Habitat Assessment & Translocation Strategy for the Green and Golden Bell Frog

Mulloon Creek Home Farm

Report prepared for the Mulloon Institute

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ACRONYMS AND ABBREVIATIONS

ACT	Australian Capital Territory
Cwth	Commonwealth
DoEE	(Cwth) Department of Environment and Energy
EEC	Endangered ecological community – as defined under relevant law applying to the proposal
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Cwth)
GGBF	Green and Golden Bell Frog
ha	Hectares
km	Kilometre
m	Metres
MCHF	Mulloon Creek Home Farm
MNES	Matters of National environmental significance under the EPBC Act (*c.f.*)
NPWS	NSW National Parks and Wildlife Service
NSW	New South Wales
OEH	NSW Office of Environment and Heritage
sp/spp	Species/multiple species
TMI	The Mulloon Institute

1 INTRODUCTION

1.1 Project background

Path-Co Pty Ltd was commissioned by the Mulloon Institute to undertake an assessment of the Mulloon Creek Home Farm property to determine the potential habitat suitability for the Green and Golden Bell Frog (*Litoria aurea*). The primary purpose of this assessment was to provide an early basis for developing a future translocation program in the hope of (re)introducing the species to the area.

1.2 Project description

It is understood that The Mulloon Institute (TMI) has been working with landholders at a catchment scale to rehydrate the landscape and improve functionality and land use management along a section of Mulloon Creek near Bungendore, NSW. In 2006, the Mulloon Institute, with backing from the Southern Rivers Catchment Management Authority, and through the Mulloon Creek Natural Farms business, carried out a Natural Sequence Farming rehydration pilot project at degraded sections of Mulloon Creek within the property, as well as in certain other areas of the property, such as existing major drainage gullies that feed into the creek.

This work has included the installation of numerous weirs within the creek to reinstate more natural 'pool and riffle' sequences (mainly along the northern section of the creek), as well as a step-diffusion project along the large drainage channel that flows east to the creek floodplain from near the main manager's residence. The primary aim of this work was to slow the movement of water through the site to recharge the groundwater system within the floodplain to reduce erosion and improve the productivity of the landscape, including the overall biodiversity values of the aquatic and terrestrial systems in the area. Substantial tree planting and other vegetation remediation works have also been undertaken to support this work.

Based on the success to date of the project at a property scale, a multi-faceted scientific research program to collect hydrological, soil, and biological data to assess the impact of the catchment scale approach, is being undertaken. More recently, a number of early environmental (baseline) studies have been completed including:

- Invertebrate Survey of Mulloon Creek (2015-2016; prepared by Research School of Biology, Ecology and Evolution, ANU, ref: Cooper and Wallenius 2017)
- Mulloon Creek Baseline Fish Survey (Autumn 2016, prepared by Institute of Applied Ecology, University of Canberra, ref: Starrs and Lintermans 2016)
- Frog surveys along Mulloon Creek (Spring 2017; prepared by ACT & Region Frogwatch, ref: Hoefer 2017)

It is also understood that through discussions with NSW Office of Environment and Heritage (OEH), some minor funding has been made available to TMI from the NSW Enviro Trust grant. With this funding, TMI would like to conduct a frog habitat assessment of Mulloon Creek and its associated floodplain, as well as within the existing farm dams and wetlands located within the property. The primary purpose of this assessment is to undertake a

preliminary investigation of the existing habitat values within MCHF and to consider the site's potential for a possible future translocation or reintroduction of the Green and Golden Bell Frog (GGBF). Subsequent to this habitat assessment, is the need to understand what the key components or matters are to be considered in the development of a species reintroduction project.

These project aims and objectives are described in further detail below, followed by a summary of the approach and scope of works undertaken for this assessment, a brief review of the known habitat requirements for the species, and a summary of the habitat assessment results including the potential values of the site for the GGBF. Following this a preliminary strategy for developing a reintroduction project, including a review of previous GGBF reintroduction and/or translocation projects, and an early strategy and general overview of the actions required to commence implementation of a GGBF reintroduction project at MCHF.

1.3 Aims and objectives of this assessment

The aims of this consultancy project are primarily twofold and include the following:

- Assess the habitat values within the Mulloon Creek Home Farm property, including both selected sections of Mulloon Creek as well as all (accessible) farm dams or other artificially constructed wetlands within the immediate catchment area, to determine their potential suitability for the GGBF
- Based on the habitat assessment and review of available information, prepare a preliminary strategy for the future development of a reintroduction/translocation plan, including:
    - A review of previous GGBF translocation projects to identify what factors may contribute to the success or failure of such projects;
    - Information on habitat rehabilitation requirements such as general design and other mitigation measures deemed necessary to enhance habitat values for the species and which may/should be adopted by the proposed reintroduction program at MCHF,
    - A general strategy and list of actions to commence preparation of a formal reintroduction project (to be approved/endorsed by relevant authorities to allow implementation of the project), including general information on the approach for undertaking releases, and requirements for future monitoring of habitats and introduced populations; and
    - Preliminary advice on the identification of potentially suitable release sites

It is also hoped/intended that this assessment may serve to provide some initial baseline data on the general amphibian habitat values for future comparison and to identify changes in the habitat values at Mulloon Creek over time.

1.4 Study area and site context

The study area is identified as the Mulloon Creek Home Farm (MCHF) floodplain on Mulloon Creek and is located approximately 3 km south of the King's Highway and about 12 km east of the township of Bungendore, NSW.

The Study Area itself subject to the habitat assessment is defined as being the (approximately 2.5 km) stretch of Mulloon Creek from "The Barn" (aka the Pump Shed) in the south of the floodplain area, to the northern end of the floodplain area at "Peter's Pond" and the Wetlands Walk. The study area will encompass all of the aquatic habitats of the floodplain area, including the creek and (main) drainage gullies and associated dams or other wetlands, as depicted in Figure 1 below.

Mulloon Creek is in the upper Shoalhaven River catchment, south-eastern NSW. Arising in the Tallaganda State Forest and flowing in a northerly direction before joining Reedy Creek, which then flows into the Shoalhaven River north of Braidwood. The upper catchment is heavily vegetated with native Eucalypt forest, however since settlement of the area, the lower half of the Mulloon Creek catchment has been cleared and current land use consists of extensive livestock grazing, as well as some other smaller rural enterprises.

The MCHF comprises approximately 1740 hectares (4300 acres) of land, with about 728 hectares (1800 acres) of relatively intact forest with the balance primarily cleared grazing land.

In 2005, the late Founder Tony Coote AM and his wife Toni invited innovative landscape thinker Peter Andrews OAM to their property which then led to a union to transform the property and the deeply eroded creek that ran through it. Subsequently, in 2006 a Natural Sequence Farming Pilot Project was undertaken, with landscaping works commencing along 3kms of Mulloon Creek within the property. The primary objective of the project was to slow the flow of water through the system and raise the creek's water level, including de-energising and spreading flood waters, to reinvigorate the floodplain. This work included installing a series of erosion control structures (living leaky weirs), fencing to exclude stock and wildlife, and planting of thousands of trees, shrubs, reeds and rushes. The project was supported and supervised by Southern Rivers Catchment Management Authority and co-funded by the National Landcare Program.

Over ten years later, the creek has become a healthy, vibrant ecosystem, filtering water through its extensive reed beds, capturing flood sediments, recycling nutrients and providing complex habitat for birds, mammals, reptiles, frogs, fish and invertebrates. Productivity in the floodplain through which the creek flows has also increased by 60%.

The Natural Sequence Farming Pilot Project has successfully demonstrated improvements to the health and productivity of a degraded section of Mulloon Creek, resulting in:

- increased flora and fauna
- improved water quality
- sustained water flow
- 60% increase in agricultural productivity.

The observed improvements in the condition of the creek, including the establishment of slow-flowing pools (including a "chain-of-ponds" system as discussed further in this report) with extensive reeds and rushes, has led to the idea that the site could be suitable for the GGBF which was previously known to occur in the region. This idea was discussed with experts from the NSW Office of Environment and Heritage (OEH), and consequently, this

study was commissioned to begin early considerations for the potential of a GGBF reintroduction project to be undertaken at MCHF.

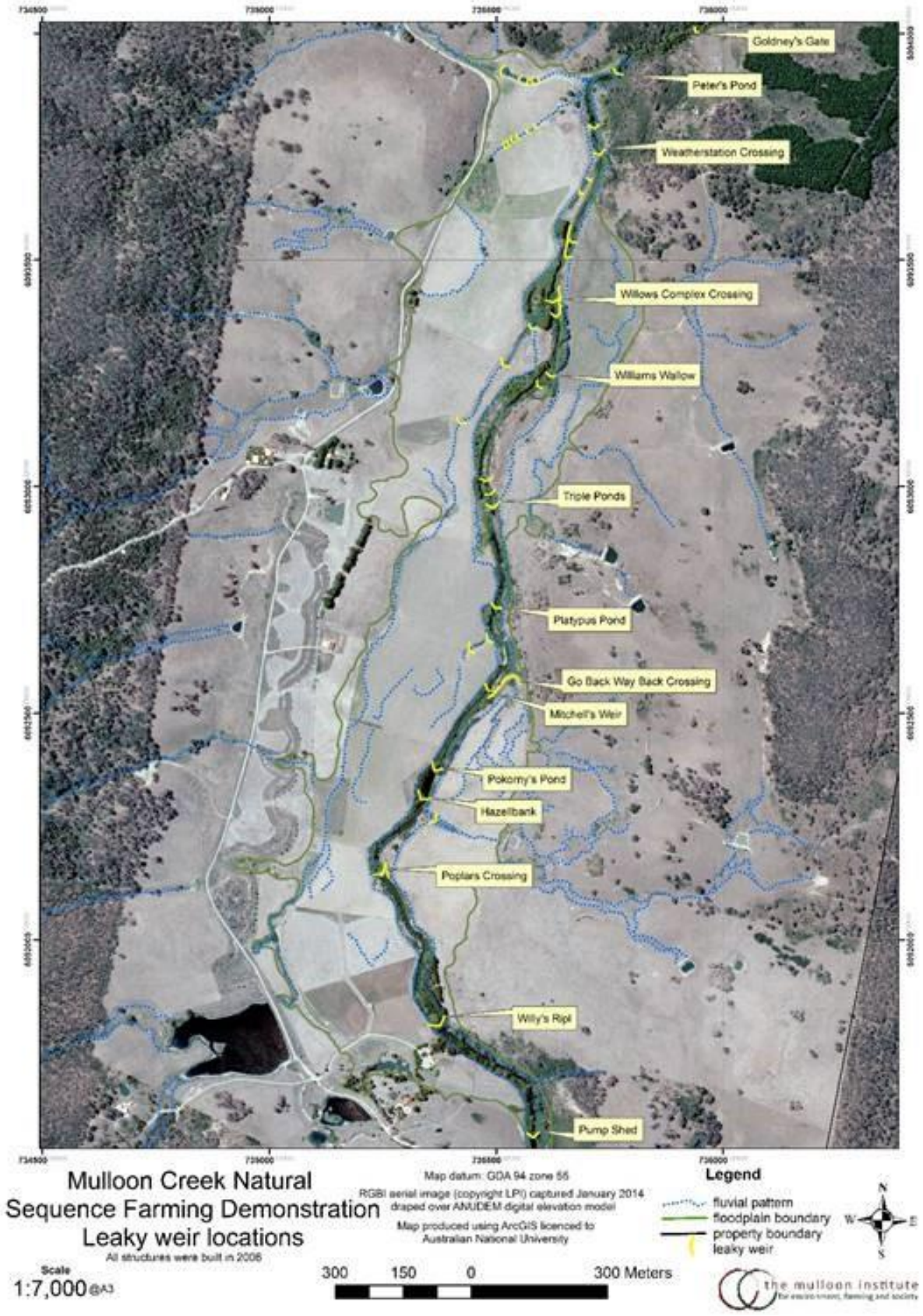

Figure 1. Study area – Mulloon Creek Home Farm

2 REVIEW OF THE ECOLOGY OF THE GGBF

In order to appropriately assess the potential suitability of sites within MCHF for consideration as a potential site to undertake a reintroduction project for the GGBF, it is first important to gain an understanding of the habitat requirements and certain other behavioural traits such as movement behaviour.

Provided below is a summary overview of the ecology of the GGBF, including a review of its previous and current distribution and possible reasons for the species decline, the species known habitat requirements and movement patterns, as well as known threats.

2.1 General description & biology of the species

The green and golden bell frog *Litoria aurea* (Lesson 1829) is a large and striking Australian tree frog (Anura: Hylidae) with dull olive to bright emerald-green, and often gold striping colouration on its dorsal side, and with bluish colouration on in the inner thighs (Cogger 2000). Females are larger bodied than males, with males typically reaching between 57-69 mm and females 65-108 mm (snout-vent length, SVL).

The species has been known to breed from August to April, but generally between September to February, with southern, higher altitude populations appearing to have a narrower window of opportunity for breeding than populations in the north or at lower altitudes. Breeding is often stimulated by (heavy)rain with male frogs calling mostly at night, but also occasionally by day. Clutch sizes usually range from 2000-6000 eggs and metamorphosis can take between 2-12 months, with newly metamorphosed frogs measuring between 20-30 mm SVL (Barker *et al.* 1995; Daly 1995; Pyke & White 2001).

Although a member of the 'tree frog' group, *L. aurea* is primarily a ground dwelling species. Where it occurs, it is often a conspicuous species that can be seen basking in full sun on or in emergent or floating aquatic vegetation, as well as on rocks and pond banks (S. Patmore *pers. obs.*).

Taxonomically *L. aurea* has been classified as a member of a species-group commonly known as 'bell frogs'. This group is believed to contain five other species: *L. cyclorhyncha* (Boulenger, 1882), *L. castanea* (Steindachner, 1867), *L. dahlii* (Boulenger, 1896), *L. moorei* (Copland, 1957), and *L. raniformis* (Keferstein, 1867). Of these species, three are found in south-eastern Australia: *L. aurea, L. castanea* and *L. raniformis* (Courtice & Grigg 1975; Thomson *et al.* 1996; Pyke & White 2001).

2.2 Distribution and status

The GGBF was once widely distributed throughout much of coastal NSW and eastern Victoria (White and Pyke 1996; Gillespie 1996). The former range of the species extended from Byron Bay in north-eastern NSW, south to Gippsland in Victoria, and as far inland as Bathurst and Tumut, NSW (Mahony 1996; Goldingay 1996.). The GGBF was also common across the northern parts of the Southern Tablelands in the Canberra, Queanbeyan and

Braidwood region (Osborne *et al*. 1996). A review of the Atlas of Living Australia website[1] also shows an historic record of the species close to the township of Bungendore.

The GGBF like many amphibian species worldwide has undergone dramatic population declines and disappearances over the past 30-40 years (reviewed in Pyke & White 2001). Since the 1980s the GGBF has undergone a dramatic decline with disappearances reported from 80% of its native range (Pyke & White 1996). The GGBF now mostly occurs in coastal lowland areas in NSW and Victoria, with the NSW coastal populations observed to have reduced in number and are becoming more isolated from other populations (White & Pyke 1996),although there has apparently been no similar decline in distribution and abundance in Victoria (Gillespie 1996). The current species' range is thought to extend from around Brunswick Heads in northern New South Wales (about 50 kilometres south of the Queensland border) to around Lake Wellington, just west of Lakes Entrance in south-eastern Victoria (DoEE 2019).

In the ACT and the Southern Highlands of NSW, the species reportedly disappeared suddenly between 1978–1981 (Osborne et al. 1996), and in NSW more broadly, the species has apparently disappeared completely from all highland areas above 250 m, except for one population near Captains Flat that was rediscovered in floodplain wetlands of the upper Molonglo River in early 2000 (Osborne *et al*. 2008). This population is situated just over 20 km to the southwest of the subject site.

Given the decline in the distribution and abundance of the species it is now listed as 'Endangered' under the former NSW *Threatened Species Conservation Act 1995* (now replaced by the *Biodiversity conservation Act 2016*), and as 'Vulnerable' under the Federal *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). In Victoria, however, the species is still considered common within a restricted range in East Gippsland (Gillespie 1996).

It is not clear what has caused the loss of populations observed in the GGBF, although several factors have been suggested. These include the introduced fish species *Gambusia holbrooki* predates on eggs and tadpoles (Morgan & Buttemer 1996; White & Pyke 1996); habitat augmentation/modification, fragmentation and loss through various developments and agricultural practices (White & Pyke 1996); chytridiomycosis, a fatal fungal disease (Berger et al. 1999; Mahony 1999); pollution (Goldingay 1996); and the use of fertilisers (Hamer 2002).

It is possible that a combination of the above threatening processes are acting synergistically, and which can vary under different conditions and/or in different habitats. A key part of the debate also is why some sympatric pond breeding species (e.g. *Limnodynastes peronii*, *Crinia signifera* and *Litoria peronii*) have not also declined (Mahony 1996).

The key threats to the species and which are likely to contribute to the continued observed decline of the species are summarised below.

[1] https://www.ala.org.au/

2.3 Threats

The Major threats identified for the GGBF include (DEWHA 2009):

- habitat removal.
- habitat degradation (which includes siltation, changes to aquatic vegetation diversity or structure reducing shelter, increased light and noise, grazing, mowing, fire).
- habitat fragmentation.
- reduction in water quality and hydrological changes (for example, pollution, siltation erosion and changes to timing, duration or frequency of flood events)
- disease (for example, infection of the frog with chytrid fungus (*Batrachochytrium dendrobatidis*) resulting in chytridiomycosis).
- predation (for example, by the introduced Mosquito Fish, Cats (*Felis catus*) or Foxes (*Vulpes vulpes*)).
- introduction or intensification of public access to Green and Golden Bell Frog habitats.

