Habitat Creation and Captive Breeding Plan - Green and Golden Bell Frog at Arncliffe

Arncliffe

Prepared for
Roads and Maritime Service

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Contents

List of figures

List of tables

Abbreviations

Abbreviation	Description
Bd	*Batrachochytrium dendrobatidis*
EIS	Environmental Impact Statement
ELA	Eco Logical Australia Pty Ltd
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
HCCBP	Habitat Creation and Captive Breeding Plan
ppt	Parts per trillion
Roads and Maritime	NSW Roads and Maritime Services
RTA	Roads and Traffic Authority
SMC	Sydney Motorway Corporation
TSC Act	*Threatened Species Conservation Act 1995*
UoN	The University of Newcastle
WCX M5 AT	WestConnex M5 Asset Trustee
1998 POM	Management Plan for the Green and Golden Bell Frogs (*Litoria aurea*) at Arncliffe (Dr Arthur White, 1998)

Executive summary

The proposed construction of the New M5 is likely to result in impacts on the Arncliffe population of the Green and Golden Bell Frog. The EIS for the project included provisions for the management of these impacts which included the creation of additional habitat and as an insurance against the possible loss of the population from the site, the establishment of a captive bred population with the intention to release the captive bred stock within the newly created habitat. These actions would provide for greater security of the species in the Arncliffe area.

This Habitat Creation and Captive Breeding Plan (HCCBP) should be read in conjunction with the overarching strategic Green and Golden Bell Frog Plan of Management (ELA 2017).

The local Arncliffe population has been monitored since 1999/2000. Data on the population estimates between 2002/03 and 2014/15 were presented in the EIS. Since then further survey has been undertaken and information about the 2015/16 monitoring period is provided here. Together this data indicates that the population was relatively stable between 2003/04 and 2013/14. During the last two survey seasons, there is evidence that the population has declined. This population requires ongoing management to prevent further decline.

This HCCBP outlines the actions required to establish new habitat and the management of that habitat to assist in the management of the frog population. Information about the management of the existing RTA frog ponds including the management of impacts arising from the construction of the New M5 can be found in the Green and Golden Bell Frog Plan of Management (ELA 2017). The RTA ponds are managed in accordance with the Management Plan for the Green and Golden Bell Frogs (*Litoria aurea*) at Arncliffe (Dr Arthur White, 1998).

This HCCBP also outlines the requirements for the establishment of a captive breeding program for the Arncliffe population. Previous plans, such as the Management Plan for the Green and Golden Bell Frog Key Population on the lower Cooks River (DECC 2008a), advocated the establishment of a captive breeding colony to act as an insurance against stochastic events. This HCCBP provides details on the process involved in establishing a captive breeding colony, key performance indicators and reporting requirements.

An initial draft of the HCCBP was peer reviewed by two external peer reviewers. This plan has been updated following comments from the Department of Planning and Environment (DP&E).

1 Introduction

Roads and Maritime Services (Roads and Maritime) has approval to construct and operate the New M5, which comprises a new, tolled multi-lane road link between the existing M5 East Motorway, east of King Georges Road, and St Peters. The project also includes an interchange at St Peters and connections to the existing road network. The project was declared to be State Significant Infrastructure (SSI) and approval was granted under Part 5.1 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). In addition to State approval, the project is a controlled action under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Construction activities associated with the project are expected to result in direct impacts to foraging habitat and indirect impacts to the habitat of *Litoria aurea* (Green and Golden Bell Frog) at Arncliffe. The impacts to the breeding ponds relate to indirect impacts from construction approximately 32 metres from the ponds. Direct impacts involve removal of around 7.82 hectares of foraging, sheltering and dispersal habitat on the adjacent Kogarah golf course. In addition, permanent road facilities are proposed on land owned by Roads and Maritime, adjacent to the existing purpose built breeding ponds

1.1 Purpose of Plan

The proposed works for the construction of the New M5 would result in some impacts to the habitat of the Green and Golden Bell Frog at Arncliffe. The EIS included provisions for the management of these impacts which included the creation of additional habitat and the establishment of a captive bred population. These actions would provide for greater security of this species in the Arncliffe area. This plan outlines the actions required to ensure that habitat created is suitable and that the captive breeding program meets the required standards.

This document provides the basis for an adaptive management approach to the management of captive breeding and habitat creation program. Over time, more data will become available on characteristics of the Arncliffe population and how the population is responding to the potential construction and operation impacts of the New M5. Where relevant this will be included in future revisions of the HCCBP.

This plan is informed by various management plans developed for the species and the site (**Figure 1**). This plan is to be implemented by Roads and Maritime. The Habitat Creation and Captive Breeding Program must be implemented and the Marsh Street habitat area established within 12 months of the commencement of construction, unless otherwise agreed by the Secretary. An extension of the submission date to 30 September 2017 was granted by the Secretary.

1.2 Structure of plan

This plan should be read in conjunction with the Green and Golden Bell Frog Plan of Management - Arncliffe (ELA 2017), which describes likely impacts, construction mitigation measures and actions to improve the habitat values of habitat areas on the Kogarah Golf Course, including the RTA ponds. It is noted that the RTA ponds are managed separately to the New M5 project in accordance with the 1998 POM. This plan is divided into two main sections to address the creation of new habitat and, the establishment of a captive breeding colony.

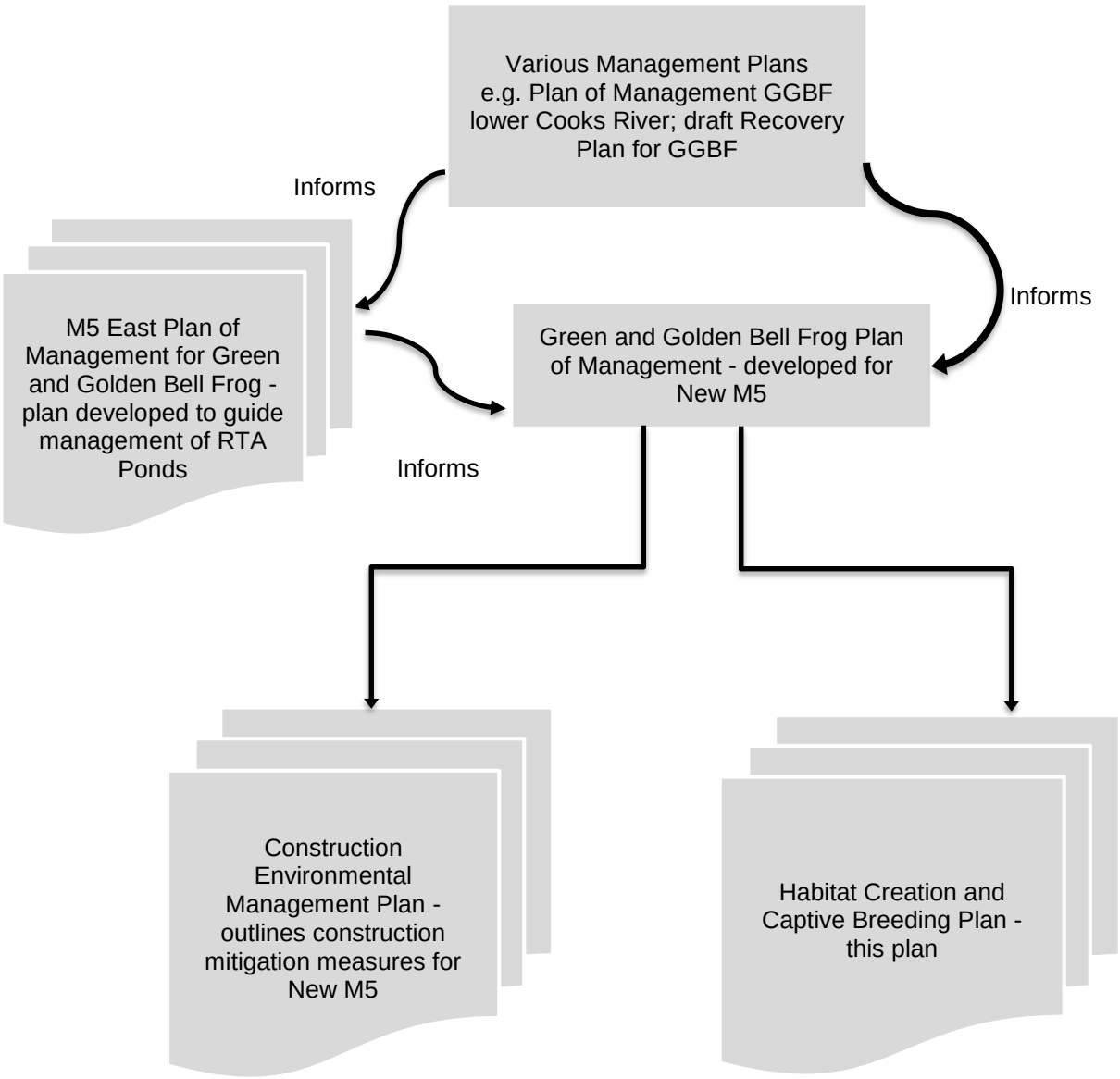

Figure 1: Relationship of this plan to other management plans

2 Habitat Creation Plan

2.1 Site description

A new compensatory habitat area for Green and Golden Bell Frogs has been proposed as a mitigation measure to minimise impacts on the frogs and forms the basis of Condition of Approval B15 for the Project. The Marsh Street habitat ponds will be constructed on a parcel of land to the east of the Marsh Street and West Botany Street intersection and south of the existing M5 motorway (the site) (**Figure 2**). The site is owned by NSW Roads and Maritime.

