



Green-thighed Frog Monitoring 2019/2020

Breeding Ponds

Oxley Highway to Kempsey, Pacific Highway Upgrade

Prepared for Transport for NSW

July 2020

Document control

Project no.:	1702 (5.15)
Project client:	Transport for NSW
Project office:	Port Macquarie
Document description:	Green-thighed Frog monitoring 2019/2020: breeding ponds report
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Internal review:	Amanda Griffith
Document status:	R0
Local Government Area:	Port Macquarie-Hastings and Kempsey

Document revision status

Author	Revision number	Internal review	Date issued
Jodie Danvers	D1	Radika Michniewicz	16/06/2020
Jodie Danvers	D2	Radika Michniewicz	1/07/2020
Radika Michniewicz	D3	Amanda Griffith	1/07/2020
Radika Michniewicz	R0		
Radika Michniewicz	R1		16/12/2020

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Cover photograph: Green-thighed Frog located at Constructed Pond Site 3W in 2018 (Photo: M. Stanton) (left) and Site 3W (Pond 4) during Stage 2 2020 monitoring (right).

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Executive summary

Context

This report documents the 2019/2020 monitoring period, the third of five monitoring periods for the Green-thighed Frog breeding ponds, as required for the Oxley Highway to Kempsey (OH2K) Pacific Highway upgrade project (the Project). Transport for NSW (TfNSW) is required to manage and monitor the effectiveness of biodiversity mitigation measures implemented as part of the Project, including installation of 25 breeding ponds for the Green-thighed Frog (at five sites). Monitoring of ponds is to be performed in accordance with the methodology presented in the Ecological Monitoring Program (EMP) (RMS 2019).

Aims

The aim of the Green-thighed Frog breeding ponds monitoring is to determine if Green-thighed Frogs are using the purpose-built compensatory breeding habitat and thus determine whether the Project is meeting the performance indicators for the species. Corrective actions are also to be provided where required.

Methods

Surveys were undertaken in accordance with the EMP in two stages. Stage 1 surveys focussed on adult frog detection after a sufficient rainfall trigger; Stage 2 surveys focussed on tadpole detection (indicating successful breeding). Stage 1 surveys involved a 30-minute nocturnal active search at the Collombatti reference site and at each of the constructed pond sites, as well as a peripheral habitat search. Stage 2 surveys involved a 20-minute active search of the ponds and adjacent vegetation and dip-netting of ponds. During Stage 2 surveys, pond depth was recorded, presence of fish and predatory larvae noted, and a photograph was taken from a designated reference point.

Key results

The key results are as follows:

- Stage 1 surveys were undertaken on 10 February 2020 after rainfall that was deemed suitable by the Project Ecologist: 24 hour rainfall between 30.4-37.8 millimetres; cumulative rainfall over 72 hours between 96.4-195.8 millimetres.
- Stage 2 surveys were undertaken on the 18 and 19 March 2020, 37 and 38 days after Stage 1 surveys.
- Adult Green-thighed Frogs were identified at the Collombatti reference site and Site 3W.
- No Green-thighed Frogs were identified at Site 1 (E or W) or Site 4 (E or W) during Stage 1 surveys.
- Stage 1 pond depth at Sites 1 and 3W varied between 15-50 cm, Site 4W contained water at only two ponds and all ponds at Site 4E were dry.
- Green-thighed Frog tadpoles were not identified at any site.
- Ponds at Site 1 (E&W) and Site 3W held water at Stage 2 surveys, while all ponds at Site 4E were dry and one pond at Site 4W held water.
- *Gambusia (Gambusia holbrooki)* was identified at Site 1E (pond 2). Native species of gudgeon were detected at the Collombatti Reference site and Site 1W (pond 1). A number of ponds holding water contained predatory invertebrates.

Conclusions

One of the three performance indicators of success has been met for Site 3W only, with the continued presence of Green-thighed Frogs at this site. The remaining sites (Sites 1 (E&W) and 4 (E&W), i.e. 20 of the 25 constructed ponds) have met the performance indicators for unsuccessful mitigation: Green-thighed

Frogs continue to be absent from Sites 1 (E&W) and 4 (E&W) and Site 4 (E&W) ponds are not retaining water for a sufficient amount of time to enable tadpoles to reach metamorphosis.

Management implications

A number of identified potential problems and contingency measures presented in the EMP are considered relevant due to the absence of Green-thighed Frogs from some monitoring sites and the constructed ponds not holding water for sufficient time after rain. Due to these outcomes, recommendations for further surveys of peripheral habitat to establish the ongoing persistence/existence of natural breeding sites of the species were developed in consultation with and endorsed by the NSW Environment Protection Authority (EPA) and TfNSW.

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1. Introduction

1.1 Context

The Oxley Highway to Kempsey (OH2K) section of the Pacific Highway Upgrade Project (the Project) was approved in 2012, subject to various Ministers Conditions of Approval (MCoA) and a Statement of Commitments (SoC). A subsequent approval with additional conditions of consent (CoA) was granted in 2014 by the then Commonwealth Department of Environment (DoE) for Matters of National Environmental Significance (MNES) listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1995* (EPBC Act). The Ecological Monitoring Program (RMS 2019) (hereafter referred to as the EMP) combines these approval conditions and defines the mitigation and offsetting requirements for threatened species and ecological communities impacted by the Project. The Green-thighed Frog (*Litoria brevipalmata*) was identified as requiring mitigation and monitoring through the course of the Projects' construction and post-construction period.

1.1.1 Legal status

The Green-thighed Frog is listed as vulnerable under the New South Wales *Biodiversity Conservation Act 2016* (BC Act). Monitoring of this species is required under the Project's approval.

1.1.2 Monitoring framework

Green-thighed Frog monitoring is to be performed in accordance with the EMP and the Green-thighed Frog Management Strategy (Lewis 2013), with the EMP taking precedence where inconsistencies occur. Construction involved direct and indirect impacts on known Green-thighed Frog habitat areas, which prevented post-construction monitoring. Therefore, monitoring relates to their presence/potential presence within purpose-built constructed breeding ponds, as per the EMP.

The EMP states: *"Monitoring will be undertaken on five occasions commencing in Years 3-7 (construction and operation phase). Each monitoring event should be at least 10-12 months apart but ultimately dependant on rainfall events."*, and that *"The first round of monitoring (Year 3) is to commence once the vegetation on the edges of the constructed ponds is considered sufficient (>20% groundcover), to be determined by a suitably qualified Ecologist."*

The Green-thighed Frog Management Strategy requires a two-component approach to Green-thighed Frog monitoring:

- monitoring of breeding ponds, and
- monitoring the integrity of the frog fences.