2.4 Habitat requirements and movement patterns

The GGBF has been described as an opportunistic species, and in NSW, it has been found in a wide variety of different natural habitats, including coastal flood plains, wetlands, marshes, swamps, dams, rock pools, lagoons, ornamental ponds, creeks, rivers, watering troughs, bath tubs and pools, and in a variety of ecological communities from grasslands to open dry sclerophyll forest (Pyke & White 2001; Pyke *et al.* 2002). The GGBF also displays habitat portioning and utilises different habitats for different purposes, and/or at different times of the year (i.e. seasonal or weather dependant habitat use). The two key areas of habitat to be considered for this species in terms of assessing the overall habitat potential of a site are breeding habitat and foraging habitat, as discussed further below.

2.4.1 Breeding Habitat

Breeding habitat for the GGBF in NSW generally includes water bodies that are still, shallow, ephemeral, generally unpolluted (although the frog is found in numerous polluted habitats), unshaded, with suitable emergent and/or other aquatic vegetation cover/types, and generally free of Mosquito Fish (*Gambusia holbrooki*) and/or other predatory fish, including eels. Gillespie (1996) also reported that in Victoria, virtually all breeding sites are free of (native) fish species and typically have dense emergent vegetation.

Breeding has been reported to be typically greater at sites that usually (but not always) are smaller than 1000 m², less than a metre deep, are ephemeral or fluctuate substantially in water level, and usually in freshwater or with low salinity, although the species is known to tolerate semi-saline water (7-8 ppt) as well (Mahony 1999: Pyke & White 2001; Pyke & White 2002; Pyke *et al.* 2002). Occupied waterbodies are usually surrounded by terrestrial habitats that consist of grassy areas with a range of diurnal shelter sites and vegetation no higher than woodlands (Pyke & White 1996), as described further below for non-breeding habitat.

The GGBF has however been recorded at sites that do not always fit the above general characteristics. For example, on the NSW south coast, the GGBF had been observed breeding in shaded areas and semi-saline lakes with native fish present (Daly *et al*. 2008). This observation obviously broadens (or challenges) the previous definitions of breeding sites as generally being unshaded, free of predators and with low salinity levels.

An assessment of the habitat use and requirements of the GGBF on the upper Molonglo River found a positive correlation between the occurrence of the species at breeding with suitable aquatic vegetation cover, including both emergent floating vegetation with plants such as *Eleocharis sphacelata*, and various Juncus species, as well as submerged and floating vegetation such Milfoil (*Myriophyllum sp.*), although the actual species of vegetation did not appear to influence these results (Patmore 2001).

In studies of the species on Kooragang Island in the Hunter River estuary, it was found that greater vegetation diversity on the banks of waterbodies was positively associated with the presence of Green and Golden Bell Frogs, and that the frogs were more likely to occur together with the plants *Juncus kraussii*, *Schoenoplectus litoralis* and *Sporobolus virginicus*. Individuals were often found sheltering in and basking on these plants. It was also found that the presence of the Eastern Mosquitofish (*Gambusia holbrooki*) did not influence waterbody occupancy and tadpoles were found co-existing with this introduced fish. (Hamer *et al*. 2002; Pyke & White 2002).

Given the above information, it appears that the GGBF is capable of breeding in a wide variety of habitat conditions, however, the two key parameters that appear to be generally consistent amongst most breeding sites is that they have suitable aquatic vegetation and in most circumstances, breeding seems restricted to aquatic habitats with still or no flowing water. In particular, the preference for breeding in still or slowing flowing ponds as opposed to streams is supported by an assessment of the impact of post-European stream change on frog habitat in south-eastern Australia (Hazell *et al*. 2003). This study notes that although gullies, or incised channels, are common in most valleys of the Southern Tablelands today, this was not the case prior to European settlement (Prosser and Winchester 1996). There is evidence in the literature that at the time of European settlement many river systems within the Southern Tablelands lacked continuous channels (Brierley and Fryirs 1999) and comprised discrete ponds (Eyles 1977b). These systems were commonly referred to as 'chains-of-ponds'. Since European settlement, many streams have experienced channel incision which causes changes in the rate of flow in stream systems. It converts broad, low-energy floods into concentrated high-energy flow. Pond-breeding species (with lentic tadpoles) are adapted to ephemeral, shallow ponds that fluctuate in water level may breed in ponds that form in the base of incised channels. However, the high energy of flood events would result in sudden, fast torrents of water, washing tadpoles downstream which then threaten lentic tadpoles such as for the GGBF (which swim with slow, regular movements and lie on the pond bottom or hide amongst thick aquatic vegetation (Daly 1995) that are not adapted to such (lotic) situations.

Other variables such as the presence of fish, water quality/salinity and possibly the degree of shade, appear to not have as strong an influence on the selection of suitable breeding habitat for the GGBF, although given the large size and slow-swimming nature of GGBF tadpoles, may make them susceptible to predation, particularly in environments where

there are abundant predators and a lack of structural complexity to enable avoidance of (e.g. hiding from) predators (Daly 1995).

It has been postulated that the loss of pond systems has increased the susceptibility of the GGBF to stochastic events like drought and disease (Hazell *et al.* 2003). The recent discovery of a population of the GGBF in farmland near Queanbeyan adds support to this hypothesis. The population occurs in an extensive, relatively natural grassland, containing well-vegetated swamps and remnants of a chain-of-ponds system (Osborne et al. 2008).

It is therefore important to note that the observed habitat requirements of the species based on its current occurrence, may not necessarily identify the habitat requirements of the species prior to the observed declines, and that the use of ephemeral breeding sites was not necessarily a feature associated with members of the bell frog group in earlier habitat descriptions (Mahony 1999). This could have some relevance in relation to management programs to either alter or restore habitat for the species, as well as for possible (re)introductions of the species into new areas/habitats.

2.4.2 Non-breeding habitat

Although most surveys for the GGBF tend to focus on the aquatic component of the species habitat (i.e. at water bodies), the species has also been recorded some distance from water in a variety of terrestrial habitats including sheltering under stones, logs or other vegetation, including amongst the base of tussocks, and under debris on flooded river flats, as well as in a mixture of vegetation community types from native grasslands to forests and woodlands (Bell 1982; Cogger 2000 as cited in Hamer 2002 and S. Patmore *pers obs*).

The use of the non-breeding habitat that surrounds a breeding site can be for a variety of purposes including primarily the following:

- Foraging;
- Refugia; and
- Dispersal (movement) between habitats

Green and golden bell frogs' preferred foraging areas generally contain areas supporting flowering plants, grasses and foliage, with tussock-forming varieties such as *Poa spp*. and other sedges such as *Phragmites spp.*, *Typha spp*. and *Lomandra spp*., considered to be of particular importance for providing both foraging habitat where they can hunt habitat for invertebrates amongst the foliage, as well as shelter sites as discussed below. This vegetation may be near breeding habitat sites or some considerable distance away.

Refuge habitat for the GGBF typically includes areas in which the frog can escape from dangers such as predation or fire, and can retreat to avoid climatic extremes for short periods, including for overwintering and/or spending extended periods during cooler months in an inactive state, particularly in cooler climate zones such as the NSW Southern Tablelands. Refuge habitat can include within the base of dense tussocks, beneath fallen logs or other debris, including building refuse such as old roof tiles, as well as in cracks and crevices (in clay soils) or in disused burrows of other animals (such as spiders or yabbies).

It has also been reported that frog habitat used during the non-breeding season may be affected by a loss of moisture in the swampy meadow environment, particularly during crucial periods, such as droughts. Intact swampy meadows (assisted and/or formed by

chain-of-ponds environments) provide extensive corridors of moist, well-vegetated terrestrial habitat, connecting sections of permanent and temporary pond habitat (Hazell *et al.* 2003). These environments are favourable for the dispersal and movement of semi-aquatic frog species, such as the GGBF, providing highly connected, extensive habitat across the landscape, and may facilitate the species persistence, or recovery from stochastic events, at a regional scale. Prolonged periods of hot weather can play a major role in regulating populations, causing mortality of large numbers of newly metamorphosed frogs (Beebee 1996). Therefore, moist, well connected habitats within an environment may be a critical factor determining the ability of a species such as the GGBF to persist in an area.

The non-breeding dispersal of the species between sites and its movement patterns generally are described further below.

2.4.3 Movement patterns, dispersal and home ranges

Unlike many frogs, the GGBF is thought to have a high dispersal capability with recorded movements in excess of 10km from known breeding ponds, including distances of up to 1.5 km in a single day/night (Pyke & White 2001). However, data from capture-recapture studies most frequently indicate that movements are generally within a 500m radius (Christy 2001; Pyke & White 2001; Hamer 2002). Accordingly, it is difficult to be definitive about the specific movement patterns and other behaviours of the GGBF, as dispersal patterns can vary between populations and seasons.

Burns (2004) noted in her PhD that most movement within the populations she studied were generally restricted to a core area of relatively permanent water bodies, although individuals dispersed into peripheral areas at times of heavy rain. The influence of seasonal conditions on movement patterns was also noted by Christy (2000) where the home range of the species at Homebush was generally large compared to other frogs, and varied according to season, with home ranges of greater than 1,200m^2 in the breeding period compared to only 20m^2 in the non-breeding period.

A radio-telemetry study of the population at two sites on the upper Molonglo River (Patmore 2001) also noted that during the breeding season, the tracked frogs tended to move very little with home ranges of generally less than 10m2, and no movements recorded outside of the wetted perimeter of the waterbodies. After the breeding season had completed, a number of frogs were observed to undertake dispersal from a site (which had dried substantially and retained very little water) to the river, covering a distance of between 180 – 200 m, and completing the movement in either a single day or over two days.

In addition to the radio-telemetry study, a pilot mark-recapture study was also undertaken (but not reported on by Patmore in his 2001 honours thesis). During this study, a large female was observed to have moved from the site where it was initially captured to another site where it was recaptured some months later, almost 3 km away. It was noted that during this time, the initial capture site had deteriorated substantially, primarily as a result of an infestation of an insect that destroyed much of the floating/submerged Milfoil (*Myriophyllum sp*.) that characterised the aquatic vegetation at this site. It is assumed that this frog would have primarily moved along the riverbank that (partly) connected these sites.

From the upper Molonglo River study, it was revealed the importance of the river in the overall environment as a likely refugia habitat, as well as movement corridor that provides important connectivity between habitats within the landscape. The overall importance of habitat connectivity for the species is summarised further below.

2.4.4 Habitat connectivity

The connectivity of habitat is considered to be of vital importance for most species of frog as it enables individuals to move between different areas of habitat at different times of the year to exploit different resources for breeding, foraging and sheltering as described above. Of particular importance is that it can also allow for interaction between frogs from different populations to maintain or improve genetic diversity to assist populations to adapt and survive.

Connectivity of amphibian habitat generally includes the following features:

- wet areas such as riverbanks or wetlands
- drainage lines
- stormwater culverts
- swales
- periodically damp areas
- connecting or partially connecting areas of vegetation the frog prefers
- easements
- laneways
- grassy open areas that do not restrict movement.

Given the species high rates of population fluctuation, habitat connectivity (including recreation of connecting habitat) is essential to allow recolonisation after localised extinction events (Pickett et al. 2014). The connectivity between habitats is considered to be a particularly important factor for the GGBF, given the reported population dynamics of the species and its apparent requirement for sites that include a number of habitats in relatively close proximity. This is supported by the study undertaken by Hazell *et al*. (2003) which considered the susceptibility of frogs such as the GGBF to hydrological changes, including the loss of natural chain-of-ponds systems, and the importance of swampy meadows (as non-breeding habitat) to connect breeding habitats as well as provide refugia in the non-breeding period, as described above.

The importance of this interconnectivity of habitats is also reflected by the site selection or occupancy of sites in previous studies of the species. A PhD study by Hamer (2002) on the ecology of the species at Kooragang Island, where a mosaic of permanent and ephemeral water bodies exists, found that the distribution of waterbodies occupied by the GGBF was aggregated and that a waterbody was more likely to be occupied if neighbouring waterbodies within 50 m were also occupied.

A more recent PhD study by Burns (2004) on the Phylogeography, Population History and Conservation Genetics of the GGBF also noted that the great majority of dispersal was likely to occur between nearest neighbouring habitat patches with only a few individuals moving longer distances.

Hamer (2002) suggests that the species uses both explosive and prolonged breeding as a reproductive strategy and that long-term population viability will be dependent on the

conservation of a mosaic of water body types within wetland landscapes, including maintaining the connectivity between these waterbodies to support the breeding behaviour and requirements of the species.

3 GGBF HABITAT ASSESSMENT AT MCHF

The assessment of the potential habitat values at MCHF for the GGBF was informed largely by the review of the species habitat requirements (provided at Chapter 2), including the known or reported parameters that appear to influence the site selection or occurrence of the species. As noted in the review, these values relate primarily to certain landscape or physical attributes, such as connectivity and proximity to other (potential) sites, as well as certain biological features, including mainly the extent and quality of aquatic vegetation. These key parameters have been used in previous studies on GGBF habitat values (i.e. Christy 2000; Patmore 2001; Hamer 2002) and are generally considered to be an acceptable approach for habitat assessments of the species.

Described below is the approach and methodology employed in this study for assessing the potential habitat quality at MCHF.

3.1 Establishment of survey sites

In order to conduct the habitat assessment in a systematic way, the study area was first required to be stratified into units that can then be subject to a more detailed assessment of habitat variables. For the MCHF study area, the first level of stratification of the habitat will be based on the type of waterbody being assessed. This was divided into sites along/within the creek, and sites outside of the creek (i.e. farm dams or other artificially constructed wetlands). This effectively divided the site into aquatic habitats that had either flowing or still water, which has been reported as a factor influencing breeding habitat, with the GGBF tending to select sites with still or no flowing water.

The sites were selected initially from a review of the aerial photography of the study area, and in the case of the creek sites, then refined further based on the ability to safely access the creek (with some areas being generally inaccessible due to extensive Blackberry infestations or steep/vertical banks). For the dam/wetland sites, all sites identified within the catchment were targeted for survey, irrespective of size or location in the study area, with the exception of a small number of dams (5) that were located at the very outer margins of the property, at the head of drainage small gullies, and at the edge (or just within) of the boundary between the cleared agricultural lands and the remnant forest vegetation bordering the property. These few sites were generally considered unlikely to support the species given their location away from the creek or other (potentially suitable) sites, and so their exclusion from the study is considered unlikely to have influenced the results of the assessment.

1. ***Sites on Mulloon Creek***

For sites located within (along) the creek, these were selected to be relatively evenly spaced, although as mentioned above, safe access and the occurrence of a suitable pond area dictated to some extent the final selection of site. Accordingly, most of the creek sites were located at existing sites along the creek that have been subject to previous works, such as rock weirs or vehicle crossings (and often have been given a reference name – see Figure 1), as these areas were generally the most easily accessible for inspection, and supported ponds created (at least in part) by these in-stream barriers.

Riffle sections were therefore generally excluded from the assessment given that:

a) There were generally few occurrences of these features as the creek was in a period of low flow at the time of survey; and,
b) These sites are generally considered unsuitable for GGBF habitat (breeding or foraging). Notwithstanding this, the general condition of these sections of the creek are still of some importance with respect to connectivity and the ability for frogs to move along the creek to different ponds, and accordingly, general notes were made from observations of other sections not subject to a formal habitat assessment survey.

2. Dam and Wetland Sites

The dam and wetland sites are categorised as all other areas of aquatic habitat located outside of the main flowing channel of Mulloon Creek. These include predominantly the artificially constructed dams located throughout the property, but also include a small artificially constructed lagoon or marsh (Site MCW06) as well as sections of what appear to be former or secondary stream channels located within the floodplain (sites MCW16, 17A and 17B) but which no longer function as part of the stream and appear to be dry under most circumstances, as at the time of this survey.

3.2 Habitat assessment methods

The assessment of the (potential) habitat values for the GGBF within the study area was stratified into macro (or landscape level) habitat values and micro-habitat features within each site, as described below.

1. *Assessment of landscape/macro-habitat factors*:

The landscape factors included in this assessment involved the following parameters:

- Type of water body (i.e. creek or dam/wetland).
- Size of waterbody (represented by estimate of length x width of the pool or dam/wetland).
- Distance of dam/wetland to creek (for dam/wetland sites only).
- Distance of dam/wetland to nearest other dam/wetland, and number of other dam/wetland sites within 500/1000 m radius. Note that this assessment did not include an assessment of the number of creek 'sites' within the specified radii as the creek is a continuous linear system and the selection of sites on the creek was somewhat arbitrary (for example, more or fewer sites could have been selected along the creek which would have artificially influenced these results). Additionally, based on the review of the species habitats, it would appear that the creek is less likely to be used as potential breeding habitat, and many other studies have tended to focus mainly on the assessment of connectivity between breeding sites.
- For dams/wetlands – record of the position in study area (as either within the floodplain terrace, or on low/mid/upper slopes of drainage gullies) and elevation.

- General assessment of the nature of connectivity between waterbodies (i.e. well vegetated or bare earth, including vegetation structure/condition such as dominant species and cover values, presence of barriers etc).