2.2 Objectives

Green and Golden Bell Frogs need various habitats for different aspects of their life cycle including foraging, breeding, sheltering, over-wintering and dispersal. They will also use different habitats or habitat components on a temporal or seasonal basis. The overall objective of the habitat creation and captive breeding plan is to provide with a high level of certainty that habitat created at Marsh Street provides greater security of the Green and Golden Bell Frog at Arncliffe by:

- providing enough detail to allow construction of new habitat at Marsh Street
- outlining the management actions that should take place in the new habitat
- outlining key performance indicators for the management of the ponds.
- monitoring the population to ascertain the effectiveness of the new habitat

2.3 Overall design

The design of the Marsh Street habitat area and ponds consists of:

- three Green and Golden Bell Frog breeding ponds, located along the western boundary of the site consisting of:
  - one pond of around 1.5 metres in depth
  - two ponds of around 0.8 metres in depth.
- water supply systems, including a header tank (with capacity of around 200 kilolitres), pipes and a drainage swale to fill and drain the ponds
- a serviced work shed, around 10 square metres in size, to support maintenance and monitoring activities, and to store equipment
- perimeter fencing, designed to enable frog passage along the north-eastern and eastern perimeter of the site and to limit predators and un-authorised access
- permanent vehicle access off Eve Street.

Figure 2 provides a sketch of the proposed design. Final design of the ponds will be completed to meet the requirements of the HCCBP.

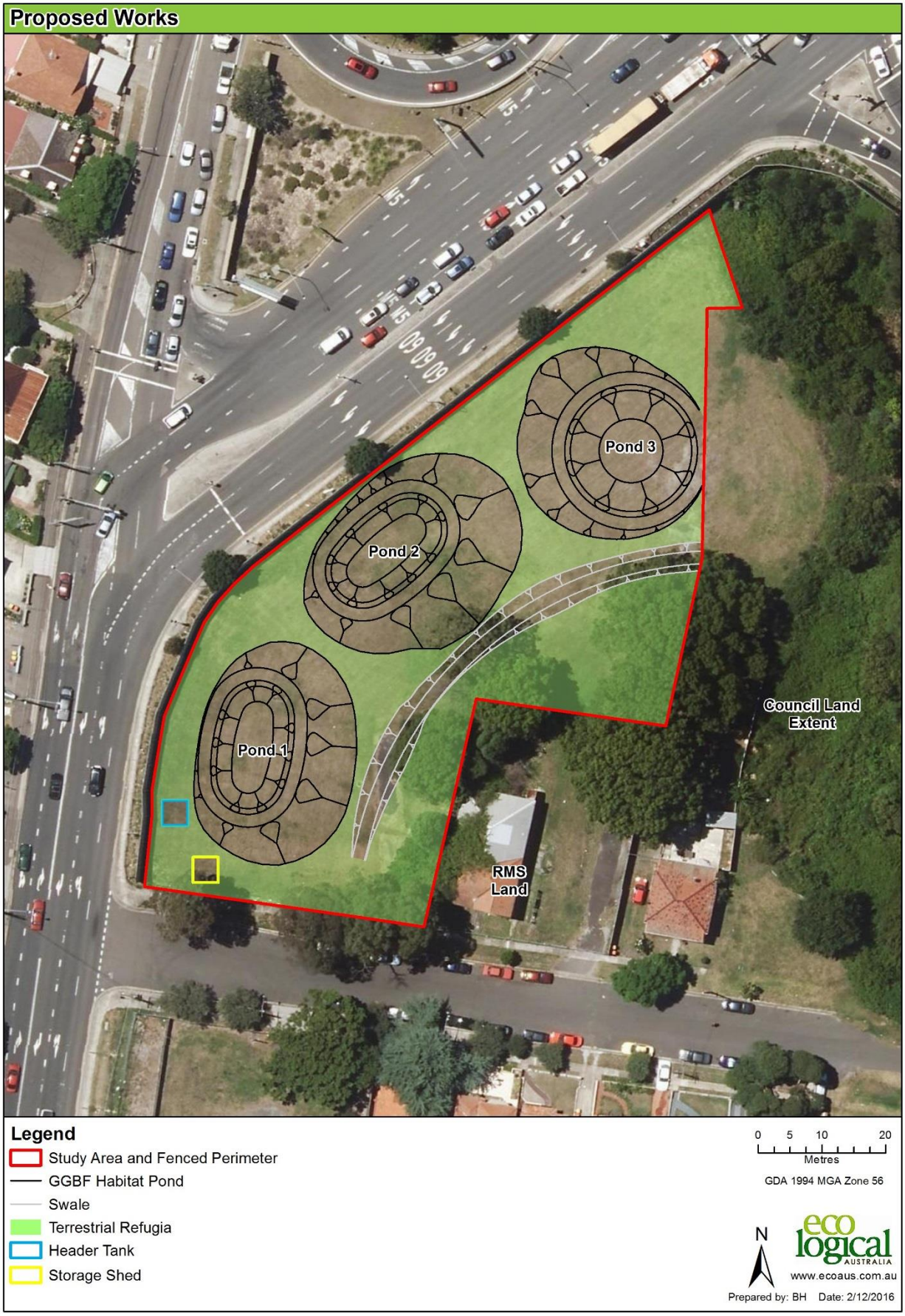

Figure 2: Proposed design for Marsh Street habitat area

2.4 Site preparation

The development of the site involves several key steps. While this document does not provide detailed design specifications, it outlines the requirements to establish habitat at Marsh Street.

2.4.1 Establish perimeter fencing

Fencing of site would need to be installed to minimise predation by foxes. Foxes have been sighted at the RTA ponds and may be responsible for a decline in the number of frogs present as a result of predation. By establishing a fence, occurrence of predators can be monitored, response to incursions conducted and the fence maintained.

Boundary fencing is required to be 1.8 metres high urban controlled access road boundary fencing (Roads and Maritime Model Drawing MD.R201.B02.A) with modifications for frog-exclusion. Part of the perimeter fencing where it adjoins Eve Street, Marsh Street and West Botany Street should be frog proof and constructed with design features adequate to prevent frog movement (Figure 3). This is to prevent frogs from moving into hostile environments. Appropriate measures will also installed on the fence to minimise the risk of an incursion of Striped Marsh Frog into the Marsh Street ponds.

The fence barrier is to be incorporate shade cloth or similar material. It is to be supported by wire to maintain a vertical surface at least 80 centimetres above ground level. At least 15 centimetres of the bottom edge is to be buried into the soil. A perpendicular section of wire fence is to be installed at the ground surface for at least one metre to prevent foxes digging under the fence and accessing the ponds.

A horizontal top section, 20 centimetres wide, is to be included on both sides (also wire supported). A solid plastic layer at the base must also be added to at least 0.5 metres high to prevent rats from chewing through the shade cloth. The perimeter fence on the eastern boundary of the site would exclude predators (e.g. fox, cat and dogs) but would allow frog access and dispersal.

