APPENDIX B28-B AMEC 2013: TARGETED SURVEYS FOR THE BOGGOMOSS SNAIL (*Adclarkia dawsonensis*)

Sinclair Knight Merz

Nathan Dam and Pipelines

Targeted Surveys for the Boggomoss Snail (*Adclarkia dawsonensis*)

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1. INTRODUCTION

1.1 Background

AMEC Environment and Infrastructure (AMEC) was engaged by Sinclair Knight Merz Pty Ltd (SKM) to lead further targeted surveys for the boggomoss snail (*Adclarkia dawsonensis*) (**Plate 1**) within the Taroom / Theodore region of central Queensland. The surveys are a requirement of the approvals process for the Nathan Dam and Pipelines Project (the Project).

Plate 1 Boggomoss Snail (*Adclarkia dawsonensis*)

The boggomoss snail is listed as critically endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and a Recovery Plan is in place (Stanisic 2008). Prior to the completion of studies on the snail as part of the Project, it was known only from two locations near the Dawson River. One location was vegetation surrounding a boggomoss or mound spring (Boggomoss No.14) on Mt Rose Station approximately 32 km north-east of Taroom while the other was 60 km downstream on a Camping and Stock Reserve at the Isla-Delusion Road crossing of the Dawson River. The Recovery Plan estimated the Isla-Delusion site as covering an area of approximately 44.5 ha and the Mt Rose site some 0.5 ha by BAAM (2009). This study provides a revised habitat area developed from an analysis of detailed mapping.

The construction of the Nathan Dam would inundate the Mt Rose site and as such the presence of the boggomoss snail and the robustness of the population at this site are important issues in the assessment of the Project.

Following extensive field surveys, SKM (2009) and JKR Ecological (2011) provided population estimates as well as revised information regarding distribution and habitat preferences of the boggomoss snail. A total of 204 sites were surveyed for the species between 2009 and 2012. The species was recorded at 18 sites, with the largest areas of habitat found at Isla Delusion Crossing (approximately 14.4 ha) and the property Southend (further downstream, approximately 16.6 ha).

JKR Ecological (2011) estimated that the total area of known habitat for the boggomoss snail was 38.81 ha. This study also concluded that based on patch-specific snail densities, a revised population estimate for the boggomoss snail was calculated at approximately 26,000 to 36,000 individuals across all sub-populations. The vast majority (15 of 18) of the sites and the occupied area are located outside of the water storage area of the proposed Project.

More recently, surveys completed in 2012 by EcoSM (2012) after major floods had affected areas of snail habitat, failed to record the species from several historic sites, including the three known sites on Mt Rose within the water storage area of the proposed Nathan Dam. EcoSM (2012) also found a marked decline in the number of live snails recorded from other sites. BAAM independently also failed to find live snails at Mt Rose or Isla Delusion in surveys conducted in April 2012.

1.2 Species Information

1.2.1 Description

The shell of the boggomoss snail is light brown, becoming greenish-yellow towards the horn, with a white lip. It is thin and semi-transparent, with an average diameter of about 2.3 cm, and is made up of 5 1/8–5 5/8 whorls. The shell is 1.5 cm high with a slightly elevated spire and a very small central depression. The animal itself is light brown to white, with the amount of grey around the neck, on the sides of the foot and above the tail differing between specimens. Black blotches on the lung roof are visible through the shell (Stanisic 1996, 2008).

1.2.2 Distribution

This aspect is discussed in more detail in **Section 4** of this report. In summary, the boggomoss snail is now thought to be distributed from the property Mt Rose to the property Nardoo in close proximity to the Dawson River. This means the species could be found over a river distance of some 90 km. In light of recent findings there is a need to update the published distributional information relating to this species.

1.2.3 Habitat

Boggomoss snails are restricted to the moister habitats on alluvial flats. Most of this habitat has been cleared for farming and little original vegetation, and therefore possible habitat, remains (Clarke & Spier-Ashcroft 2003). The suitable habitat is now mainly riparian (riverside) or associated with a limited number of mound springs though it has been suggested (BAAM 2009) that Brigalow shade lines may constitute suitable habitat.

At the Isla-Delusion site Southend, Nardoo and Kia Ora, the boggomoss snail is found in riparian woodlands dominated by Queensland Blue Gum (*Eucalyptus tereticornis*), Carnarvon Palm (*Livistona nitida*) and Coolibah (*Eucalyptus coolabah*). The species has been found in four regional ecosystems as described under the Queensland Vegetation Management Framework:

- RE 11.3.3 - *Eucalyptus coolabah* woodland on alluvial plains
- RE 11.3.4 - *Eucalyptus tereticornis* and/or *Eucalyptus* spp. tall woodland on alluvial plains
- RE 11.3.25 - *Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines
- RE 11.3.27 – Freshwater wetlands.

At Mt Rose Station, the snail has been repeatedly found in vegetation associated with a single boggomoss. It has also been recorded on a single occasion from near two other boggomosses. Boggomosses are small, raised peat bogs that form when water from aquifers of the Great Artesian Basin is pushed to the surface through fissures. The vegetation is dominated by water-tolerant species, such as Coolibah trees (*Eucalyptus coolabah*), sedges, ferns and mosses (Clarke & Spier-Ashcroft 2003; Noble *et al.* 1998). At the Boggomoss No. 14, the snail lives in deep leaf-litter. It should be noted that comparatively few boggomoss sites are actually inhabited by the boggomoss snail so the name is a misnomer.

SKM (2009) recorded the species from 15 sites within 11 discrete habitat patches, almost exclusively associated with Queensland Blue Gum and Carnarvon Palm (*Livistona nitida*) forest to open forest. Within these forests, the snail was recorded either under a deep accumulation of palm fronds or at the base of individual palm trees, where moisture accumulates due to the drainage structure of the fronds and leaves and the shade they afford. JKR Ecological (2011) reported the boggomoss snail from two additional habitat patches on Southend.

1.2.4 Life History

There is limited published information on the life history of the boggomoss snail; however, there are published accounts of reproductive lifecycle and growth patterns for other camaenid land snails in semi-arid regions of Australia. Solem and Christenson (1984) found that camaenid land snails of the Kimberley region reached half adult size in the wet season of their birth. They reach adult shell size and become mature males at the end of their second wet season, and function as males at the beginning of their third wet season; the female genitalia mature near the end of this season; and individual snails function as both males and females (are hermaphroditic) from their fourth wet season onwards. A life span of >8 years was demonstrated.

A protoconch (meaning first or earliest or original shell) is an embryonic or larval shell which occurs in some classes of molluscs, e.g. the initial chamber of an ammonite or the larval shell of a gastropod. The protoconch may sometimes consist of several whorls, but when this is the case, the whorls show no growth lines.

The whorls of the adult shell, which are formed after the protoconch, are known as the teleoconch. Quite often there is a visible line of demarcation where the protoconch ends and the teleoconch begins, and there may be a noticeable change in sculpture, or a sudden appearance of sculpture at that point.

Boggomoss snails recorded in the current study were allocated to one of four age classes as follows:

- Hatchling – clearly larval shell (protoconch) with no formation of teleoconch; likely to be only weeks old.
- Juvenile – teleoconch developing but less than half adult size; born in the current breeding season and likely to be a few months old
- Sub-adult – between half adult and full adult size; last season's offspring so likely to be around 12 months of age and have survived at least one wet season
- Adult – at or above mean adult size of 23.8 mm diameter (after Stanisic 1996); likely to be over 2 years of age and in at least their third wet season.

Adult snails may be up to 8 years old and as such the presence of live adult snails alone does not indicate that a viable, breeding population is present. A snail also needs to survive at least two wet seasons before it can contribute to the breeding population.

1.2.5 Feeding

It is assumed that, like many other snails, the boggomoss snail feeds on decaying plant matter, bacteria and fungi (Bishop 1981, cited in Clarke & Spier-Ashcroft 2003).

1.2.6 Threats

Land Clearing

Land clearing is considered to be the main threat to the boggomoss snail. Over the last three decades six million hectares of Brigalow-dominated communities have been cleared (Glazning 1995). Within the Brigalow Belt, only 2.2% of Brigalow-dominated habitats are estimated to be reserved in protected areas (Young *et al.* 1999). Much of the remaining stands are found on freehold land and are threatened by development (Fensham et al. 1998). This widespread habitat loss is believed to make the small pockets of boggomosses extremely vulnerable to direct land clearing and habitat change, such as drying out, once the surrounding vegetation is removed (Clarke & Spier-Ashcroft 2003). Other habitat at risk of land clearing is the riparian Carnarvon palm dominated habitat of the Dawson River through current agricultural land management practices.

Fire

Fire is also a major threat (Stanisic 1996). The small size of the boggomoss remnants makes them more vulnerable to the effects of fire, and particularly sensitive to hot fires (Clarke & Spier-Ashcroft 2003). Fire can affect the snail population directly, by incineration and dehydration, or indirectly through destruction of the leaf-litter that forms the snail's habitat (Stanisic 2008).

Grazing and Trampling

Grazing and trampling of habitat is a likely threat at all known sites of the boggomoss snail. All sites, except the fenced mound springs on the Mt Rose site, are currently grazed at various stocking rates. Stock grazing has a detrimental effect on the snail's habitat by introducing weeds to the area and causing compaction of the soils and leaf-litter (Greenslade 2000; Stanisic 2008). Snails may also be directly trampled. Stock grazing has been known to cause damage to boggomoss habitats in the past (Stanisic 1996).

