal surveys were conducted at 22 waterbodies, considered potential habitat for the species in the study area, on the 22 and 24 November, and 7 December 2005.

While the majority of the waterbodies surveyed do not currently support *L. raniformis* populations (i.e. absence from Areas 2 and 3), frogs were detected from five waterbodies in Area 1 (sites 1a, 1b, 1c, 1e and 1f). Breeding has been confirmed at site 1a, where a pair was observed in amplexus on 29 November 2005 and metamorphosing froglets recorded.

Several mitigation measures have been provided to protect and enhance habitat values for *L. raniformis* in the study area, including the retention of important breeding sites such as 1a and 1b and other sites where frogs have been detected, provision of additional habitat along Gum Scrub Creek, and the control of feral and domestic animals.

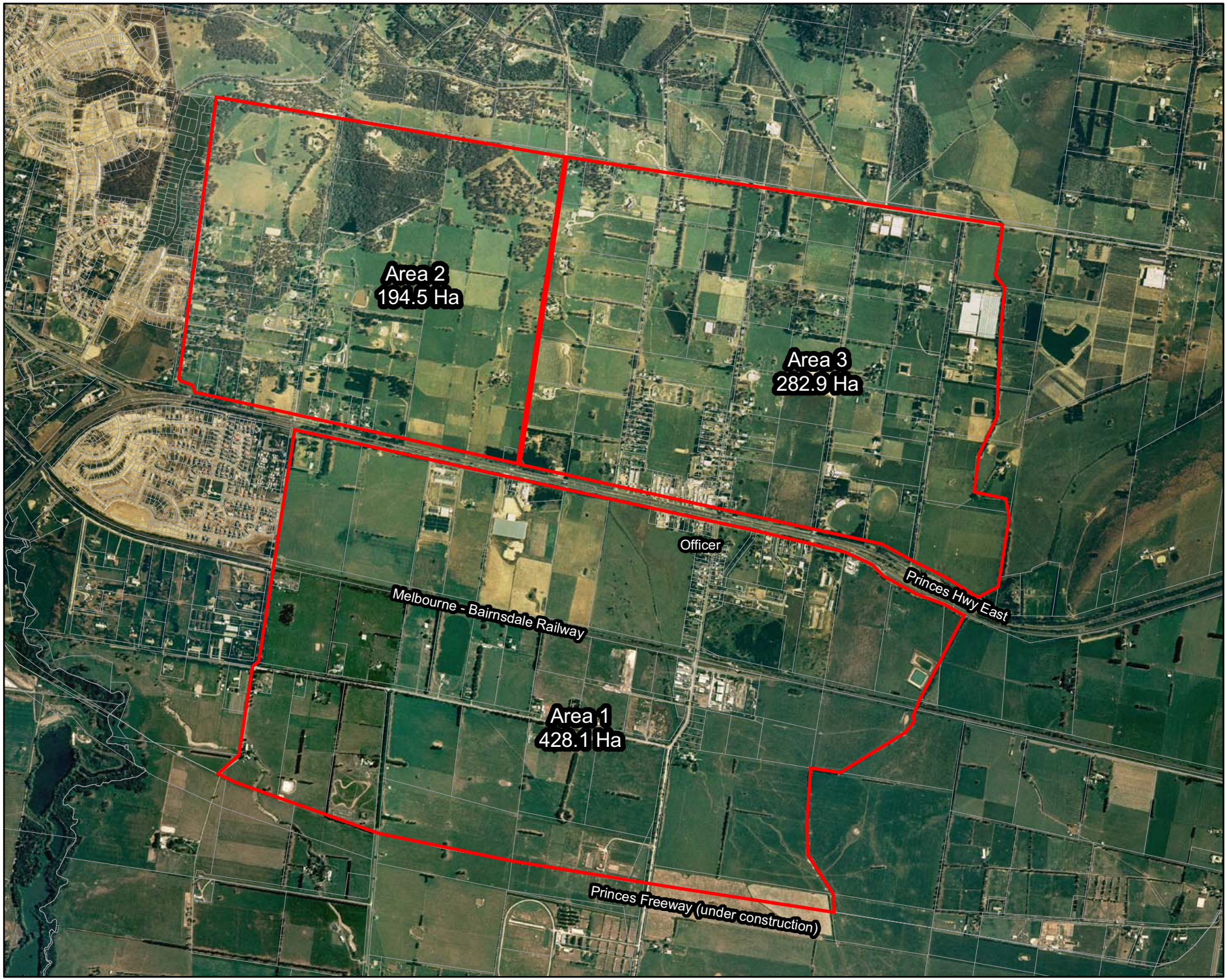
Monitoring and management of created wetlands is also essential over the first two years after establishment, during which time vegetation condition should be monitored every three months. Dense aquatic vegetation may reduce the area of open water in a wetland and reduce its suitability as breeding habitat for *L. raniformis*. If the removal of aquatic vegetation is deemed a necessary action by a qualified wetland ecologist or zoologist, then manual removal should be undertaken.