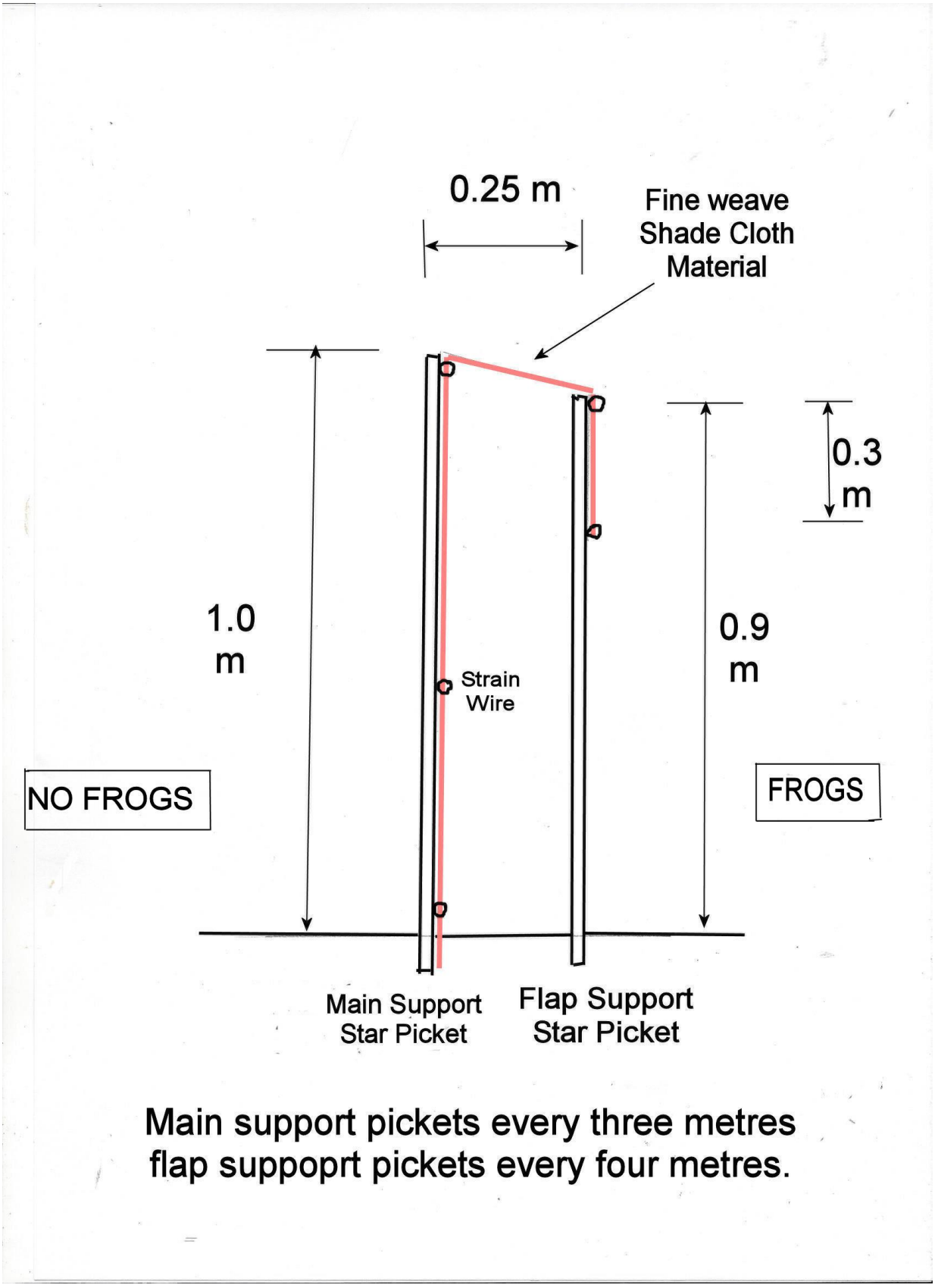

Figure 3: design for frog exclusion fencing (after A White 2016)

2.4.2 Removal of unwanted vegetation

The assessment of the site as part of the preferred infrastructure report identified there were some exotic and non-indigenous native trees present. The remainder of the site is exotic grassland. The existing trees need to be removed for construction and also to minimise shading of the ponds. When ponds are shaded for long periods, frogs tend to not favour these areas. Plants with foliage that is thought to be toxic to Green and Golden Bell Frog will be removed in consultation with the project herpetologist. The vegetation removed should be disposed of appropriately to a facility licenced to accept the waste.. If there are some plants (non-toxic) that could be used to create over wintering habitat, they should be piled neatly for use during landscaping of the new pond habitat.

2.4.3 Earthworks to reform the land contours

Three ponds will be constructed, as well as a swale to allow for shelter and dispersal. The site is generally flat towards West Botany Street, but gently slopes away towards the M5 East Motorway. A correction in this land form would be required to enable the creation of the ponds and the swale.

The three ponds should not be at the same level. The ponds need to be stepped in height, with pond one the highest and pond three the lowest. Reformation of the land would need to be done to allow for this design.

The three ponds shall be of the following dimensions:

- ponds one and two around 20 metres at the longest axes and about 0.8 metres in depth, with the lowest points around five metres in length (**Figure 4**)
- pond three around 25 metres at the longest axis and about 1.5 metres in depth, with the lowest point around 10 metres in length (**Figure 5**).

The sides of ponds one and two would slope up to the ground level.

Pond three shall contain submerged steps on the pond sides to allow for potted aquatic plants to be put in place. Pond three would be roughly circular. The pond profile will be stepped - the steps (or ledges) will be formed of rock or gabion and these ledges will support the pots that will contain the emergent plants. There will be no raised bund or lip around the pond.

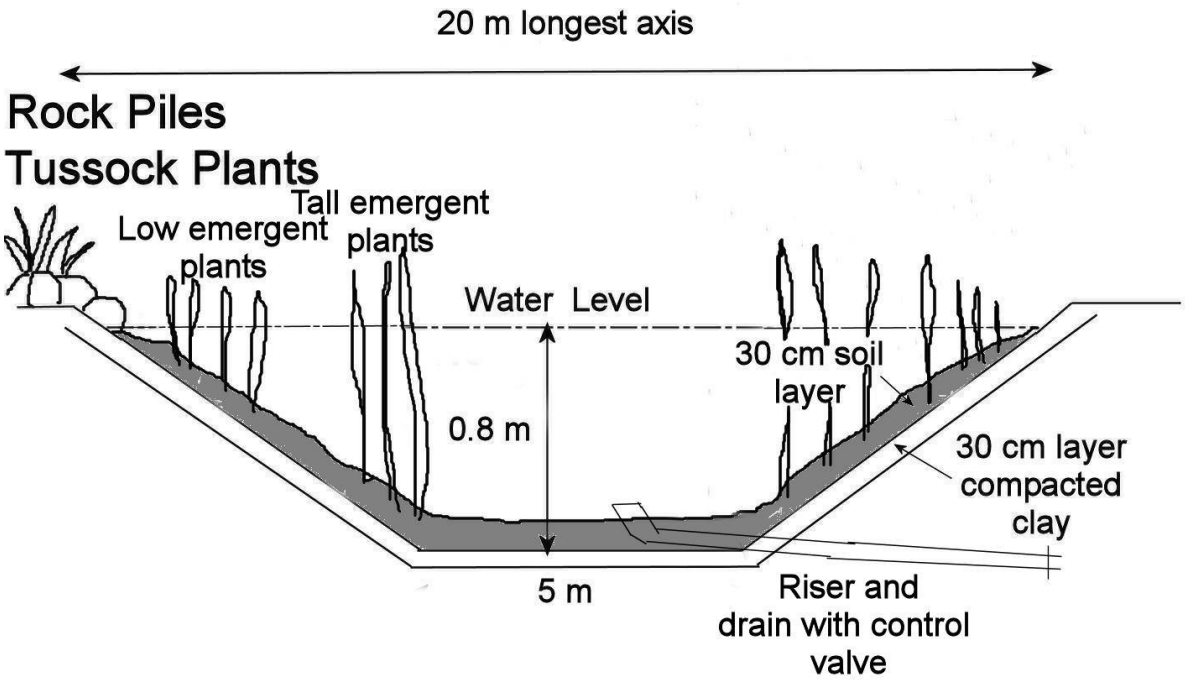

Figure 4: Concept design for ponds one and two

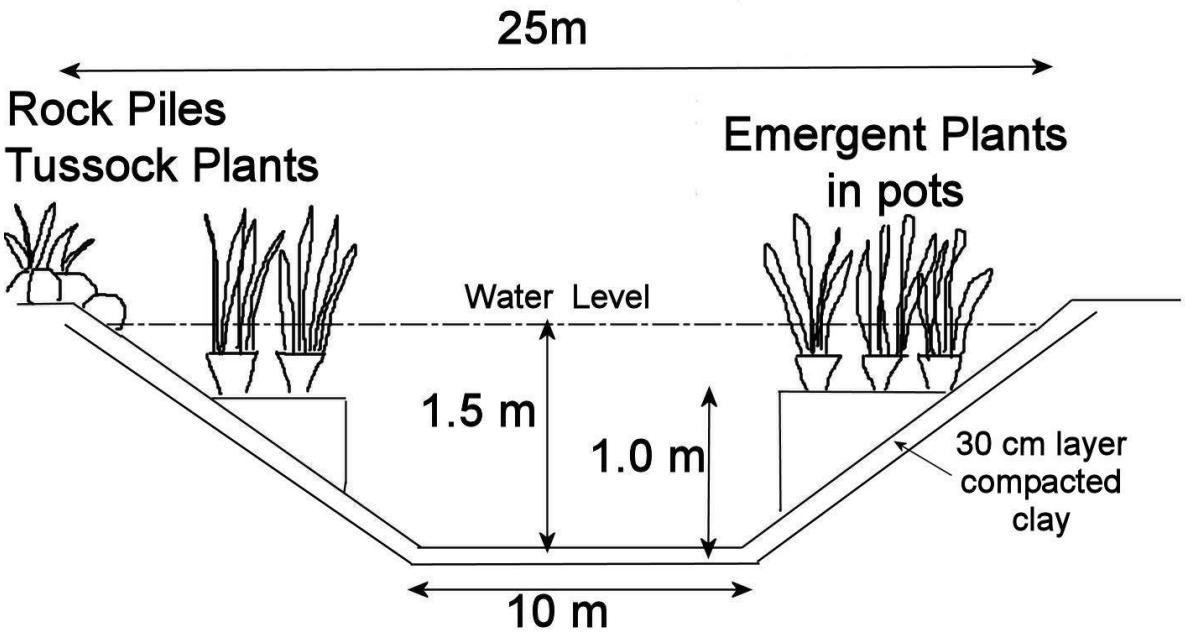

Figure 5: Concept design for pond three

A rock platform with fixing for small outboard motor is to be provided in each pond, extending into open water for pond mixing.