The boggomoss on private property has been fenced to protect the habitat from cattle grazing and trampling. However, this has led to more grass at the site, which increases the fuel load and leads to a greater risk of wildfire (Stanisic 2008).

Other Land Uses

Tree removal or development work for pastoral purposes may affect the species habitat and quarrying is permitted at the Isla-Delusion reserve.

Hydrological Changes and Flooding

Since the boggomoss snail lives on a floodplain close to a major river, changes in hydrology could threaten the species' survival (Clark & Spier-Ashcroft 2003; Stanisic 2008).

JKR Ecological (2011) and EcoSM (2012) discussed the potential impact of consecutive floods in 2010 and 2011 on populations of the species. These flood events are significant in a historical context, with only two larger events on record, both pre 1900 (1870 and 1890). Surveys completed after the floods in 2010 and 2011 showed a marked decline in the population estimate for the species.

Predation

The boggomoss snail is known to be predated upon. Surveys completed by BAAM (2009) at the Mt Rose site found that the dead shells showed a high level of predation spread across all size cohorts presumably by mice (*Mus musculus*) and rats (*Rattus fuscipes*). It is however unknown as to whether the predation occurred pre or post mortality.

Land snails are known to be preyed on by rodents, birds, beetles, ants and other snails, and these are present in the boggomoss snail habitat (Stanisic 2008). Land snails also form a part of the diet of the cane toad (*Bufo marinus*) and this species may be a threat at some sites.

2. METHODOLOGY

2.1 Desktop Analysis

Since being formally described by Stanisic (1996), six targeted surveys for the species have been completed. A desktop review of these studies was completed prior to field survey to inform site selection and provide historical data for further analyses. The following reports were reviewed:

- Stanisic (1997) *Land snails of the Taroom Boggomosses and adjacent areas*, Queensland Museum (Appendix A to *Dawson River Project Impact Assessment Study Boggomosses (Mound Springs) and other Spring-Fed Areas* report, Queensland Museum 1997)
- Biodiversity Assessment and Management Pty Ltd (BAAM) (2009) *Nathan Dam, Taroom – Results of boggomoss snail survey*, Report prepared for SunWater Pty Ltd
- Sinclair Knight Merz Pty Ltd (SKM) (2009) *Nathan Dam Project – Survey for the boggomoss snail*
- JKR Ecological Pty Ltd (2011) *Nathan Dam Project – Survey for the boggomoss snail*, Report prepared for SKM Pty Ltd
- Ecological Survey and Management (EcoSM) (2012) *Nathan Dam and Pipelines Project – Results of surveys for boggomoss snails*, Report prepared for SKM Pty Ltd.
- BAAM (Stanisic) 2012 provided results of a field survey and these were included in an independent submission on the EIS.

Key findings from these assessments are presented below.

2.1.1 Stanisic (1997)

As part of a broader survey during 1997, surveys were completed for land snails of the Taroom boggomosses and adjacent areas. A total of 56 sites were surveyed, with the majority of these sites (48 sites) located upstream of the Project site. Of these 56 survey sites, 32 sites were located on boggomoss mound springs. These surveys identified the boggomoss snail at only one site, boggomoss 8 (now known as boggomoss 14).

2.1.2 BAAM (2009)

A survey for the boggomoss snail was completed by BAAM, with field assistance by SKM, in late 2008 (subsequent report dated 2009) within the known sites (Boggomoss No. 14 at Mt Rose and Site 8 upstream of the Isla-Delusion camping area) and within habitat areas that shared similar habitat values to known sites along the Dawson River from Taroom to Theodore. The objectives of the study were to:

- Locate any additional populations within the Dawson River Valley
- Assess the condition of the existing boggomoss snail populations in an effort to more accurately estimate population sizes
- Obtain additional information about the habitat and microhabitat requirements of the boggomoss snail that would assist in the conduct of translocation trials and the recovery of the species should the Project proceed
- Select locations based on the above for the conduct of translocation trials.

A total of 53 sites were searched on the Dawson River (and its floodplain) and selected major tributaries, including Cockatoo Creek, Palm Tree Creek and Spring Creek. Twentytwo of these sites were upstream of the Mt Rose site and no Boggomoss Snails (live or dead) were found in those locations. A new location for the snail was found approximately 32 km downstream of the Mt Rose site on the Dawson River and two new populations were found in small isolated vegetation patches near boggomosses (No.15 and No.16) on Mt Rose Station. The latter sites were re-surveyed approximately six weeks after the initial surveys and no snails were found. The population estimate at Boggomoss No. 14 was revised to greater than 350 animals, up from a previous estimate of <100 animals (Stanisic 2008). Too few snails were collected from other sites to estimate the populations.

2.1.3 SKM (2009)

SKM (2009) surveyed a total of 109 sites from the upper Dawson Valley (near Injune), downstream to Theodore. The species was not found outside the Dawson Valley between Mt Rose Station and Theodore.

This survey recorded the species from 15 “new” sites. The distribution of these sites suggests a more or less continuous occupation of the riparian woodlands downstream of Mt Rose Station to approximately Theodore. The study reported a strong association of the snail with the Carnarvon Palm (*Livistona nitida*), particularly downstream of Nathan Gorge. The survey confirmed the presence of a breeding population of boggomoss snails at the Isla-Delusion Crossing and on adjacent properties, including the property Lagoona (the overall area of habitat is now referred to as Isla Delusion and has an area of approximately 55 ha). These populations are thought to possibly represent distinct sub-populations of the species. This is because of the degree of physical separation from other known populations, particularly from Mt Rose.

The SKM report also provided revised population estimates for the species, but only from the more significant habitat areas. The population estimate summed across four habitat areas was between 11 497 and 23 323 snails. It has since been shown that the estimates included a statistical error and correction of that error shows these estimates to be slightly high.

2.1.4 JKR Ecological (2011)

JKR Ecological (2011) surveyed a total of 25 sites which had not previously been surveyed for the species. Searches were primarily conducted between Taroom and Baralaba. Again no snails were found upstream of Mt Rose nor were any found downstream of Southend.

The snail was recorded from two new sites, both of which are located on the property Southend, well downstream of the Isla-Delusion Crossing.

JKR Ecological (2011) concluded that in terms of long-term population viability, the largest and most intact habitat systems which support viable sub-populations of the species occur downstream of the Isla-Delusion Crossing, particularly on the properties Lagoona (which is a part of the Isla-Delusion habitat) and Southend.

2.1.5 EcoSM (2012)

Surveys completed by EcoSM and SKM in 2012 focussed on sites which were historically known to support the species, as reported in various studies between 2009 and 2011. The aim was to assess the effect of recent significant floods which occurred in late 2010 and early 2011. The December 2010 flood was an extremely rare event with a very low probability of occurrence; approximately 0.2% in any given year (DSITIA, 2012).

No live specimens of the species were recorded from Mt Rose or Southend. Only two live individuals were recorded, both from habitats downstream of Isla-Delusion Crossing (one adult snail on Lagoona and one adult snail on Nardoo, which was surveyed for the first time (following landholder permission). Attempts to clarify population estimates and to experiment with survey design were largely unsuccessful due to the low number of snails recorded.

EcoSM (2012) found that the density of snails had declined markedly at all known sites as represented by declining returns for search effort (in terms of live snails recorded per hour of searching).

2.1.6 BAAM (2012)

BAAM surveyed Mt Rose and Isla Delusion in April 2012 and failed to find live snails at either location but did find shells at Mt Rose. This survey was independent from the EIS process.

2.1.7 Summary of Historic Surveys

Surveys to date have included substantial effort upstream of Mt Rose (96 site visits across all studies upstream) but only a single shell of the species has been found (at a site on Cockatoo Creek). That site and potential sites nearby, have been re-surveyed a number of times with no evidence of the species found. It is concluded that the species does not live upstream of Mt Rose.

Live specimens of the species have been found in the riparian zone of the Dawson River between the properties Mt Rose and Nardoo (16 km upstream of Theodore) which is a river length of approximately 90 km.

The 18 "sites" at which the species has been found have been aggregated into six major habitat patches (Mt Rose, Gyranda, Isla Delusion, Southend, Nardoo and Kia Ora) (**Figure 2.1** to **Figure 2.3**) which are thought to potentially represent distinct sub-populations. These sites are separated by a largely hostile matrix of cleared land or drier vegetation types not known to support the boggomoss snail. Direct habitat connectivity is not evident and immigration and emigration of snails seems improbable. While the species has been found outside these patches, they are considered the most likely significant and persistent populations.

The two most recent independent surveys of Mt Rose failed to find live specimens of the species so it was feared the floods may have led to local extinction. The severity of the impact on other sites was not known.