The monitoring of frog fences is being undertaken as part of the fauna fence monitoring (in conjunction with underpass monitoring periods). These results are detailed in the reporting for the fauna fence monitoring component of the Project and are summarised in this report.

The 2019/2020 monitoring represents the third of five monitoring events. To date, these monitoring events have been reported as follows:

- 2016/2017: Niche (2017)
- 2017/2018: Niche (2018)
- 2018/2019: insufficient rainfall to trigger surveys
- 2019/2020: current report.

1.1.3 Baseline data

Green-thighed Frogs were identified from seven locations during baseline surveys (Lewis 2013, Figure 1), however no tadpoles, metamorphs or juvenile Green-thighed Frogs were recorded at identified breeding sites 57 days after rain events enabled identification of adult frogs. As construction of the Project directly or indirectly impacted seven known habitat areas, frog breeding ponds were proposed at these locations. The Green-thighed Frog Management Strategy (Lewis 2013) states: “Frog breeding ponds will be constructed at four locations, two within the Oxley Highway to Kundabung Upgrade section and two within the Kundabung to Kempsey section.”

The EMP provides a summary of the location of the proposed breeding ponds:

- *Ch.9050-9350. Five ponds to be constructed on each side of the carriageway.*
- *Ch.11550. Five ponds to be constructed on each side of the carriageway (Project Ecologist to investigate the suitability of ponds in consultation with RMS and the EPA and be guided by the results of pre-clearing surveys).*
- *Ch.30660. Five ponds to be constructed on the western side of the carriageway.*
- *Ch.33650. Five ponds to be constructed on each side of the carriageway.”*

It was determined in consultation with the NSW Environment Protection Authority (EPA) that the construction of 10 ponds at Ch. 11550 was not warranted due to several surveys finding no record of Green-thighed Frogs in the area around Ch. 11550. In addition, it was determined that breeding habitat remained available locally outside the Project boundary. As such, monitoring has been undertaken of ponds constructed at the remaining three areas (baseline sites 20, 11 and 16).

1.1.4 Purpose of this report

This report complies with the monitoring requirements described within the approved EMP and the Green-thighed Frog Management Strategy (Lewis 2013) and details the findings from the third monitoring period. It represents the third of five monitoring events. The aims of this report are to summarise the methods and results of the 2019/2020 monitoring, determine if performance measures are being met, and to comment on the need for contingency measures, as per the EMP.

1.2 Performance Measures

The Green-thighed Frog Management Strategy and the EMP specify a number of performance indicators against which the success of the compensatory habitat will be measured. These are listed in Table 1 along with their inclusion in the relevant document.

Table 1: Performance indicators

Performance indicator	GThF MS	EMP
Performance indicators of success		
Continued presence of Green-thighed Frog at two/three or more of the three/four breeding pond sites.	✓	✓
Green-thighed Frogs calling from the edge of the constructed ponds.	✓	✓
The presence of tadpoles, juveniles or metamorphs at the frog breeding ponds during Stage 2 surveys.	✓	✓
Signs of the mitigation being unsuccessful		
Absence of Green-thighed Frogs from one or more of the four sites (GThF MS)	✓	✓
Absence of Green-thighed Frogs from the area (EMP)		
Ponds not holding water for a sufficient time to enable tadpoles to reach metamorphosis.	✓	✓
Ponds holding water for too long and representing unsuitable habitat (i.e. permanent versus ephemeral).	✓	✓
Exotic fish fauna recorded in breeding ponds.	✓	

GThF MS = Green-thighed Frog Management Strategy (Lewis 2013); EMP = Ecological Monitoring Program (RMS 2019).

1.3 Monitoring Timing

The EMP specifies that:

“Monitoring will be undertaken on five occasions commencing in Years 3-7 (construction and operation phase). Each monitoring event should be at least 10-12 months apart but ultimately dependant on rainfall events. On each occasion the site would be surveyed for 30 minutes during Stage 1 and for 20 minutes during stage 2 (see section 4.9.3). Four of the five monitoring events are to occur during the operational phase of the Project (Years 4-7). The first round of monitoring (Year 3) is to commence once the vegetation on the edges of the constructed ponds is considered sufficient (>20% groundcover), to be determined by a suitably qualified Ecologist. The timing would be staggered accordingly for either stage of the Upgrade.”

1.4 Reporting

Annual reporting of monitoring results is required to include:

- Detailed description of monitoring methodology employed
- Results of the monitoring period
- Discussion of results, including how the results compare against performance measures, if any modifications to timing or frequency of monitoring periods or monitoring methodology are required and any other recommendations
- If contingency measures should be implemented.

All reports prepared under the EMP will be submitted to the NSW Department of Planning, Industry and Environment and the NSW EPA.

1.5 Limitations

The following limitations to the monitoring procedure were encountered:

- A definitive statement as to the fulfilment of performance indicators relating to ponds drying too soon or holding water for too long cannot be made for some or all of the ponds, due to surveys requiring Stage 2 surveys to be undertaken 30-40 days after Stage 1 and the minimum water retention period of 30 days and maximum water retention period of 60 days. As such, data concerning the presence of water in the ponds prior to or after Stage 2 surveys cannot be captured without additional surveys, which were beyond the identified scope of the monitoring program.

2. Survey Methods

2.1 Monitoring Sites

The monitoring site locations are shown in Figures 1 to 4. These sites correspond to the proposed pond locations as required by the EMP and are described in Table 2. The Collombatti site was used as the reference site.

Table 2: Survey sites

Site name (map ID)	Proposed frog pond sites (EMP)
Collombatti Reference (Ref)	As required by Stage 1 surveys: <i>“Upon the study area receiving the required rainfall, a reference site would be visited to determine the extent of Green-thighed Frog activity”</i>
1E	Ch.9050-9350. Five ponds to be constructed on each side of the carriageway (10 in total)
1W	
3W	Ch.30660. Five ponds to be constructed on the western side of the carriageway
4E	Ch.33650. Five ponds to be constructed on each side of the carriageway (10 in total)
4W	

2.2 Survey Method

The survey method described within the EMP (extracted from the Green-thighed Frog Management Strategy) was employed for all surveys and is provided below.