2.4.4 Creation of swale

To the south and east of the three frog ponds, a drainage and habitat swale will be created. This swale will be capable of receiving water from two of the three ponds via a piped drainage outlet. The swale needs to be of a suitable size to allow for ponds to be periodically drained. The swale will need to be appropriately vegetated to prevent erosion of the ground surface during pond draining or heavy rainfall. The swale will be planted with species suitable for shelter and foraging habitat (**Table 3**).

2.4.5 Water supply

The relatively small size of the site and the dominance of the site by frog habitat means that an onsite detention basin cannot be incorporated into the current design.

A new potable water supply therefore needs to be established. The reference design indicates that this would be from an existing supply on Eve Street, close to the West Botany Street intersection. A header tank of 200 kilolitres is required to allow pressure to fill the three ponds. Water needs to be aged for at least 48 hours in the storage tank so that chlorine can be lost from the water prior to use in ponds. Chlorine is toxic to Green and Golden Bell frog tadpoles. Other physical parameters including pH, electrical conductivity and dissolved solids will be monitored prior to use.

The water supply will also provide for reticulated water supply to fill ponds as well as drainage pipes so that ponds can be emptied if and when required. Pond three will need to have its own water supply but no drain (because the pond will be set so low into the ground it cannot be gravity drained). Any drainage works required for this pond (e.g. should it become contaminated with fish or unwanted pollutants) will need to be carried out by an external pump.

2.4.6 Creation of terrestrial refugia

Terrestrial refugia would be established in close proximity to the ponds. Green and Golden Bell frogs are found in a considerable variety of wetlands (see DECC 2008b, Pyke et al. 2002, Heard et al. 2006, Heard et al. 2012, Mahony et al. 2013).

Therefore the structural components of the Marsh Street ponds are designed to include features that are common to many wetlands where bell frogs occur. The two nearby created RTA ponds have supported a Green and Golden Bell Frog population for over a decade. The structure of the ponds are based on the design of these ponds.

2.4.7 Line ponds

The three ponds will be lined with compacted clay to a depth of about 0.3 metres. The compacted clay provides a relatively waterproof barrier to eliminate or minimise leaks from the ponds. Following the clay lining, an additional layer of topsoil to a depth of 0.3 metres would be placed in ponds one and two to provide a substrate for planting aquatic vegetation.

2.4.8 Provide storage shed

A small storage shed with water, power and sewer connections will be constructed with vehicle access off Eve Street. This will allow for the safe storage of maintenance gear.

2.4.9 Planting ponds

Emergent aquatic plants will be planted into ponds one and two directly into the topsoil layer lining the sides of the ponds. Plants will be planted into pots and placed on the submerged steps for pond three.

The plants should follow those recommended in the best practice guidelines for Green and Golden Bell Frog habitat (DECC 2008c). Aquatic plants suggested in the guideline include species listed below in Table 1.

Table 2: List of recommended aquatic plants

Species	Local	Species	Local
Alisma plantago aquatica	✓	*Isolepis nodosa*	✓
Amphibromus neesii	×	*Juncus kraussii* subsp. *australiensis*	✓
Baumea articulata	✓	*Juncus usitatus*	✓
Baumea rubiginosa	✓	*Lepironia articulata*	✓
Bolboschoenus caldwellii	✓	*Philydrum lanuginosum*	✓
Bolboschoenus fluviatilis	✓	*Phragmites australis*	✓
Carex appressa	✓	*Baloskion tetraphyllum* subsp. *meiostachyum*	✓
Carex fascicularis	✓	*Schoenoplectus mucronatus*	✓
Cotula coronopifolia	✓	*Schoenoplectus validus*	✓
Crinum pedunculatum	✓	*Suaeda australis*	✓
Eleocharis acuta	✓	*Triglochin procerum*	✓
Eleocharis sphacelata	✓	*Triglochin striata*	✓
Gahnia sieberiana	✓		

While the plants listed above are recommended, the likely plants to be used at this site include *Baumea rubiginosa*, *Bolboschoenus caldwellii*, *Eleocharis sphacelata*, *Philydrum lanuginosum*, *Schoenoplectus validus* and *Triglochin procerum*. These plants are generally available in the quantities likely to be required. The planting should be diverse and not a monoculture of one species. Optimal planting densities are not known and not specified in any of the guideline documents (DECC 2008a, 2008c).

2.4.10 Planting pond banks

The edge of the ponds and pond banks need to be vegetated. Plants should be locally indigenous and suited to the creation of sheltering and foraging habitat for the frogs. Species have been suggested in the best practice guideline (DECC 2008c). The species include those listed below (**Table 3**).

Table 3: Tussock plants to be used around pond banks

Species	Species
Bothriochloa macra	*Microlaena stipoides*
Chloris truncata	*Paspalum distichum*
Dianella caerulea	*Pennisetum alopecuroides*
Dianella revoluta	*Poa labillardieri*
Eragrostis elongata	*Poa sieberiana*
Imperata cylindrica	*Rytidosperma caespitosum*
Lomandra longifolia	*Themeda triandra*

Local seed must be sought and horticultural varieties avoided. Some local Councils may have native plant nurseries from which plants could be sourced. Alternatively, a specialist native plant nursery should be engaged to provide the appropriate number of plants. Plant species and planting densities will be determined by the selected bush regenerator/landscaper, in consultation with, the supervising site ecologist and site construction manager.

To facilitate the establishment of plants and to increase planting success, the following techniques and guidelines are preferred methods:

- planting can occur at any time of year, although optimal times are early spring and early autumn
- planting should commence as soon as practicable after completion of the ponds
- when first planted, plants should be drench watered rather than lightly watered to encourage a deep root system
- if very dry conditions are experienced immediately after planting, then the watering of recently planted seedlings should be undertaken every week up until six weeks post planting
- *Jutemate*© and "tree" guards should be considered for use around plantings if they are likely to improve plant growth, minimise mortality and inhibit weeds
- plantings will require regular maintenance such as watering, protection from damage and replacement of dead seedlings.

The planting of weed species listed on the Weeds Australia NSW weeds list (www.weeds.org.au) is prohibited for the life of the project.

No exotic perennial grasses listed on the Final Determination of the NSW Scientific Committee for the key threatening process *Invasion of native plant communities by exotic perennial grasses,* are allowed to be introduced, planted, sown or laid on the site.

There is no certification process in place in Australia to guarantee landscaping materials are disease free. All materials and plants would be sourced from suppliers that adhere to the relevant Australian and industry standard for planting and landscaping materials (Australian Standard AS 4419 (2003) soils for landscaping and garden use and Australian Standard 4454 (2012) composts, soil conditioners and mulches).

2.4.11 Planting around ponds

Planting between the ponds would include similar measures to the planting of the banks. These plantings would provide for dispersal, shelter and foraging habitat. Suitable ground cover plantings will be provided using native species such as those listed in **Section 2.4.10**. Tussock vegetation should be prolifically planted along boundaries to the site and in the areas between ponds and along overflow channels. While best practice guidelines nominate appropriate plant species (DEC 2008c), no density information is available. The plantings will be diverse.

All measures listed in **Section 2.4.10** will be used to maximise success of planting as well as minimising weeds.

2.4.12Establish supplementary feeder sites

Supplementary feeding sites should be considered early in the creation of this habitat. This is because the diversity of grasses is low and subsequently the diversity of invertebrates is also likely to be low. Although relatively little has been published about the dietary preferences of this species, prey items include a variety of insects as well as other frogs. The establishment of composting bins will encourage

proliferation of insects. These prey items would colonise across the site encouraging frogs to disperse through the site.

The supplementary feeding sites will be employed to ensure that frogs inside the Marsh Street ponds have adequate food. Additional insect food will be provided in two ways:

- Two ground-level, timber-framed compost bins will be located close to the frog ponds. The bins will have a loose sheet of plastic secured across the top to prevent birds from removing the vegetable matter. The vegetable matter is to be replenished with fresh vegetable wastes each week and this will serve to attract ground insects to the bins. Bins of this type have been used successfully to assist the establishment and maintenance of Green and Golden Bell frogs at Woonona.
- Commercially bred crickets will be purchased as required and released in the compost bins. It is expected that the crickets will disperse away from the bins at night and many will be preyed upon by the frogs. The decision to add crickets to the enclosure will be based on any apparent weight changes in the frogs in the frog ponds.

2.4.13 Pond monitoring

Ponds should be tested for leakages and repaired to ensure levels are able to be maintained. Prior to introduction of any Green and Golden Bell Frogs, the following parameters should be tested:

- water temperature
- turbidity
- dissolved oxygen
- salinity not greater than 5 parts per trillion (ppt)
- pH
- electrical conductivity
- that ponds are predator free (i.e. absence of *Gambusia holbrooki* (Plague Minnow)).

2.5 Habitat features

2.5.1 Breeding

Ponds one and two are designed to provide for suitable breeding habitat. These ponds will be shallow enough to receive adequate solar radiation and thus warming of the water which is assumed to encourage breeding. Emergent vegetation in ponds would need to be managed to limit shading (see Section 2.6.1 for a description of the management requirements).

The size of the ponds will be greater than 40 m^2, which have been shown to be preferred by male calling bell frogs (Bower et al. 2013) and may improve breeding success. The ability to seasonally dry and flood the ponds is another important feature of this habitat as this mimics seasonal variations in natural wetlands and may also be preferred by bell frogs (Bower et al. 2013).