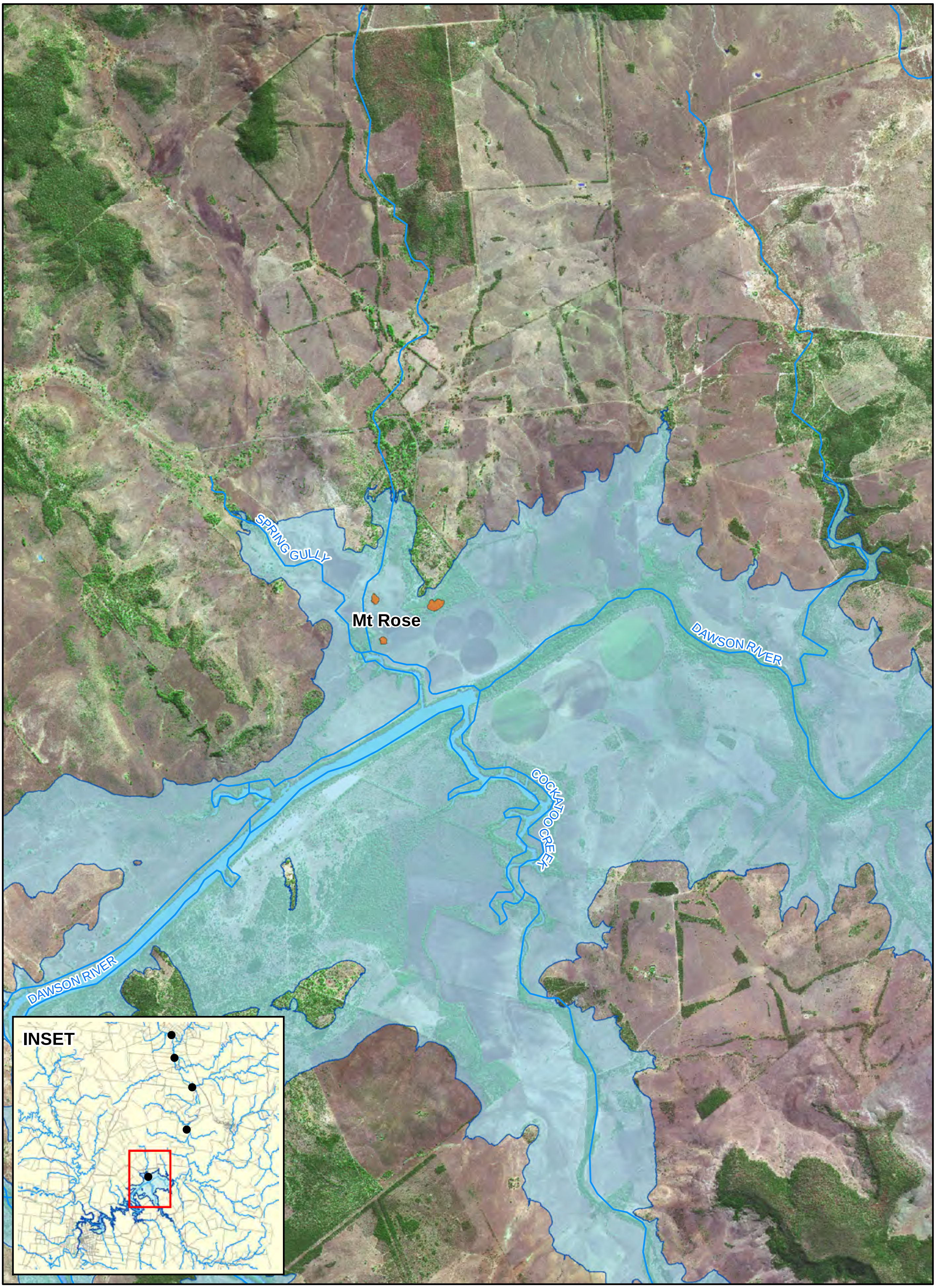
2.2 Scope of Work for Current Survey

Given the failure to locate the species in any reasonable numbers after the 2010/2011 flood events, it was considered important to gain information on the persistence of the snail at sites known to historically have supported it. The objectives of this survey were to assess:

- The presence or absence of the boggomoss snail at Mt Rose (specifically boggomoss No. 14, 15 and 16)

- The presence or absence of the boggomoss snail at the previously identified major habitat patches downstream from the proposed Nathan dam
- Interpret the effect of floods
- Assess habitat suitability and identify any apparent threats.

It was not intended to estimate populations at a site because the random basis of these approaches requires substantial search effort at locations which are very unlikely to support the species. Instead, the focus was on assessing if the species still existed at a site, so favoured microhabitats were targeted for searching. Secondarily it was hoped to find evidence of on-going breeding.



LEGEND

- Watercourse
- Main Roads
- Snail Habitat Area
- Full Supply Level (183.5 m AHD)

Projection: GDA94 Zone 56

Figure 2-1

0 0.5 1 2
Kilometres

Scale 1:75,000 (at A4)

N

SKM SunWater Making Water Work

NATHAN DAM AND PIPELINES
SUPPLEMENTARY EIS REPORT

Overview Map
Mt Rose

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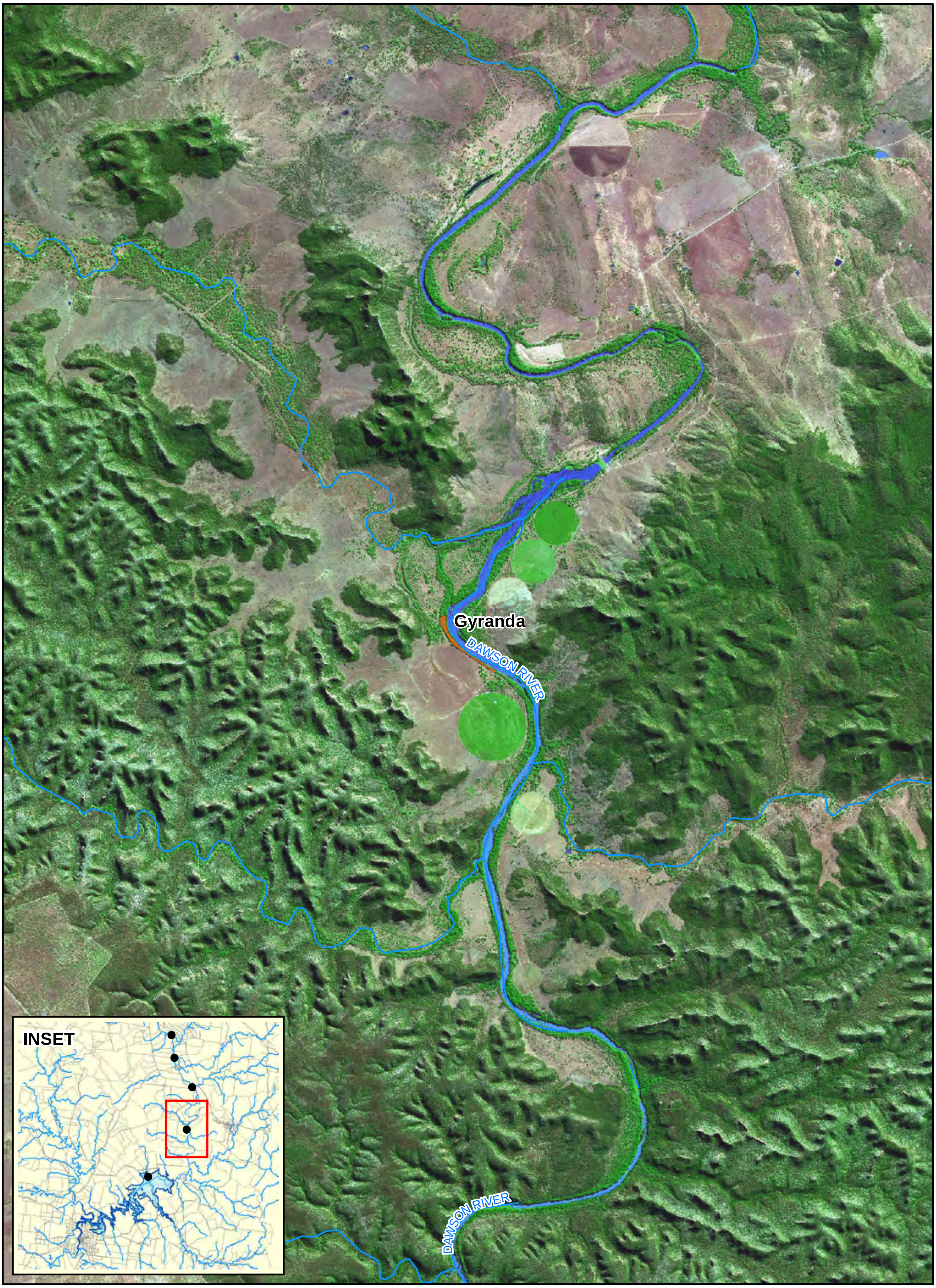

LEGEND

- Watercourse
- Main Roads
- Snail Habitat Area
- Full Supply Level (183.5 m AHD)

Projection: GDA94 Zone 56

Figure 2-2

0 0.5 1 2
Kilometres

Scale 1:75,000 (at A4)