2. *Site-based habitat variables included in the assessment*:

The site-based habitat factors included in this assessment involved the following parameters:

- Water depth and general assessment of water quality (i.e. visual assessment of turbidity, presence of algal scums or other surface sheens, odours etc).
- Bank height and grade/slope.
- Aquatic macrophyte vegetation assessment including:
  - percentage of aquatic vegetation cover of wetted area including percentage floating/submerged and emergent vegetation, notes on the dominant vegetation types (note: aquatic vegetation was not always identified to species level as some evidence suggests that the actual species of plant is not as important as the type (i.e. emergent of floating, as well as tussock-forming varieties like *Poa spp*.) and the overall extent of cover provided by vegetation types. Consequently, most vegetation was identified to genus level only).
  - percentage cover of perimeter "riparian" vegetation and width (and dominant species – Blackberry was generally discounted from contributing toward riparian cover values given this plant is generally not considered a suitable form of riparian vegetation for the GGBF and should not contribute toward an increased habitat value for this parameter).
- Extent of bare ground at water's edge – distance of water to riparian vegetation line.
- Nature of surrounding terrestrial vegetation, including flora species, extent cover, notes on management of surrounding land uses (i.e. evidence of grazing or cultivation), as well as notes on the presence/occurrence of nearby shelter sites, including inter-tussock spaces, signs of cracks or other cover items that can be used for shelter.
- Level of shading of waterbody.

3. *Additional notes to be collected*:

During the site visits additional notes will be collected from opportunistic observations, mainly in relation to the presence of (other) frogs at each site based on either/both visual or acoustic records, including observations of spawn or tadpoles, as well as observations of any potential predators. Other information collected during the survey included mainly ambient conditions such as weather and recent rain activity.

The above habitat assessment variables were included in the site assessment data sheets, provided at Appendix A.

3.3 Survey timing

The site survey was undertaken by Sam Patmore (an experienced ecologist who has previously conducted research on the species) on the 8th and 9th May 2019.

Weather conditions during the survey were generally cool/cold, ranging from between 5 to 8^0C and cloudy on the 8/5/2019 and 6 to 12^0C and sunny/partly cloudy on the 9/5/2019. Winds were moderate on both days, ranging from periods of light winds (<10kph) to gusty period with wind of around 20kph+.

3.4 Survey limitations

The Autumn timing of the survey, as well as the brief assessment approach taken, meant that some potentially important habitat assessment variables were unable to be adequately sampled or surveyed. The primarily relate to the following:

- The assessment does not include a formal survey for other frogs or potential predators (such as in accordance with published survey guidelines for these species). Further detailed information on the other species of fogs or predators likely to be present in the study area can be found within the existing reports on these fauna types previously referred to. Further surveys for these are likely to be undertaken (including requirements to determine the extent of chytrid infection of existing amphibian populations as recommended in the translocation strategy at Chapter 5), and this information can be built into the assessment in due course.
- Physical/chemical properties of waterbodies (such as Dissolved Oxygen, Temperature, pH, Salinity etc) were not measured as part of this assessment. It is believed that a single measurement in time under this study will not yield any meaningful information given the fluctuations over time that would be expected in these parameters. These parameters require regular systematic monitoring (over time) to get an accurate picture of the physical/chemical properties of each waterbody as they may relate to the presence, persistence and overall condition of the habitat for amphibians, and the GGBF specifically (see recommendations in the translocation strategy at Chapter 5 for further consideration of this). It is understood that some studies have already been undertaken in these areas and can be considered if/when required (such as for future planning of the reintroduction program).

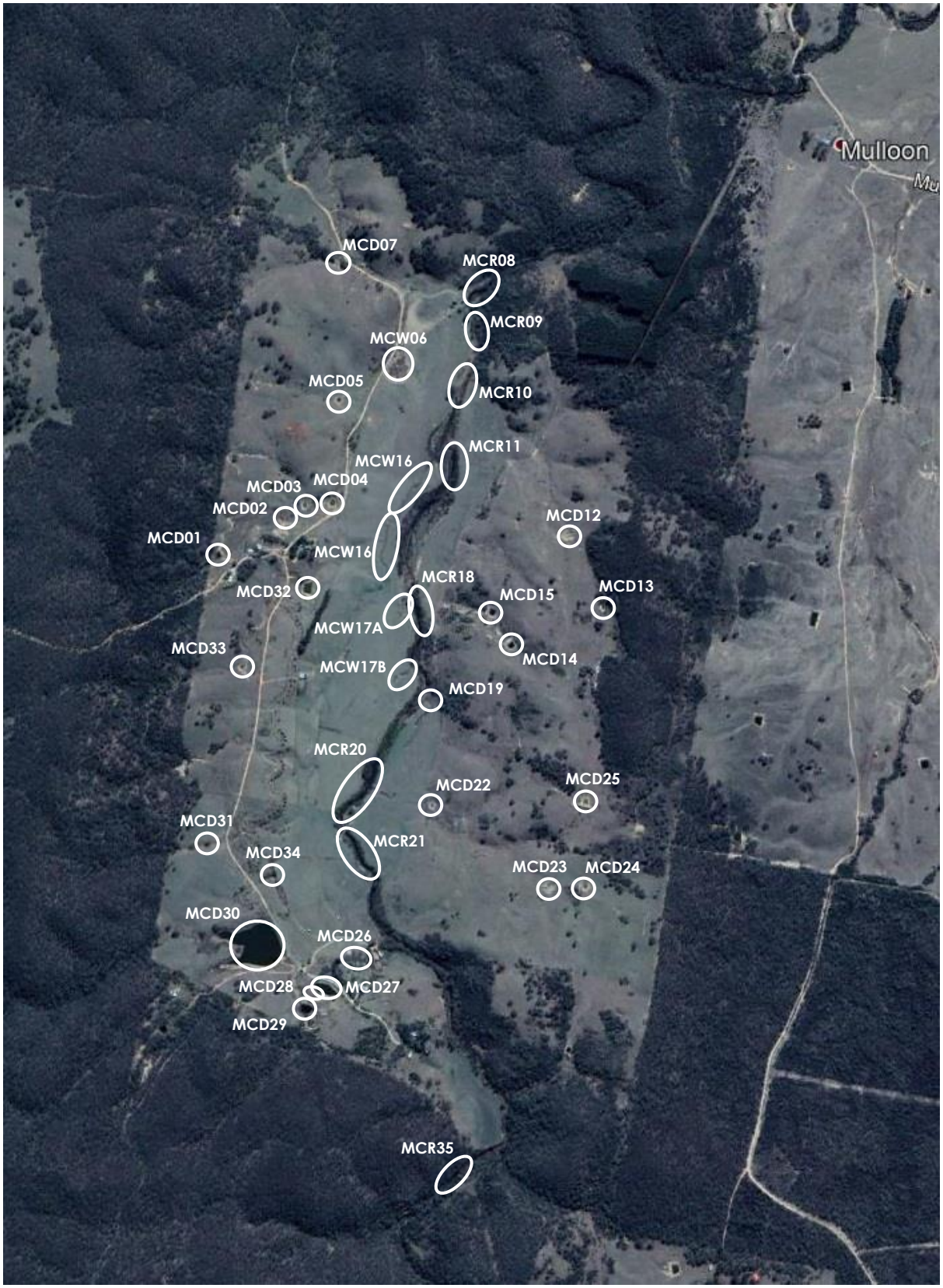

Figure 2. Location of survey sites within the study area.

4 RESULTS - HABITAT VALUES FOR GGBF AT MCHF

4.1 Summary of survey sites

4.1.1 General overview of survey sites

Habitat assessments were conducted at a total of 35 sites, comprising 24 farm dams, seven sites at pools along the creek, and four sites categorised as 'wetlands', being areas that were not within the primary creek channel and were not constructed as a farm dam, but would be periodically inundated from time to time. The location of each of survey site is shown in Figure 2. Datasheets for each site, including the GPS co-ordinates of each site, is provided at Appendix A.

In terms of site coverage, all of the farm dams located within the (sub) catchment of the MCHF study area were surveyed with the exception of a small number of farm dams located at the very upper reaches of gullies, and outside of the cleared parts of the property, occurring generally within the edges of the forested margins at the outer edges of the study area. Given the distance and context of these sites, they were generally considered unlikely to provide suitable habitat for the GGBF, although future assessment of these sites may be warranted, depending on the outcomes of the proposed GGBF reintroduction program.

With regard to the creek surveys, five of the seven sites were located generally within the northern half of the creek where it flows through the study area. Site MCR21 was located approximately 250 m south of MCR20 (located at about the midway point, or just south), while MCR35 was located at the very southern end of the creek within the overall study area. It was noted that from just south of MCR21, the creek was flowing within a highly incised channel with, very steep (to vertical in many places) banks, up to 5 m in height or higher, and generally surrounded by a dense riparian area comprising large trees and shrubs (some native and some deciduous, i.e. poplars and willows), as well as thick infestations of Blackberry (*Rubus fruticosus* aggregate) (see Photo 54 at Appendix D). This southern section of the creek was generally considered to provide limited suitable breeding habitat for the species (although its importance as a potential movement corridor would still exist, but limited due to the thick Blackberry infestations), and given the difficulty and safety issues with accessing this part of the creek, no further (formal) site assessments were conducted there, with the exception of site MCR35.

For all sites in the study, water quality was generally observed to be good, particularly within the creek as well as in most of the farm dams, although some dams were observed to have some turbidity, primarily those where stock had relatively free access to the dam. Other than some minor-moderate turbidity at some of the sites, there was very little other indicators of poor or reduced water quality within the study sites. In general, there was very little algae observed at any of the sites, although some red algal scum was evident immediately downstream of some of the weir systems in the creek, usually extending only a few metres downstream of the weirs. No major or notable odours or surface sheens/ slicks in the water was observed at any of the sites.

The other key physical and biological parameters of the sites in the study area are described further below, as considered by this assessment.

4.1.2 Proximity of sites to the creek and other sites

Note: as described in the survey methods, the distance and number of a site to other sites excluded sites along the creek, given that the creek sites are not considered to be discrete sites, occurring within a connected linear creek system. However, the distance from a site to the creek is considered important and has been included in the overall habitat assessment mapping further below. The creek sites were also considered for the number of other (non-creek) sites, to ascertain which sections of the creek provide the greatest level of potential connectivity (through proximity) to other potential sites in the study area.

Location of Dams

For the dam sites, most of these were found to be located within the mid or upper parts of the drainage gullies that feed into the creek and ranged from between 250 m (MCD04) to 660 m (MCD24) from the creek. The exception to this was site MCD19, which was a small dam situated near the confluence of a western-flowing drainage gully and the creek, located approximately 25 m from the creek itself. All dams also had at least 2 other dams or a wetland site located within 500 m, with the exception of dam MCD31, which had only one other site (MCD30) located within 500 m. The dam sites with the highest number of other sites within 500 m were MCD02, MCD03, MCD04 (n=8 sites for each).

Location of Wetlands

For the wetland sites (MCW06, MCW16, MC17A and MCW17B), with the exception of MCW06 (a small, artificially constructed series of small marsh swamps) which is located approximately 170 m from the creek, the other three sites are all situated close to and (almost) directly connected with the creek. These three wetland areas (MCW16, MCW17A and MC17B) all appear to have been naturally formed as former or secondary stream channels (although none of these contained any water at the time of the survey).

These wetland sites are all located within the low-lying floodplain area, and all have numerous other sites located within 500 m, with MCW16 having 13 other sites within 500 m (of at least some part of this long linear channel), which was the most of any site in the stud area, and MCW17A and MCW17B having nine and seven other sites within 500 m respectively. MCW06 was found to have only five other sites within 500 m, being situated in the northern portion of the study area.

Creek Sites

With regard to the sites along the creek, the site that has the highest number of (non-creek) sites within a 500 m radius is site MCR18, with 11 other sites within 500 m of this site. The next highest is site MCR11, with seven other sites within 500 m, whilst the remaining creek sites (MCR08, MCR09, MCR10, MCR20, MCR21 and MCR35) all having four or less other sites within 500 m, with site MCR35 having no sites located within 500 m.

4.1.3 Biological and other features of sites

As previously described, the key biological parameters considered to be of primary importance in determining habitat suitability for the GGBF, generally include aspects of

the aquatic vegetation, such as the percentage cover of aquatic vegetation generally, as well as to some extent the type of vegetation cover, including whether it is emergent, submerged or floating, or riparian vegetation. The species of aquatic vegetation is also important to some extent, although there is typically no individual or specific species of plant that accurately determines habitat suitability. Notwithstanding this, native aquatic sedges such as *Eleocharis spp*., *Juncus spp*., *Phragmites spp*, and *Typha spp*. are typically regarded as being characteristic species of habitats where the species has been recorded. Some riparian species such as *Lomandra spp*. as well as tussock-forming plants such native *Poa spp*., are also regarded as being important components of the biological habitat features of a site.

The observations of aquatic vegetation as well as other features of the habitat such as the degree of shading of a water body are summarised below.

Aquatic Vegetation

Aquatic vegetation cover varied markedly across all sites within the study area, from 0% cover at numerous dam sites, to almost 100% cover at other sites, such as MCW06 and MCD19, which were both observed to support dense or rank growth of *Typha sp*., covering almost the entirety of each waterbody (and with both water bodies supporting only shallow water of less than about 0.3 m depth).

In general, most of the creek sites were found to support good levels of aquatic vegetation cover (with respect to GGBF habitat), typically consisting of Emergent macrophytes such as Typha sp., Phragmites sp. and Eleocharis sp., as well as some floating or submerged aquatic vegetation, including Milfoil (*Myriophyllum sp*.), *Persicaria sp, Potomogeton sp.* and Water Lilies (*Nymphaea sp.*).

In comparison, the majority of the dam sites supported very little aquatic vegetation, typically consisting of either no aquatic vegetation at all (i.e. 0% cover), or with small patches of emergent vegetation (mostly *Juncus sp*., although some *Eleocharis sp.* was observed in a small number of farm dam sites) of less than 10-20% cover. Almost all of the farm dam sites supported no submerged or floating aquatic vegetation, with a few sites observed to support less than 10% cover of species such as *Potomogeton* or *Persicaria sp*., and occasionally some limited Milfoil.

For the wetland sites, apart from MCW06, which supported a dense cover of *Typha sp*. as stated above, the other three sites (MCW16, MCW17A and MCW17B) all had no notable aquatic vegetation present, likely a result that these sites are very infrequently inundated, and supported no standing water at the time of the site survey.

Degree of shading

The other key variable considered in this assessment was the degree of shading of waterbodies, given the GGBF is a diurnal basking species, and typically (although not always as reported in Section 2), selects sites that are generally unshaded or have little shade.

In general, all of the farm dams were found to be either completely unshaded or were subject to only limited shade of generally less than 20%, from surrounding riparian or woodland vegetation (such as sites MCD01, MCD07, MCD13, MCD19, MCD26). Additionally, all four of the wetland sites were also observed to be either completely free

of shade or relatively unshaded (with MCW17B having 20% shade, and the other three 5% or less shade).

In contrast, most of the creek sites were found to have at least some shading (of at least 30%), and at some sites, this ranged up to 80%, and generally ranged around 50-60%. As mentioned previously, the creek south of site MCR21 was observed to be surrounded by tall riparian trees and woodland, and would have been subject to very high levels of shade from at least about 50% shade up to almost 80% shade (i.e. MCR35) or possibly more (at other unsurveyed sections)

The above landscape, physical and biological parameters are discussed further below in terms of the overall habitat values of the site for the GGBF as well as identifying those sites within the study area that would appear to provide better quality or potential habitat for the species.

4.2 Habitat assessment and mapping

Identifying areas of better quality potential habitat for the GGBF, and particularly, their distribution within the study area, is considered to be a key component toward the development of a future reintroduction program and potential release sites, as explained later in this report.

To assess and describe the potential habitat values at MCHF for the GGBF in a meaningful and concise way, an approach was devised to attribute a value/score (from Low, Moderate and High) to each site based on the key habitat parameters used in the site surveys. This approach is described in further below.

4.2.1 Approach

The habitat assessment provided in this study involved a generalised approach to identify potentially suitable areas of habitat for the GGBF. This involved primarily the establishment of a Habitat Assessment Score system to ultimately ascribe each survey site into categories of either Low, Moderate or High quality potential habitat. This simplified approach then enable the preparation of a basic plan of the study area showing the broad distribution and location of areas of potentially better quality habitat versus those areas considered to be of low quality habitat value.

The HAS approach taken in this study uses a selection of some of what are considered to be the key parameters for determining habitat suitability (such as proximity of other waterbodies and aquatic vegetation cover features, as described previously in the review of the habitat requirements for the species in Chapter 2). These key parameters are described further below and in Table 1, including how the habitat assessment scoring has been applied to each.

The scoring ranges applied are somewhat arbitrary, and could be modified, however, they are set to generally reflect what might traditionally be regarded as good habitat for the GGBF. Certain parameters that may seem related may have different boundaries between ranges. For example, Distance to Creek and Distance to Nearest Other Site do

not share the exact same range values although they may seemingly be measuring a similar component of the habitat. In the first example, as the creek is seen to be more of a refugia and less likely to be breeding habitat, the distance to move to this is not seen as being as important as the distance to other potential breeding sites (as per previous research on the importance of metapopulation dynamics and habitat patch connectivity). It is doubtful than a change of about 100 m in the scoring range for these parameters would have a great bearing on the final results in any event.

It is recognised that this approach has some limitations and possible weaknesses, given that the final assessment scores are not strictly applied in a quantitative manner, however it is noted that the scope this study was designed to be a preliminary as well as a somewhat rapid assessment. Accordingly, it is not designed or intended to provide a rigorous statistical analysis of values within the site, but an early and rapid assessment tool that can be later modified if/where required as further information comes through. The limitations of this approach are discussed further below.