2.5.2 Feeding

The planted out banks and spaces in between the ponds would provide feeding habitat suitable for the frogs. In addition to these planted areas, the supplementary feeder sites would also provide prey items. Maintenance of high quality feeding habitat would be important to encourage population increases for this species.

2.5.3 Sheltering

The pond banks, aquatic vegetation, boulder field, swale and tussocky areas in between the ponds would provide sheltering habitat for adults. Rock piles and some of the emergent vegetation would also

provide for basking habitat for the adult frogs, while aquatic vegetation would provide sheltering habitat for tadpoles.

2.5.4 Dispersal

One of the challenges for this site would be to provide dispersal habitat that could eventually encourage movement between the RTA ponds and this site. The current design does not achieve this but could be considered in the future. Green and Golden Bell frogs are a highly dispersive species, particularly as a juvenile and long term reproductive success relies on accessibility to habitat (see Hamer 2017). Ongoing monitoring of habitat areas within the RTA and Marsh Street ponds and Kogarah Golf Course will provide opportunity to review frog dispersal from habitat areas.

There are records of frogs from the spoon drain that runs along Eve Street, but it is not known what the likelihood would be of frogs using this area currently. There are few refugia along this route (via Eve St and the cycleway) to the RTA ponds and dispersing frogs would be exposed to predation and potentially vehicle strike.

The underpass that was constructed between the RTA ponds and the Marsh Street wetlands is not used by the Green and Golden Bell Frog (DECC 2008a). Based on a large survey and sampling at the site, there is no evidence or observations of Green and Golden Bell Frogs using this underpass. The reasons for this are not known as this species is known to be able to disperse distances longer than the underpass length (Hamer et al. 2008, Wassens et al. 2008) and have been reported to use culverts.

Movement and mortality of Green and Golden Bell frogs within the Eve Street cycleway will be monitored during population monitoring of the Marsh Street ponds. If monitoring indicates that frogs are using the Eve Street cycleway for connectivity, the requirement for a frog underpass within the cycleway will be reviewed in consultation with DP&E, OEH and relevant frog specialists.

2.5.5 Overwintering

Translocations of Green and Golden Bell Frogs to other areas in Sydney have failed because of the lack of suitable over-winter habitat (White and Pyke 2015). While the provision of boulder fields in the RTA ponds could be considered as over wintering habitat, no frogs have been found using these fields for this purpose. The need for a boulder field will be confirmed with frog specialists prior to installation.

A recent study into the types of over wintering habitat that may be used found that vegetated mounds may provide this habitat type (White and Pyke 2015). The study, which was conducted at Arncliffe and Woonona, found that frogs used both covered and uncovered vegetation mounds, however only one frog was ever encountered in a torpid state, while the remaining frogs using the mounds were still active.

While the relationship between the different designs tested is not well understood, the provision of this habitat type is considered to be vital to ensure frogs are able to seek refuge during the colder months. In addition to the habitat provision, control of predators such as rats must also be undertaken. This is because rats are known predators of bell frogs and may gravitate towards this habitat feature in search of prey.

From the scant evidence available, the type and use of overwinter habitat remains poorly known and therefore no single design is preferred. A range of options must therefore be provided and the use of each option evaluated independently.

2.6 Management of habitat features

Following completion of construction, Roads and Maritime will undertake the management and monitoring of the habitat features at Marsh Street. The monitoring of the habitat features must be consistent with the approved Green and Golden Bell Frog Plan of Management (ELA 2017).

2.6.1 Breeding

The site will be intensively managed and monitored in perpetuity. Ponds will be drained or flooded as required to replicate wetting and drying cycles in natural wetlands. This is thought to encourage Green and Golden Bell Frog colonisation into the ponds. Draining of the ponds is also observed at the RTA ponds to be an effective method to manage Plague Minnow which predate tadpoles. Ponds one and two would be periodically drained and flooded as part of the management of these ponds in response to observations of Plague Minnow. While there is not enough space or number of ponds to provide for testing of the effectiveness of this approach at this site, it has been known to work well in controlling Plague Minnow at the RTA Ponds.

Frog ponds require at least some open water and limited shading. The Sydney Olympic Park Authority and the best practice guidelines (DECC 2008c) recommended a maximum of 80 percent vegetation cover in the ponds. Experience from the RTA ponds at Arncliffe also show that managing plant growth by reducing cover in the breeding ponds is important.

Fences are to be maintained to exclude vertebrate mammal predators such as foxes and cats. Where possible, striped marsh frogs will also be excluded from the Marsh Street ponds. The frog exclusion fencing would also need to be maintained to ensure that the fence retains integrity.

Presence of predatory fish will be monitored and if present, the ponds should be drained to kill these fish.

Annual or bi-annual salt flushing would be required to minimise the prevalence of chytrid. Salt flushing has worked well at the RTA ponds. Exposure at varying salt concentrations was found to limit growth and infective capacity of chytrid in an experiment on *Litoria peronii* (Stockwell et al. 2012). However caution should be applied when salt loading into ponds is proposed because the threshold in *Litoria peronii* was found to be close to the concentrations required to limit chytrid growth and infection (Stockwell et al. 2012). That study found that exposure to salt concentrations of 5 parts per trillion (ppt) and chytrid infection had a cumulative effect on that species. Salt flushing should therefore not exceed 5 ppt. Despite this, the experimental proof that chytrid can be managed in natural settings remains elusive.

2.6.2 Landscaping and weed treatment

An appropriately qualified bush regenerator (at least Cert III in Conservation and Land Management) will be engaged for planting of the landscaped habitat area and for weed control activities. Weed control is to focus on controlling adverse impacts to constructed frog habitats. Weed control is to be undertaken as required, or on at least an annual basis. Weed monitoring would be undertaken on a bi-annual basis with other site monitoring.

A diversity of plants will be retained as more diverse plantings are likely to result in greater invertebrate diversity. Plantings will not be dominated by one species only. The areas would be managed to ensure weeds do not invade planted areas.

Weed treatment methods are to be low impact, manual and as necessary with minimal herbicide application. No widespread spraying of herbicides is to occur in the created habitat area. Herbicide application should be limited to cut and paint techniques. If any hand spraying proves

necessary/essential the type of herbicide used e.g. glyphosate, a sensitive formulation with a low toxicity surfactant should be selected, e.g. Round-Up Biactive®. However the addition of other surfactants to the formulation, as is often practised to improve herbicide effectiveness, must be avoided (DEC 2005). Hand spraying is only to occur in the non-active period for the frogs (i.e. cooler winter months) only after a pre clearing survey is conducted by the project ecologist.

Supplementary feeding areas should be checked to ensure that rodents or other pests are eradicated and that the compost is still providing frog prey items.

2.6.3 Overwintering

This habitat type should be monitored to ensure that it remains intact pre- and during the cooler months. The vegetation mounds should be visually inspected to ensure they have not collapsed. If the mounds are to be covered, the covers should provide adequate coverage over the mound frames. Covers used in White and Pyke (2015) were black plastic. A supply of this will be retained in the storage shed for use when and if covers fail. Failed covers must be replaced on the same day as failure is detected. Experimental and published evidence of over-wintering habitat use for Green and Golden Bell frogs remains limited.

3 Captive breeding plan

3.1 Background

As part of the original M5 East project opened in 2001, Roads and Maritime provided breeding ponds for the Green and Golden Bell Frog on Roads and Maritime owned land occupied by Kogarah Golf Club in Arncliffe.

The RTA ponds are located adjacent to the construction compound for the New M5 at Arncliffe. The RTA ponds are located to the north-east of the proposed Marsh Street frog habitat area.

3.2 Monitoring frog activity

Formal monitoring of the frogs in the area started in November 2000.

Monitoring was initially confined to the remaining areas of the Marsh Street wetland and Eve Street wetlands, however, with the construction of the two frog ponds at Arncliffe and the partial loss of the Marsh Street wetland, monitoring focussed almost entirely on the RTA ponds, the Kogarah Golf Course and the remaining portion of the Marsh Street wetland. The new frog habitats are known as the RTA ponds.

Monitoring has been ongoing with most survey work being carried out during the warmer months of the year (from August to May).

3.3 Early results

Surveys carried out over the summers of 1999-2000 and 2000/01 showed a progressive increase in the number of adult Green and Golden Bell Frogs found in the two frog ponds at Arncliffe and a decrease in the number of frogs in the Marsh Street wetlands.

A graph showing the results of the monitoring effort between 2002/03 and 2014/15 is shown below (**Figure 6**). This graph demonstrates presumed recent declines in the size of the population. While no specific study of the reasons for decline has been undertaken, Dr Arthur White believes this could be due to a range of factors including:

- excessive plant growth overshadowing of the existing frog ponds
- more extensive mowing of grassed areas on the Kogarah Golf Course increasing the risk of predation to frogs foraging on the golf course.

Roads and Maritime (M5 East asset team) undertook works within the RTA ponds over summer 2015/16 which removed the excessive plant growth in the existing frog ponds. Subsequent maintenance works in September 2017 have also been undertaken to address actions raised as part of the six monthly monitoring program for the ponds.