“Monitoring of the constructed breeding ponds would ideally be undertaken on a rainfall event basis when 24-hour rainfall totals exceed 75 millilitres or a cumulative total of 150 millilitres over a 72-hour period. Such rainfall events would be monitored via the Bureau of Meteorology (BOM) website, specifically the Port Macquarie (Station No. 060183) and/or Kempsey (Station No. 059017) weather stations. Where sufficient rainfall is unlikely to occur during the monitoring period, the Project Ecologist will determine whether smaller rainfall events are suitable to conduct a monitoring event. The suitability of the rainfall trigger chosen would be subject to the reference site visit outlined in Stage 1 below. Surveys would be performed using a two-stage process outlined below.

a) Stage 1 – Determining Presence and Breeding Activity

Upon the study area receiving the required rainfall, a reference site would be visited to determine the extent of Green-thighed Frog activity. The survey would comprise a 30 minute nocturnal active search at each of the four breeding pond areas (sites) using a hand held spotlight. Peripheral habitats (i.e. <50 m) would also be surveyed at this time. Upon the completion of Stage 1 surveys the next stage would be implemented.

b) Stage 2 – Determining the Success of the Breeding Event

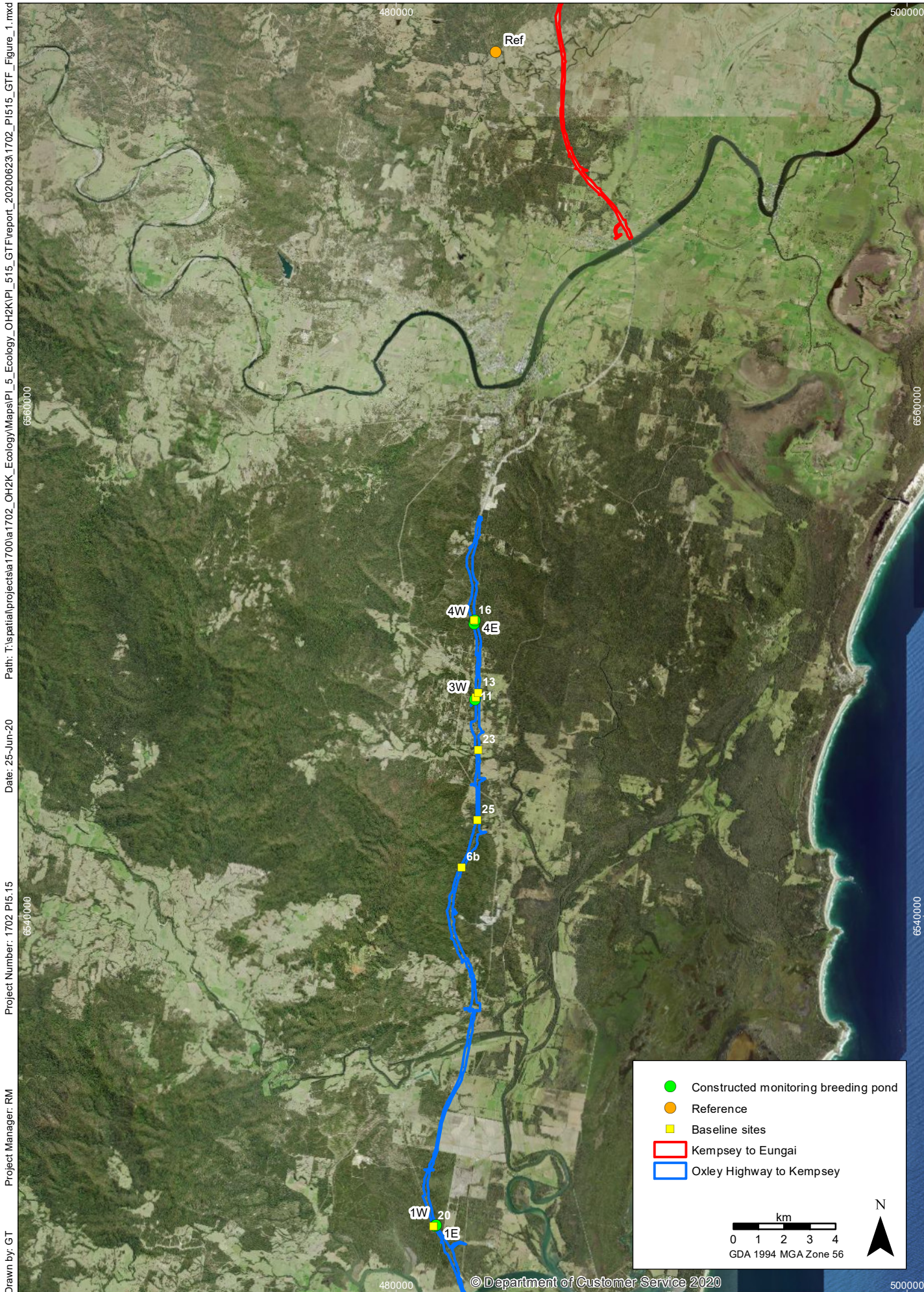
All sites would be subject to follow-up surveys between 30-40 days after Stage 1 to assess the outcome of the breeding event. This follow up survey will comprise:

- *A 20 minute active search for metamorphs and juvenile frogs around the pond edge and vegetation immediately adjacent to the pond (i.e. <10 m).*
- *Dip-netting of the constructed pond and subsequent tadpole identification. Specific attention will be given toward identifying the presence of fish (both native and exotic) along with predatory invertebrates such as dytiscid larvae.*

- *The depth of the ponds would be measured from the permanently installed water staff.*
- *Photo taken from a designated photo point (to be established during the first Stage 2 survey)."*

2.3 Analysis

Monitoring results are to be analysed in accordance with the performance indicators specified within the EMP. In the case of the Green-thighed Frog, performance measures are based on presence/absence results and pond habitat quality and do not require statistical comparison between survey events.



Green-thighed Frog constructed breeding pond locations
 Pacific Highway Upgrade - Oxley highway to Kempsey

FIGURE 1

Imagery: (c) LPI 2014-10-06

Path: T:\spatial\projects\1700\1702_OH2K_Ecology\Maps\PI_5_Ecology_OH2K\PI_515_GTF\report_20200623\1702_P1515_GTF_Figure_2_site_1.mxd
Date: 01-Jul-20
Project Number: 1702 P15.15
Project Manager: RM
Drawn by: GT



Green-thighed Frog constructed breeding ponds - Site 1
Pacific Highway Upgrade - Oxley highway to Kempsey

FIGURE 2

Imagery: (c) NearMap 2017-12-13



Path: T:\spatial\projects\1700\1702_OH2K_Ecology\Maps\PI_5_Ecology_OH2K\PI_515_GTF\report_20200623\1702_PL1515_GTF_Figure_3_site_3.mxd
 Date: 01-Jul-20
 Project Number: 1702 PL15.15
 Project Manager: RM
 Drawn by: GT

Green-thighed Frog constructed breeding ponds - Site 3
 Pacific Highway Upgrade - Oxley highway to Kempsey



FIGURE 3
 Imagery: (c) DigitalGlobe 2019



Green-thighed Frog constructed breeding ponds - Site 4
Pacific Highway Upgrade - Oxley highway to Kempsey

FIGURE 4

Imagery: (c) DigitalGlobe 2019

3. Results

Field data from Stage 1 and Stage 2 monitoring for all sites are provided in Annex 1. Photo monitoring results are provided in Annex 2.