Table 1 Summary of Landscape/Physical and Biological parameters used in the habitat assessment

Parameter	Scoring Ranges and Values		
	Low (=1)	Moderate (=2)	High (=3)
Distance to Creek	>501 m	201 – 500 m	0 - 200 m
Distance to nearest other site (ex ck)	>401 m	201 – 400 m	0 – 200 m
Number of sites within 500 m (ex ck)	0 - 4	5 - 10	>10
Position/Elevation	>761 m	743 – 760 m	<743
Connectivity (to other sites & creek)	As rated by visual assessment		
Aquatic Vegetation Cover (%)	0 - 25	26 - 50 & 90 - 100	51 - 90
Emergent Vegetation Cover (%)	0 - 25	26 - 50 & 90 - 100	51 - 90
Riparian Vegetation Cover (%)	<30	31 - 60	60 – 100
Degree of Shade (%)	0 - 20	21 – 60	61 - 100

In taking this approach, each site was then able to receive a final overall habitat assessment score for assessing its potential value for the GGBF (see Table 2). However, in arriving at a final habitat assessment score for each site, two approaches were considered in this assessment. The first involved combining the landscape/physical parameters only to arrive at a value rating of either low, moderate or high, and a score of 1, 2 or 3 applied to each respectively, and then doing the same for the biological parameters. The 2 value scores from each of these broad habitat categories was then combined to arrive at a single score (of between 2 and 6). This initial approach, whilst having some merit as it evens out the respective value of each parameter within each of the 2 categories as well as accounting for the fact that there are 5 landscape/physical parameters versus only 4 biological parameters, so that there would be an undue weighting toward the landscape/physical characteristics as a determinant of overall habitat value. However, when assessing the scores it was found that a number of dam sites (including MCD02, MCD29, MCD30, MCD31 and MCD34) achieved a score of 4, which, based on the value ranges established for this assessment (see below), would place it in the "moderate" condition category. This result did not seem to be appropriate given these farm dams had very little aquatic or emergent vegetation cover, and with such little vegetation cover, would appear generally unsuitable for the GGBF. On closer inspection of the data, it seemed that a moderate score for riparian vegetation had strongly influenced the results at these sites.

An alternative final assessment scoring approach was taken which involved removing the combined scoring and ranking for each of the two broad habitat categories (of either landscape/physical or biological parameters) and simply taking a combined score (of between 9 and 27) for all parameters combined, and then ascribing a final condition rating category (of low, moderate or high) to this final score (as shown below). In doing this, it was noted that all farm dams, including those mentioned above under the initial approach, were then categorised as being of low habitat value, as would be expected based on the observed condition of these sites. The exception to this are sites MCD04 and MCD19, as well as all of the 'wetland' sites MCW06, MCW16, MCW17A and MCW17B were identified as being of moderate value, however, all of these sites achieved a score rating of moderate under both approaches. The main factor contributing to this moderate score level for these sites was generally their proximity to the creek and/or other sites.

The second approach was deemed to be more appropriate when the outcomes of the scoring were assessed, and consequently, this was the approach adopted for this assessment. For this approach, when all scores were combined together, the final habitat value score for each site was based on the following ranges from the habitat assessment scores:

Table 2. Habitat assessment scoring ranges and values

Habitat Assessment Score Range	Habitat Value for the GGBF
9 to 18	Low
19 to 22	Moderate
23 to 27	High

Note: further modification of the scoring can (and eventually should) be applied, including an initial re-calculation of scoring by removing at least one of the landscape/physical parameters, although other parameters could be added or removed in this assessment approach. However, at this stage, the results obtained appear to reflect the general perceptions formed of the value of each study site based on personal experience with the species and its habitat preferences, and so they are considered suitable for this initial habitat assessment.

4.2.2 Accepted limitations of the habitat assessment approach

Given the preliminary and generalised nature of this assessment, statistical analysis and comparison of the site data is not considered appropriate, as not all the data is entirely quantitative and therefore cannot easily be combined in a statistical model. Furthermore, most habitat assessment models conducted for this (and other amphibian or fauna species more broadly) often relies on some presence/absence or abundance data, so that habitat variables can be measured against these results to determine which value has the most influence on the occurrence of the species, and therefore may be considered to be of greater value to the species.

It is also recognised that other variables could be used in the assessment which may also influence habitat suitability for the species. This could potentially include parameters such

as bank height and grade (as high and steep or vertical banks may not be suitable for the species.

Additionally, the value ascribed to certain variables could be modified. For example the value ascribed to the number of other waterbodies within a 500 m (or even using a 1,000 m) radius could be modified, with a score of 2 (i.e. moderate value) given to waterbodies with 3 or more other waterbodies within 500 m, rather than 6 as applied in this assessment (however, there would be less separation between sites in the resulting values, with the vast majority of sites being in the moderate category, including a likely increase in the number of sites in the high category as that range value would also be reduced to include a lower number of sites within 500 m if the moderate value range was reduced to include 3 (or even 4) or more other sites within 500 m).

Consideration will be given to future modification and improvement of this assessment and mapping approach for the final development of the introduction program discussed below in Section 5, and after review and comment/discussion on this preliminary assessment.

4.3 Summary results and conclusions of the habitat assessment

A summary of the results of the habitat assessment score as described above for each site included in the study area is provided in Table 3, and a map depicting these values at each site location is provided in the figures at Appendix C. A general summary of the sites is provided further below in relation to the habitat values at sites along Mulloon Creek as well as at the farm dam and wetland sites.

4.3.1 Habitat along Mulloon Creek

Mulloon Creek was observed to support numerous ponds that are considered likely to be suitable for the GGBF (based only on the habitat values included in this assessment), with generally good aquatic vegetation cover, water quality, as well as overall connectivity and position in the landscape.

However, based on the available literature on habitat selection by the species (see Section2), it is possible that the creek may not provide suitable breeding habitat due to risks associated with flood events that can wash away eggs and tadpoles, or lead to increased siltation which can smother eggs and prevent development, and potentially support increased numbers of predators. This is reflected in the observed breeding behaviour of the species which tends to breed in still water. However given the reported low abundance of potential predators (Starrs and Lintermans 2016), including the presence of some fish barriers such as the leaky weirs installed in the last decade or so, as well as the presence of numerous large pools that have very slow flowing water, it is possible that the GGBF could use certain sites within the creek as breeding habitat at times.

Notwithstanding this, the creek is still considered as being of critical importance in the overall habitat values for the species at MCHF as it is likely to provide refugia habitat (particularly during drought or drying of other waterbodies), as well as serving as a potentially important movement corridor for frogs to move between sites.

Based on the habitat assessment scores derived from this study, 6 of the 8 creek sites received a score of Moderate or higher, with sites MCR20 and MCR35 receiving a score of Low. The particular sections of the creek that appear to have the highest potential value for the GGBF are sites MCR11 and MCR18, which both received a High habitat assessment score value (with scores of 24 and 25 out of 27 respectively). MCR08 and MCR10 were just outside of the High value rating, receiving scores of 22 and 23 respectively (with a score of 24 earning a High value rating). All of these sites are located within the northern half of the creek where it flows through the study area.

As noted previously, the creek starts to become generally unsuitable from shortly south, or upstream, of MCR21 (with MCR20, approximately 250 m north or downstream of MCR21, also receiving a Low score). From this point upstream, the creek is heavily incised along the western bank, in most places with (near) vertical or undercut banks, as well as lots of thick patches of Blackberry (which may restrict movements into adjacent terrestrial habitats), as well as high levels of shade from riparian trees (which is likely to reduce habitat suitability given the lack of basking opportunities for frogs).

4.3.2 Dam and wetland habitats

4.3.2.1 GGBF habitat values at farm dams

Based on the habitat assessment scores, none of the dams in their current form are likely to be suitable for GGBF, and none of these sites received a High value habitat score, with only 2 of the 24 farm dams (MCD04, MCD19) receiving a Moderate value score (the rest receiving a Low value score). These two sites received this score largely as a result of their proximity to the creek and elevation scores, with MCD04 displaying generally little in the way of suitable aquatic vegetation, whilst MCD19 displaying a dense rank growth of Typha with little open or standing water. Consequently, these sites, whilst receiving a Moderate score are generally considered unsuitable for GGBF habitat when considering all factors included in this assessment (although MCD19 could be improved markedly through removing/reducing the Typha as well as planting more suitable surrounding riparian vegetation).

Some other farm dam sites displayed certain features that may superficially appear suitable, although again, when considering all factors combined, are unlikely to be suitable for the GGBF. An example of this would be the four dams within the step-diffusion system (i.e. MCD01-MCD014). Although some of the vegetation characteristics of these ponds appear suitable (primarily surrounding riparian vegetation with lots of tussocks), including close proximity and good connectivity to each other, the overall distance and generally poor connectivity to the creek as well as their position in the landscape (topography), mean that these sites are unlikely to suitable in their current form. However, these sites could potentially be improved by increasing connectivity to the creek, including improving some of the existing vegetation characteristics of these sites.

4.3.2.2 GGBF habitat values at wetland sites

All four of the wetland sites (MCW06, MCW16, MCW17A and MCW17B) all received a Moderate habitat value score in this assessment. This score value was achieved primarily as a result of the landscape and physical attributes of these sites, including (particularly for the latter three sites) their close proximity and connectivity to the creek, the number of

other sites within 500 m, and position in the landscape (topography). Sites MCW16, MCW17A and MCW17B all received an overall low value score for their biological attributes, with all three sites having no aquatic (emergent or submerged/floating) vegetation, and little/no riparian vegetation. Site MCW06 by contrast was observed to support a dense infestation of Typha.

Despite their current Moderate habitat value score (based on existing conditions), all four of these sites are considered to provide potentially high value habitat potential for the GGBF subject to the implementation of certain habitat creation/restoration activities, and could potentially be candidate release sites for the future proposed GGBF reintroduction program as discussed in Section 5.

4.3.3 Summary conclusions of the habitat values at MCHF for the GGBF

In summarising the findings of this preliminary habitat assessment for the GGBF at MCHF, it was found that the study area supports at least some sites that could be regarded as providing suitable potential habitat for the species in its current form, however all of these sites are located in the northern half of the creek itself. It is debatable as to what the actual habitat values are for the species within the creek, with previous research and other anecdotal evidence suggesting that the creek is unlikely to provide potential breeding habitat, and consequently its overall value may be limited to refugia and connectivity habitat only. Further investigation may therefore be required if these sites are to be considered as potential release sites for any future reintroductions of the GGBF to MCHF.

None of the dam sites in their current form are considered likely to provide any potential suitable habitat for the GGBF. This is primarily a result of both connectivity (including proximity to the creek and other sites) and topography, as well as in most circumstances, unsuitable aquatic vegetation characteristics. It is possible that some of the dam sites, mainly those located in closer proximity to the creek and which have potential options for establishing a viable movement corridor to connect these sites to the creek, could provide future potentially suitable habitat if the aquatic vegetation conditions were improved along with improving connectivity.

The identified wetland sites all were regarded as having only moderate habitat values for the GGBF in their current condition. However all of these sites display certain physical characteristics that could make them potentially suitable sites if the aquatic habitats, including water levels, as well as aquatic vegetation characteristics were improved.

In conclusion, the habitat assessment described above, some sites have been identified as having either current or future (subject to rehabilitation etc) potential habitat for the GGBF. On this basis, further investigation of a possible reintroduction program would seem warranted. Those sites identified as having some potential habitat value for the GGBF, either in their current form or with active intervention (i.e. rehabilitation), and which could potentially be candidate sites for releases in a reintroduction program are discussed in further detail at Section 5.

Finally, it is important to acknowledge that this assessment included consideration only of some key landscape/physical and biological habitat parameters, and that there are other possible factors that may play a critical role in determining whether the site may be capable of supporting the species if reintroduced. The parameters are mainly in relation

to the existing status of any chytrid infections in the existing amphibian populations in the study area, as well as chemical properties of sites, which may also play an important in determining if the site is suitable for the species. Assessment of these parameters is beyond the scope of this preliminary assessment, and therefore cannot be further considered by this study (and have been assumed for now to be benign factors). The requirement to obtain further information on these matters is identified in the proposed strategy for a reintroduction program at Section 5.

Table 3. Summary results of habitat assessment score for each site

Site	Habitat Type	Combined Score (-/27)	Habitat Value
MCD01	Dam	15	LOW
MCD02	Dam	18	LOW
MCD03	Dam	17	LOW
MCD04	Dam	19	MODERATE
MCD05	Dam	16	LOW
MCW06	Wetland	22	MODERATE
MCD07	Dam	13	LOW
MCR08	Creek - Pool	22	MODERATE
MCR09	Creek - Pool	21	MODERATE
MCR10	Creek - Pool	23	MODERATE
MCR11	Creek - Pool	24	HIGH
MCD12	Dam	15	LOW
MCD13	Dam	11	LOW
MCD14	Dam	15	LOW
MCD15	Dam	17	LOW
MCW16	Wetland	21	MODERATE
MCW17A	Wetland	20	MODERATE
MCW17B	Wetland	20	MODERATE
MCR18	Creek - Pool	25	HIGH
MCD19	Dam	21	MODERATE
MCR20	Creek - Pool	18	LOW
MCR21	Creek - Pool	20	MODERATE
MCD22	Dam	16	LOW
MCD23	Dam	14	LOW
MCD24	Dam	14	LOW
MCD25	Dam	12	LOW
MCD26	Dam	18	LOW
MCD27	Dam	16	LOW
MCD28	Dam	16	LOW
MCD29	Dam	18	LOW
MCD30	Dam	18	LOW
MCD31	Dam	16	LOW
MCD32	Dam	16	LOW
MCD33	Dam	13	LOW
MCD34	Dam	18	LOW
MCR35	Creek - Pool	15	LOW

5 PRELIMINARY GGBF REINTRODUCTION STRATEGY

5.1 Project description

As identified in the project aims, this component of the assessment aims to identify the key factors to be addressed for developing a future (formal) GGBF reintroduction project at MCHF, as well as providing an early strategy for how a project would be prepared and delivered.

The development of this strategy has included the following general approach:

- Review of the existing published information in relation to wildlife reintroduction or translocation projects generally, including a review of previous projects that attempted to introduce or translocate GGBF into new or restored habitats to identify what are the likely factors that influence the success or failure of these projects,
- Information on process to identify suitable reintroduction sites, including both early and ongoing actions required to make sites ready for a reintroduction; and,
- Identification of specific sites within the MCHF study area that may be suitable as potential release sites for the GGBF reintroduction project,

5.2 Review of previous introduction/translocation projects

Provided below is a summary review of the kay matters involved with wildlife translocation projects generally as well as a review of previous GGBF translocation projects specifically to gain an understanding of the factors that may relate to the success of failure of a reintroduction or translocation project. This information is necessary to understand when considering the proposal to undertake a GGBF reintroduction at MCHF.

5.2.1 Overview of wildlife translocation

Translocation is generally defined as the deliberate reintroduction of species into an area where it once occurred or introduction to an area where it never occurred. Translocation may also involve the supplementation of a declining population with additional individuals. Captive breeding may be a component of a translocation program and be used as a source of animals for such initiatives, although translocation could also include the relocation of individuals from one site to another. Translocation programs are usually devised to assist in the conservation of a threatened species, within the context of a broader recovery strategy (e.g. Greer, 1996; DEC 2005; White and Pyke 2008; Germano *et al.* 2015).

Translocation programs can provide a measure of security for critically endangered populations in the event of catastrophes (such as the impacts of habitat loss or modification, fire or disease. However, translocations are generally seen as an experimental management technique for most species, and not necessarily a mitigation measure and does not always reduce the impact of an action on a species. Furthermore, reintroductions are often expensive in terms of financial and human investments, often with little success, as described further below in the case of the GGBF.

The general proposal of undertaking reintroductions as a conservation strategy has been widely accepted in principle as desirable, with some exceptions. Greer (1996) argued

that translocation breaks forever the historical natural link between the organism and place, and that the process is a last resort, only to be considered to save a species or significant population from extinction. Berger *et al.* (1999) however argued that it is extremely important to demonstrate that human intervention, which can not only explain declining population trends in amphibians, can also successfully reverse them, and recommend captive breeding and re-introducing species back into localities within their historic range as an appropriate conservation management action.

Further, the low representation of extant populations in some regions means that reintroduction is the only means available for the species to again exist at the previous extent of its former distribution. The more difficult question however may involve proposals to supplement existing populations that are in decline, particularly if the cause of the decline is unknown or not managed, as released individuals are likely to suffer the same fate (or mortality) that has caused that population to decline in the first place.

Consequently, although there is a well-intentioned desire to reinstate a species into previously occupied landscapes, the factors that originally caused the decline have to be understood and mitigated prior to any reintroduction.

This matter is considered to be of critical importance in considering attempts to translocate the GGBF, including the current intention to develop a proposal to reintroduce the species to the sites at the MCHF. These matters are considered in further detail below based on the review of previous attempts to translocate this species.

5.2.2 Review of previous GGBF translocation projects

In Australia, several attempts at translocating or reintroducing the GGBF have been undertaken with an estimated $14.14 million spent on mitigation-based translocations for this single species of frog over the past 15 years, as compared with an estimated $3.29 million devoted to conservation based translocations for all other amphibian species combined during the same time period (Germano *et al*. 2015).

The current evidence from attempts to translocate or reintroduce the GGBF indicates that it is a difficult species to successfully introduce into habitats, with little very instances of reported breeding and recruitment of subsequent generations to establish a viable population (Daly *et al.* 2008; White and Pyke 2008). Consequently, there has been considerable debate over recent years about the general effectiveness of translocation projects as a conservation strategy for this species. Added to this are also inherent risks involved in translocation of large amphibian species such as the GGBF at both the population and individual levels, including the possible spread of disease (at the population level) and potentially the heightened predation-risk (at the individual level).

The re-introductions that have been attempted for the GGBF are generally viewed as being largely experimental and not a standard management option for solving the problem with the observed decline of the species (DEC 2005), and so far no reintroductions or translocations of the species are believed to have satisfied the goal of self-sustaining populations (Daly *et al*. 2008).