Figure 6: Maximum known number of adults between 2002/03 and 2014/15 at the RTA ponds (White unpubl. data)

The surveys have estimated the maximum known number of adults based on the Petersen-Lincoln index. Note that this estimate for 2013/14 could not be made due to the low numbers of frogs captured on the two successive nights surveyed in February 2014. The 'zero' does not mean there were no frogs present; it was that the estimate could not be reliably performed. No errors or confidence limits were calculated for any of these data.

Sex ratios are important to understand in populations of Green and Golden Bell Frog. This is because this species relies on a fast growth rates and rapid maturation to maintain the population (Pickett et al. 2014). These lifecycle attributes increase the importance of breeding events to enable replacement of adults in subsequent generations as adults generally do not live beyond two years (Bower et al. 2014). To enable successful breeding and to improve genetic diversity, there would need to be enough males and females to breed. The table below describes the proportion of females and males tagged per survey season for the area that includes the RTA ponds, Kogarah Golf Course and the Marsh Street wetlands (**Table 4**).

Population age structures were not provided in any of the RTA pond monitoring reports from White (White 2003 – 2015). Age structure are important to understand if there are enough adults of suitable breeding age to sustain the population. The monitoring report has been updated to include an estimation of age structure.

Table 4: Proportion of male and female Green and Golden Bell Frogs from 2002/03 to 2014/15 (White unpubl. data)

Survey season	Female	Male	Unknown*
2002/03	0.3	0.7	-
2003/04	0.25	0.5	0.25
2004/05	0.4	0.6	-
2005/06	0.3	0.7	-
2006/07	0.35	0.65	-
2007/08	0.4	0.6	-
2008/09	0.2	0.8	-
2009/10	0.25	0.75	-
2010/11	0.3	0.7	-
2011/12	0.35	0.65	-
2012/13	0.45	0.55	-
2013/14	0	1	-
2014/15	0.25	0.75	-

* denotes that the individual captured would have been too young to determine sex. Proportions have been rounded to the nearest whole number.

3.4 Factors influencing frog numbers

Monitoring the frog population at the RTA ponds has determined that the current population is unlikely to remain without constant management and is considered to have poor long-term viability (White 2015). Since 2003, observations of tadpoles indicated that breeding has occurred in the RTA ponds in every year except 2014.

The Arncliffe population is thought to be small (less than 50 adult frogs). Threats to the population include habitat loss, modification and disturbance, presence of chytrid, habitat fragmentation, poor water quality, poisonous foliage from Camphor Laurel as well as pollutant issues and predatory threats (e.g. cats, plague minnow, foxes, dogs and rats).

Testing for chytrid occurred in 2006/07. Only twelve frogs were tested and of these, seven had chytrid antibodies and four had detectable chytrid spores. Chytrid has clearly been present in the population for some time and the continued survival of the population, despite chytrid being present, is similar to the results found for other urban Green and Golden Bell Frog populations. No dead frogs with identifiable chytrid have ever been found at Arncliffe.

3.5 Breeding

Since 2003, breeding has occurred in the RTA ponds in every year except 2014. Tadpoles had been seen in the pond to the east of the Crescent Lake on the Kogarah Golf Course in January / February 2003 and November 2005 (A Hamer, pers. comm. 2017; A White, pers. comm. 2015). This is the only reference to tadpoles being found outside of the RTA breeding ponds. It is expected that these frogs dispersed from the RTA ponds. Dispersal of bell frogs from permanent wetlands to ephemeral wetlands

has been reported by Hamer et al. (2008), and is a well-recognised aspect of their ecology. However, the relative importance of breeding in ephemeral situations, to the long-term persistence of a local population remain unknown.

3.6 Recent survey season

Between November 2015 and February 2016, survey of the RTA ponds and Kogarah Golf Course was undertaken.

Initially the survey design was based on the previous surveys conducted at Arncliffe, which were that each wetland was surveyed for two nights. However, to ensure the data met the assumptions of the Pollock's robust design for analysis in MARK, the survey was altered to ensure that recapture rates were above 20 percent per precinct. This meant surveying at one of the precincts night after night to meet the recapture rates required for analysis. For the survey in February 2016, survey was conducted for five consecutive nights to achieve a recapture rate of about 28 percent. See **Appendix A** for a description of the monitoring methods.

Data was collated and examined. The population program 'MARK' was used to analyse the field capture and recapture data with the aim to provide a robust population estimate and to understand dynamics of the frog population at the RTA ponds. However the recapture rates did not approach the rates required to perform the analysis. Recaptures in the first two surveys were zero and about 30 percent in the third. See **Appendix B** for the full report on the analyses performed.

The survey showed that in November 2015, only six adults were captured and in February 2016, only eight adults were captured. The sex ratio in November was 1F:5M and in February 2F:6M. Some of the animals that were captured and tagged in February were only one year old and could not be sexed. They are not included in the sex ratio of adults reported above.

Breeding was observed with tadpoles of other species present at the site. In mid-January 2016 small *Litoria* tadpoles were found in a large, ponded area between the RTA ponds and the Kogarah Golf Course. When they were large enough, they were positively identified as Green and Golden Bell Frog tadpoles. This is the only evidence of breeding in the 2015/16 season.

3.7 Why captive breed?

Captive breeding has been suggested for this population previously in the Plan of Management for the Lower Cooks River (DECC 2008a) as an insurance in the event of the extinction of the wild population. That Management Plan was prepared to satisfy Action 11.3.4 of the Recovery Plan and Priority Action Statement (PAS) Action 21 for the Green and Golden Bell Frog. These required the then Department of Environment and Climate Change to prepare and implement a 'Green and Golden Bell Frog Management Plan' for each key population on NPWS estate and to liaise with other public authorities (e.g. local councils, government departments) to encourage the preparation and implementation of a 'Green and Golden Bell Frog Management Plan' for key populations occurring on other public lands.

The Plan of Management developed for this site in response to the New M5 (ELA 2016), suggested that part of a measure to provide greater security for this population included collection and captive breeding. A review by an independent expert agreed with establishing an ex-situ breeding colony. Both the creation of new habitat areas to be managed in perpetuity and the captive colony should provide for greater security of the population well after the New M5 construction is completed.

The population at Arncliffe has been stable between 2003 and 2012, however the population was relatively small, with a maximum known number of adults 110 in the 2012 population. Since 2012, there

has been a rapid decline in the maximum number of known adults. In the 2013/14 survey season, the population could not be reliably estimated (**Figure 6**). This is thought to have been as a result of two major factors: predation by foxes and a change in the areas of 'rough' on the golf course (A White, pers. comm.).

Even without the New M5 construction, it may have been necessary to consider an ex-situ population of the Arncliffe Green and Golden Bell Frogs. This is because the population is relatively small, making it vulnerable to stochastic events that may result in extinction in the area.

The Lower Cooks River plan (DECC 2008a) also suggested resolution of the population's genetics and comparison with other populations. This was to determine whether outcrossing between other populations would be possible if not beneficial. The population at Arncliffe may suffer from inbreeding. Inbreeding can lead to a reduction in reproductive success and therefore further decline in frog numbers. Franklin (1980) suggested that the minimum effective population size to avoid inbreeding depression and thus a loss of fitness is 50, and to avoid erosion of evolutionary potential this is 500. However a recent review by Frankham et al. (2014) suggested these numbers are closer to 250-500 to avoid inbreeding and 2,500-5,000 to avoid evolutionary erosion.

A molecular population genetic study of the population at Arncliffe revealed that this population is not a different species to other Green and Golden Bell Frog populations across the species' range. It should be possible to therefore outcross with other Green and Golden Bell Frog populations in the event that the captive adults do not successfully breed (Burns et al. 2004).

3.8 Captive breeding process

The intention of the captive-breeding program is to create a viable captive population of Green and Golden Bell Frogs that can serve as an insurance population. Secondly, it would provide tadpoles and young frogs for a seeding population to be established elsewhere (e.g. the Marsh Street frog habitat area).

An organisation or institution that has the suitable experience and has the demonstrated capacity will be the likely host for the captive frogs. The facility that would host the breeding program is the Symbio Zoo at Helensburgh. This facility would hold the animals and breed them each spring/summer when habitat is available for the release of the progeny. If deemed necessary by the project's team of frog specialists, the captive population will be supplemented by juvenile frogs (or even tadpoles) collected at Arncliffe at later dates. Collection will continue for as long as necessary to establish a captive colony. The captive breeding process must be consistent with the approved Green and Golden Bell Frog Plan of Management (ELA 2017).

3.8.1 Establish captive breeding facilities

The facility would need to provide a dedicated holding room for the Arncliffe Frogs. As the initial input of frogs is likely to be small, extra attention will need to be given to these frogs to ensure their health and readiness for breeding. Additional measures such as ultra-violet lamps and food supplements would also be required.

The facility would need to prepare a management program for the frogs that details how each pair would be housed and maintained. The dietary regimes and supplements would need to be detailed, as would all health checks (including skin swabs). Captive Breeding Facility Standard Operating Procedures vetted by Arncliffe Green and Golden Bell Frog expert, Dr Arthur White, and frog experts from Taronga Zoo have been developed.