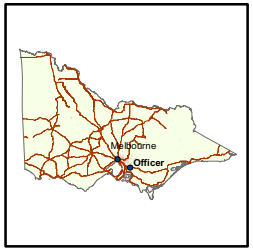
Any enhancement works along Gum Scrub Creek should be monitored every three months to determine the progress of vegetation rehabilitation. Water quality in the creek should be monitored at these times, paying particular attention to turbidity, total dissolved solids, salinity, and nutrient levels, which are potential gauges of the impact of residential and other development in the catchment. Habitat features along movement corridors, such as rock piles, and vegetation condition should be inspected to determine their suitability for *L. raniformis*. Furthermore, prior to any disturbance of the creek, frog salvage and translocation measures should be undertaken, only after all the necessary permits and approvals are obtained. Frog salvage and translocation measures should follow an appropriate Frog Salvage and Translocation Protocol.

The status of *L. raniformis* at existing and created wetlands should be determined at least once a month over the activity period (i.e. September to March) and once during the non-breeding period. Waterbodies which the species is known to occupy, created wetlands and potential habitat (where the species was not recorded during the present study) should be surveyed using diurnal and nocturnal survey techniques, similar to the methodology used in this study.

There is also potential to include created wetlands within the network of waterbodies currently being surveyed in the mark-recapture study to determine the colonisation and movement patterns, and population size, of *L. raniformis* in the south-east corner of the study area.