3.1 Frog Fence Monitoring

Frog fence monitoring is detailed within the fauna fence reporting component for the Project. Minor maintenance issues, such as vegetation encroaching on fences, were identified. No Green-thighed Frogs were identified as road kill. Recommendations regarding vegetation clearing around frog fences were made. Detailed survey results and discussion are provided within the fauna fence monitoring report (Niche 2019).

3.2 Stage 1 - Determining Presence and Breeding Activity

3.2.1 Conditions

Suitable rainfall, as specified within the EMP, did not occur until February 2020, almost two years after the previous trigger and monitoring event (March 2018). Stage 1 surveys were undertaken on 10 February 2020 when rainfall was deemed suitable by the Project Ecologist. Rainfall and temperatures for relevant weather stations are provided in Table 3.

Table 3: Rainfall and temperatures for 10 February 2020

BOM weather station	24hr rainfall (mm)	72hr rainfall (mm)	Min temperature °C	Max. temperature °C
Port Macquarie Airport AWS #60139	30.4	195.8	14.8	20.3
Kempsey Airport AWS #59007	37.8	96.4	13.2	17.4

3.2.2 Nocturnal active searches

Adult Green-thighed Frogs were identified at the Collombatti reference site and Site 3W; two individuals were observed and approximately three additional individuals were heard calling at the reference site and one Green-thighed Frog was observed in adjacent habitat in close proximity to pond 4 and 5 at Site 3W.

No Green-thighed Frogs were identified at Site 1 or Site 4 during Stage 1 surveys.

A number of frog species were heard calling at the Collombatti reference site, Site 1, Site 3W and Site 4W. Other species identified include the Striped Marsh Frog (*Limnodynastes peronii*), Common Eastern Froglet (*Crinia signifera*), Bleating Tree Frog (*Litoria denata*), Eastern Dwarf Tree Frog (*Litoria fallax*), Peron's Tree Frog (*Litoria peronii*), Tyler's Tree Frog (*Litoria tyleri*), Broad-palmed Rocket Frog (*Litoria latopalmata*), Green Tree Frog (*Litoria caerulea*), Dusky Toadlet (*Uperoleia fusca*), Great Barred Frog (*Myxophyes fasciolatus*) and Dainty Tree Frog (*Litoria gracilentata*).

These results are summarised in Table 4.

3.2.3 Pond depth during Stage 1

Water depth of the ponds varied during Stage 1 surveys and can be summarised as follows:

- Collombatti reference site: depths ranging from 40 to greater than 50 centimetres (cm).
- Site 1W: between 15-30 cm
- Site 1E: between 25-40 cm
- Site 3W: between 38-50 cm
- Site 4W: between 0-20 cm (ponds 2 and 3 were dry).
- Site 4E: did not hold water.

Table 4 presents Stage 1 water depths.

3.2.4 Vegetation structure and other observations

As discussed in Niche (2018), it is possible that invasive grass species present at many ponds is too dense and possibly unsuitable for Green-thighed Frogs, a species that requires leaf litter for foraging (OEH 2018) and a more open low ground vegetation (Hero 2004), such as ferns and mat rushes. Each site is discussed below and site photos provided in Annex 2 show the level of vegetation and exposure of ponds at each site.

Site 1

Site 1 (E&W) ponds are all very exposed in sunny locations with canopy cover generally absent and dominated by perennial grasses. The presence of bulrushes at pond 1 at Site 1E and pond 5 Site 1W may indicate that these ponds are acting as semi-permanent water bodies and holding water for too long.

Site 3W

Site 3W appears to have a more established vegetation structure, with greater complexity of canopy and ground covering vegetation layers, including presence of *Lomandra* spp. within the ground layer. The adjacent habitat to the west consists of a larger ephemeral pond within a swamp forest providing good habitat for Green-thighed Frogs. Pond 4 was observed to be overflowing into adjacent habitat during both Stage 1 and Stage 2 surveys. In addition, the ponds at Site 3W appear to be much deeper than ponds at Site 4 and are capable of holding up to approximately 60 cm of water.

Site 4

Site 4E ponds are situated on a ridgetop within a narrow strip of open forest that is bounded by the Pacific Highway and a wide easement. The forest vegetation immediately north and south of the ponds may provide some cover, however the ponds are mostly exposed and have no ground cover vegetation. Site 4W ponds are mostly exposed with little to no canopy cover and a lack of ground cover surrounding the ponds. Site 4E and 4W ponds are notably shallower than other sites and are not capable of holding water for 30 days, if at all.

3.3 Stage 2 - Determining the Success of the Breeding Event

Stage 2 surveys were undertaken on 18 and 19 March 2020, 37 and 38 days after Stage 1 surveys.

3.3.1 Active searches and dip-netting

A number of tadpoles were caught at the Collombatti reference site, Site 1 (E&W) and Site 3W. The majority of ponds at Site 4 (E&W) were dry and the one pond with water did not contain tadpoles.

Tadpoles were identified as either Striped Marsh Frog, Eastern Dwarf Tree Frog or *Crinia* spp. Unidentified specimens were not Green-thighed Frog tadpoles.

3.3.2 Predatory fish and invertebrates

Firetail Gudgeon (*Hypseleotris gali*) and mayfly larvae were identified at the Collombatti reference site. Various predatory invertebrates were detected at Sites 1 (E&W, 6 ponds), 3W (3 ponds) and 4W (pond 1). Predatory fish were detected in one pond at Site 1 (E&W), species included Gambusia (*Gambusia holbrooki*) and Striped Gudgeon (*Gobiomorphus australis*). Predator presence is summarised as follows:

- Site 1W: four of five ponds with at least one predator type
- Site 1E: two of five ponds with at least one predator type
- Site 3W: three of five ponds with predatory invertebrates
- Site 4W: one pond with predatory invertebrates, remaining ponds dry
- Site 4E: no predators detected (ponds dry).

3.3.3 Pond depth during Stage 2

Table 4 provides the Stage 1 and Stage 2 water levels, including the hydroperiod requirements according to Lewis (2013). According to Lewis (2013), ponds should have a maximum depth of 400 mm and hold water for between 30-40 days at sunny exposed sites or 50-60 days at shaded locations. The constructed ponds can be classed as both sunny exposed sites and shaded sites (see Table 4). Water should therefore be retained up to 40 days in exposed ponds or 60 days in shaded ponds. Stage 2 surveys were undertaken 37 and 38 days after Stage 1.