3.8.2 Collection of frogs for the captive colony

The source frogs for the captive colony would be collected from the Arncliffe population at different locations and times. In order of time, first frogs to be collected would be those collected during the pre-clearing surveys (from July 2016), then additional frogs would be collected from the golf course or RTA breeding ponds if required. These frogs may be collected during the routine monitoring nights or may be collected opportunistically. See detailed protocols for frog collection in Table 2 of the Green and Golden Bell Ffrog Plan of Management (ELA 2016).

3.8.3 Transportation of frogs

The frogs collected would be placed a medium-sized clip-lock plastic bag containing a small amount (5-10 millilitres) of bottled spring water. Each frog would be micro-chipped if not already tagged and the details of the frogs (sex, weight, condition, location, date) would be recorded on a database established for this population.

The frogs in the sealed plastic bags would be placed in a secure Esky for transportation to the facility. The maximum time frame that a frog can be in a bag/esky is three hours. All frogs that are collected for the captive-breeding colony will be isolated. There they are screened for a range of pathogens including chytrid. If the frog has a low Bd score (named after the fungus, *Batrachochytrium dendrobatidis*, which causes chrytrid disease), it will be treated with a range of anti-fungal agents until all traces of chytrid are removed. It can then be transferred to the captive-breeding facility for possible use in the breeding program.

If the frogs has a high Bd score, it will be euthanased, as past experience has shown that these animals cannot be fully cleared of chytrid and that it ultimately reappears in the frog. When the frogs are deemed to be pathogen free they will be cleared from quarantine and relocated to the controlled breeding facility, where they would remain throughout the rest of their lives.

3.8.4 Husbandry

All animal husbandry will follow standards developed by an established keeping facility. The protocols outlined in Murray et al (2011) and consistent with the approved Green and Golden Bell Frog Plan of Management (ELA 2016) must be implemented.

While in captive care the frogs would need to be regularly weighed and measured to monitor growth, as well as examined for signs of injury or disease.

Frogs would not be paired until the female frog shows evidence of sexual development e.g. egg storage in oviduct or responses to calling male frogs. A paternity register would be kept for all mating attempts. Pair combinations would be varied each season to maximise genetic diversity.

Young tadpoles would be fed a mixed vegetable diet and would be given daily UVG exposure. Water in the tadpole tanks would be continuously recirculated and filtered. Tadpoles would need to be kept in tanks where water filtering allowed for removal of waste.

3.8.5 Veterinary care

Veterinary care would be required throughout the project. Veterinary work undertaken would include the following:

- pre- quarantine screening
- chytrid fungus swabs and testing
- microchipping
- on call consults and associated procedures

- pathology tests
- euthanasia
- pre-release screening and testing.

3.8.6 Tadpole relocation

As the Green and Golden Bell Frog is a pond breeding species, tadpoles with hind limb buds are the preferred stage for relocation into the ponds in the Frog Habitat Area at Arncliffe. Pickett et al. (2013) reported that tadpoles have an 80% mortality rate in the wild. By 'head-starting' the animals for release, the mortality could be reduced, because mortality rates in captivity are much lower. Young froglets (metamorphs with tail buds) may also be translocated. Some tadpoles may be released into the RTA ponds where it has been assessed as suitable in consultation with relevant parties. Tadpoles may receive supplementary feed after being released and surveys would be undertaken to determine tadpole survival at the release sites.

Tadpoles would be transported in sealed plastic bags in an esky in water from the rearing tank. Holding bags would be allowed to become thermally stable in the water in the release ponds before the bags are opened. A test release of a small clutch of tadpoles (~5) should be performed to determine if the water quality is suitable for tadpoles prior to a major release of animals. Tadpoles will be initially released into baskets to assist in monitoring.

3.8.7 Duration of captive-breeding colony

The captive breeding program will be maintained until such time as the establishment of the population at Marsh Street is deemed effective by the project herpetologist in accordance with the Conditions of Approval and in consultation with OEH, Roads and Maritime and the project's frog specialists. Continuation of the breeding program beyond this date will be determined by Roads and Maritime in consultation with OEH and DP&E.

3.8.8 Monitoring and reporting

The outcomes of the captive breeding program must be reported annually to the Department of Planning and Environment for the duration of the program. Annual report should include:

- number of extant animals
- number of new animals accepted into the program (SOP GGBF003)
- number of progeny (if any)
- results of any testing for chytrid (SOP GGBF0004 and GGBF006)
- number of mortalities (as per GGBF Register of Deceased Animals)
- results of autopsies on expired frogs (SPO GGBF008)
- results of water quality testing (SOP GGBF011)
- any medical treatments administered to frogs (as per Animal History Record).

The Standard Operating Procedures provided by Symbio Wildlife Park include many issues to be monitored. These range from daily checklists to animal health and welfare.

4 Monitoring and reporting

The activities in this plan would need to be monitored for success. While many aspects of the habitat creation could be measured (e.g. fencing integrity – no holes in fence) and corrective actions provided (e.g. fix holes in fence within two days of detection), the chief aim of the habitat creation is to ensure ongoing survival of the Arncliffe population following introduction from the captive breeding program. The monitoring and reporting proposed focuses on the Green and Golden Bell Frog breeding success and establishment of the population at the Marsh Street ponds.

4.1 Monitoring

The aim of the monitoring program is to provide information for adaptive management on the effectiveness of the habitat created as part of the project. Monitoring of the Arncliffe population during construction is managed by the Green and Golden Bell Frog Plan of Management. Once tadpoles / metamorphs are released into the Marsh Street habitat ponds, monitoring will extend to the Marsh Street ponds and surrounding area (as determined by the project herpetologist).

Monitoring of the GGBF population at suitable areas outside the construction area during construction would be undertaken by the Project Herpetologist engaged by the M5 Asset Trustee (or CDSJV if delegated). A minimum of four surveys would be undertaken per month between September and May during the construction period. These surveys are to be opportunistic and undertaken during favourable climatic conditions. In accordance with the *Survey Guidelines for Australia's Threatened Frogs* (DEWHA 2010), small wetlands (<50 metres at greatest length) would be covered in a period of about one hour. Banks and emergent vegetation will also be searched.

The areas outside the construction area that would be monitored would include the Kogarah Golf Course, the Kogarah Golf Course habitat enhancement areas, the new Marsh Street ponds and nearby suitable areas within an approximate radius of 2 kilometres. This will give a more useful indication of GGBF distribution and habitat use within the locality.

The GGBF surveys will still be mark/recapture based so that a population estimate is still possible using the Peterson/Lincoln Index, and to track the movement of marked individuals.

Tadpole surveys would be undertaken each month between September and May at sites where GGBFs have been detected and sufficient water is present for breeding to occur. Long-handled sampling nets and/or tadpole traps would be used to detect tadpoles. Any tadpoles captured will be measured, staged (using standard staging in Gosner (1960)), identified (using Anstis 2013) and released.

All frog surveys would be carried out in accordance with the Hygiene protocol for the control of disease in frogs (DECC 2008b) to minimise the spread of Chytrid disease.

All captured Green and Golden Bell Frogs would be measured, weighed, sexed and inspected for reproductive condition and signs of illness or injury. Frogs larger than 40 millimetres snout-vent length would be micro-chipped and tissue samples will be taken by web punching between the third and fourth hind toe. This will be undertaken by an appropriately licenced herpetologist with ethics approval to undertake the above procedures. The frogs would then be released at point of capture.

Monitoring can commence at the new Marsh Street habitat once it has been created and tadpoles or metamorphs are introduced to this habitat area. Monitoring will be consistent with the RTA ponds and if higher densities of GGBFs are found, the Pollock's robust design could be implemented. Monitoring of

other suitable frog habitat in the vicinity of the Marsh Street frog habitat area will be considered and discussed with the Herpetologist following the completion of construction.

4.2 Monitoring of habitat features at Marsh Street

Details of the habitat features required are outlined in Sections 2.5 and 2.6 of this Plan. The features will need to be managed under the direction of a suitably qualified and experienced bush generator, the appointed project ecologist or frog expert (Table 5). If the habitat features require maintenance they must be undertaken in accordance with the best practice guidelines for the establishment and management of Green and Golden Bell Frog Habitat (DECC 2008c), frog hygiene protocols (DECC 2008b) and the Green and Golden Bell Frog plan of Management for Arncliffe (ELA 2016).