FIGURES





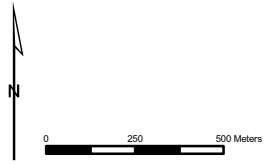
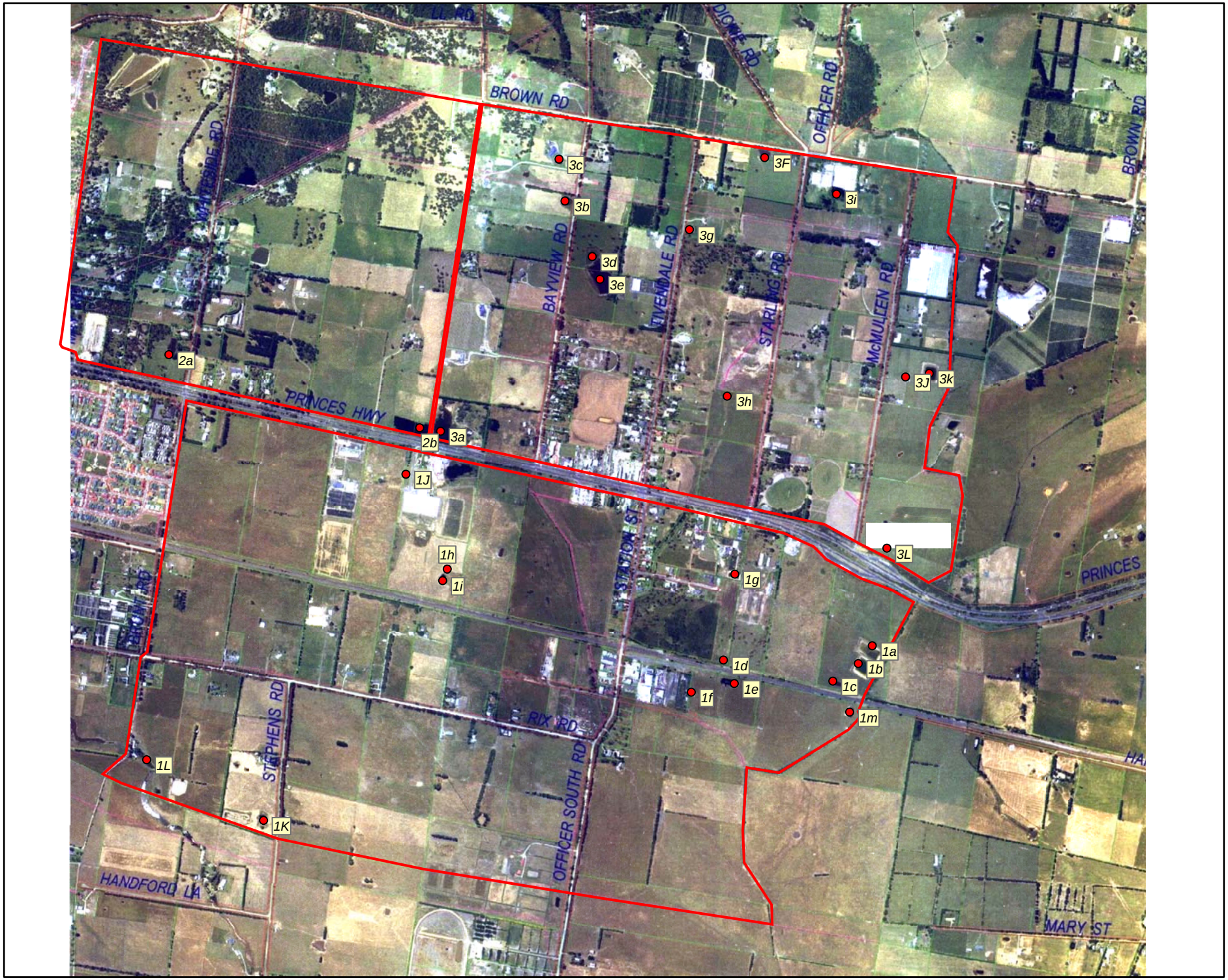
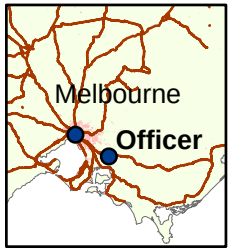


Figure 1
Study Area Location
Officer Structure Plan

ecologypartners

EP Dwg Number: 189 Fig 1
Drawn by: LS
Revision: B
Issue Date: 19/06/2006





Legend

- Frog Survey Location
- Study area boundaries

N

0 125 250 500
Meters

Figure 2
Survey Locations
Officer Structure Plan

ecology partners

EP Dwg Number: 189 Fig 2
Drawn by: LS
Revision: A
Issue Date: 26/04/2006

Legend

2005/06 Survey

- Litoria raniformis recorded

Previous Surveys

- Litoria raniformis recorded

Labels:
(11/05/2003 - 15) = date of record and numbers;
(A) = Adult; (J) = Juvenile;
(M) = Male; (F) = Female;
(S) = Seen

1:40,000 at A2

0 0.5 1 2 3 4 5
Kilometers

ecologypartners

EP Dwg Number: 189 Fig 3
Drawn by: LS
Revision: D
Issue Date: 21/06/2006

Figure 3
Locations of the Growling Grass Frog
Litoria raniformis in Cardinia Shire

Habitat protection/connectivity

Investigate habitat creation/augmentation

Study area boundary

Note: Areas of Growling Grass Frog habitat outside of the study area also need protection and enhancement where possible.

N

0 125 250

Meters

ecologypartners

Figure 4
Key areas for habitat preservation, creation and connectivity for *Litoria raniformis* (Growling Grass Frog) Officer Structure Plan

EP Dwg Number: 189 Fig 4
Drawn by: LS
Revision: C
Issue Date: 16/06/2006

APPENDICES

Appendix 1 – Significance Assessment

Criteria used by Ecology Partners Pty. Ltd. to define conservation significance, vegetation condition and habitat quality is provided below.