The GGBF has been shown to successfully colonise adjacent areas from a source population (e.g. Homebush Bay, Orica -Brick and Block site at Port Kembla and Sussex Inlet

Sewage treatment ponds) but reintroduced populations have failed to establish (Daly *et al*. 2008; Pyke *et al.* 2008).

Other reported reintroduction or translocation projects undertaken for the species as reported in the NSW Draft Recovery Plan (DEC 2005), include a reintroduction project at Joseph Banks Reserve at Botany and translocation/introduction project at Marrickville and Long Reef/Collaroy, described below:

- An early attempt at reintroduction at Joseph Banks Reserve initially failed but this was attributed to both the presence of *Gambusia* and possible "poaching" by school children. A subsequent attempt was carried out following eradication, using the ichthyocide 'rotenone', of *Gambusia* and an educational program that involved school children was instituted by Taronga Zoo in conjunction with their education centre staff and 'Frog Focus' program. A small number of frogs are understood to have survived and continue to exist at the site, but no breeding is thought to have occurred.
- At Marrickville an initial small introduction achieved high recruitment success, but subsequent supplementation was thwarted by cannibalism by the original animals. Breeding events within this 'contained' colony has also occurred. However further developments at this site have indicated the catastrophic impact of the arrival of the frog chytrid pathogen. It is believed that the arrival of infected *Limnodynastes peronii,* which had previously been excluded, may have introduced the pathogen and resulted in total mortality of the introduced GGBF colony. Further reintroductions have occurred with slightly elevated salinity levels provided in an attempt to attenuate the action of the pathogen. These latest releases have failed to result in a viable adult population and the projects continuance is currently being reassessed.
- An introduction trial at Long Reef Golf Course has also been undertaken and involved the release of large numbers of tadpoles and metamorphlings. These introductions appear to have had early success with many tadpoles reaching metamorphosis followed by high mortality and/or disappearance of the juveniles. These mortality levels appear to have prevented sufficient females from reaching reproductive maturity in the second year and so enable breeding to take place. The release of captive reared females to supplement the prior tadpole releases is now proposed to increase the likelihood of breeding success within this population.

5.3 Strategy for developing a GGBF reintroduction program at MCHF

It is generally accepted that the reintroduction of a species should focus on sites where localised extinction has occurred, and based on previous records of the species prior to its decline in the early 1980's, there is a good possibility that the GGBF would have once previously occurred at the MCHF, or at least along other (nearby) sections of Mulloon creek. Given this, and the noted improvement of the general condition of the creek over the last decade of rehabilitation projects undertaken at MCHF, as well as the habitat results described in Section 4 including some of the superficial/perceived similarities between the study area and the upper Molonglo River sites where the species still persists,

a proposal to undertake a reintroduction project at MCHF would appear to have some merit.

On this basis, provided below is a preliminary strategy or outline of the key matters to be addressed in developing a GGBF reintroduction project at MCHF. The development of this project will obviously take many years, and consequently, will need to be prepared and implemented in stages. To facilitate this, the steps or tasks to be undertaken in the development of the reintroduction project have been presented generally in order of timing from project commencement to implementation, including information or other tasks to be addressed within each stage, that will provide guidance and support for the future development of a reintroduction project.

Note that those aspects of the strategy that are of a more administrative nature are identified and discussed at a summary level only.

5.3.1 Establishment of Project Team

The establishment of a Project Team is an obvious first step that will be required in order to progress the development of the project plan. The project team will likely include the following:

- MCHF property manager
- MI representative/s
- Relevant experts (i.e. Dr M. Mahony, Dr A. White, Dr W. Osborne etc)
- Government (NSW OEH) Representative (i.e. Rod Pietsch, Dave Hunter)
- Other stakeholders (to be identified)

Key early tasks of the project team will be to:

- Identify clear roles and responsibilities of each team member
- Prepare early consultation strategy, including a process for ongoing liaison with relevant approval authorities (such as Animal Ethics approvals and other statutory approvals identified as being required to support the project)
- Prepare the outline of the proposal, including clear identification of scope and target requirements, particularly in relation to statutory requirements. This is expected to be necessary to secure funding to commence undertaking the project in detail. The preparation of the plan is discussed further below

5.3.2 Preparation of GGBF Reintroduction Project Plan

Set out below is a summary overview and preliminary strategy for commencing the preparation of the MCHF GGBF translocation project, which includes the key matters to be addressed and adequately resolved in order to obtain the required approvals of the project and to commence implementation of the plan.

Obviously, the initial component on the project is likely to include the standard approach to project such as the establishment of aims, objectives, success criteria and associated ongoing monitoring and management requirements, project timeframes, and ultimately, the project scope and delivery based on available funding. These features of the plan will obviously be discussed and decided upon by the project team after it has been established and had a chance to meet and discuss the project, and therefore are not

considered further in this report (with the exception of some monitoring and management issues).

Most of the initial time and effort in the preparation of this draft plan will be to resolve much of the outstanding information requirements that are likely to play a large role in developing an appropriate project proposal. These are discussed further below. Following this will be the final selection of suitable sites for a release, including possible habitat restoration requirements that may be required in order maximise the chance of success of the reintroduction project.

5.3.2.1 Further Research Requirements

To complete the draft plan, a number of matters will require further investigation and resolution. These include mainly the need to understand further issues related to Chytrid, including confirming the current status of chytrid infection in existing amphibian populations, as well as the current environmental conditions that occur at the site that may play some role in determining whether the GGBF is likely to be able to persist at the site if introduced, as explained further below.

The presence of the amphibian chytrid is suspected to be the crucial factor in the decline of the GGBF (DEC 2005), and is thought to play an important role in the success or failure of introduction or translocation projects for this species. While many species of frog appear to be able to persist while infected with this pathogen (e.g. *Crinia signifiera, Limnodynastes peronii, Limnodynastes tasmaniensis, Litoria verreauxii* and *Litoria peronii*), unfortunately the GGBF is highly susceptible to the disease (DEC 2005; Daly *et al.* 2008). As noted previously, the extant populations appear to occur in areas where environmental factors exclude or mediate chytrid, such as in semi-saline or contaminated sites.

It would appear therefore that in order for the GGBF to be able to establish a self-sustaining viable population through a reintroduction project, the receiving habitat should/must contain some of those factors that occur in other areas where the species has managed to persist despite the fungus. These factors appear to be mostly in relation to the background chemical properties of sites, with either low-lying coastal sites with some salinity, and/or sites that have some contamination/pollution by heavy metals or other sources, comprising the majority of sites where extant populations still persist. This is possibly further demonstrated by the extant population on the upper Molonglo River which is situated in a floodplain system about 15 km downstream of Captain's Flat which supported a former gold mine. It is reported that there were a number of collapses of the mine tailings dams in the early half of the 20th century, and consequently, the floodplain system where many of the heavy metals and other pollutants from the mine tailings eventually settled, is known to have sediments that still contain some background levels of these contaminants. Chytrid has been confirmed in this GGBF population, and yet it appears to be able to still persist in this environment and it has been suggested that these contaminants may be acting to suppress the fungus in some way.

Given the above information, it is therefore believed possible, if not likely, that the reintroduction of the GGBF at MCHF may only be successful if the receiving environment (release sites) exhibit some form of pollution or other chemical composition of the sediments in order to provide this buffer against the fungus. Accordingly, further

investigation, including assessment of the chemical properties of the sediments and waters at MCHF is required.

In addition to the above, the importance of understanding the Chytrid issue for reintroduction projects can have implications for how the release is managed and undertaken. Previous research has shown that frogs exposed to Chytrid as recently metamorphosed juveniles acquired higher infection loads and experienced lower immune function and lower survivorship than subadults and adults, indicating an ontogenetic decline in chytridiomycosis susceptibility (Abu Bakar *et al.* 2016). This evidence may suggest that releases should be undertaking using more mature frogs that are less likely to be susceptible to Chytrid, however the study did not look at this issue with the larval and tadpole stages. Further review of this issue should therefore also be undertaken to confirm the appropriate life stage of individuals to be released.

It has also been suggested that temperature may play a role in the virulence of the Fungus, with frogs apparently more immune-compromised or susceptible during colder temperatures (Campbell *et al*. 2019). Presumably this may be because during the warmer periods, frogs are sloughing their skin more rapidly, or perhaps have greater immune capacity during warmer periods, whilst during the cooler periods, their energy levels are reduced, the skin is sloughed less regularly, and the immune system may eb compromised, making frogs more susceptible to the disease. Consequently, there may be a requirement to time the releases to avoid releasing individuals late in season. This may be of particular importance for a reintroduction to sites in the Southern Tablelands which can experience below zero temperatures, even in Autumn.

5.3.2.2 Identification of appropriate source material (from captive bred populations)

Further review and investigations will be required to determine the most appropriate available source individuals from an existing captive-bred population to be used in the reintroduction project. This may/will include confirmation of the following key matters:

- where the stock will come from, and that there are no potential issues with genetics or disease (generally considered unlikely to be an issue, particularly with respect to genetics given there is no existing population that would be affected and the results of Emma Burns' PhD 2004 indicating translocation and reintroduction programs for the GGBF may be viable conservation strategies based on the genetic evidence as there are no historically isolated groups that should be viewed as separate Evolutionary Significant Units); and,
- confirming the number of individuals and their age-class required to undertake an appropriate release effort (as too few individuals may result in inadequate recruitment and the failure to establish a viable population, and the inappropriate age-class may increase susceptibility to Chytrid, as discussed above). Obviously, the provider of the material will need to be consulted with to ensure that there is available and sufficient stock of the right age-class and at the right time of year to undertake the releases.

With respect to potential providers of the source population for use in the reintroduction program, based on the available information at the time of writing this assessment report, there are a number of captive-bred populations of the GGBF that could potentially be

used for the source specimens. These are summarised below (as taken from the NSW Recovery Plan, DEC 2005):

- Taronga Zoo has an established captive-breeding program with representative specimens from Rosebery and Arncliffe and also the Australian Museum holds some individuals from Homebush. Taronga Zoos program has already demonstrated an ability to produce significant numbers of offspring from prescribed source stock and have bred Rosebery provenance stock through three generations.
- Newcastle University holds stock from the lower Hunter area for research purposes.
- The Australian Reptile Park has also indicated a preparedness to undertake a captive-breeding program for conservation purposes and currently maintains stock from Broughton Island for educational display purposes.
- A licensed, privately held collection of GGBF with a Merimbula provenance are also being maintained with the support of Bega Valley Shire Council and DEC and used in the reintroduction project at Pambula (e.g. Daly *et al*. 2008).

It is also recommend in the development of the reintroduction plan that consideration be given to eventually establishing and maintaining a captive population of GGBF either at the site (particularly if there is evidence of recruitment), or in the local area and working in partnership with the NSW and ACT governments (as recommended in the NSW Recovery Plan).

5.3.2.3 Identify target release site

The reintroduction project plan will need to clearly identify the sites where releases are proposed including justification for the selection of those sites. Section 6 provides a preliminary review of possible sites that are considered to have potential as release sites and the reasons why.

In considering the general approach to identifying an appropriate release site, as noted previously, the connectivity of sites appears to be a key factor determining habitat suitability for the species. It is also believed that for a tablelands site such as this and based on previous experience with the Molonglo River population, that connectivity to the creek is also of vital importance for refugia, particularly in drought, but also as a potential movement corridor between other sites.

As other factors such as vegetation characteristics, and potentially even hydrological characteristics, of the waterbodies can be artificially manipulated to some extent, particularly within dams or wetland sites, the physical location of the existing waterbodies (i.e. proximity to the creek and other sites) is potentially a main governing factor in site selection as the sites cannot be physically moved.

In order to demonstrate visually how the connectivity of habitats for the GGBF could be designed, provided below is a figure adopted from EPBC significant Impact Guidelines for the GGBF which shows how GGBF habitat should be assessed and consequently how impacts to this habitat would be considered. Whilst this project does not constitute an impact to GGBF habitat, this figure is nevertheless useful in considering the habitat requirements for both breeding and non-breeding habitat at a site, and how these habitats should be considered with respect to their spatial arrangements within the system and to other habitat areas.

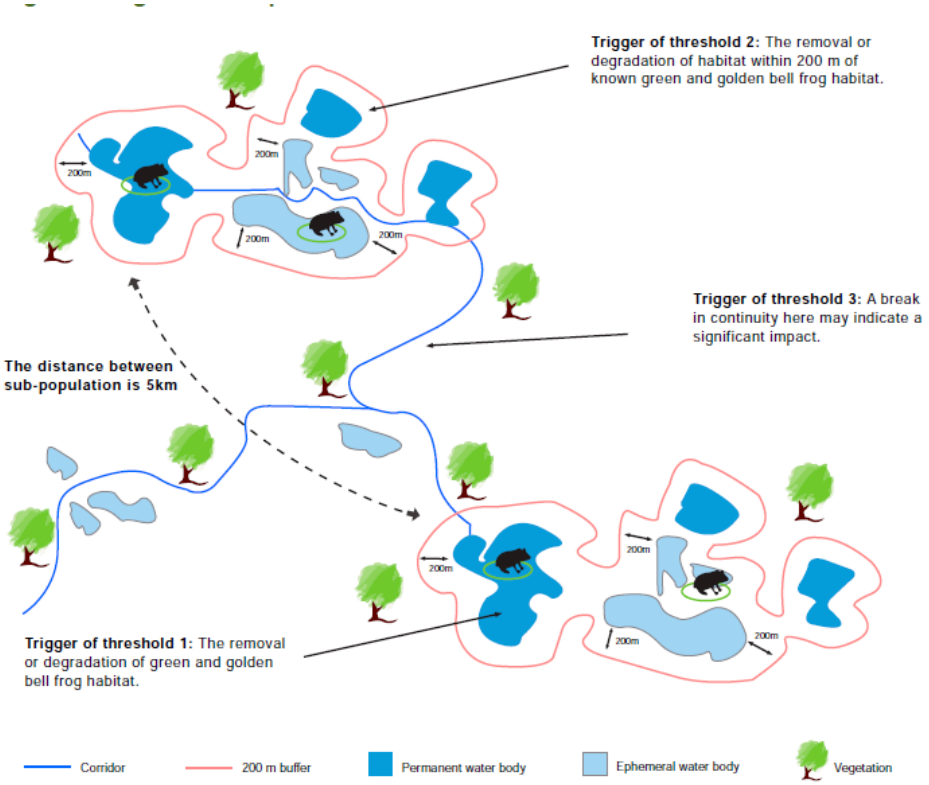

Figure 3. EPBC Significant thresholds for impacts on the GGBF.

As the GGBF has a reported high dispersal capability, there could be issues with frogs leaving the release site and (for whatever reason) not returning to breed at the selected site, which could reduce recruitment levels, and ultimately lead to a failure of a self-sustaining viable population becoming established.

Consequently, it is believed that in the early stages of the project, maintaining a 'frog fence' around the perimeter of the site will be important to retain frogs within the site (likely to be at least for a few breeding seasons) to assist with potential breeding success, but also to exclude/manage predators and limit grazing impacts/stock access.

Examples of the approach to establishing a fence around a site (adopted from the NSW *Best practice guidelines Green and golden bell frog habitat* (DECC 2008)), are shown in Figure 4 below in relation to fencing around the site itself (for rural areas, particularly if some limited stock access may be required), as well as in Figure 5 further below, in relation to the broader arrangement of integrated fencing across a range of habitats for maintaining appropriate connectivity of suitable habitat sites as well as exclusion of frog movements into other unsuitable areas.

Specific details of the construction design for this fencing are provided in Section 5.3.4 on the early actions to implement the plan.

Finally, it will be important for the project plan to have a clear understanding and establish a set of accepted criteria that can be used to assess and determine that the proposed release site is in a condition that is suitable and ready for the release of GGBF into the site.

Further discussion on potentially suitable release sites at MCHF as well as preliminary recommendations in relation to possible habitat restoration and protection requirements for these sites is provided below in Section 6.

Figure 4. Example of rural bell frog habitat creation/protection (adopted from DECC 2008)

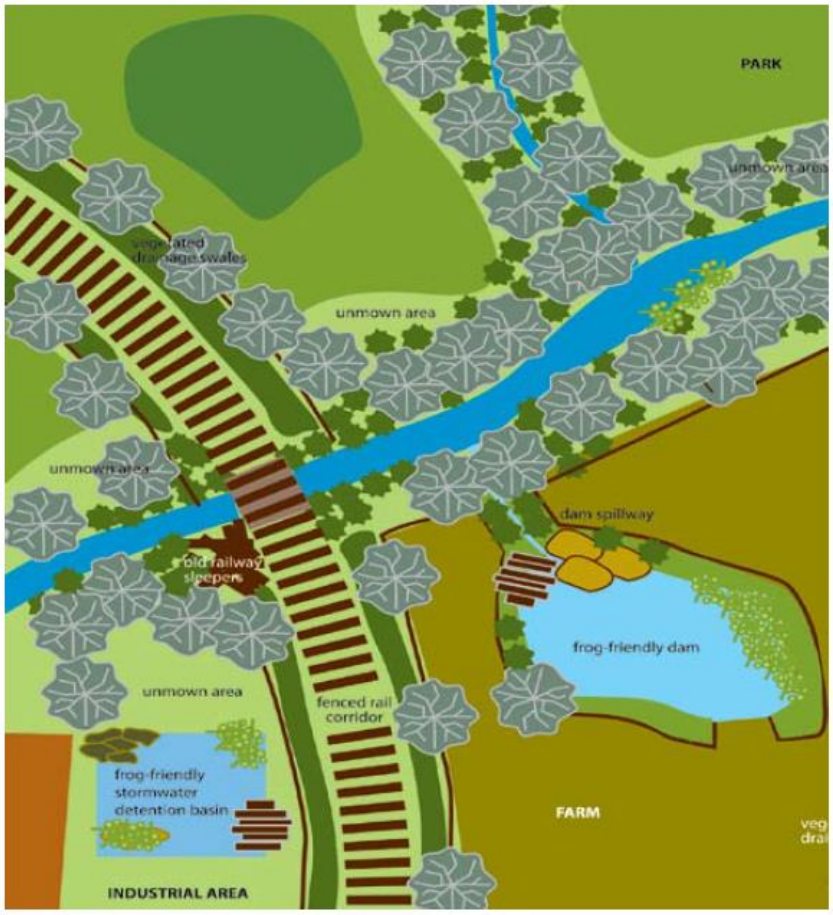

Figure 5. Example of GGBF habitat integrated across mixed land uses (adopted from DECC 2008).