Table 5: Monitoring requirements for habitat features

Issue	Indicator	Response action	Frequency	Who
Breeding habitat	Ponds become shaded by emergent plants Plague Minnow presence	Ponds will be drained or flooded as required to replicate wetting and drying cycles in natural wetlands. Ponds one and two would be periodically drained and flooded as part of the management of these ponds in response to observations of Plague Minnow. Should Plague Minnow or other exotic species be observed/captured during frog monitoring or observed at other times, then the fish should be caught and euthanised.	Monitoring to commence six months after establishment of features Monitor every six months for shading and Plague Minnow	Project ecologist and expert advisers, Bush regenerator
Feeding, sheltering habitat	Habitat declines in quality (>5% weed cover) Native plants reach attrition of greater than 10%	Weed control is to focus on controlling adverse impacts to constructed frog habitats. Weed control is to be undertaken as required, or on at least an annual basis. Native plants must be replaced at the densities and species type outlined in section 2.4.10 and 2.4.11. Management measures outlined in section 2.4.10 must be carried out.	Monitoring to commence six months after establishment of features Monitor every six months or in response to management actions. Monitor plants every six months. Newly	Project ecologist, bush regenerator

Issue	Indicator	Response action	Frequency	Who
			replaced plants need to be watered every week for six weeks following planting.	
Overwintering habitat	Vegetation mounds collapse Covers on mounds fail and leave mounds exposed	Check for presence of frogs then re-establish vegetated mounds and cover Covers to be replaced	Monitoring to commence six months after establishment of features Monitor mounds every six months Monitor covers every six months or following storms	Project ecologist, Bush regenerator

4.3 Key performance indicators

Key performance indicators are listed in **Table 6**. These indicators relate only to the higher level objective of the New M5 GGBF Plan of Management (POM) and the desired outcomes of both the POM and this HCCBP, that is the ongoing survival of the Green and Golden Bell Frog population at Arncliffe. The captive breeding program and release to the Marsh Street ponds will be maintained until such time as the establishment of the population at Marsh Street is deemed effective by the project herpetologist in accordance with the Conditions of Approval and in consultation with OEH, Roads and Maritime and the project's frog specialists. Management measures will be implemented in accordance with the requirements of the POM and this HCCBP.

Table 6: Key performance indicators for RTA ponds and Marsh Street ponds

Issue	Indicator	Threshold	Response action	Who
Arncliffe population survival	Successful annual breeding within Arncliffe habitat areas following release of captive bred tadpoles	Tadpoles not present	Release tadpoles with hind limb buds from the captive colony into Marsh Street ponds and RTA ponds (where appropriate)	Project ecologist and expert reviewers; captive breeding facility
Captive breeding	Release of tadpoles from at least three different parent	No tadpoles produced No deformities	Substitute with alternate males within breeding program in accordance	Project ecologist, expert advisers and captive breeding

	combinations	within tadpoles	with the priority list	facility
Marsh Street pond population establishment	Colonisation of the Marsh St Habitat and ongoing survival of the Arncliffe population.	No calling males, no gravid females, no tadpoles, no emerging metamorphs, no dispersed juveniles.	Check for other factors e.g. predators, water quality Multiple releases of tadpoles Retain captive colony	Project ecologist, expert advisers and captive breeding facility

4.4 Reporting

Results of the monitoring, review and any amendments must be reported annually to the Secretary of the Department of Planning and Environment and provided to OEH. This should be done after the monitoring results have informed the next iteration of the plan; the plan has been reviewed and amended. This report should be provided at the conclusion of the spring-summer survey season. This is to ensure that any decisions about introduction of tadpoles or any corrective action can be made as soon as possible.

The annual report would be provided to Roads and Maritime. The monitoring results should be included on the Roads and Maritime website.

Data analysis can be undertaken as soon as data is collected. Incorporation of data analysis would add value to more fully understanding the population dynamics and size. This analysis will be included into the annual report.

If any other corrective actions are required, these should be reported on an as needs basis. Examples would be the detection of holes in the frog proof fence, which should be reported and acted on immediately. Given these actions and triggers are unpredictable and unplanned, the reporting and response should be fit for purpose and respond to new information adaptively. This would allow for the likely uncertainty and provide flexibility in responding to emerging circumstances.

While there is not enough space at Marsh Street to design a fully replicated experimental approach for the habitat creation and captive breeding, consideration should be given to the production of a scientific paper.

4.5 Review of plan

This plan must be reviewed annually. The review must be conducted after the population monitoring has been completed and after population size at the RTA ponds and Kogarah Golf Course has been estimated. The annual review must be carried out in consultation with relevant agencies (OEH, DP&E and Roads and Maritime) with input from an independent frog expert.

Information included in the review would be all of the monitoring results, details of any corrective actions, details of any action or activity carried out to increase the security of the population at Arncliffe.

The plan must be amended if the review indicates that elements of the plan require updating. These should reflect the effectiveness of mitigation and the ongoing survival of the population at Arncliffe.

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Appendix A Field survey method for January and February 2016

The below describes the field survey method employed during the January and February 2016 monitoring season for Green and Golden Bell Frog at Arncliffe. All monitoring was undertaken by Dr Arthur White and his associates.

Precinct	Date	Person Hours
Golf Course North	27/1/2016	4
Impact Area	28/1/2016	4
Enhancement Area	30/1/2016	4
RTA Ponds	31/1/2016	4
Enhancement Area	3/2/2016	4
RTA Ponds	4/2/2016	4
RTA Ponds	6/2/2016	4
RTA Ponds	7/2/2016	4
RTA Ponds	8/2/2016	4
RTA Ponds	9/2/2016	4

The Jan/Feb 2016 monitoring program was changed part way through the monitoring season to ensure that the data could be analysed using MARK. Instead of surveying the four precinct areas twice during the session, we repeatedly surveyed the RTA ponds for 5 nights during February. The data had shown that there were not enough frogs on the golf course to enable any sort of population estimate and only the RTA ponds had any hope of providing useful data but consecutive recaptures were required.

The survey routine for each night was the same. Each search area was surveyed for 2 hours by 2 survey staff (i.e. a total of 4 person hours) after sun down. Upon arrival at a waterbody on the site, GGBF mating calls were simulated for 2 minutes and that was followed by a 1 minute listening period. Further mating call simulations were done throughout the night as well.

After the listening period following the mating call simulations, a ground search commenced of the area for non-calling GGBFs using head-lamps. This often entailed a slow search of the low vegetation or ground cover. At larger water bodies, one survey member would slowly move around the perimeter of the pond searching, while the other survey member waded into the pond to search through emergent reeds and other aquatic vegetation.

Any GGBF that was caught was immediately placed in a sealed plastic bag so that it could not escape. When the two survey members reconvened after having completed the search of the waterbody, the frogs were processed and released. Processing involved sexing, measuring snout-vent length, weighing the frog and checking it for any signs of injury or disease. If the frog was a recapture its tag number and location was recorded on the field data sheet. If it was a new frog, a passive-induction tag was inserted beneath the skin on the right-hand side and the tag manipulated down into the groin of the frog.

Appendix B Results from MARK analysis

Methods for attempted modelling process of mark-recapture data using Robust Design

Population size estimates and apparent survival for the periods between survey events were modelled using Pollock's robust design. Pollock's robust design can be used to estimate population size at each primary period (N), apparent survival probability between primary periods (ϕ), temporary emigration between primary periods (γ), capture probability (*p*) and recapture probability (*c*). Apparent survival consists of two elements – deaths and emigration – that are not separable without directly measuring emigration or death independently in some way, which was not done in this study.

Robust design has a number of assumptions including: that capture and survival probability are independent of one another; secondary survey periods are closed to migration, mortalities and recruitment; marks are unique and are not lost; and survival probabilities are equal between individuals (Pollock 1982; Amstrup, McDonald et al. 2005; Nichols 2005). For the purposes of modelling sparse data, the assumption was made that capture and marking individuals did not alter their capture probabilities, and so *p* was made to equal *c* in many models (although these were also tested separately to see if improved, sensible estimates could be formed). The probability of temporary emigration occurring was also forced to equal zero in many cases due to the short time frame of surveys, which often maximises the number of estimable parameters. Standard goodness of fit tests used to test the assumption that every marked animal in the population has the same probability of recapture and survival is not available for robust design models (Burnham and Anderson 2002).

An *a priori* set of candidate models were fit to each data set to identify the most parsimonious model. Base models were created in program MARK, version 6.1 (White and Burnham 1999) with combinations of time varying (t) and constant (.) survival and capture/recapture probabilities and population sizes. Statistical models were interpreted using a multi-inference approach where Akaike's Information Criterion was used as an objective means of model selection (Burnham and Anderson 2001). Models were ranked from lowest to highest AIC_c and ΔAIC_c values were calculated by subtracting the lowest AIC_c score from that of each of the other models. Models with ΔAIC_c of less than two are considered to be the best of the candidate set in representing reality (Burnham and Anderson 2002). Akaike weights (*w*) were also calculated to quantify the relative strength of evidence in support of a particular model, given the data available (Burnham and Anderson 2002).

Results

Two models were attempted; one using the mark-recapture data from the entire site combined and one using the data from the RTA ponds only. The vast majority of the animals marked were recorded in the RMS ponds with no movement observed between the other precincts. Thus, modelling these ponds alone would likely break fewer assumptions than modelling the entire site together.

A total of 9 unique animals were marked during the survey period, with several others sighted but not captured. All of these except one were captured in the RTA ponds, with the remaining animal being caught once in the impact precinct and once in the enhancement precinct, suggesting some movement between precincts on occasion. Within the RTA ponds, a total of 2 unique individuals were captured during the first primary survey period with no recaptures; 4 unique individuals captured during the second primary survey period with no recapture; and 7 unique individuals captured during the third primary survey period with 2 recaptures.

Due to the limited number of recaptures – zero in either of the first two primary survey events and only 2 out of 7 (ca. 28%) in the third primary period – all models were unable to converge. This included the simplest *a priori* candidate model with the least parameters, where γ' and γ" were constrained to zero, ϕ and N were assumed to be constant and $p = c(.)$.

Generally speaking, a minimum of 20% recapture rate is required for models to converge and a higher rate of 40% plus is desirable for the models to be more robust.

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