A1.1. Rare or Threatened Categories for listed Victorian taxa

Table A1.1. *Rare or Threatened categories for listed Victorian taxa.*

Rare or Threatened Categories
CONSERVATION STATUS IN AUSTRALIA (Based on the EPBC Act 1999, Briggs and Leigh 1996*)
EX - Extinct: Extinct is when there is no reasonable doubt that the last individual of the species has died.
CR - Critically Endangered: A species is critically endangered when it is facing an extremely high risk of extinction in the wild in the immediate future.
EN - Endangered: A species is endangered when it is not critically endangered but is facing a very high risk of extinction in the wild in the near future.
VU - Vulnerable: A species is vulnerable when it is not critically endangered or endangered but is facing a high risk of extinction in the wild in the medium-term future.
R* - Rare: A species is rare but overall is not currently considered critically endangered, endangered or vulnerable.
K* - Poorly Known: A species is suspected, but not definitely known, to belong to any of the categories extinct, critically endangered, endangered, vulnerable or rare.
CONSERVATION STATUS IN VICTORIA (Based on DSE 2005, DSE 2003, FIS)
x - Presumed Extinct in Victoria: not recorded from Victoria during the past 50 years despite field searches specifically for the plant, or, alternatively, intensive field searches (since 1950) at all previously known sites have failed to record the plant.
e - Endangered in Victoria: at risk of disappearing from the wild state if present land use and other causal factors continue to operate.
v - Vulnerable in Victoria: not presently endangered but likely to become so soon due to continued depletion; occurring mainly on sites likely to experience changes in land-use which would threaten the survival of the plant in the wild; or, taxa whose total population is so small that the likelihood of recovery from disturbance, including localised natural events such as drought, fire or landslip, is doubtful.
r - Rare in Victoria: rare but not considered otherwise threatened - there are relatively few known populations or the taxon is restricted to a relatively small area.
k - Poorly Known in Victoria: poorly known and suspected, but not definitely known, to belong to one of the above categories (x, e, v or r) within Victoria. At present, accurate distribution information is inadequate.

A1.2. Defining Ecological Significance

Table A1.2. Defining Ecological Significance.

Criteria for defining Ecological Significance	
NATIONAL SIGNIFICANCE	
Flora	National conservation status is based on the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) list of taxa considered threatened in Australia (i.e. extinct, critically endangered, endangered, vulnerable).
	Flora listed as rare in Australia in *Rare or Threatened Australian Plants* (Briggs and Leigh 1996).
Fauna	National conservation status is based on the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) list of taxa considered threatened in Australia (i.e. extinct, critically endangered, endangered, vulnerable).
	Fauna listed as extinct, critically endangered, endangered, vulnerable, Rare or Lower Risk (near threatened, conservation dependent or least concern) under National Action Plans for terrestrial taxon prepared for the Department of Environment and Heritage: threatened marsupials and monotremes (Maxwell *et al.* 1996), bats (Duncan *et al.* 1999), birds (Garnett and Crowley 2000), reptiles (Cogger *et al.* 1993), and amphibians (Tyler 1997).
	Species that have not been included on the EBPC Act but listed as significance according to the *IUCN 2004 Red List of Threatened Species* (IUCN 2004).
Communities	Vegetation communities considered critically endangered, endangered or vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* and considering vegetation condition.
STATE SIGNIFICANCE	
Flora	Threatened taxa listed under the provisions of the *Flora and Fauna Guarantee Act 1988*.
	Flora listed as extinct, endangered, vulnerable or rare in Victoria in the DSE Flora Information System (most recent Version).
	Flora listed in the State Government's *Advisory List of Rare or Threatened Plants in Victoria*, 2005 (DSE 2005).
	Flora listed as poorly known in Australia in *Rare or Threatened Australian Plants* (Briggs and Leigh 1996).
Fauna	Threatened taxon listed under Schedule 2 of the *Flora and Fauna Guarantee Act 1988*.
	Fauna listed as extinct, critically endangered, endangered and vulnerable on the State Government's *Advisory List of Threatened Vertebrate Fauna in Victoria - 2003* (DSE 2003).