5.3.2.4 Ongoing monitoring and management considerations for selected sites

The primary ongoing management considerations of the reintroduction of the GGBF at selected sites is mainly in relation to undertaking regular monitoring and performing the management response tasks set out in the plan.

The main monitoring tasks required are likely to be in relation to:

- The status of the population, including numbers and age-classes, evidence of breeding (i.e. amplexus, spawn or tadpoles) including the presence of Chytrid in the population,
- weeds and vegetation condition in general, and
- the presence of potential predators,

In terms of the ongoing management responses to the monitoring, it is possible that subsequent releases of GGBF individuals may be required to supplement the initial release population, particularly if little or no recruitment has been observed. However, the monitoring results could also indicate that Chytrid has infected the population, and that the released frogs are appearing to have no environmental or immune-based defence against the fungus, and that mortalities are being observed. In this case, careful consideration would need to be given as to whether the project should continue.

The criteria for how any future reintroductions/supplementations would occur, or the project abandoned due to Chytrid mortalities (or possibly other reasons), should be clearly determined and identified in the reintroduction project plan.

Ongoing management measures in relation to weeds or predator would be in accordance with standard guidelines and should also be clearly identified in the project plan. The plan should also detail specifications for revegetation actions, including the planting/sowing of suitable plant species (i.e. Eleocharis, Poa, Juncus, Lomandra etc – see Section 5.3.4.1 below for further information on revegetation parameters).

Additional ongoing management requirements are likely to include the maintenance of the frog fence to ensure it remains in a proper function order. Consequently, this structure should be inspected on a regular basis.

5.3.3 Finalise Plan and Submit for Approval

Once the project plan been developed and finalised it will need to be approved before any reintroductions can take place. At this early stage, these approval requirements will include Animal Ethics approvals, although it is unknown what other State or Federal statutory or other licensing approvals may be required.

The Animal Ethics Committee approval will be required to be obtained according to the "Code of practice for the care and use of animals in research in Australia" (National Health and Medical Research Council and Commonwealth Scientific and Industrial Research Organisation).

At the federal level, it is noted however that the project is not an action that would be likely to result in a significant impact to this or any other species, and consequently, it is unlikely to trigger the requirement for a referral to the commonwealth government in accordance with provisions of the EPBC Act. However, the *EPBC Policy Statement for the Translocation of Listed Threatened Species – Assessment under Chapter 4 of the EPBC Act*

(SEWPaC 2013), may be considered an action required to be referred in its own right. For the purposes of deciding whether a proposed action is a controlled action (section 75) the decision-maker is not able to consider any beneficial impacts of the translocation (subsection 75(2)). The central question in relation to a controlled action decision on a stand-alone conservation translocation proposal is therefore: '*Will the translocation have a significant adverse impact on a protected matter?*'.

At the state level, the project is considered to be generally in accordance with the NSW Recovery Plan for the species, although what formal approval is required to undertake the project (beyond the ethics approval) is not known at this stage. It is likely that a licence would be required from NSW OEH for working with a threatened species.

Consequently, part of the plan development will be to further investigate and confirm the project approval requirements, including undertaking some preliminary consultation with these entities during the project development to ensure that any early concerns or recommendation from these entities are addressed by the plan.

5.3.4 Implementation of the Plan – Early Actions

Once the plan has been approved, there are a number of early actions to be completed before a reintroduction can take place, some of which may be time-consuming, and therefore should be understood early in the plan development so that they can be implemented as soon as possible after approval to proceed has been granted. These early stages are likely to include the following general actions:

- Preparation of release sites and the surrounding environment, including:
    - Fencing of the site to an adequate distance to include sufficient foraging and shelter habitat away from the waterbody, as described previously. Preliminary fencing details are described further below.
    - Weed and potentially predator removal (although predator removal may be unlikely for the preliminarily selected release sites – see Section 6)
    - Site revegetation to ensure that release sites support suitable aquatic and riparian vegetation. Preliminary recommendations for site revegetation are described further below.
    - Installing hydrological controls if required to ensure that the water levels within the release site are adequately maintained. This can include inundating areas to hold water on a more frequent basis, but also may include controls to allow periodic draining of the water to reflect more natural ephemeral cycles. Preliminary recommendations for hydrological controls to be established at selected sites are described further below.
- Working with the providers of the captive-bred source population to ensure that adequate stock of the appropriate age-class(es) is available at the appropriate time for release.
- Establish a project field team responsible for undertaking the following on-site activities:
    - Releasing individuals into the habitat
    - Ongoing Monitoring of the population and the general habitat condition at the release site.

Provided below are some preliminary recommendations for establishing and maintaining habitat controls (for fencing, revegetation and hydrological features) at selected sites for releases to ensure that the habitat values of these sites are suitable for supporting the species. Note that these controls are primarily in relation to the identified wetland sites as described in Section 6 below.

Note also that the information below is provided at a high level for consideration and discussion of future site establishment actions. The final details on the preparation of the release sites and the surrounding environments (prior to undertaking the releases) should be designed and clearly stated in a landscape management and rehabilitation plan (or similar document) to be included with the reintroduction project plan. The plan should also be prepared in accordance with the NSW *Best practice guidelines Green and golden bell frog habitat* (DECC 2008).

5.3.4.1 Frog fencing

As stated, frog fencing is recommended to be installed at release sites to keep frogs restricted to the site, as well as to prevent predators and possible stock access to the site. This fencing will need to remain in place until sufficient evidence that successful recruitment has occurred before consideration should be given to its removal or opening up of sections to allow dispersal from the site. The details on the fencing to be included in the plan should include both the area/location of the fencing around the site as well as the type of fencing to be provided.

With regard to the area to be fenced around each site, this should be determined on a case-by-case scenario. Generally, there is little information available to identify what would be a suitable design, although a minimum buffer width of at least 30-40 m would be considered appropriate, depending on the condition of the habitat and availability of suitable foraging/sheltering habitat (i.e. structural complexity of the terrestrial area). See Figures 4 and 5 above for examples of how the habitat could be defined and fenced as per the best practice guidelines.

Frog-exclusion fences have been used routinely on construction sites and other hazardous areas where threatened frog species occur. Frog exclusion fences typically consist of a continuous curtain of impervious material (usually shade cloth fabric) strung between support posts. The fence is at least 1 metre high and has an overhanging lip. Standard fence designs usually have a 25-50 cm horizontal lip and then another 20-30 cm hanging vertical lip at the top of the fence. The overhanging lip is designed to prevent frogs climbing over the fence (see Figure 6). The base of the fence is buried to stop frogs from digging under the fence. If there are gates in the fence, the base section of the gate can still maintain a seal with the ground by being weighed down with length of flexible chain.

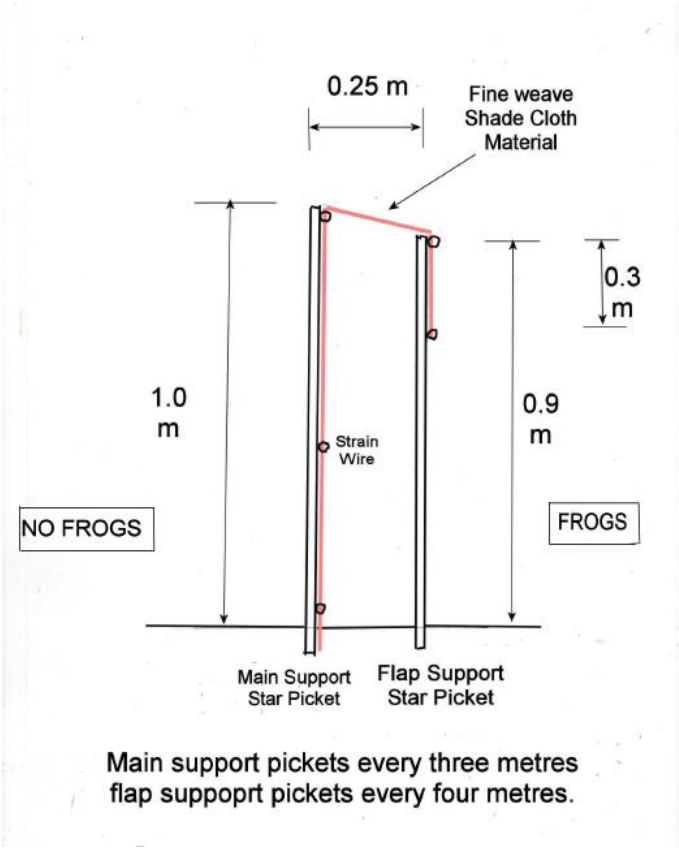

Figure 6. Typical frog exclusion fence design (image courtesy ELA 2016)

5.3.4.2 Site revegetation

As stated previously, aquatic and riparian vegetation is an important component of GGBF habitat and the identified release sites must support suitable vegetation characteristics in order to be considered suitable candidate sites for a reintroduction program. As discussed in Section 6 below, the identified target sites for releases include a number of the mapped "wetland" sites, however these sites do not, in their current condition, support suitable aquatic or riparian vegetation. Consequently, it will be important to undertake some active revegetation to establish appropriate vegetation characteristics at the sites in order to make them suitable as potential GGBF habitat.

Suitable aquatic (emergent and submerged/floating) vegetation species recommended for use in the revegetation actions include (generally in order of preference):

Emergent species:

- Tall Spikerush (*Eleocharis sphacelata*)
- Rushes (*Juncus spp*. including Common Rush, *J. usitatus* and Pale Rush, *J. pallidus*)
    - (note: the Spiny Rush *J. acutus* is recognised as an environmental weed in some places and is not recommended for use)
- Jointed Twigrush (*Baumea articulata*)
- River Clubrush (*Schoenoplectus validus*)
- Sedges (*Carex spp.* including Tall Sedge *C. appressa* and possibly Tassel Sedge *C. fascicularis* which is reportedly cultivated (Romanowski 1998))

Submerged/floating species:

- Pondweeds (*Potomogeton spp*.)
- Aquatic Buttercups (*Ranunculus spp*.)
- Watermilfoil (*Myriophyllum spp*.)
- Marshworts/Water Lilies (*Nymphaea spp*.)
- Hornwort (*Ceratophyllum sp*. – may be commercially available as widely used as aquarium plant (Romanowski 1998))

Further investigation will be required to determine the availability of these species (either commercially or via propagation from existing native stock within the property) as well as specific planting treatments that may be required to ensure the successful propagation/establishment at sites. Consultation with a qualified Landscape Architect is therefore recommended to inform/prepare the revegetation plan.

In undertaking any plantings, it will be important to avoid as much as possible the formation of dense thickets of emergent vegetation within the waterbody, although over time this may naturally occur if not managed by direct removal or through hydrological controls as discussed below. It is believed that an appropriate target would be between 40-80% overall cover of the waterbody, with the remaining area of the waterbody being open surface water (but which may have submerged floating water). This level of cover will allow greater movement of frogs (particularly the ability for large adult basking frogs to quickly jump underwater to hide), as well as allows increased basking opportunities (for both adults and tadpoles) through more light penetration closer to the water surface.

In addition to the above, certain native aquatic species are already present at Mulloon Creek which could have potential use and have been recorded within known GGBF habitat at other sites in NSW, including notably Cumbungi (*Typha spp*.) and Common Reedgrass (*Phragmites australis*). However, it is recommended that these two species in particular should be avoided as they have the potential to form dense infestations (i.e. rank growth) within waterbodies that can reduce the amount of open water as well as potentially basking opportunities for frogs. If/where these species become established at release sites (such as through natural colonisation), it is recommended that they be managed by regular removal/thinning to limit their spread.

Other common aquatic plants that may occur in waterbodies in the area (and which may be commercially available and/or easily propagated from stock) include Azolla. This species can also invade and smother waterbodies reducing the amount of available open water, and consequently is not recommended for use. However, it is noted that this plant can be harvested for fertiliser as it is nitrogen-fixing, and therefore some beneficial use of this plant may be possible if it is managed appropriately (Romanowski 1998).

Riparian species (including for use in corridors):

Suitable riparian and corridor species recommended for use in the revegetation actions include (generally in order of preference):

- Tussock grasses (including River Tussock *Poa. labillardieri*, and Poa Tussock *P. sieberiana*)
- Rushes (including Pinrush *J. filicaulis* as well as those species stated above for emergent vegetation – for use in low-lying areas that are seasonally wet)
- Common Swamp Wallabygrass (*Amphibromus nervosus*)

- Mat-rush (*Lomandra spp*.)
- Flax-lily (*Dianella spp*.)
- Knotweed (*Persicaria spp*.)

Some trees and shrubs may be planted, particularly if required to assist in bank stabilisation or addressing other erosion concerns, however, these should be planted as sporadically as possible to limit shading of the waterbodies.

5.3.4.1 Hydrological controls

The need to implement hydrological controls at potential release sites at MCHF is primarily for any non-creek sites selected for releases (including those discussed in Section 6). For these sites, it will be important to ensure that they have the appropriate hydrological features in order to be capable of supporting a viable breeding population of the GGBF. This includes primarily the waterbody maintaining an adequate amount of water at the appropriate times of year to facilitate breeding and tadpole development through to metamorphosis (but which may or should otherwise be ephemeral/temporary in nature).

As noted in the literature review at Section 2 of this report, breeding has been reported to be typically greater at sites that usually (but not always) are smaller than 1000 m², less than a metre deep, and are ephemeral or fluctuate substantially in water level, (Mahony 1999: Pyke & White 2001; Pyke & White 2002; Pyke *et al.* 2002). Based on this as well as observations on the habitats at the Upper Molonglo River (as the nearest comparable habitat to the Mulloon Creek site), provided below is a preliminary consideration of the likely hydrological features that are considered necessary for a suitable release site in relation to the area of the waterbody, the water depth and the periodicity or seasonal timing and duration of the water being available for breeding success[2].

Area

In general, there is no known prescribed minimum area of water considered necessary in order to the GGBF to attempt breeding, with reported attempts of breeding in ornamental garden ponds of as little as 10 m² in area. Given the landscape features of Mulloon Creek, as well as the fact that this program seeks to reintroduce a species into an area where there is no nearby extant population, it is believed that as large an area as possible/practicable hold water (i.e. the wetted perimeter of the waterbody) to support as many adult breeding frogs as possible.

Ideally it is thought that a non-creek (i.e. dam or wetland) release site should occupy an area (of the wetted perimeter under ideal conditions in the breeding season) of at least 100m². This area should be capable of supporting at least 30 adult breeding frogs (based on observations of the population at the Upper Molonglo River wetland sites, Patmore *pers obs*).

As noted that breeding may be greater at sites smaller than 1000 m², however it is not clear whether any restriction on the size of an artificially inundated wetland should be established for this program as there is no strong evidence of a negative trend in waterbody size and breeding success. It is possible that large sites may be more

[2] Important to note breeding often triggered by rain and therefore maintaining hydrological controls over a wetland release site is no guarantee of breeding occurring without other suitable climatic factors occurring (and assuming all other factors discussed are also addressed).

permanent and could potentially support greater numbers of predators which could then reduce breeding success. However, for an artificially modified and controlled site this may not be as much of a threat, and so no restriction on the maximum size or area of a wetland is recommended at this stage.

Perhaps the key consideration with the area of the wetted perimeter is to avoid as much as possible during the breeding seasons any extensive areas of bare/exposed banks between the water's edge and the surrounding vegetation (although some bare earth sections of banks will be satisfactory).

Depth

While breeding may be reported to be (occasionally) greater at sites less than a metre deep, there is also no strong evidence of a negative trend in waterbody depth and breeding success. As above for the area/size of the waterbody, it may be that deeper sites are possibly more permanent and could support greater numbers of predators which could then reduce breeding success. Similarly, artificially modified and controlled sites that are ephemeral may potentially be able to reduce or remove this threat.

Although there is no (known) reported minimum depth of a waterbody required for breeding success, given that the GGBF is a large and conspicuous species which is readily preyed upon and requires adequate cover/shelter (for both adult and tadpole phases), it is thought that the adequate minimum depth of a wetland should be at least 0.3 m deep and preferably a minimum of 0.5 m deep (during the main breeding period).

The proposed emergent aquatic vegetation species stated above, particularly the Tall Spikerush and Rushes, should be capable of growing well in these depths. Additionally, variable depths across the waterbody area may be ideal to assist in controlling where these species occur (i.e. deeper areas of water may be beneficial to limit the amount of cover provided by some emergent aquatic vegetation so that it does not completely smother a wetland with rank growth).

Periodicity and timing

It has been reported that characteristics of aquatic habitat, such as hydroperiod, can strongly influence frog community structure (Semlitsch et al. 1996). Consequently, having some control of the duration of inundation (or hydroperiod) is likely to be essential in establishing suitable sites for the longterm conservation of the species and its habitats

Based on the observed and reported breeding periods for the species in the Southern Tablelands region of NSW, the ideal period to implement hydrological controls to ensure wetlands are adequately inundated is from mid-late September when breeding could commence to early April when most tadpoles should have metamorphosed. However, it is possible that the waterbody need not be inundated for this entire period, and that a minimum period of 4 months may be adequate to allow for a breeding event to occur and for development of tadpoles to metamorphs. Obviously, the longer the water is available (without being permanent), the more opportunities for breeding events there are to occur which would increase the potential chances of successful recruitment. Ideally, the timing of the inundation of a wetland would occur with or just prior to a moderate rainfall event so that water was available at the time when initial breeding activity is likely to be triggered.