SKM SunWater Making Water Work

NATHAN DAM AND PIPELINES
SUPPLEMENTARY EIS REPORT

Overview Map
Gyranda

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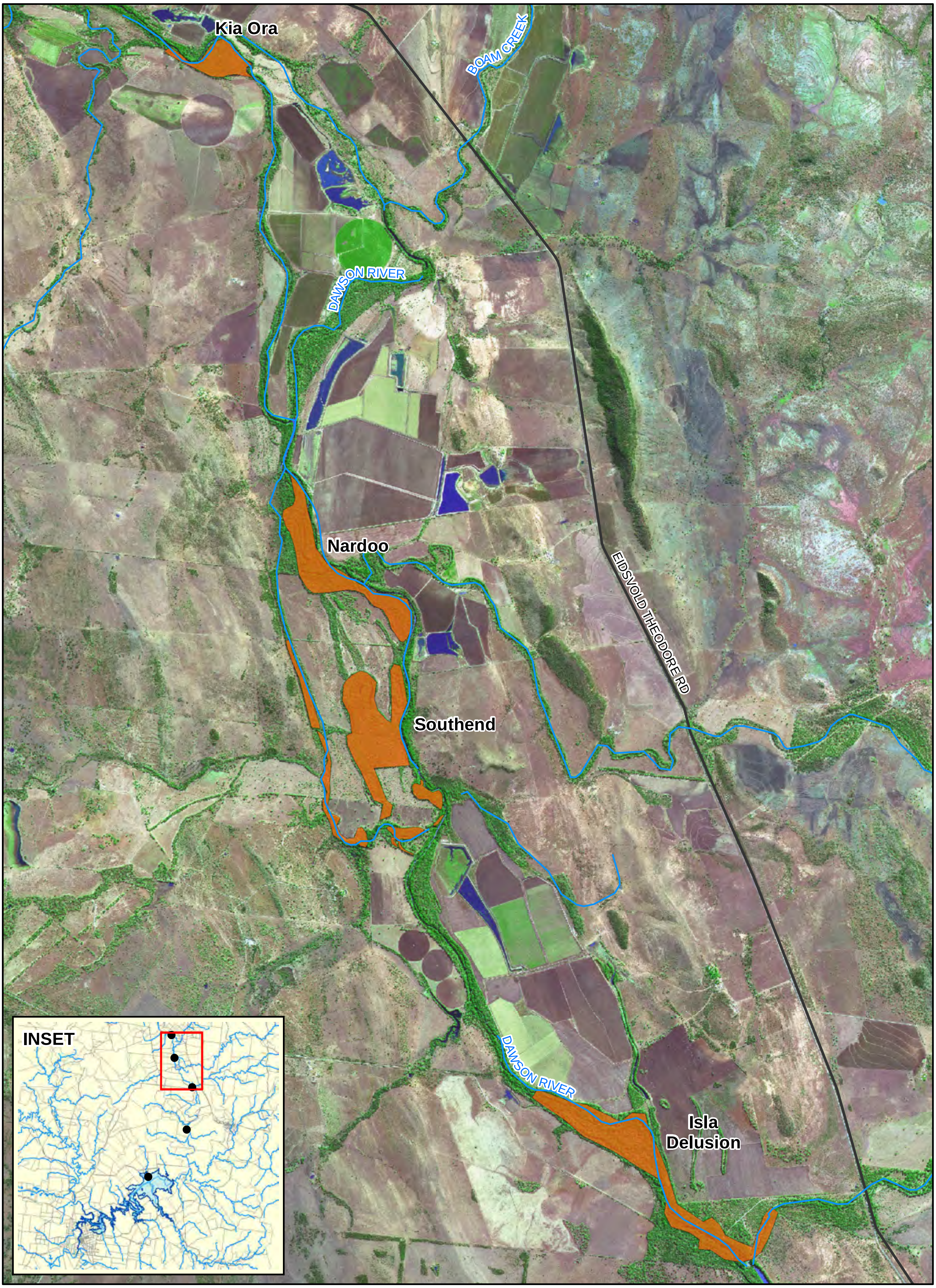

LEGEND

- Watercourse
- Main Roads
- Snail Habitat Area
- Full Supply Level (183.5 m AHD)

Projection: GDA94 Zone 56

Figure 2-3

0 0.5 1 2
Kilometres

N

Scale 1:75,000 (at A4)

SKM SunWater Making Water Work

NATHAN DAM AND PIPELINES
SUPPLEMENTARY EIS REPORT

Overview Map Kia Ora, Nardoo, Southend and Isla Delusion

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2.2.1 Selection of Field Survey Sites

Field survey sites for this study replicated those sampled in previous studies, with a focus on the most important sites (based on the number of snails recorded and area of habitat available). The most important sites based on historic survey results were considered to be:

- Mt Rose (**Figure 3.2**)
- Gyranda (**Figure 3.3**)
- Isla Delusion (**Figure 3.4**)
- Southend (**Figure 3.5**)
- Nardoo (**Figure 3.6**)
- Kia Ora (**Figure 3.7**).

Live snails of various age classes have been found, sometimes on repeated occasions, at these sites so they are assumed to have, at least at those times, represented viable populations.

Boggomoss No. 14 at Mt Rose was a strong focus of survey effort during this study. Two other boggomosses at Mt Rose (boggomoss No. 15 and boggomoss No. 16) have been surveyed three times each but snails were only recorded on the second survey event, reported by BAAM (2009). Snails recorded on the second survey event included two live juveniles and one live sub adult from boggomoss No. 15 and two live adults and two live juveniles from boggomoss No. 16. Confirmation of the status of these populations is of interest as they represent the only other records within the direct impact area of the Project.

2.3 Field Survey Methods

2.3.1 Selection of Habitat Patches for Intensive Surveys

The mound springs on Mt Rose were systematically and thoroughly searched for boggomoss snails, including active searching of all available microhabitats. This intensive survey was considered necessary because the total habitat area is relatively small so a search of the entire area is feasible and negates any debate over extrapolating population estimates from a small sample area to the full habitat area. Six mound springs assessed as exhibiting the correct vegetation type and microhabitat features on Mt Rose were intensively searched.

At the five downstream sites, smaller patches of habitat within the larger site were selected for intensive surveys, with all suitable microhabitats within the patch were surveyed. Habitat patches were selected on the basis that they clearly contained suitable microhabitat elements such as accumulated leaf litter or flood debris and were likely to support the boggomoss snail. It was not possible to search all habitats within the entire site at these locations due to the extensive area of suitable habitat present. The aim was to achieve the greatest probability of finding the species if it was present.

2.3.2 Mapping of Habitat Patches

Once a suitable habitat patch was selected to search, a GPS polygon was mapped around the perimeter so as to accurately record the patch size and location. Patch size was assessed through professional judgement of what constituted potentially suitable habitat for the boggomoss snail and what was reasonably “searchable” within the limitations imposed by time constraints. Only areas assessed as containing at least some or all of the required microhabitat features were searched and mapped. The entire area of suitable terrestrial habitat was mapped on each mound spring at Mt Rose. The data was recorded using a hand held GPS device.

2.3.3 Active Search Methods

Active searching of each habitat patch was completed by a team of four field ecologists. Methods employed to search specific micro-habitats within habitat patches consisted of the use of hand searches assisted by the use of a garden cultivator (the cultivator was used in a manner similar to that of a garden rake) to rake and/or lift leaf litter or flood debris. Logs which could be lifted and replaced by field teams were also searched.

Each habitat patch was thoroughly and systematically searched using this technique, until all available suitable micro-habitats within the patch had been searched. Details of the type of microhabitat and the number of microhabitats searched were also recorded.

3. RESULTS

3.1 Description of Survey Sites

Six sites were surveyed as part of this study (**Plate 2**). A description of each of the sites is provided in **Table 3.1**.

Table 3.1 Survey Site Overview

Survey Site	Location	REs Present	Vegetation Condition	Proximity to Dawson River (m)	Description of Landform*	Observed Threats
Mt Rose	On the Glebe Weir Road, approximately 31 km north-east of Taroom.	11.3.3, 11.3.4, 11.3.25, 11.3.27,	Good. No evidence of canopy dieback or attrition due to fire or pests. Some areas of extensive pig damage and introduced grass species prevalent.	Boggomoss No. 14 – 1400 m Boggomoss No. 15 – 1700 m Boggomoss No. 16 – 1100 m	Gently undulating plains on Quaternary Alluvium - Alluvial sand, gravel, silt and clay.	• Flood related scouring and litter reduction. • Prolonged inundation • Rooting by feral pigs. • Trampling by cattle.
Gyranda	Off the Eidsvold Theodore Road, 14 km west of Cracow.	11.3.25	Poor. Extensive dieback due to prolonged inundation, heavily weed infested and extensive pig damage.	0–100	Undulating plains on Quaternary Alluvium - Alluvial sand, gravel, silt and clay.	• Flood related scouring and litter reduction. • Prolonged inundation • Rooting by feral pigs. • Trampling by cattle.
Isla Delusion	On the Isla Delusion Crossing Road, 18 km north-west of Cracow.	11.3.3, 11.3.25	Excellent. No evidence of dieback or attrition due to fire or pests.	0–200	Undulating plains on Quaternary Alluvium - Alluvial sand, gravel, silt and clay.	• Flood related scouring and litter reduction. • Rooting by feral pigs.

Survey Site	Location	REs Present	Vegetation Condition	Proximity to Dawson River (m)	Description of Landform*	Observed Threats
Southend	Off the Isla Delusion Crossing Road, 20 km south south-east of Theodore.	11.3.25	Good. No evidence of canopy dieback or attrition due to fire or pests. Some areas of extensive pig damage and introduced grass species prevalent.	0–1300	Undulating plains on Quaternary Alluvium - Alluvial sand, gravel, silt and clay.	• Flood related scouring and litter reduction. • Rooting by feral pigs.
Nardoo	Off the Leichardt Hwy, 15 km south south-east of Theodore.	11.3.3, 11.3.25	Good. No evidence of canopy dieback or attrition due to fire or pests. Some areas of extensive pig damage and introduced grass species prevalent.	0–300	Undulating plains on Quaternary Alluvium - Alluvial sand, gravel, silt and clay.	• Flood related scouring and litter reduction. • Rooting by feral pigs.
Kia Ora	Off the Leichardt Highway, 9 km south south-east of Theodore.	11.3.3, 11.3.25	Good. No evidence of canopy dieback or attrition due to fire or pests. Some areas of extensive pig damage and introduced grass species prevalent.	0–400	Undulating plains on Quaternary Alluvium - Alluvial sand, gravel, silt and clay.	• Flood related scouring and litter reduction. • Prolonged inundation • Rooting by feral pigs.