Criteria for defining Ecological Significance	
	Listed as Data Deficient or Insufficiently Known under National Action Plans for terrestrial species prepared for the Department of Environment and Heritage: threatened marsupials and monotremes (Maxwell *et al.* 1996), bats (Duncan *et al.* 1999), birds (Garnett and Crowley 2000), reptiles (Cogger *et al.* 1993), and amphibians (Tyler 1997).
Communities	Ecological communities listed as threatened under the *Flora and Fauna Guarantee Act 1988*.
	Ecological vegetation class listed as threatened (i.e. endangered, vulnerable) or rare in a Native Vegetation Plan for a particular bioregion (DSE Website) and considering vegetation condition.
REGIONAL SIGNIFICANCE	
Flora	Flora considered rare in any regional native vegetation plan for a particular bioregion.
	Flora considered rare by the author for a particular bioregion.
Fauna	Fauna with a disjunct distribution, or a small number of documented recorded or naturally rare in the Gippsland Plain Bioregion.
	A particular taxon that is has an unusual ecological or biogeographical occurrence or listed as Lower Risk – Near Threatened, Data Deficient or Insufficiently Known on the State Government's Advisory List of *Threatened Vertebrate Fauna in Victoria* - 2003 (DSE 2003).
Communities	Ecological vegetation class listed as depleted or least concern in a Native Vegetation Plan for a particular bioregion (DSE Website) and considering vegetation condition.
	Ecological vegetation class considered rare by the author for a particular bioregion.
LOCAL SIGNIFICANCE	
Local significance is defined as flora, fauna and ecological communities indigenous to a particular area, which are not considered rare or threatened on a national, state or regional level.	

A1.3 Defining Site Significance

The following geographical areas apply to the overall level of significance with respect to the current survey.

National: Australia

State: Victoria

Regional: Gippsland Plain Bioregion

Local: Within 10 kilometres surrounding the study area

Table A1.3. Defining Site Significance.

Criteria for defining Site Significance
NATIONAL SIGNIFICANCE
A site is of National significance if: - it regularly supports, or has a high probability of regularly supporting individuals of a taxon listed as 'Critically Endangered' or 'Endangered' under the *Environment Protection and Biodiversity Conservation Act 1999* and/or under National Action Plans for terrestrial taxon prepared for the Department of Environment and Heritage. - it regularly supports, or has a high probability of supporting, an 'important population' as defined under the *Environment Protection and Biodiversity Conservation Act 1999* of one or more nationally 'vulnerable' flora and fauna taxon. - it is known to support, or has a high probability of supporting taxon listed as 'Vulnerable' under National Action Plans. - it is known to regularly support a large proportion (i.e. greater than 1%) of a population of a taxon listed as 'Conservation Dependent' under the *Environment Protection and Biodiversity Conservation Act 1999* and/or listed as Rare or Lower Risk (near threatened, conservation dependent or least concern) under National Action Plans. - it contains an area, or part thereof designated as 'critical habitat' under the *Environment Protection and Biodiversity Conservation Act 1999,* or if the site is listed under the Register of National Estate compiled by the Australian Heritage Commission. - it is a site which forms part of, or is connected to a larger area(s) of remnant native vegetation or habitat of national conservation significance such as most National Park, and/or a Ramsar Wetland(s).
STATE SIGNIFICANCE
A site is of State significance if: - it occasionally (i.e. every 1 to 5 years) supports, or has suitable habitat to support taxon listed as 'Critically Endangered' or 'Endangered' under the *Environment Protection and Biodiversity Conservation Act 1999* and/or under National Action Plans. - it regularly supports, or has a high probability of regularly supporting (i.e. high habitat quality) taxon listed as 'Vulnerable', 'Near threatened', 'Data Deficient' or 'Insufficiently Known' in Victoria (DSE 2003, 2005), or species listed as 'Data Deficient' or 'Insufficiently Known' under National Action Plans. - it contains an area, or part thereof designated as 'critical habitat' under the *Flora and Fauna Guarantee Act 1988*. - it supports, or likely to support a high proportion of any Victorian flora and fauna taxa. - it contains high quality, intact vegetation/habitat supporting a high species richness and diversity in a particular Bioregion. - it is a site which forms part of, or connected to a larger area(s) of remnant native vegetation or habitat of state conservation significance such as most State Parks and/or Flora and Fauna Reserves.