In addition to the ability to artificially inundate wetlands, it may also (or is likely to) be important to have the ability to drain or at least substantially lower water levels to assist in controlling predators as well as to control vegetation growth as described previously. This is not seen as a necessary early step in the site preparation but may need to be implemented at a later stage subject to monitoring of predators and vegetation cover values as mentioned elsewhere.

5.3.5 Potential future considerations to expand the distribution of the GGBF at MCHF

Once it has been established that frogs are breeding successfully (i.e. recruitment), consideration may/should then be given to expanding the distribution of the species within the MCHF. Initially, it is thought that most appropriate way to do this would be to allow for natural dispersal from the initial population if it is displaying recruitment. Although taking a precautionary principle, this should possibly only occur after a second consecutive year of successful recruitment at the site.

It will be important to consider opportunities to allow frogs to leave the initial site to colonise other areas. It is believed that the primary focus of this would be to provide opportunities to move directly from the site to the creek. This would enable frogs to seek refugia in times of drought or low water levels within the breeding/release, as well as providing a potential movement corridor to move through to colonise other sites. Consequently, the project plan will also need to identify and include information on the establishment, maintenance and/or improvement of connectivity between selected site(s) and the creek as well as other (nearby) potential sites. This should include the establishment of a well-defined corridor from the site to an appropriate section of the creek, that should ideally be fenced, and if appropriate, rehabilitated to establish appropriate terrestrial vegetation conditions/structure for GGBF (i.e. tussock forming grasses and sedges). Ideally, these corridors should be located along natural drainage gullies/swales so as to increase the likelihood of these areas being sufficiently moist to encourage dispersal movements.

Before establishing a connection from a site to the creek, the identified section of the creek should also be rehabilitated (if necessary) to ensure optimum conditions for the GGBF are provided. This would likely include the following:

- Removal of Blackberry along banks of pool
- Removal/thinning of large riparian trees (if present) to limit shading of pool
- Rehabilitate banks with suitable vegetation species/structure

The above matters should also ideally be addressed in a site management plan which should be included as a key component of the overall GGBF reintroduction project plan.

6 Potential release sites at MCHF

Based on the review of the habitat requirements for the species, although some reports suggest that the species may utilise some slow-flowing streams for breeding habitat, the general consensus appears to be that still ponds such as marshes, wetlands, swamps, lagoons and some farm dams are the preferred habitats for breeding. Additionally, as demonstrated in the literature review at Section 2, stream-based environments may not be suitable as release sites given the risks to the species associated with predation as well as risks to breeding success from stochastic events such as floods (e.g. Hazell *et al*. 2003) as well as the fact that these sites cannot be easily fenced to retain frogs within the site (the absence of which may result in high levels of dispersal which would reduce the number of potential breeding adults, and thus reduce the overall recruitments levels).

There is some evidence to suggest (from the Molonglo River population) that farm dams, particularly those located just above the floodplain system, are not usually selected by the species. This could be because of factors such as a lack of aquatic vegetation cover (as observed at many of the dams at the Molonglo River site), but it is also possible that other factors may be at play, particularly in relation to the chemical properties of the water and sediments, and how these may interrelate with the species ability to tolerate or persist in environments where the chytrid fungus is present. In this regard, the farm dams were often situated above the floodplain floor, and it is possible that they do not share the same chemical properties in the sediments. This theory however remains largely unproven although some studies have suggested possible links between species occurrence and background pollution; thought to be supressing the fungus in some way.

Given the above, it is believed for the purposes of this assessment that until more is known both about the site as well as relationships between chytrid infection of GGBF and surrounding chemical properties of the environment, that dams located above the floodplain system not be chosen for introduction sites. Over time, it is hoped that, should these sites be considered suitable, that the species would naturally disperse into these areas from a successfully established introduced population at other sites in the property.

In addition to the above, recommendations within the best practice guidelines as well as evidence from previous projects suggests that sites where the species is to be introduced should be fenced off to keep the released frogs in and to keep predators out (as previously described). This is unlikely to be practicably achievable along the creek, at least in the first instance, and also comes with the added risks of continual damage/failure of fencing during flood events.

Notwithstanding the above, it is believed that there may be some merit in undertaking limited releases of tadpoles (if there is sufficient stock available and surplus to the anticipated needs for releases at the targeted sites discussed below) within the creek. This is based on the observed conditions within certain sections of the creek that supported habitat features generally considered suitable for the species, and consequently no, or relatively little, active rehabilitation of these sites is considered necessary prior to a release being undertaken (of tadpoles only). This is obviously of some benefit as it would help to limit the overall financial costs and reduce the timeframes to implementation of the project (compared with releases at wetland sites that require active rehabilitation as discussed further below).

The potential creek sites for releases are identified as MCR11 and MCR18 which both received a High habitat assessment score, as well as potentially MCR08 (aka 'Pete's Pond') and MCR10 which both received a Moderate habitat assessment score (but at the upper end of the range), and maintain potential connectivity to the other non-creek release sites (i.e. MCW06) discussed further below.

It is believed that releases directly into the creek should be seen largely as an additional trial experiment to the main focus of the introductions at the identified candidate sites discussed further below. Ongoing monitoring of these releases should therefore be undertaken to determine the potential value in doing further releases at suitable sections of Mulloon Creek (if ongoing supplementation of the population is required beyond the initial release), as well as for consideration at other creeks/aquatic systems that may be considered for future reintroduction projects elsewhere.

Based on this assessment, in order to maximise the chances of success of the GGBF reintroduction project at MCHF, it is believed that early planning efforts should be targeted towards releases at suitable 'wetland' sites. Based on the review of the potential habitats available at MCHF and with consideration of the habitat requirements of the species, as well as what might be practicably achievable to implement, it is believed that the sites with the greatest potential to support a reintroduction of the species are sites MCW06, MCW16 and MCW17A, described further below.

It is acknowledged that these wetland sites will come with some associated cost implications, as none of these sites are considered suitable for release sites in their current form. Some moderate/substantial actions are required to rehabilitate these sites, particularly in relation to hydrology controls, as these sites are currently dry (or almost dry), and would appear to be dry under most circumstances, making them unsuitable as potential breeding sites in their current form. Additionally, the existing vegetation characteristics are also unsuitable and require some revegetation actions. Details of revegetation actions and hydrological controls likely to be required have been previously described in Section 5.3.4.

The re-establishment of these areas as wetlands with some interconnecting corridors of swampy meadow habitat would also assist in forming a more natural chain-of-ponds which can have multiple benefits for not only the GGBF and other frog species, but also in relation to the hydrology of the system and stream health in general (as described in Hazell et al. 2003). The potential corridor locations that could connect these sites (to the creek in the first instance) are shown in Figures C1 and C2 at Appendix C. Details of the suitable vegetation characteristics that should be aimed to be provided for via active revegetation are described in Section 5.3.4.2.

The key features of these wetland sites, including some early comments on actions required to improve the habitat conditions within these sites to support the GGBF are discussed in further detail below.

6.1.1 Site MCW06

A summary of the key features of site MCW06 that may make it a potentially suitable candidate release site for the GGBF, as well as actions likely to be required to improve the habitat for the species, include:

- The site is located in the floodplain (and therefore may provide better capacity for hydrological controls, and potentially may support suitable chemical properties of sediments and water that may be of benefit with respect to the Chytrid issue as previously described – this matter is still subject to further investigation).
- The site could be easily fenced.
- The site occurs as a series of smaller ponds which superficially look suitable for GGBF habitat. However, in their current condition, these ponds are possibly too shallow and may require deepening to hold more open standing water on a more regular basis. Consequently, some additional hydrological controls may be required (i.e. pumping water from the creek to inundate the wetland).
- The existing vegetation characteristics of the site appear to be moderately suitable. However, the current patch of rank Typha growth which dominates the site (combined with little open water) is possibly too dense for it to be ideal GGBF habitat. Consequently, there is likely to be a need to thin this vegetation. Additionally, the creation of sections of deeper water (as mentioned above) may help to create areas where the Typha will not grow to limit it becoming too dense over the entire wetland area, and to provide some areas of open water.
- The site has good potential connectivity to creek via the existing minor swale to MCR08 (Pete's pond) – although a fenced corridor to the creek may sever some connectivity for stock movements between paddocks on either side of the swale.

6.1.2 Site MCW16

A summary of the key features of site MCW16 that may make it a potentially suitable candidate release site for the GGBF, as well as actions likely to be required to improve the habitat for the species, include:

- The site is located in the floodplain (as suggested above, this may be important with respect to hydrological controls as well as potentially environmental buffering of the Chytrid fungus).
- The site is located very close to the creek with excellent future potential connectivity (with a distance of less than 50 m separating the closest part of the site to the creek).
- The close proximity to the creek, combined with the existing bank profiles (regraded to address previous erosion of this channel) mean that it would have good potential to establish appropriate hydrological controls within the wetland area.
- The site provides good future potential connectivity to other sites and has the most number of other sites (n=13) situated within 500 m of any of the sites in the study area.
- The site could be easily fenced as it occurs as a long narrow linear channel, generally parallel with and close to the creek (and potentially with minimal impact to stock movements in the property).
- As the site occurs as a long narrow linear channel, it provides some opportunity for the wetland area to be designed/created to occur as a series of ponds, potentially adding further habitat value for the GGBF. Further to this is the possible opportunity to undertake the habitat restoration in a series of stages along the length of the wetland channel.

- The site is currently subject to relatively unrestricted grazing and supports short pasture grasses and exotic forbs and is devoid of any significant vegetation (i.e. trees and shrubs) with only some minor blackberry. Given this, it may therefore present a good opportunity for effective site rehabilitation (as it is almost a blank canvas to start with from a vegetation perspective).

6.1.3 Site MCW17A

A summary of the key features of site MCW17B that may make it a potentially suitable candidate release site for the GGBF, as well as actions likely to be required to improve the habitat for the species, include:

- The site is located in the floodplain (as suggested for the above sites, this may be important with respect to hydrological controls as well as potentially environmental buffering of the Chytrid fungus).
- The site is located very close to the creek with excellent future potential connectivity (with a distance of less than 50 m separating the closest part of the site to the creek).
- The close proximity to the creek, combined with the existing bank profiles (regraded to address previous erosion of this channel) mean that it would have good potential to establish appropriate hydrological controls within the wetland area. The site is also relatively small and so this may make controls easier to implement/manage.
- The site provides good future potential connectivity to other sites (n=9) situated within 500 m.
- The could be easily fenced with existing site fencing already in place which could be used/adapted to be a frog fence. This fence already restricts stock access, and there would be no interruption to stock movements from any modification to the fencing this site. However, there is no existing fence between the site and the creek, and so a frog fence would need to be installed there.

6.1.4 Consideration of other sites

Consideration was given to the possible use of the step-diffusion ponds in the gully system immediately north of the manager's residence (i.e. MCD01 – MCD04) as a release site given the landscape improvement activities undertake in this area over the years. Although sections of the gully appear to support some suitable habitat for the species (i.e. a relatively wide and flat gully with extensive Poa and Juncus that frogs could forage/shelter within), the dams themselves are generally considered to be unsuitable (in their current condition) as potential breeding (or release) sites. The main reasons behind this conclusion are that:

- there is inadequate aquatic vegetation in any of these dams (although this could be rectified with targeted rehabilitation); and,
- sites such as these that are located above the floodplain floor may be unsuitable in relation to their chemical properties and potential environmental buffering requirements against the Chytrid fungus as previously discussed.

7 CONCLUSIONS AND SUMMARY

An assessment was undertaken at a number of aquatic sites at Mulloon Creek Home Farm to determine the potential suitability of these sites as habitat for the Green and Golden Bell Frog. The primary purpose of this assessment was to determine if any of these sites may provide suitable habitat conditions for the species based on its known ecology and consequently, could potentially be capable of supporting the species if reintroduced to the site.

The habitat assessment included a site-based survey of 36 sites, including 24 farm dams and four additional 'wetland' sites, as well as 8 sites along Mulloon Creek within the MCHF study area. The surveys collected information on landscape and physical features, such as connectivity, including proximity to the creek and other sites, as well as biological features, including primarily aspects of the aquatic and riparian vegetation at each site.

It is noted that this assessment was an initial assessment only and based primarily on the characteristics described above. Other aspects of the environment which may also play an important role in determining the overall suitability of the site as GGBF habitat were not included in this assessment. These include factors such as the levels of predators, as well as the status of the Chytrid fungus in the extant amphibian population at the site (and possibly associated with this is the role that the chemical properties of the water and sediments at these sites may have on the susceptibility of frogs to the fungus). Further investigation of these matters will be required and have been identified in this report.

The habitat assessment found that some sites within the study area support features that may be considered suitable as GGBF habitat. This included mainly sites along the northern half of the creek where it flows through the study area. These sites were moderate to large sections of slow flowing pools that were observed to provide good aquatic vegetation characteristics, as well as having (generally) good connectivity and proximity to other sites. Two sites in particular along the creek (MCR11 and MCR18) were observed to have high potential habitat values based on the habitat assessment scoring approach adopted in this study.

All except 2 of the 24 farm dams included in this study were assessed as having low potential as suitable GGBF. This was primarily on account of the lack of aquatic vegetation cover at these sites, although for most sites, the distance to the creek and number of other sites within 500 m were often also contributing factors in these sites receiving a low value score. The 2 dams that were scored as having moderate habitat potential were sites MCD04 and MCD19.

Site MCD04 is located at the bottom, or the last dam, in the step-diffusion system, just to the north of the manager's residence in the central part of the study area, and because of its closer proximity to the creek and other sites, fell into the moderate value scoring range. However, this site, like most other farm dams, lacked any suitable aquatic vegetation cover and consequently, is unlikely to provide suitable habitat for the species (in its current form). This site's location above the floodplain may also contribute to it being unsuitable for reasons previously discussed in relation to the chemical properties and the associated influence of the Chytrid fungus.

Site MCD19 is a small farm dam located very close to the creek near the confluence of one of the western-flowing drainage gullies and the creek, about midway between sites MCR18 and MCR20. This site was found to be mostly dry, but in contrast to most other farm dams, this site supported a dense patch of Typha covering the majority of the dam area. Given its proximity to the creek and other sites, this site received a moderate value score rating.

The 4 wetland sites were all assessed as having moderate potential as suitable GGBF habitat. This result appeared to be influenced primarily by the location of these sites (i.e. proximity to the creek and other sites), with 3 of the 4 sites dry at the time of the survey, and supporting almost no aquatic or riparian vegetation, whilst the fourth wetland site (MCW06) was observed to support very little water but was dominated by a thick patch of Typha.

Given the results of the habitat assessment, it is apparent that the MCHF supports some areas that may be regarded as potentially suitable for the GGBF (based only the physical and biological properties included in the assessment). However, currently all of the suitable sites are restricted to the creek. Based on these results, there would appear to be some merit in further investigating the opportunities for undertaking a reintroduction project for the species at MCHF.

Arguments do exist in relation to the merits of attempting reintroduction or translocation programs. These tend to focus on issues of maintaining genetic integrity of extant populations, but also around factors such human intervention to restore a species into an environment from where it had declined/disappeared. Debate arises particularly when the cause of the decline is not entirely clear, and there is no guarantee that any translocation of a species may not suffer the same fate that caused the initial decline of the species. In addition, previous attempts at translocation of this species have been time consuming, expensive and the overall success of the projects has yet to be demonstrated.

Notwithstanding the issues that exist around reintroduction and translocation programs (particularly for amphibians and the GGBF specifically), this assessment has prepared an initial strategy to assist with the future development of a GGBF reintroduction project at the MCHF property, as well as identified a number of sites within the study area that display certain features that may make them suitable as potential candidates for release sites.

In considering the actions required to develop a GGBF reintroduction project for the property, there are a number of early actions that are considered necessary to commence preparation of a reintroduction plan. These include actions that may be considered to be more a general administration and project management nature (such as the identification of a project team and clear set of objectives for the project), as well as further research requirements, particularly with respect to the existing status of Chytrid infection within the extant amphibian populations at the site, as well as investigations of the existing chemical properties of the sediments and waters within the study area that may play an important role in the susceptibility of the GGBF to Chytrid infection. This research is considered necessary at an early stage to determine whether there is merit in continuing with the project, or whether there is evidence to suggest the project would fail because of these existing environmental factors.

On the assumption that the further research supports the case for a GGBF reintroduction project to proceed at MCHF, this assessment identified a number of key factors that should be taken into consideration for the selection of suitable release sites. These included primarily landscape or physical features (such as proximity of sites to other sites and the creek), as these factors are likely to be harder to artificially manipulate. Furthermore, the evidence from various research projects on this species points to the importance of connectivity of habitats, including the establishment of a mosaic of interconnected habitats providing a range of habitat use functions including for breeding, foraging, shelter and dispersal uses.

Biological factors such as vegetation characteristics of the sites, and to some extent the presence of predators, can be artificially improved through targeted site rehabilitation (i.e. removal of weeds and subsequent revegetation with appropriate vegetation types) or predator removal programs. Consequently, these factors are not considered to be as critical in the selection of suitable release sites (on the assumption there is sufficient program funding to undertake these improvement actions).