Water levels during Stage 2 surveys can be summarised as follows:

- Site 1W - all five constructed ponds held water (10-25 cm deep)
- Site 1E - all five constructed ponds held water (15-30 cm deep)
- Site 3W - four of five constructed ponds held water (15 - 40 cm deep)
- Site 4W - one of five constructed ponds held water (15 cm deep)
- Site 4E - all five constructed ponds were dry.

Minimum water retention period – 30 days

As surveys were undertaken 37 and 38 days after Stage 1, the presence of water at 30 days cannot be stated for those ponds that held water at Stage 1 but were dry during Stage 2 surveys. As such, conclusions as to the likelihood of water presence at 30 days have been drawn based on individual pond conditions, weather and recent rainfall.

Stage 2 water depth was impacted by rainfall immediately prior to surveys. Port Macquarie Airport Weather Station recorded 26.4 mm of rainfall in the 24 hours prior to surveys. Despite this rainfall, all ponds at Site 4E and 4 ponds at Site 4W were dry during Stage 2 surveys, therefore the assumption can be made that Site 4 ponds do not hold water for the minimum required 30 or 50 days (depending on sun exposure; Lewis (2013) and see Table 7). All Site 1 (E&W) and Site 3W ponds were considered to successfully retain water for the minimum required period (i.e. more than 30 days).

Maximum water retention period – 40-60 days

Given that Stage 2 surveys were undertaken 37 days after Stage 1 surveys and Lewis (2013) states a suitable hydroperiod of up to 40 days for exposed sites or up to 60 days for shaded sites, it is not possible to state if ponds held water beyond the suggested hydroperiod. In addition, as water retention is dependent not only on pond permeability but on weather conditions and local rainfall, it is difficult to draw conclusions regarding the likelihood of ponds to dry within the recommended hydroperiod.

While assessment of water levels after Stage 2 was not possible due to survey limitations, it was considered likely that ponds with water levels of 30 cm or above during Stage 2 monitoring would have retained water for periods beyond 40 days, but this is difficult to estimate beyond 60 days (maximum hydroperiod prescribed by Lewis (2013)). Research has shown that an extended hydroperiod is unlikely to impact the breeding of this species, as long as the pond is ephemeral (Lemckert *et al.* 2006, and Lemckert *pers. comm.*). Therefore, water retention within ponds somewhat beyond the preferred hydroperiod is not considered as important to the survival of this species as the retention of water for periods long enough to allow for metamorphosis to occur.

Table 4: Monitoring results summary

Site	Hydroperiod (Lewis 2013)	Site condition	GTF	Other frog species	Pond	Stage 1 depth (cm)	Stage 2 depth (cm)	Minimum water retention period	Maximum water retention period
1W	Ponds to support water for up to 30-40 days	Sunny exposed ponds. Established vegetation surrounding ponds.		Common Eastern Froglet	1	30	20	Successful	Not available due to survey limitations
					2	30	25	Successful	Not available due to survey limitations
					3	20	20	Successful	Not available due to survey limitations
					4	15	10	Successful	Not available due to survey limitations
					5	30	20	Successful	Not available due to survey limitations
1E		Sunny ponds with vegetation immediately adjacent to east. Established vegetation immediately surrounding ponds.		Common Eastern Froglet	1	25	20	Successful	Not available due to survey limitations
					2	30	30	Successful	Not available due to survey limitations
					3	25	30	Successful	Not available due to survey limitations
					4	40	15	Successful	Not available due to survey limitations
					5	35	20	Successful	Not available due to survey limitations
3W	Ponds to support water for up to 30-60 days depending on whether the location is shaded or unshaded.	Sunny ponds with vegetation immediately adjacent to the west	Yes – in adjacent habitat	Broad-palmed Rocket Frog, Green Tree Frog, Striped Marsh Frog, Common Eastern Froglet, Eastern Dwarf Tree Frog, Bleating Tree Frog, Peron's Tree Frog	1	40	50	Successful	Not available due to survey limitations
					2	40	60	Successful	Not available due to survey limitations
					3	38	40	Successful	Not available due to survey limitations
					4	50	60	Successful	Not available due to survey limitations
					5	38	40	Successful	Not available due to survey limitations
4W	Ponds to support water for 30 days*	Mostly exposed ponds with limited canopy cover. Minimal ground cover immediately surrounding ponds.		Eastern Dwarf Tree Frog	1	20	15	Successful	Not available due to survey limitations
					2	0	0	Unsuccessful	Did not retain water
					3	0	0	Unsuccessful	Did not retain water
					4	20	0	Unsuccessful	Unsuccessful
					5	20	0	Unsuccessful	Unsuccessful
4E	Ponds to support water for 30 days*	Shaded ponds amongst surrounding open woodland. Little to no ground cover immediately surrounding ponds.			1	0	0	Unsuccessful	Did not retain water
					2	0	0	Unsuccessful	Did not retain water
					3	0	0	Unsuccessful	Did not retain water
					4	0	0	Unsuccessful	Did not retain water
					5	0-1	0	Unsuccessful	Did not retain water

* Ponds at sunny exposed sites should hold surface water for between 30-40 days, and between 50-60 days at shaded locations (Lewis 2013). Discussions with TfNSW concluded that Site 4 (E&W) ponds should be classified as shaded or only partly shaded. Metamorphosis may occur within 28 days (Lewis 2013) and field records show metamorphosis occurring at an exposed site within 40 days (Lemckert *et al.* 2006). As such, it is considered that ponds at Site 4 (E&W) should support water for 30-60 days to allow for a range of sunny and shaded locations, to provide enough time for metamorphosis to occur (in accordance with Table 3-1, Lewis 2013).

3.4 Cumulative Results

Summary results of monitoring events to date are provided in Table 5, with records of Green-thighed Frogs shaded in darker grey. To date, Green-thighed Frogs have not been detected at Site 1 (E&W) or Site 4 (E&W), while Site 3W has shown success in all three monitoring periods. Site 4 ponds are considered to have shown insufficient water retention in both monitoring periods. Water retention post-survey is difficult to determine due to the survey design, but is considered less important than detection of insufficient water retention, and is not included in the cumulative results.