Criteria for defining Site Significance
REGIONAL SIGNIFICANCE
A site is of Regional significance if: - it regularly supports, or has a high probability of regularly supporting regionally significant fauna as defined in Table A1.2. - is contains a large population (i.e. greater than 1%) of flora considered rare in any regional native vegetation plan for a particular bioregion. - it supports a fauna population with a disjunct distribution, or a particular taxon that has an unusual ecological or biogeographical occurrence. - it is a site which forms part of, or is connected to a larger area(s) of remnant native vegetation or habitat of regional conservation significance such as most Regional Parks and/or Flora and Fauna Reserves.
LOCAL SIGNIFICANCE
Most sites are considered to be of at least local significant for conservation, and in general a site of local significance can be defined as: - an area which supports indigenous flora species and/or a remnant Ecological Vegetation Class, and habitats used by locally significant fauna species. - an area which currently acts, or has the potential to act as a wildlife corridor linking other areas of higher conservation significance and facilitating fauna movement throughout the landscape.

A1.4. Defining Vegetation Condition

Table A1.4. Defining Vegetation Condition.

Criteria for defining Vegetation Condition
Good condition - Vegetation dominated by a diversity of indigenous species, with defined structures (where appropriate), such as canopy layer, shrub layer, and ground cover, with little or few introduced species present.
Moderate condition - Vegetation dominated by a diversity of indigenous species, but is lacking some structures, such as canopy layer, shrub layer or ground cover, and/or there is a greater level of introduced flora species present.
Poor condition - Vegetation dominated by introduced species, but supports low levels of indigenous species present, in the canopy, shrub layer or ground cover.

A1.5. Defining Habitat Quality

Several factors are taken into account when determining the value of habitat. Habitat quality varies on both spatial and temporal scales, with the habitat value varying depending upon a particular fauna species.

Table A1.5. *Defining Habitat Quality.*

Criteria for defining Habitat Quality
HIGH QUALITY
High degree of intactness (i.e. floristically and structurally diverse), containing several important habitat features such as ground debris (logs, rocks, vegetation), mature hollow-bearing trees, and a dense understorey component.
High species richness and diversity (i.e. represented by a large number of species from a range of fauna groups).
High level of foraging and breeding activity, with the site regularly used by native fauna for refuge and cover.
Habitat that has experienced, or is experiencing low levels of disturbance and/or threatening processes (i.e. weed invasion, introduced animals, soil erosion, salinity).
High contribution to a wildlife corridor, and/or connected to a larger area(s) of high quality habitat.
Provides known, or likely habitat for one or more rare or threatened species listed under the EPBC Act, FFG Act, or species considered rare or threatened according to DSE 2003.
MODERATE QUALITY
Moderate degree of intactness, containing one or more important habitat features such as ground debris (logs, rocks, vegetation), mature hollow-bearing trees, and a dense understorey component.
Moderate species richness and diversity - represented by a moderate number of species from a range of fauna groups.
Moderate levels of foraging and breeding activity, with the site used by native fauna for refuge and cover.
Habitat that has experienced, or is experiencing moderate levels of disturbance and/or threatening processes.
Moderate contribution to a wildlife corridor, or is connected to area(s) of moderate quality habitat.
Provides potential habitat for a small number of threatened species listed under the EPBC Act, FFG Act, or species considered rare or threatened according to DSE 2003.
LOW QUALITY
Low degree of intactness, containing few important habitat features such as ground debris (logs, rocks, vegetation), mature hollow-bearing trees, and a dense understorey component.
Low species richness and diversity (i.e. represented by a small number of species from a range of fauna groups).
Low levels of foraging and breeding activity, with the site used by native fauna for refuge and cover.
Habitat that has experienced, or is experiencing high levels of disturbance and/or threatening processes.
Unlikely to form part of a wildlife corridor, and is not connected to another area(s) of habitat.
Unlikely to provide habitat for rare or threatened species listed under the EPBC Act, FFG Act, or considered rare or threatened according to DSE 2003.

Appendix 2 – Survey results

Table A2.1. Results of present survey – 2005.