Note *: Geology and landform information sourced from the Bureau of Mineral Resources, Geology and Geophysics, First Edition 1967.

Plate 2 Typical Habitat, Mt Rose

Plate 3 Typical Habitat, Gyranda

Plate 4 Typical Habitat, Isla Delusion

Plate 5 Typical Habitat, Southend

Plate 6 Typical Habitat, Nardoo

Plate 7 Typical Habitat, Kia Ora

As discussed in **Section 2.2.1**, selected patches of suitable habitat within each of the six survey sites were intensively surveyed until all microhabitats were exhausted. A description of each such habitat patch is provided in **Table 3.2**.

Table 3.2 Description of Habitat Patches Surveyed

Survey Site	Patch No.	Historical Site Description	Patch Size (ha)
Mt Rose	1	Boggomoss No. 14 (BAAM 2009); 12-10 (EcoSM 2012)	1.024
	2	Boggomoss No. 15 (BAAM 2009); 12-11 (EcoSM 2012)	0.142
	3	Boggomoss No. 16 (BAAM 2009); 12-12 (EcoSM 2012)	0.274
	4	Not previously surveyed, considered potentially suitable	0.231
	5	Not previously surveyed, considered potentially suitable	0.461
	6	Not previously surveyed, considered potentially suitable	0.276
Gyranda	1	D4 (SKM 2009); Ad8, (JKR Ecological 2011)	0.032
	2	D4 (SKM 2009); Ad8, (JKR Ecological 2011)	0.037
	3	D4 (SKM 2009); Ad8, (JKR Ecological 2011)	0.01
	4	D4 (SKM 2009); Ad8, (JKR Ecological 2011)	0.01
Isla Delusion	1	Isla Delusion Camping Reserve (BAAM 2009); JR 16, JR 18 (SKM 2009); 12-7 (EcoSM 2012)	0.082
	2	Isla Delusion Camping Reserve (BAAM 2009); JR 16, JR 18 (SKM 2009); 12-7 (EcoSM 2012)	0.032
	3	Isla Delusion Camping Reserve (BAAM 2009); JR 16, JR 18 (SKM 2009); 12-7 (EcoSM 2012)	0.058
	4	Isla Delusion Camping Reserve (BAAM 2009); JR 16, JR 18 (SKM 2009); 12-7 (EcoSM 2012)	0.03
	5	Isla Delusion Camping Reserve (BAAM 2009); JR 16, JR 18 (SKM 2009); 12-7 (EcoSM 2012)	0.015
	6	Isla Delusion Camping Reserve (BAAM 2009); JR 16, JR 18 (SKM 2009); 12-7 (EcoSM 2012)	0.037
	7	Isla Delusion Camping Reserve (BAAM 2009); JR 16, JR 18 (SKM 2009); 12-7 (EcoSM 2012)	0.054
	8	Isla Delusion Camping Reserve (BAAM 2009); JR 16, JR 18 (SKM 2009); 12-7 (EcoSM 2012)	0.023
	9	Isla Delusion Camping Reserve (BAAM 2009); JR 16, JR 18 (SKM 2009); 12-7 (EcoSM 2012)	0.048
	10	Isla Delusion Camping Reserve (BAAM 2009); JR 16, JR 18 (SKM 2009); 12-7 (EcoSM 2012)	0.027
	11	Isla Delusion Camping Reserve (BAAM 2009); JR 16, JR 18 (SKM 2009); 12-7 (EcoSM 2012)	0.035
	12	Isla Delusion Camping Reserve (BAAM 2009); JR 16, JR 18 (SKM 2009); 12-7 (EcoSM 2012)	0.091
Southend	1	D14, D15, VH24, VH25 (SKM 2009); Ad9, Ss12 (JKR Ecological 2011); 12-6 (EcoSM 2012)	0.058

Survey Site	Patch No.	Historical Site Description	Patch Size (ha)
	2	D14, D15, VH24, VH25 (SKM 2009); Ad9, Ss12 (JKR Ecological 2011); 12-6 (EcoSM 2012)	0.038
	3	D14, D15, VH24, VH25 (SKM 2009); Ad9, Ss12 (JKR Ecological 2011); 12-6 (EcoSM 2012)	0.02
	4	D14, D15, VH24, VH25 (SKM 2009); Ad9, Ss12 (JKR Ecological 2011); 12-6 (EcoSM 2012)	0.024
	5	D14, D15, VH24, VH25 (SKM 2009); Ad9, Ss12 (JKR Ecological 2011); 12-6 (EcoSM 2012)	0.014
	6	D14, D15, VH24, VH25 (SKM 2009); Ad9, Ss12 (JKR Ecological 2011); 12-6 (EcoSM 2012)	0.025
	7	D14, D15, VH24, VH25 (SKM 2009); Ad9, Ss12 (JKR Ecological 2011); 12-6 (EcoSM 2012)	0.032
	8	D14, D15, VH24, VH25 (SKM 2009); Ad9, Ss12 (JKR Ecological 2011); 12-6 (EcoSM 2012)	0.033
Nardoo	1	12-4, 12-5 (EcoSM 2012)	0.067
	2	12-4, 12-5 (EcoSM 2012)	0.025
	3	12-4, 12-5 (EcoSM 2012)	0.022
	4	12-4, 12-5 (EcoSM 2012)	0.026
	5	12-4, 12-5 (EcoSM 2012)	0.064
	6	12-4, 12-5 (EcoSM 2012)	0.05
Kia Ora	1	DF36, DF37 (SKM 2009)	0.129
	2	DF36, DF37 (SKM 2009)	0.081
	3	DF36, DF37 (SKM 2009)	0.249
	4	DF36, DF37 (SKM 2009)	0.114
	5	DF36, DF37 (SKM 2009)	0.153
	6	DF36, DF37 (SKM 2009)	0.061
	7	DF36, DF37 (SKM 2009)	0.052
	8	DF36, DF37 (SKM 2009)	0.328

The location of each habitat patch searched at each survey site is shown in **Figure 3.2** to **Figure 3.7**.

Microhabitats were grouped into four microhabitat types for recording purposes; leaf litter at the base of trees, logs, leaf litter mats and mounded flood debris. A count of each microhabitat type surveyed was completed at each site (**Table 3.3**), for example 312 trees with an accumulation of leaf litter at their base were searched at the Mt Rose site.

Table 3.3 Availability of Microhabitats within Search Areas

Survey Site	Leaf Litter at Base of Trees (No. of trees)	Logs (No. of Logs)	Leaf Litter Mats (No. Mats)	Mounded Flood Debris (No. Mounds)	Total Microhabitats Searched	Microhabitats per Hectare
Mt Rose	312	155	23	5	495	206
Gyranda	81	8	34	0	123	1382
Isla Delusion	397	24	103	0	524	984
Southend	158	20	45	5	228	934
Nardoo	241	14	110	1	366	1440
Kia Ora	486	62	24	8	580	497

The greatest availability of microhabitats (on a per hectare basis) was observed at Nardoo. The lowest availability of microhabitats on a per hectare basis was observed at Mt. Rose, which subsequently had the second lowest number of snails recorded next to Gyranda, which was observed to be in poor condition due to a combination of factors.

3.2 Active Searching

3.2.1 Climatic suitability

Climatic data obtained from the Bureau of Meteorology (BoM, 2013) shows that the ambient air temperatures during field surveys averaged between 15-29 ^{o}C. Prior to the first field survey, there was 77 mm of rainfall in early March 2013 (**Figure 3.1**). A substantial rainfall event also occurred in early April 2013, between field surveys. The presence of rain may increase the suitability of ground conditions for the snail, and may therefore increase the likelihood of observing 'active' snails. However the presence of recent rainfall will not affect detection rates using the diurnal active search methods employed in this study.