Table 5: Cumulative monitoring results

Site (pond)	2016/2017			2017/2018			2019/2020		
	# GTF	#GTF TP	Pond WR	# GTF	#GTF TP	Pond WR	# GTF	#GTF TP	Pond WR
Ref	1	0	Y	0	0	Y	2, 3C	0	Y
1W(1)	0	0	Y	0	0	Y	0	0	Y
1W(2)	0	0	Y	0	0	Y	0	0	Y
1W(3)	0	0	Y	0	0	Y	0	0	Y
1W(4)	0	0	Y	0	0	Y	0	0	Y
1W(5)	0	0	Y	0	0	Y	0	0	Y
1E(1)	0	0	Y	0	0	Y	0	0	Y
1E(2)	0	0	Y	0	0	Y	0	0	Y
1E(3)	0	0	Y	0	0	Y	0	0	Y
1E(4)	0	0	Y	0	0	Y	0	0	Y
1E(5)	0	0	Y	0	0	Y	0	0	Y
3W(1)	0	0	Y	C	0	Y	0	0	Y
3W(2)	0	0	Y	1, C	1	Y	0	0	Y
3W(3)	0	0	Y	C	0	Y	0	0	Y
3W(4)	1	0	Y	1, C	3	Y	1 (adjacent)	0	Y
3W(5)	1	0	Y	C	0	TS	0	0	Y
4W(1)	0	0	TS	0	0	TS	0	0	TS
4W(2)	0	0	TS	0	0	TS	0	0	TS
4W(3)	0	0	TS	0	0	TS	0	0	TS
4W(4)	0	0	TS	0	0	TS	0	0	TS
4W(5)	0	0	TS	0	0	TS	0	0	TS
4E(1)	0	0	TS	0	0	TS	0	0	TS
4E(2)	0	0	TS	0	0	TS	0	0	TS
4E(3)	0	0	TS	0	0	TS	0	0	TS
4E(4)	0	0	TS	0	0	TS	0	0	TS
4E(5)	0	0	TS	0	0	TS	0	0	TS

C = heard calling in vicinity of pond; #GTF TP = number of Green-thighed Frog tadpoles; Pond WR = minimum water retention period met; Y = Yes; TS = water not retained for the minimum period.

3.5 Pond Location

Given the lack of records of Green-thighed Frogs at the constructed breeding ponds to date, a brief review of the location of the constructed ponds with regard to the baseline records was undertaken to aid discussions. Table 6 provides details of monitoring sites and baseline survey information. It should be noted that the two areas where Green-thighed Frogs have not been detected (Sites 1 and 4) were heavily impacted by habitat removal during construction. The species persists at Site 3 where direct impacts did not occur.

Table 6: Constructed pond location review

Site Name (map ID)	Proposed frog pond sites (EMP)	Baseline site	Baseline location details	Baseline notes (Lewis 2013)	Location comment
1 (E&W)	Five ponds each side of the carriageway	20	Blackmans Point Road	> 3 males calling on western side of highway. Another 2-3 males calling 300 m north on the eastern side of highway.	Ponds constructed as per Lewis (2013). East and west ponds are located at the chainage point where the species was identified of the western side of carriageway. The species was detected 300 m further north on the eastern side. The western ponds are isolated in a strip of vegetation between the Pacific Highway and Telegraph Road. Extensive works occurred in this location in association with the Blackmans Point Road Interchange.
3W	Five ponds on the western side of the carriageway	11	South west side of Pipers Creek	No tadpoles, metamorphs or juvenile frogs recorded. Some small pools of water to 30 mm with tadpoles of other species seeking refuge in leaf litter. Males chorusing in regrowth Acacia vegetation around 30-40 m west of existing highway.	Ponds constructed as per Lewis (2013). Ponds directly adjoin adjacent suitable habitat to the west. This area was not directly impacted by the Project.
4 (E&W)	Five ponds on each side of the carriageway	16	South east of Bloodwood Rest Area on top of cut within existing powerline easement	No tadpoles, metamorphs or juvenile frogs recorded. Main pools occur on the access track running east across the powerline easement.	Ponds constructed as per Lewis (2013). Eastern ponds are located within isolated vegetation between the Pacific Highway and an access track constructed to access the power easement. The section of the easement where the species was identified was directly impacted by the Project and is no longer present.

4. Discussion

A discussion of the 2019/2020 monitoring results in relation to the performance measures detailed in the EMP and the Green-thighed Frog management Strategy (Lewis 2013) is provided in Table 7 and Table 8.

Table 7: Performance indicators of success

Performance indicators of success	Discussion
Continued presence of Green-thighed Frog at two or more of the three breeding pond sites.	This performance measure has not been met. An individual Green-thighed Frog was identified in adjacent habitat at only one (Site 3W) of the three breeding pond sites.
Green-thighed Frogs calling from the edge of the constructed ponds.	This performance measure has been met for one of the three sites. An individual Green-thighed Frog was observed at Site 3W only and the species been consistently recorded in the vicinity of this site in each monitoring period.
The presence of tadpoles, juveniles or metamorphs at the frog breeding ponds during Stage 2 surveys.	This performance measure has not been met. No Green-thighed Frog tadpoles were caught during the 2019/2020 surveys.

Table 8: Signs of the mitigation being unsuccessful

Performance indicators of unsuccessful mitigation	Discussion
Absence of Green-thighed Frogs from one or more of the three sites (GThF MS). Absence of Green-thighed Frogs from the area (EMP).	This performance indicator of unsuccessful mitigation has been met. Green-thighed Frogs were not recorded at two (Site 1 and Site 4) of the three breeding pond sites or within the broader area of these sites.
Ponds not holding water for a sufficient time to enable tadpoles to reach metamorphosis.	This performance indicator of unsuccessful mitigation has been met for 9 of the 25 constructed ponds. According to Lewis (2013), ponds should have a maximum depth of 400 mm and hold water for between 30-40 days at sunny exposed sites or 50-60 days at shaded locations. Water should therefore be retained for at least 30 days and up to 60 days in these ponds. Stage 2 surveys were undertaken 37 and 38 days after Stage 1. All ponds at Site 1 and Site 3 contained water during Stage 1 and Stage 2 surveys, i.e. they held water long enough for breeding cycles to occur as per Lewis (2013). This performance indicator of unsuccessful mitigation has therefore not been met for these sites. However, during Stage 2 surveys Site 4W and 4E ponds were found to be dry except for one pond at Site 4W holding 15 cm of water. It is therefore considered likely that nine of the 10 ponds did not hold water for the minimum required 30 or 50 days (depending on sun exposure; Lewis (2013)). This performance indicator of unsuccessful mitigation has therefore been met for these 9 ponds.
Ponds holding water for too long and representing unsuitable habitat (i.e. permanent versus ephemeral).	This performance indicator of unsuccessful mitigation cannot be assessed due to survey limitations. Given that Stage 2 surveys were undertaken 37 and 38 days after Stage 1 surveys and Lewis (2013) states a suitable hydroperiod of up to 40 days for exposed sites or up to 60 days for shaded sites, it is not possible to state if ponds have held water beyond the suggested hydroperiod. However, water retention within ponds somewhat beyond the preferred hydroperiod is not considered as important to the survival of this species as the retention of water for long enough to allow for metamorphosis to occur.
Exotic fish fauna recorded in breeding ponds (GThF MS).	This performance indicator of unsuccessful mitigation has been met at Site 1E. Exotic fish were recorded in constructed pond 2 at Site 1E for the 2020 monitoring period. Other predatory invertebrates were recorded in a number of ponds.