Site	Survey date/s	Waterbody type and size (approx. metres)	Dominant flora	Surrounding habitat	Refuge sites	Water quality	Fish present	%CAN	%OP	%FR	%EM	%SUB	%FL	DISTWATER (site)	DISTOCC (site)	Max. abundance of *GGF*
1a	6/11/05, 16/11/05, 21/11/05, 29/11/05	Farm dam 70x40	*Eleocharis acuta*, *E. phacelata*, *Chara* sp.	Pasture Gum Scrub Creek	Cracked clay, rocks	Good	No	0	90	80	5	40	0	20 (1b)	20 (1b)	12
1b	6/11/05, 16/11/05, 21/11/05, 29/11/05	Farm dam 50x50	*Eleocharis acuta*, *Chara* sp.	Pasture Gum Scrub Creek	Cracked clay, rocks	Good	Common Jolly-tail Short-finned Eel	0	95	20	0	40	0	20 (1a)	20 (1a)	6
1c	16/11/05, 21/11/05, 29/11/05	Farm dam 40x10	*Juncus* sp.	Pasture	None	Poor	Mosquito Fish Short-finned Eel	0	95	20	0	0	0	50 (1b)	50 (1b)	1
1d	16/11/05, 21/11/05, 29/11/05	Farm dam 10x15	*Phragmites australis*	Pasture remnant swamp scrub	Vegetation debris	Good	Mosquito Fish	0	70	25	20	0	0	50 (1e)	160 (1f)	0
1e	16/11/05, 21/11/05, 29/11/05	Farm dam 50x20	*Phragmites australis*	Pasture	None	Moderate	Short-finned Eel	0	60	0	40	0	0	50 (1d)	120 (1f)	1
1f	21/11/05, 29/11/05	Farm dam 15x15	*Eleocharis acuta*, *E. phacelata*, *Azolla* sp., *Lemna* sp.	Pasture	Farm debris	Good	No	0	10	10	30	0	60	120 (1e)	120 (1e)	4
1g*	24/11/05	Nursery irrigation dam 40x10	None	Pasture plant nursery	Nursery equipment	Poor	No	0	100	0	0	0	0	320 (1d)	540 (1a)	0
1h	24/11/05, 7/12/05	Farm dam 10x10	*Eleocharis acuta*	Pasture	Farm debris	Poor	No	0	95	5	0	0	0	15 (1i)	1067 (1f)	0

Site	Survey date/s	Waterbody type and size (approx. metres)	Dominant flora	Surrounding habitat	Refuge sites	Water quality	Fish present	%CAN	%OP	%FR	%EM	%SUB	%FL	DISTWATER (site)	DISTOCC (site)	Max. abundance of *GGF*
1i	24/11/05, 7/12/05	Farm dam 30x15	*Eleocharis acuta*, *Potamogeton ochreatus*, *Ottelia ovalifolia*	Pasture	Farm debris	Good	No	0	70	10	0	20	20	15 (1h)	1067 (1f)	0
1j*	24/11/05	Reclaimed effluent dam 50x40	None	Plant nursery	Nursery equipment/ debris	Poor	No	0	100	0	0	0	0	500 (1k)	2255 (1f)	0
1k	24/11/05, 7/12/05	Farm dam 25x15	*Eleocharis acuta*, *E. sphacelata*	Pasture	None	Moderate	No	5	70	100	30	0	0	500 (1l)	1755 (1f)	0
1l	24/11/05	Deeply canalised drainage line	None	Pasture	None	Poor	European Carp, Mosquito Fish	0	90	10	10	0	5	499 (1k)	1310 (1f)	0
1m	16/11/05, 21/11/05, 29/11/05	Farm dam 25x15	*Typha* sp.	Pasture	None	Poor	Short-finned Eel, Mosquito Fish	0	95	20	5	0	0	50 (1c)	50 (1c)	0
2a	24/11/05, 7/12/05	Farm dam 50x25	*Eleocharis sphacelata*, *Juncus* sp.	Pasture planted *Eucalyp -tus* sp.	Leaf litter, rocks	Good	No	0	80	95	20	0	0	905 (2b)	2443 (1f)	0
2b	22/11/05, 24/11/05, 7/12/05	Large farm dam 130x40	*Phragmites australis*, *Typha* sp., *Juncus* sp., *Melaleuca ericifolia*	Pasture	Vegetation debris	Moderate	Short-finned Eel	0	90	30	0	0	0	20 (3a)	1458 (1f)	0
3a	22/11/05, 24/11/05, 7/12/05	Large farm dam 100x60	*Typha* sp.	Pasture	Vegetation debris	Good	No	0	75	60	10	0	0	20 (2b)	1323 (1f)	0
3b	6/11/05, 24/11/05, 7/12/05	Farm dam 40x30	*Eleocharis sphacelata*, *Juncus* sp.	Pasture	Leaf litter	Moderate	Mosquito Fish	0	70	90	25	0	0	135 (3c)	1984 (1f)	0