Based on the key habitat considerations for selecting suitable candidate release sites, as well as the results of the habitat assessment completed in this study, some sites have been identified as being potentially suitable as release sites for reintroducing the GGBF to MCHF. In general, these sites were all located in the northern half of the study area, and all of the sites were located in the low-lying floodplain area. The reasons these general areas were selected is primarily because:

- there is generally greater connectivity (including proximity) of sites in the north, both to the creek as well as to other non-creek sites,
- the condition of the creek in the southern half of the property becomes generally unsuitable for the GGBF, with very high (>5 m in most places) and much steeper (vertical in many places) banks, and with very high levels of shade, as well as areas of very dense Blackberry along the banks
- there is a possibility that sites located in the floodplain floor may support some background chemical properties that could help to buffer against the Chytrid fungus (yet to be proven).

Given these broad factors, the sites identified by this assessment as having some potential as candidate release sites for the GGBF include some of the creek sites (MCR08, MCR10, MCR11 and MCR18), as well as three of the 'wetland' sites (MCW06, MCW16 and MCW17B). However, it is believed that the initial focus of the reintroduction project should be toward the wetland sites as opposed to the creek sites. This is because the creek sites could potentially support predators that may prey on released animals, as well as the fact that the creek is a long continuous system that would be difficult/impractical to fence. Fencing of the release site is considered important to keep predators out and the released animals restricted to within the release site (at least for the first stages of the overall project), to maximise the chance of subsequent recruitment. A number of projects have noted the high dispersal capability of this species, and it is believed likely that a portion of the released population would leave the site, leaving fewer breeding animals at the site during the breeding periods, thus reducing the chances of achieving sufficient recruitment within the released population.

Based on the above, it is recommended that sites MCW06, MCW16 and MCW17B be considered and investigated further as the potential (initial) release sites for the reintroduction of species to MCHF. In particular, these sites were chosen as they offer good/excellent potential connectivity to the creek and to some extent other non-creek sites, and these sites could each be (relatively easily) fenced. However, all of these sites would require some additional site preparation works (beyond simply fencing them off) to make them suitable as potential GGBF habitat.

These additional measures include primarily vegetation management (improvement) actions, such as weed removal and replacement planting with suitable vegetation types, including both aquatic and riparian vegetation species. However, all of these sites currently are either completely dry (i.e. MCW16 and MCW17B) or hold very little water, with no areas of open standing water (i.e. MCW06) and would appear to be like this under most (typical) circumstances. Consequently, it will be necessary to establish some hydrological controls within these waterbodies (i.e. the ability to artificially flood or drain the wetlands) to make them suitable for the species, particularly as potential breeding habitat. As these sites, particularly MCW16 and MCW17B are located in very close proximity to the creek (less than 50 m at the closest point for both sites), it is hoped that the establishment of these hydrological controls would not be prohibitively difficult or expensive.

The initial reintroduction strategy provided in this assessment also identified a number of ongoing management actions that would need to be considered and incorporated into the reintroduction project plan. These are mainly in relation to ongoing monitoring and associated management responses on factors including (but not necessarily limited to):

- The status of the population, including numbers and age-classes, evidence of breeding (i.e. amplexus, spawn or tadpoles) including the presence of Chytrid in the population,
- weeds and vegetation condition in general,
- the presence of potential predators, and,
- condition of site fencing.

The ongoing management responses to the monitoring will require further discussion and development, but may include subsequent releases of GGBF individuals to supplement the initial release population if observed numbers and/or recruitment levels are below the expected results, including potentially ceasing the project if the results indicate mortalities such as through Chytrid infection are unacceptably high, and that there would appear little chance of the project succeeding in its aim to establish a self-sustaining viable population of the species at MCHF. Other ongoing management measures in relation to vegetation condition, predators and fencing, would be in accordance with standard guidelines. These monitoring criteria and management responses should all be clearly determined and identified in the reintroduction project plan.

Once the GGBF reintroduction project plan has been finalised, it will require approval before the project can be commenced/implemented. This approval would include, at a minim, Animal Ethics Committee approval, but may also require additional state and federal government approvals. These will need to be identified during the course of the project development.

8 REFERENCES

Abu Bakar, A., Bower, D.S., Stockwell, M.P., Clulow, S., Clulow, J. and Mahony, M. (2016): Susceptibility to disease varies with ontogeny and immunocompetence in a threatened amphibian. *Oecologia*, Volume 181, Issue 4, pp 997–1009.

Barker J, Grigg GC, Tyler MJ, ed. (1995) *A field guide to Australian frogs*. Surrey, Beatty & Sons, Chipping Norton.

Berger, L., Speare, R. and Hyatt, A. 1999. *Chytrid fungi and amphibian declines: overview, implications and future directions*. Pp. 23-33 in *Declines and Disappearances of Australian Frogs*. Ed. by A. Campbell. Environment Australia, Canberra.

Brierley G.J. and Fryirs K. 1999. Tributary-trunk relations in a cut-and-fill landscape: a case study from Wolumla catchment, New South Wales, *Australia. Geomorphology* 28: 61–73. (cited in Hazell et al. 2003).

Burns, E.L. (2004). *Phylogeography, Population History and Conservation Genetics of the Endangered Green and Golden Bell Frog* (Litoria aurea). Ph.D. Thesis. School of Biological, Earth and Environmental Sciences, University of New South Wales (unpublished).

Campbell, L., Bower, D.S., Clulow, S., Stockwell, M., Clulow, J. and Mahony, M. (2019) Interaction between temperature and sublethal infection with the amphibian chytrid fungus impacts a susceptible frog species. *Scientific Reports*. 9, Article number: 83 (2019)

Christy, M. (2000). *The Ecology of the Green and Golden Bell Frog,* Litoria aurea. PhD Thesis, University of Sydney.

Cogger, H.G. (2000). *Reptiles and Amphibians of Australia - 6th edition*. Sydney, NSW: Reed New Holland.

Cooper, P.D. and Wallenius, T. (2017). *Invertebrate survey of Mulloon Creek 2015-2016. Final report to the Mulloon Institute*. Research School of Biology, the Australian National University, Canberra

Department of Environment and Conservation NSW (2005) Draft Recovery Plan for the Green and Golden BellFrog (*Litoria aurea*). DEC NSW, Hurstville, NSW.

Department of Environment and Climate Change NSW (2008) *Best practice guidelines Green and golden bell frog habitat* (DECC 2008). DECC NSW, Sydney NSW 1232.

Department of Sustainability Environment, Water Populations and Communities (SEWPac) (2013) *Commonwealth EPBC Act Policy Statement – Translocation of listed threatened species – assessment under chapter 4 of the EPBC Act* (SEWPaC, 2013). Commonwealth Government of Australia, Canberra, ACT.

Daly G (1995) Observations on the green and golden bell frog *Litoria aurea* (Anura: Hylidae). *Herpetofauna*, 25, 2-9.

Daly, G. and Senior, C. (2003). Surveys for and habitat assessment of the Green and Golden Bell Frog *Litoria aurea* on the far south coast of New South Wales. *Herpetofauna* 33: 86-102.

Daly, G., Johnson, P., Malolakis, G., Hyatt, A. and Pietsch, R (2008). Reintroduction of the Green and Golden Bell Frog *Litoria aurea* to Pambula on the south coast of New South Wales. *Australian Zoologist* volume 34 (3) pp 261-270.

Department of the Environment, Water, Heritage and the Arts (DEWHA) (2009). *Background Paper to EPBC Act Policy Statement 3.19 - Nationally Threatened Species and Ecological Communities. Significant Impact Guidelines for the vulnerable green and golden bell frog* (Litoria aurea). Canberra, ACT: DEWHA. Available from: http://www.environment.gov.au/epbc/publications/litoria-aurea.html.

EcoLogical Australia (ELA) (2016) *Green and Golden Bell Frog Plan of Management - Arncliffe*. Prepared for NSW Roads and Maritime Service.'

Eyles R.J. 1977b. Changes in drainage networks since 1820, Southern Tablelands, NSW. *Australian Geographer* 13: 377–386 (cited in Hazell et al. 2003).

Germano, J.M., Field, K.J., Griffiths, R.A., Clulow, S., Foster, J., Harding, G. and Swaisgood, R.R. (2015). Mitigation-driven translocations: are we moving wildlife in the right direction. *Frontiers in Ecology* 2015; 13(2): 100–105.

Gillespie, G.R. (1996) Distribution, habitat and conservation status of the Green and Golden Bell Frog *Litoria aurea* (Lesson, 1829) (Anura: Hylidae) in Victoria. *Australian Zoologist*. 30: 199-207

Goldingay, R.L. (1996) The Green and Golden Bell Frog *Litoria aurea* - from riches to ruins: conservation of a formerly common species. *Australian Zoologist*. 30: 248-256

Goldingay, R. and Lewis, B (1999) Development of a Conservation Strategy for the Green and Golden Bell frog *Litoria aurea* in the Illawarra Region of New South Wales. *Australian Zoologist* 31(2): 376-387

Greer, A. (1996). Why Green and Golden Bell Frogs *Litoria aurea* should not be translocated - a personal opinion. *Australian Zoologist* 30: 257-8.

Hamer, A. (1998) Aspects of the ecology of the Green and Golden Bell Frog (*Litoria aurea*) on Kooragang Island, New South Wales, Australia. Major Project Report, M. Env. Studies, University of Newcastle.

Hamer, A.J. (2002) Ecology of the endangered green and golden bell frog *Litoria aurea*: roles of habitat determinants, spatial dynamics, population demography and threatening processes. PhD Thesis, School of Environmental and Life Sciences. University of Newcastle, Newcastle.

Hamer, A.J., Lane, S.J. and Mahony, M.J. (2002). Management of freshwater wetlands for the endangered green and golden bell frog (*Litoria aurea*): roles of habitat determinants and space. *Biological Conservation*. 106(3): 413-424

Hazell, D., Osborne, W. and Lindenmayer, D. (2003) Impact of post-European stream change on frog habitat: southeastern Australia. *Biodiversity and Conservation* 12: 301–320, 2003.

Hoefer, A.M. (2017) *Project report Findings of frog surveys along Mulloon Creek Spring 2017*. Report prepared for the Mulloon Institute by ACT and Region Frogwatch, Ginninderra Catchment Group.

Mahony, M. (1996). The decline of the Green and Golden Bell Frog *Litoria aurea* viewed in the context of declines and disappearances of other Australian frogs. *Australian Zoologist*, 30: 237-247.

Mahony, M.J. (1999) A review of the declines and disappearances within the bell frog species group (*Litoria aurea* species group) in Australia. In: *Declines and Disappearances of Australia Frogs* Cambell A (ed) pp. 81-93. Environment Australia.

Mahony, M. (2001) *A proposal for rehabilitation of freshwater habitat to enhance the persistence of the endangered green and golden bell frog* (Litoria aurea*) on Kooragang Island*. Draft Report presented to the Kooragang Island Wetland Rehabilitation Project (Hunter Catchment Management Trust) pp1-7

Mahony, M.J., Hamer, A.J., Pickett, E.J., McKenzie, D.J., Stockwell, M.P., Garnham, J.I., Keely, C.C., Deboo, M.L., O'Meara, J., Pollard, C.J., Clulow, S., Leckert, F.L., Bower, D.S., and Clulow, J. (2013). Identifying Conservation and Research Priorities in the Face of Uncertainty: a Review of the Threatened Bell frog Complex in Eastern Australia. *Herpetological Conservation and Biology*. 8(3):519−538.

Morgan, L.A. and Buttemer, W.A. 1996. Predation by the non-native fish *Gambusia holbrooki* on small *Litoria aurea* and *Litoria dentata* tadpoles. *Australian Zoologist* 30: 143-149.

Osborne, W.S., M.J. Littlejohn & S.A. Thomson (1996). Former distribution and apparent disappearance of the *Litoria aurea* complex from the Southern Highlands of New South Wales and the Australian Capital Territory. *Australian Zoologist*. 30(2):190-98.

Osborne, W., S. Patmore, D. Hunter & R. Pietsch (2008). Preliminary observations on a highly-restricted tableland population of Green and Golden Bell Frogs on the Upper Molonglo River, NSW. *Australian Zoologist*. 34(3):271-284.

Patmore, S.R. (2001) Distribution, habitat use and movement patterns of the Green and Golden Bell Frog, *Litoria aurea* (Anura: Hylidae) on the upper Molonglo River, NSW B. App Sci. Hons. Thesis (unpublished). University of Canberra.

Pickett, E.J., M.P. Stockwell, D.S. Bower, C.J. Pollard, J.I. Garnham, J. Clulow & M.J. Mahony (2014). Six-year demographic study reveals threat of stochastic extinction for remnant populations of a threatened amphibian. *Australian Ecology*. 39:244-53.

Prosser I.P. and Winchester S.J. (1996). History and processes of gully initiation and development in eastern Australia. *Annals of Geomorphology* Suppl.-Bd. 105: 91–109. (cited in Hazell et al. 2003).

Pyke, G.H., Rowley, J., Shoulder, J. and White, A.W. (2008). Attempted Introduction of the endangered Green and Golden Bell Frog to Long Reef Golf Course: A step towards recovery? *Australian Zoologist* 34: 361-372.

Pyke, G.H. and White, A.W. (2001). A review of the biology of the green and golden bell frog *Litoria aurea*. *Australian Zoologist* 31: 563-598.

Pyke, G.H., White, A.W., Bishop, P.J. and Waldman, B. (2002). Habitat-use by the green and golden bell frog *Litoria aurea* in Australia and New Zealand. *Australian Zoologist* 32: 12-.31.

Romanowski, N. (1998). *Aquatic and Wetland Plants: A field guide for non-tropical Australia*. Published by University of New South Wales Press Ltd. Sydney NSW 2052.

Semlitsch R.D., Scott D.E. and Pechmann J.H.K. (1996). *Structure and dynamics of an amphibian community: evidence from a 16-year study of a natural pond*. In: Cody M.L. and Smallwood J.A. (eds), *Long-Term Studies of Vertebrate Communities*. Academic Press, San Diego, California, pp. 217–248.

Starrs, D. and M. Lintermans (2016) *Mulloon Creek baseline fish survey. Autumn 2016*. Final report to the Mulloon Institute. Institute for Applied Ecology, University of Canberra, Canberra.

Thomson, S.A., Littlejohn, M.J., Robinson, W.A. and Osborne, W.S. (1996) Taxonomy of the *Litoria aurea* complex: a re-evaluation of the Southern Tableland populations of the Australian Capital Territory and New South Wales. *Australian Zoologist*. 30: 158-169

White, A.W. and Pyke, G.H. (1996) Distribution and CNOservaitp Status of the Green and Golden Bell Frog Litoria aurea in NSW. Australian Zoologist, 30(2):177-189.

White, A.W. and Pyke, G.H. (2008) Frogs on the hop: the translocation of Green and Golden Bell Frogs *Litoria aurea* in Greater Sydney. *Australian Zoologist*. 34(3) 249-260.

APPENDIX A: COMPLETED SITE DATA SHEETS

APPENDIX B: HABITAT ASSESSMENT SCORING AT EACH SITE

SITE	DTC	DTNOW	NOW-500	ELEV	CONNECT	AVC	EmVeg	RipVeg	SHADE	COMB SCORE	HABITAT VALUE
MCD01	1	2	2	1	2	1	1	2	3	15	LOW
MCD02	2	3	2	2	2	1	1	2	3	18	LOW
MCD03	2	3	2	2	2	1	1	1	3	17	LOW
MCD04	2	3	2	3	2	1	1	2	3	19	MOD
MCD05	2	3	2	2	1	1	1	1	3	16	LOW
MCW06	3	3	1	3	2	2	2	3	3	22	MOD
MCD07	2	2	1	2	1	1	1	1	2	13	LOW
MCR08	3	2	1	3	3	3	2	3	2	22	MOD
MCR09	3	2	1	3	3	3	2	3	1	21	MOD
MCR10	3	3	1	3	3	3	2	3	2	23	MOD
MCR11	3	3	2	3	3	3	2	3	2	24	HIGH
MCD12	2	2	1	2	2	1	1	1	3	15	LOW
MCD13	1	2	1	1	1	1	1	1	2	11	LOW
MCD14	2	3	2	1	1	1	1	1	3	15	LOW
MCD15	2	3	2	2	2	1	1	1	3	17	LOW
MCW16	3	3	3	3	3	1	1	1	3	21	MOD
MCD17A	3	3	2	3	3	1	1	1	3	20	MOD
MCD17B	3	3	2	3	3	1	1	1	3	20	MOD
MCR18	3	3	3	3	3	2	2	3	3	25	HIGH
MCD19	3	3	2	3	2	2	2	1	3	21	MOD
MCR20	3	3	1	3	2	1	1	3	1	18	LOW
MCR21	3	2	1	3	2	2	2	3	2	20	MOD
MCD22	3	2	1	3	1	1	1	1	3	16	LOW
MCD23	1	3	1	2	1	1	1	1	3	14	LOW
MCD24	1	3	1	2	1	1	1	1	3	14	LOW

MCD25	1	2	1	1	1	1	1	1	3	12	LOW
MCD26	3	3	1	3	2	1	1	1	3	18	LOW
MCD27	2	3	1	2	2	1	1	1	3	16	LOW
MCD28	2	3	1	2	2	1	1	1	3	16	LOW
MCD29	2	3	1	2	2	1	1	3	3	18	LOW
MCD30	2	3	2	3	1	1	1	2	3	18	LOW
MCD31	2	2	1	2	1	1	1	3	3	16	LOW
MCD32	2	2	2	3	1	1	1	1	3	16	LOW
MCD33	1	2	1	2	1	1	1	1	3	13	LOW
MCD34	2	3	2	3	1	1	1	2	3	18	LOW
MCR35	3	1	1	3	1	1	1	3	1	15	LOW

APPENDIX C: HABITAT ASSESSMENT MAPPING OF THE STUDY AREA

APPENDIX D: SITE PHOTOS