GThF MS = Green-thighed Frog Management Strategy (Lewis 2013); EMP = Ecological Monitoring Program (RMS 2019).

5. Recommendations

5.1 Contingency Measures

The EMP lists potential problems and contingency measures for various components of the monitoring program. Those considered relevant to the Green-thighed Frog monitoring program are listed and discussed in Table 9.

Table 9: Contingency measures

Potential problem	Contingency measure proposed in EMP	Discussion of proposed measure
Ponds not used by Green-thighed frog.	Survey adjacent areas to confirm frogs remain in area. Review/modify ponds to improve potential site suitability problems.	Green-thighed Frogs have not been recorded at Site 1 (E&W) or Site 4 (E&W) during any surveys. This contingency measure is considered relevant.
Ponds not holding water long enough to enable breeding to succeed.	Review/modify ponds either by placing a semi permeable layer or further excavation.	A number of ponds were dry at Stage 2 surveys, as per Table 8. This contingency measure is considered relevant.
Ponds holding water for too long encouraging competition from non-target frog fauna.	Improve drainage.	Site 1 E&W has at least two ponds with bulrushes and one with exotic fish, which may indicate they are holding water for too long. This contingency measure is considered relevant.
Exotic fish species recorded in breeding ponds.	Modify pond to ensure it dries out.	Exotic fish were observed in pond 2 at Site 1E. This contingency measure is considered relevant.

5.2 Recommendations

Recommendations in Table 10 below are provided to address the proposed contingency measures identified in the EMP and corrective actions provided in the Green-thighed Frog Management Strategy.

Following previous recommendations, works to improve water retention of the ponds at Site 4 (E&W) were commenced on 18 August 2017. Initial works to decrease the permeability of the material forming the ponds proved unsuccessful. As a result, works were again commenced at Site 4E mid-March 2018. This work was put on hold following the trigger rainfall of the 2018 monitoring event. These amelioration works were completed in June 2018. Similar works were also undertaken at Site 4W.

Table 10: Signs of the mitigation being unsuccessful and corrective actions

Performance indicators of unsuccessful mitigation	Action described in GThF MS	Note	Recommendations developed in consultation with and endorsed by TfNSW and EPA.
<p>Absence of Green-thighed Frogs from one or more of the four sites (GThF MS)</p> <p>Absence of Green-thighed Frogs from the area (EMP).</p>	<p>The corrective action for this would be to firstly, implement additional surveys of adjacent areas to confirm Green-thighed Frogs remain in that general area, and secondly, undertake a review and if deemed necessary modify the ponds to improve any site suitability problems.</p>	<p>Applies to: Site 1 (E&W) and Site 4 (E&W)</p>	<p>Compensatory habitat for the Green-thighed Frog has been provided for within the offset strategy for the Project. Offset areas were assessed and considered to provide suitable habitat for this species. As such, the intent of the constructed frog ponds was not to provide compensation for lost habitat but to provide artificial habitat to act as an experimental mitigation for this species (Parsons Brinckerhoff 2006): “A suggested mitigation measure to account for the loss of potential breeding habitat is the creation of artificial breeding ponds adjacent to the new road. Such breeding ponds have not been constructed or trialled previously, Although such ponds have been suggested on other sections of the Pacific Highway where the species occurs, they have not as yet been constructed or trialled. As such the creation of frog breeding ponds should be considered experimental.” (Parsons Brinckerhoff 2007).</p> <p>Given the experimental nature of the ponds, it was not the intent that the ponds act as an indicator of successful mitigation for this species. Adaptive management/monitoring was highlighted as necessary to determine their effectiveness.</p> <p>Given the lack of success of constructed ponds to date it is recommended that surveys of peripheral habitat be undertaken to establish the ongoing persistence/existence of natural breeding sites of the species by undertaking extended habitat and frog surveys. This would be achieved via the following:</p>
<p>Ponds not holding water for a sufficient time to enable tadpoles to reach metamorphosis.</p>	<p>The corrective action for this would involve a review and if deemed necessary, modify the ponds by placing a semi permeable layer or further excavation.</p>	<p>Applies to: all ponds at Site 4E and Site 4W</p> <p>TfNSW have undertaken works to improve ponds at site 4E on at least three separate occasions using four different approaches, however ponds still do not hold water for the required period.</p>	<ul style="list-style-type: none"> • A review of background and baseline data was undertaken to gain a better understanding of the baseline survey areas and observations. • Baseline data and review of satellite imagery has been used to inform the key areas for extended surveys (where property access is possible) to demonstrate ongoing presence/existing natural breeding sites in proximity to the Project. • Reconnaissance surveys have been completed to ground truth aerial data/mark access tracks and waypoint locations that are considered to contain suitable habitat. Photos/waypoints regarding habitat suitability of the peripheral (accessible) habitat were taken and limitations of the search area have been determined. • Areas flagged during the baseline data review and reconnaissance surveys as suitable for extended surveys were chosen based on safe access during heavy rain/flooding and are primarily located in areas/along access tracks that were surveyed during baseline surveys. • A water level check in the days/week prior to a predicted trigger event would be undertaken to determine existing water levels. Noting that 50% capacity would be considered adequate levels to assume flooding during a trigger event.