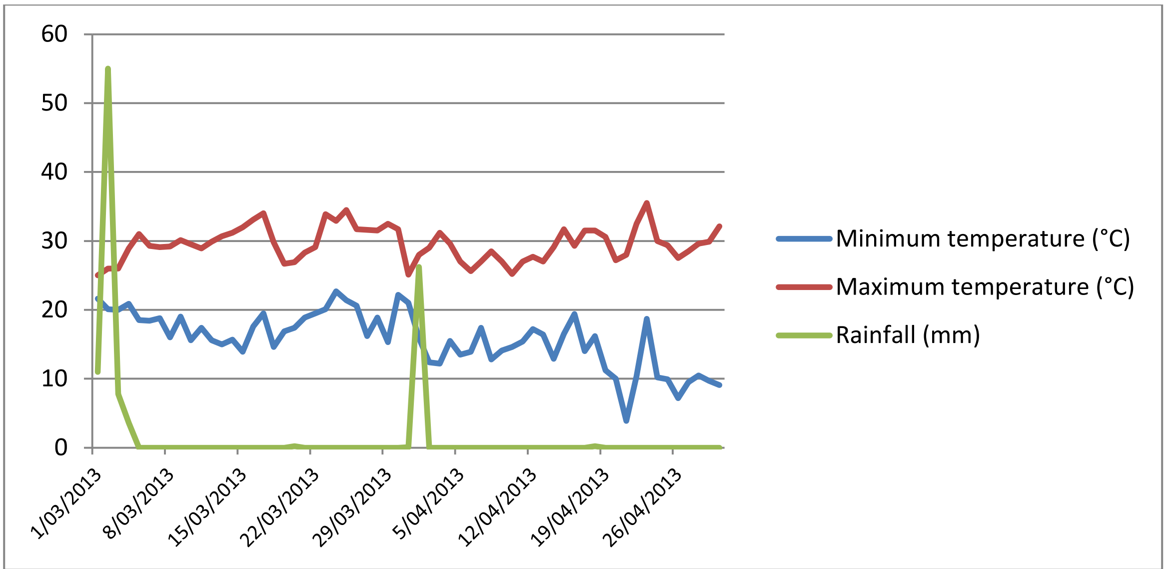


Figure 3.1 Daily Min/Max Temperature and Rainfall During Survey Period

LEGEND

- Live Snails Found
- Dead Snails Found
- Shells Found
- Suitable Habitat, Searched

Projection: GDA94 Zone 56

Figure 3-2

0 25 50 100
Metres

N

Scale 1:6,000 (at A4)

SKM SunWater Making Water Work

NATHAN DAM AND PIPELINES
SUPPLEMENTARY EIS REPORT

Mt Rose -
Habitat Patches Surveyed

Path: I:\QENV2\Projects\QE06601\QE06601.280 Spatial\ArcGIS\Figures\Final\28_Ecology\BoggomossSnail\Figures\130503_NathanDam_Ecology_Figure3-2_MtRose_HabitatPatchesSurveyed.mxd Produced: 25/06/2013

LEGEND

- Live Snails Found
- Dead Snails Found
- Shells Found
- Suitable Habitat, Searched

Projection: GDA94 Zone 56

Figure 3-3

0 20 40 80
Metres
Scale 1:3,000 (at A4)
N

SKM SunWater Making Water Work

NATHAN DAM AND PIPELINES
SUPPLEMENTARY EIS REPORT

Gyranda -
Habitat Patches Surveyed

Path: I:\QENV2\Projects\QE06601\QE06601.280 Spatial\ArcGIS\Figures\Draft\Ecology\Fauna\130503_NathanDam_Ecology_Figure3-2_Gyranda_HabitatPatchesSurveyed.mxd Produced: 29/05/2013

LEGEND

- Live Snails Found
- Dead Snails Found
- Shells Found
- Suitable Habitat, Searched

Projection: GDA94 Zone 56

Figure 3-4

0 25 50 100 150
Metres

N

Scale 1:7,500 (at A4)

SKM SunWater
Making Water Work

NATHAN DAM AND PIPELINES
SUPPLEMENTARY EIS REPORT

Isla Delusion -
Habitat Patches Surveyed

Path: I:\QENV2\Projects\QE06601\QE06601.280 Spatial\ArcGIS\Figures\Draft\Ecology\Fauna\130503_NathanDam_Ecology_Figure3-4_IslaDelusion_HabitatPatchesSurveyed.mxd Produced: 29/05/2013

LEGEND

- Live Snails Found
- Dead Snails Found
- Shells Found
- Suitable Habitat, Searched

Projection: GDA94 Zone 56

Figure 3-5

0 25 50 100
Metres

N

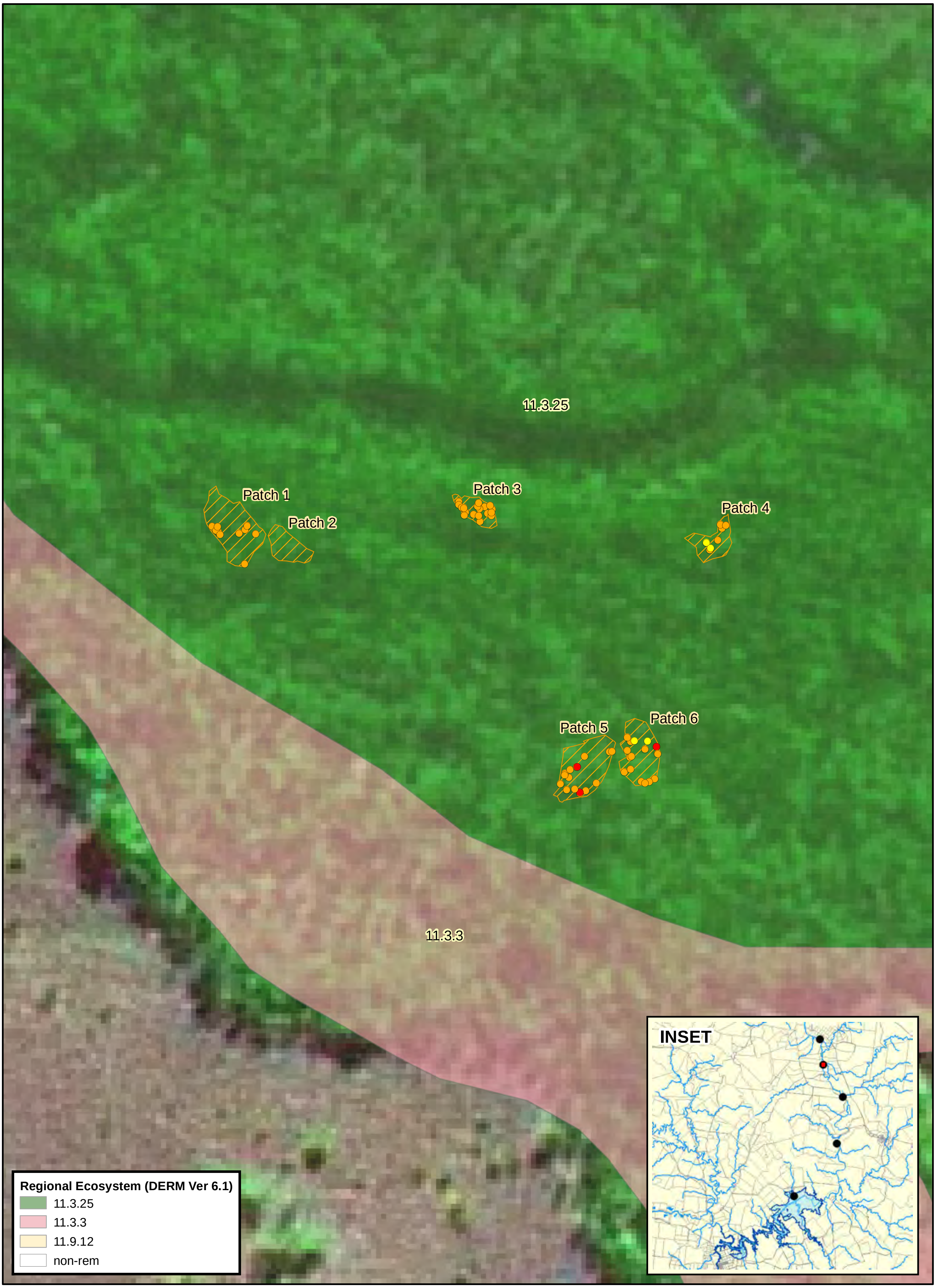
Scale 1:6,000 (at A4)

SKM SunWater Making Water Work

NATHAN DAM AND PIPELINES
SUPPLEMENTARY EIS REPORT

Southend -
Habitat Patches Surveyed

Path: I:\QENV2\Projects\QE06601\QE06601.280 Spatial\ArcGIS\Figures\Draft\Ecology\Fauna\130503_NathanDam_Ecology_Figure3-5_Southend_HabitatPatchesSurveyed.mxd Produced: 29/05/2013



LEGEND

- Live Snails Found
- Dead Snails Found
- Shells Found
- Suitable Habitat, Searched

Projection: GDA94 Zone 56

Figure 3-6

0 20 40 80
Metres
N

Scale 1:2,500 (at A4)

SKM SunWater Making Water Work

NATHAN DAM AND PIPELINES
SUPPLEMENTARY EIS REPORT

Nardoo -
Habitat Patches Surveyed

Path: I:\QENV2\Projects\QE06601\QE06601.280 Spatial\ArcGIS\Figures\Draft\Ecology\Fauna\130503_NathanDam_Ecology_Figure3-6_Nardoo_HabitatPatchesSurveyed.mxd Produced: 30/05/2013

LEGEND

- Live Snails Found
- Dead Snails Found
- Shells Found
- Suitable Habitat, Searched

Projection: GDA94 Zone 56

Figure 3-7

0 20 40 80
Metres
N

Scale 1:4,000 (at A4)

SKM SunWater Making Water Work

NATHAN DAM AND PIPELINES
SUPPLEMENTARY EIS REPORT

Kia Ora -
Habitat Patches Surveyed

Path: I:\QENV2\Projects\QE06601\QE06601.280 Spatial\ArcGIS\Figures\Draft\Ecology\Fauna\130503_NathanDam_Ecology_Figure3-7_KiaOra_HabitatPatchesSurveyed.mxd Produced: 29/05/2013

3.2.2 Search Effort

A team of four field ecologists completed active searching over a total of 10 days (18–24 March, 2–10 April and 21–25 April 2013). A total of 258 hours of active searching was completed. The search effort for each site varied due to differences in the area of the habitat patches within each site and differences in the number of microhabitats available within each patch. Each patch was surveyed with the same amount of 'effort'; however a larger patch with a greater number of suitable microhabitat features obviously took longer to survey than a smaller habitat patch with less available suitable microhabitats. The total search effort for each site, in person hours, is shown in **Table 3.4**. The proportion of available habitat surveyed was calculated by assessing the 2013 search area against the total area of the site presented in previous studies (SKM 2009, JKR Ecological 2011 in particular).