Site	Survey date/s	Waterbody type and size (approx. metres)	Dominant flora	Surrounding habitat	Refuge sites	Water quality	Fish present	%CAN	%OP	%FR	%EM	%SUB	%FL	DISTWATER (site)	DISTOCC (site)	Max. abundance of *GGF*
3c	24/11/05, 7/12/05	Farm dam 25x15	*Juncus* sp.	Pasture	Rocks	Moderate	No	0	95	10	0	0	0	135 (3b)	2146 (1f)	0
3d	24/11/05, 7/12/05	Farm dam 50x30	*Juncus* sp., *Eleocharis sphacelata*	Pasture	None	Poor	?	0	40	70	50	0	0	15 (3e)	1728 (1f)	0
3e	6/11/05, 24/11/05, 7/12/05	Large farm dam 100x50	*Juncus* sp.	Pasture	None	Poor	?	0	95	80	0	0	0	15 (3d)	1606 (1f)	0
3f	6/11/05, 24/11/05, 7/12/05	Farm dam 30x20	*Paspalum distichum*, *Eleocharis acuta*	Pasture	Logs	Poor	No	0	95	100	0	0	0	283 (3i)	1944 (1a)	0
3g	6/11/05, 24/11/05, 7/12/05	Farm dam 30x15	*Typha* sp., *Juncus* sp., *Potamogeton ochreatus*	Pasture	Rocks	Moderate	No	0	90	5	5	5	0	338 (3e)	1755 (1a)	0
3h	24/11/05	Drainage line 20x10	*Typha* sp., *Eleocharis sphacelata*	Pasture old quarry	Rocks	Good	No	0	5	0	95	0	0	607 (3e)	1093 (1a)	0
3i*	24/11/05	Nursery irrigation dam 40x20	*Eleocharis acuta*	Plant nursery	Nursery equipment/ debris	Moderate	No	0	95	5	0	0	0	283 (3f)	1755 (1a)	0
3j	24/11/05, 7/12/05	Farm dam 15x15	*Eleocharis sphacelata*, *Potamogeton ochreatus*, *Chara* sp.	Pasture	Farm debris	Good	No	0	50	0	20	70	30	50 (3k)	1053 (1a)	0
3k	24/11/05, 7/12/05	Farm dam 50x40	*Eleocharis acuta*, *Chara* sp.	Pasture	Farm debris	Good	No	0	50	90	0	80	50	50 (3j)	1066 (1a)	0
3l	24/11/05, 7/12/05	Farm dam 20x10	*Eleocharis acuta*, *E. sphacelata*, *Ottelia ovalifolia*	Pasture	None	Good	No	0	20	0	60	0	20	378 (1a)	378 (1a)	0

Site	Survey date/s	Waterbody type and size (approx. metres)	Dominant flora	Surrounding habitat	Refuge sites	Water quality	Fish present	%CAN	%OP	%FR	%EM	%SUB	%FL	DISTWATER (site)	DISTOCC (site)	Max. abundance of *GGF*
					Mean		**(range)**	**0.2 (0-5)**	**74 (5-100)**	**35 (0-100)**	**16 (0-95)**	**9 (0-80)**	**7 (0-60)**	**213 (15-1160)**	**1086 (20-2443)**	

Notes:

* indicates a targeted survey for *L. raniformis* was not conducted due to unsuitable habitat.

%FRING is percentage cover of waterbody bank covered by fringing veg. Maximum abundance of *L. raniformis* was determined from mark-recapture study (Hamer & Organ 2006a)

%CAN = Percentage of Canopy, %OP = Percentage of Open Water, %FR = Percentage of fringing vegetation, %EM = Percentage of emergent vegetation

%SUB = Percentage of submerged vegetation, %FL = Percentage of floating vegetation

DISTWATER = Distance to nearest site (metres), DISTOCC = Distance to nearest occupied site (metres)

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