Performance indicators of unsuccessful mitigation	Action described in GThF MS	Note	Recommendations developed in consultation with and endorsed by TfNSW and EPA.
Ponds holding water for too long and representing unsuitable habitat (i.e. permanent versus ephemeral).	The corrective action for this would be to improve drainage to ensure the pond dries out.	Cannot be accurately assessed due to survey limitations.	<ul style="list-style-type: none"> • Stage 1 Field surveys of peripheral habitat identified during the above reconnaissance surveys –two teams of 2x ecologists over two nights once the trigger rainfall has occurred. Noting surveys shall aim to be undertaken when the sites/peripheral habitat are under flood conditions, with ongoing precipitation, i.e. a trigger rainfall event in isolation as per EMP may not provide suitable conditions, hence preceding rainfall and water levels would be taken into consideration with the trigger rainfall. • Stage 2 Field surveys to be undertaken 30 days after Stage 1 field surveys • Dip netting would be undertaken at constructed frog ponds only • During Stage 2 Field surveys, record water depth of constructed ponds and natural ponds/depressions within peripheral habitat where (i) frogs observed during Stage1 field surveys and (ii) within any other sites (depressions) observed during Stage 1 surveys and deemed suitable by qualified ecologist as high potential breeding sites. <p>Following the outcomes of Stage 1 and 2 surveys:</p> <ul style="list-style-type: none"> • Where the species is recorded within the defined peripheral habitat and/or existence of natural breeding sites is confirmed, no further work would be undertaken on the constructed ponds. • Where peripheral habitat surveys do not detect the species and/or habitat is not deemed suitable, further discussions with EPA would be undertaken.

GThF MS = Green-thighed Frog Management Strategy (Lewis 2013); EMP = Ecological Monitoring Program (RMS 2016)

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Annex 1. 2019/2020 monitoring results

Table 11: Stage 1 field data

Site	Pond	Date	Time	Water depth (cm)	GTF observed from pond	GTF calling from pond	GTF observed 10-100 m from pond	GTF calling 10-100 m from pond	Activity/habitat note	Comments/other species	Air temp (°C)	Humidity	Wind	Cloud cover %
Collombatti Ref site		10/02/2020	21:04	50	2	3	NA	NA	Active along with numerous other frogs. GTF calling 10-15m from road edge.	Striped Marsh Frog, Tyler's Tree frog, Dainty Tree frog, Bleating Tree Frog, Common Eastern Froglet, Dusky Toadlet, Great Barred Frog.	20.3	93	0	100
1 W	1	10/02/2020	2:00	30	0	0	0	0	Some ponds look semi-permanent due to presence of bulrushes	Common Eastern Froglet calling	22	94	0	50
	2			30	0	0	0	0						
	3			20	0	0	0	0						
	4			15	0	0	0	0						
	5			30	0	0	0	0						
1 E	1	10/02/2020	2:30	25	0	0	0	0	Pond 1 overgrown with bulrushes	Common Eastern Froglet calling adjacent to ponds	21	94	0	50
	2			30	0	0	0	0						
	3			25	0	0	0	0						
	4			40	0	0	0	0						
	5			35	0	0	0	0						
3 W	1	10/02/2020	19:50	40	0	0	1	0	GTF found in adjacent habitat	Broad-palmed Rocket Frog, Green Tree Frog, Striped Marsh Frog, Common Eastern Froglet, Eastern Dwarf Tree Frog, Bleating Tree Frog, Peron's Tree Frog	21.3	98	0	100
	2			40	0	0	0	0						
	3			38	0	0	0	0						
	4			50	0	0	0	0						
	5			38	0	0	0	0						
4 W	1	10/02/2020	20:37	20	0	0	0	0			21.3	98	0	100





Site	Pond	Date	Time	Water depth (cm)	GTF observed from pond	GTF calling from pond	GTF observed 10-100 m from pond	GTF calling 10-100 m from pond	Activity/habitat note	Comments/other species	Air temp (°C)	Humidity	Wind	Cloud cover %
	2			0	0	0	0	0		Eastern Dwarf Tree Frog				
	3			0	0	0	0							
	4			20	0	0	0	0						
	5			20	0	0	0	0						
4 E	1	10/02/2020	1:06	0	0	0	0	0			19.7	94	0	95
	2			0	0	0	0	0						
	3			0	0	0	0	0						
	4			0	0	0	0	0						
	5			1	0	0	0	0						
















Table 12: Stage 2 field data














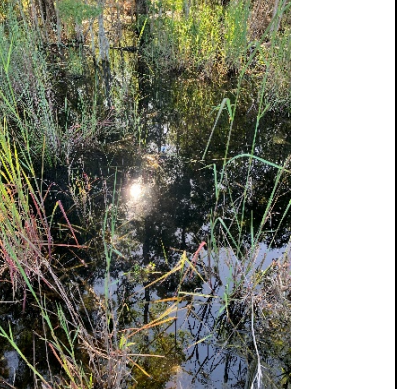

Site	Pond	Depth (cm)	No. GTF (juv)	No. of tadpoles	Tadpoles identified	Presence of Fish	Predatory Invertebrates	Comments
Ref	Collombatti	40-60	0	10	Striped Marsh Frog, <i>Crinia</i> sp.	Y	Y	Firetail Gudgeon and mayfly larvae
1W	1	20	0	0		Y	Y	Striped Gudgeon and insects
	2	25	0	10	Striped Marsh Frog		Y	Insects
	3	20	0	10	Striped Marsh Frog		Y	Backswimmers, overflowing
	4	10	0	20	Striped Marsh Frog			Overflowing edge
	5	20	0	20	Striped Marsh Frog		Y	Mayfly larvae
1E	1	20	0	20	Striped Marsh Frog			
	2	30	0	0		Y		Gambusia
	3	30	0	0			Y	Dragonfly nymph
	4	15	0	20	Striped Marsh Frog, <i>Crinia</i> sp.			
	5	20	0	0				
3W	1	50	0	0			Y	Cades Fly
	2	60	0	0			Y	Backswimmers
	3	40	0	2	Striped Marsh Frog		Y	Water Beetle
	4	60	0	3	Eastern Dwarf Tree frog, unknown (confirmed not GTF)			Connected to swamp behind
	5	40	0	6	unknown (confirmed not GTF)			Unknown tadpoles smaller and shorter tail than GTF
4W	1	15	0	0				Backswimmer
	2	0	0	0				Dry
	3	0	0	0				Dry
	4	0	0	0				Dry
	5	0	0	0				Dry
4E	1	0	0	0				Dry
	2	0	0	0				Dry
	3	0	0	0				Dry
	4	0	0	0				Dry
	5	0	0	0				Dry












Annex 2. Photo monitoring














Table 13: Individual pond photos

Site	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5
1W 2017					
1W 2018					
1W 2020					

Site	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5
1E 2017					
1E 2018					
1E 2020					

Site	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5
3W 2017					
3W 2018					
3W 2020					

Site	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5
4E 2017		*		R0	*
4E 2018					
4E 2020					

Site	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5
4W 2017				*	*
4W 2018					
4W 2020					

NA = not applicable, * group pond photos provided in Table 14.

Table 14: Site photos

Site ID	Summer 2017	2018	2020
Collombatti Reference			
Site 1W			

Site 1E



Site 3W



Site 4W



Site 4E



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