Table 3.4 Search Effort by Site

Survey Site	Search Effort (Person Hours)	Proportion of Available Habitat Surveyed (%)
Mt Rose	96	100%
Gyranda	18	1.3%
Isla Delusion	52	1.8%
Southend	32	3.7%
Nardoo	32	0.5%
Kia Ora	28	33.0%
TOTAL Search Effort	**258**	

3.2.3 Search Results

Live boggomoss snails were recorded at five of the six survey sites. Snails were not recorded at Gyranda. This survey recorded a total of 152 live boggomoss snails. This includes:

- 3 adults at Mt Rose
- 4 adult, 3 sub-adult and 1 hatchling at Isla Delusion
- 5 adult, 6 sub-adult and 3 juveniles at Southend
- 25 adult, 76 sub-adult and 24 juveniles at Nardoo
- 2 adults at Kia Ora.

The search results for each habitat patch surveyed are shown in **Table 3.5**.

Table 3.5 Search Results by Site and Patch

Survey Site	Habitat Patch	Live Boggomoss Snails
Mt Rose	Patch 1	3 adult
	Patch 2	0
	Patch 3	0
	Patch 4	0
	Patch 5	0

Survey Site	Habitat Patch	Live Boggomoss Snails
	Patch 6	0
	SUBTOTAL (Mt Rose)	**3**
Gyranda	Patch 1	0
	Patch 2	0
	Patch 3	0
	Patch 4	0
	SUBTOTAL (Gyranda)	**0**
Isla Delusion	Patch 1	0
	Patch 2	2 (1 adult, 1 hatchling)
	Patch 3	2 (1 adult, 1 sub-adult)
	Patch 4	3 (1 adult, 2 sub-adult)
	Patch 5	1 adult
	Patch 6	0
	Patch 7	0
	Patch 8	0
	Patch 9	0
	Patch 10	0
	Patch 11	0
	Patch 12	0
	SUBTOTAL (Isla Delusion)	**8**
Southend	Patch 1	7 (3 adult, 3 sub-adult, 1 juvenile)
	Patch 2	3 (1 adult, 1 sub-adult, 1 juvenile)
	Patch 3	0
	Patch 4	0
	Patch 5	1 adult
	Patch 6	2 sub-adult
	Patch 7	1 juvenile
	Patch 8	0
	SUBTOTAL (Southend)	**14**
Nardoo	Patch 1	13 (3 adult, 10 sub-adult)
	Patch 2	0
	Patch 3	36 (4 adult, 12 sub-adult, 20 juvenile)
	Patch 4	5 (1 adult, 4 sub-adult)
	Patch 5	28 (8 adult, 16 sub-adult, 4 juvenile)
	Patch 6	43 (9 adult, 34 sub-adult)
	SUBTOTAL (Nardoo)	**125**
Kia Ora	Patch 1	0

Survey Site	Habitat Patch	Live Boggomoss Snails
	Patch 2	0
	Patch 3	0
	Patch 4	0
	Patch 5	0
	Patch 6	0
	Patch 7	0
	Patch 8	2 adult
	SUBTOTAL (Kia Ora)	**2**
TOTAL		**152**

A total of 2316 microhabitats were searched throughout the entire survey. The number of live snails per microhabitat searched per site searched is shown in **Figure 3.8**.

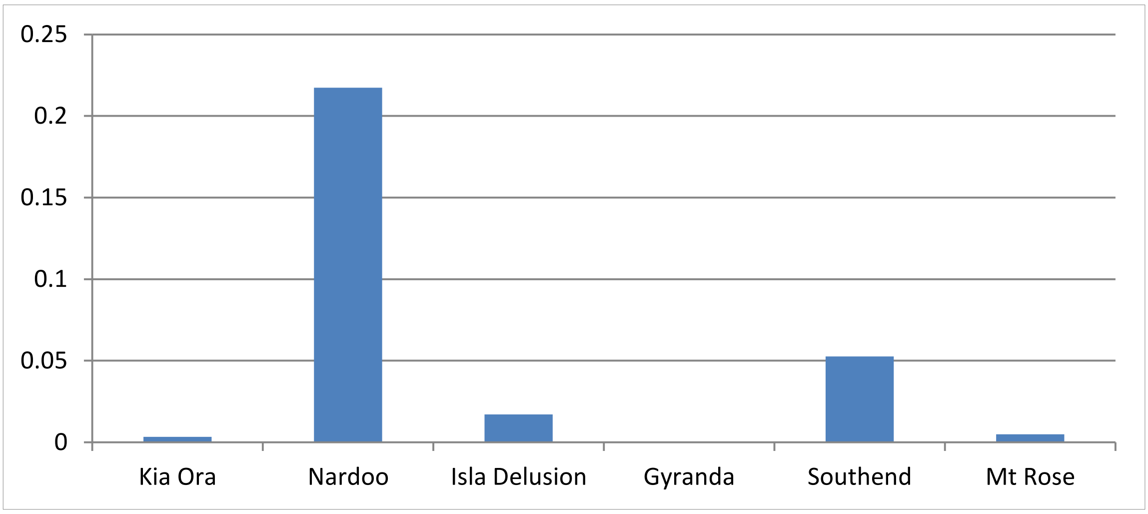


Figure 3.8 Number of Live Snails Per Microhabitat Searched for Each Site

Whilst the number of live snails recorded per microhabitat was clearly significantly higher at Nardoo than at other sites, the magnitude of difference is noteworthy.

The number of live snails recorded per person hour searched (a measure of catch per unit effort or CPU) for each site is shown in **Table 3.6**. Approximately 14 times the number of snails per search hour was recorded at Nardoo compared to Mt Rose. This is indicative of a much higher density of snails, and given the size of the habitat patch, a much larger population.

Table 3.6 Number of Live Snails Per Person Hour Searched for Each Site

Survey Site	Snails recorded per person hour searched
Mt Rose	0.03
Gyranda	0
Isla Delusion	0.15
Southend	0.43
Nardoo	3.9

Kia Ora	0.07

Table 3.7 shows that the number of snails per hectare was clearly highest at Nardoo followed by Southend and Isla Delusion.

Table 3.7 Number of Live Snails Recorded Per Hectare

Survey Site	Area Intensively Sampled (ha)	Snails per Hectare	Total Area of Habitat at Site (ha)	Proportion of Site Surveyed
Mt. Rose	2.408	13.3	2.4 *	100%
Gyranda	0.089	0	7.1 (JKR Ecological 2011)	1.3%
Isla Delusion	0.532	45.1	14.4 (JKR Ecological 2011)	1.8%
Southend	0.244	135.2	16.64 (JKR Ecological 2011)	3.7%
Nardoo	0.254	496.1	55 (from air photo interpretation, this study)	0.5%
Kia Ora	1.167	4.2	3.54 (SKM 2009)	33.0%

* The area of habitat at Mt Rose has previously been reported as 0.75 ha by BAAM (2009). This study includes the area of terrestrial habitat at Mound Springs 14, 15 and 16 combined.

3.3 Combined Results 2009–2013

The combined search results (regional locations with recorded live snails) by site from surveys throughout 2008–2013, and Ingram & Stanisic (1997) are presented in **Attachment 1**. A significant result from the 2013 survey is that the total number of live snails recorded at Nardoo exceeded the total number of live snails recorded across all previous studies.

4. DISCUSSION

4.1 Impact of Flood Events

JKR Ecological (2011) and EcoSM (2012) discussed the potential impact of consecutive flood events in 2010 and 2011 on populations of the boggomoss snail. These floods are significant in a historical context, with only two larger events on record, both from pre 1900 (1870 and 1890).

It does not require floods that large to inundate all of the boggomosses on which snails have been recorded at Mt Rose, of which Boggomoss 14 has the highest elevation (176.27 m AHD). Historical water level data covering the period 1920 to 2013 at three flood gauges (130303A, 130303B and 130338A) near Glebe Weir record 10 flood events that would have inundated Boggomoss 14 (and the other boggomosses), with an average duration of three days per event. The average interval between flood events large enough to inundate Boggomoss 14 is 9.3 years.

The consecutive floods of 2010 and 2011 may have led to a reduction in the availability of suitable microhabitat within all sites known to have historically supported the boggomoss snail. It is likely that the leaf litter will take some time to re-accumulate. It is also likely that the snails too were washed away with the floodwaters.

The snails recorded at Mt Rose were found under flood debris on the highest point of the mound spring. Two were under a single pile of leaf litter and one was under a small log amongst accumulated leaf litter and flood debris. These debris piles were not associated with trees or large logs and were effectively out in the open, albeit beneath a blue gum canopy. The availability of suitable microhabitats at Mt Rose has recovered somewhat post flooding, particularly the availability of leaf litter beneath sandpaper figs. The floods however are certainly a major impacting influence on individual boggomoss snails and their habitat.

A proportion of the boggomoss snail population within flood affected habitat is likely to survive flooding impacts. For example, the three live adult snails found at Mt Rose were located in an area which had been inundated to a depth of at least 1.5 m for an extended period of time based on the height of flood debris in the branches of canopy vegetation. As described by JKR Ecological (2011), this survivorship of adult snails indicates that riparian sub-populations can and do survive major floods. Although evidence suggests that the snails can survive major floods, it is likely that sustained impacts will lead to a profound impact on population size and fecundity. Given the search effort at Mt Rose during the current survey, it is unlikely that a significant number of snails exist at the site but were not observed during survey. As the species is likely hermaphroditic, the persistence of a small number of adults suggests potential for the population to expand, however, no evidence of recruitment to the Mt Rose population was evident, with all specimens recorded being adult snails (**Plate 8**). Recovery would also need the small number of individuals remaining to not succumb to predation, fire, or an additional flood event.

It is also plausible that the population at this site was stable throughout the drought period, and that the moist environment near the mound spring afforded the species protection from the chronic impacts of the drought.

Gyranda, a site known to have supported the species pre 2010, was not found to support the boggomoss snail in 2013. This site exhibited significant degradation due to flooding, pig damage and weed invasion since first visited in 2009. Prolonged inundation upstream of Gyranda weir has resulted in attrition of canopy trees and subsequent thinning of the tree canopy.

It is considered likely that population numbers at other sites were reduced by major floods in 2010–2011 and have recovered over the past wet season at most sites. For example at Isla Delusion the CPU (snails per search hour) has been:

- Pre-flood = 0.57 (SKM 2009)
- Post-flood = 0.04 (EcoSM 2012)
- Recovery = 0.15 (AMEC 2013).

Plate 8 Adult Boggomoss Snail, Mt Rose Station

4.2 Snail Populations

JKR Ecological (2011) reviewed population structure from available data. Key features of that analysis have been updated as follows:

- BAAM (2009) observed no live adults of the boggomoss snail in their sample of Mt Rose Boggomoss site 14. The vast majority of records were of juvenile snails, with two sub-adult snails recorded. This may be indicative of very high juvenile and sub-adult mortality or an artefact of sampling bias away from the preferred habitats of adult boggomoss snails (although the current study found that all life stages co-occur in the same habitats and microhabitats). The current study recorded only adult snails, suggesting that there has been limited or no recruitment since the last survey or since the floods.

- SKM (2009) found a high proportion of live adults, smaller proportion of sub-adults and no live juveniles in their sample of Southend, Kia Ora and Isla-Delusion. The high proportion of adults indicated a high reproductive potential although the lack of juveniles suggested that breeding had not occurred immediately prior to the sampling event. The presence of live sub-adults at Southend, Kia Ora and Isla-Delusion indicated survival over the 12 months post-hatching and prior to the sampling event. The current study found a higher proportion of sub-adult and juvenile snails at Southend and Isla Delusion, suggesting strong recruitment to these populations.
- JKR Ecological (2011) found live adults and sub-adult snails in additional habitat patches on Southend. The fact that this habitat had been inundated for an extended period of time during recent flooding suggested persistence of the boggomoss snail in the riparian and floodplain zones of the Dawson River despite the impacts of flooding.
- The population structure at Nardoo suggests a high rate of survivorship, with 19% of snails recorded juveniles, 60% sub-adults and 21% adults. This suggests repeated years of successful breeding despite the floods.

Early reports regarded Boggomoss 14 at Mt Rose as a significant population centre and small numbers of snails were also recorded on one occasion at two nearby sites. Intensive survey of all three sites during the current survey yielded only three live snails at one site (the original Site 14). All live snails recorded at this site were adults. As all potential microhabitats were searched, the total population size at Mt Rose is extremely small.

The findings of this survey also show that there are other more significant populations of the species, all of which are located a significant distance downstream of the proposed Nathan Dan area. A range of age classes were observed at multiple patches within three sites; Isla Delusion, Southend and Nardoo.

Searching at Nardoo found a total of 125 snails (adults, sub-adults and juveniles). This is the greatest number of live specimens ever recorded from a single habitat and 60% of all boggomoss snails ever collected. It was also a good catch per unit effort. Considering that only a very small portion of the available suitable habitat at Nardoo was searched (0.2 ha of an estimated 55 ha site), it is likely that the total population of the species at this site is much greater.

In terms of the total proportion of each site surveyed, Mt. Rose is considered to have been comprehensively sampled, whereas the larger sites largely remain relatively under-sampled. It is considered highly probably that they support much larger populations of boggomoss snails than actually recorded by surveys completed to date.

Breeding of the boggomoss snail usually occurs during the wet season. The 2011/2012 wet season prior to the current survey is likely to have resulted in breeding. Juvenile and hatchling snails observed during the current surveys are likely to represent the outcome of this breeding so are likely to be less than several months of age. As such it can reasonably be concluded that successful breeding and recruitment continues to occur at Isla Delusion, Southend and Nardoo. Considering all age cohorts were recorded at these three sites, it can be presumed that repeated seasonal breeding is occurring.

5. SUMMARY AND SIGNIFICANCE OF RESULTS FOR THE CONSERVATION OF THE SPECIES

During this study, live boggomoss snails were found at five sites known to historically support the species (Mt Rose, Isla Delusion, Southend, Nardoo and Kia Ora).

Within the Nathan Dam and Pipelines Project area, just three adult boggomoss snails were found at Mt Rose Station in a single patch of habitat of approximately 1 ha. Given the search intensity undertaken across the entire area of available habitat at the Mt Rose site, it can be concluded that the population is extremely small. Moreover, the habitat available at Mt Rose is restricted to a single, small and very isolated patch of vegetation surrounding one mound spring. As this population cannot be replenished by populations upstream, the long term probability of extinction of the species at Mt Rose is higher than at other known sites. Genetic suppression (lack of genetic diversity), although not a documented threat to the species, may be a long term conservation issue at this site because the population is so small. Threatening processes such as pig rooting, invasion of grassy species, predation by introduced rodents and a high fire risk are also likely to place this remnant population under pressure.

The long term sustainability of this population is very questionable. Major habitat areas for the boggomoss snail are located downstream of the proposed Project area with no sites of occupancy known or expected upstream. Several downstream areas support robust populations of the species within relatively extensive areas of vegetation. At least three downstream sites currently support breeding populations. The density of live snails observed at one site, Nardoo, vastly exceeds that observed in any previous study and emphasises the significance of habitats located between Isla Delusion Crossing and Theodore to the on-going conservation of the species. It also shows that the more we look in these downstream areas, the more we find and there remain significant areas of likely suitable habitat within the riparian zone of the Dawson River or anabranches that have never been searched (these are evident on the figures in this report).

Given the severity of recent flooding and the evidence of continued successful breeding at these downstream sites, the populations appear relatively secure.

Conservation efforts should therefore focus on sites downstream of the proposed Nathan Dam, where confirmed breeding populations are present within relatively large areas of habitat. It is also suggested that the proposed mitigation strategy of translocation of the remaining individuals at Mt Rose would be in the best interests of those individuals. However given the very low number of individuals, the plan to establish separate populations is unlikely to be viable and it may be more prudent to consider translocating them to join an existing downstream population.

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ATTACHMENT 1 – RAW DATA FOR REGIONAL LOCATIONS WITH RECORDED LIVE SNAILS, ALL SURVEYS 2008–2013, AND INGRAM & STANISIC (1997)

Regional Location	Property Name / Site	Site Reference Number	Coordinates	Survey: Organisation (Year)	Survey Intensiveness (person hours)	Adult	Sub-Adult	Juvenile	Total (live)	Adult (dead)	Sub-Adult (dead)	Juvenile (dead)	Total (dead)	Total (combined)
Theodore	Dawson River Anabranch (Leichhardt Highway - near weir)	VH2	S:24°56'12.54" E:150°3'0.994"	SKM (2009)	1				0	1			1	1
		18		BAAM (2008)	4				0				0	0
Kia Ora	Kia Ora (Leichardt Highway)	DF35	S:25°01'32.7" E:150°07'14.3"	SKM (2009)	1				0	2			2	2
	Kia Ora (Leichardt Highway)	DF36	S:25°01'16.5" E:150°07'01.7"	SKM (2009)	2	1		1	2	2			2	4
	Kia Ora (Dawson River)	DF37	S:25°01'17.4" E:150°06'47.5"	SKM (2009)	1	1			1				0	1
	Kia Ora	D8, Vh1, VH12, Vh13, VH22, VH23, DF29, DF30, DF31		SKM (2009)	9.8				0				0	0
	Kia Ora	Patch 1	S:25°01'19.07" E:150°06'53.80"	Amec (2013)	28*				0				0	0
	Kia Ora	Patch 2	S:25°01'16.64" E:150°07'2.11"	Amec (2013)					0				0	0
	Kia Ora	Patch 3	S:25°01'12.94" E:150°07'4.78"	Amec (2013)					0				0	0
	Kia Ora	Patch 4	S:25°01'7.15" E:150°06'58.61"	Amec (2013)					0				0	0
	Kia Ora	Patch 5	S:25°01'14.55" E:150°06'51.03"	Amec (2013)					0				0	0
	Kia Ora	Patch 6	S:25°01'13.36" E:150°06'49.99"	Amec (2013)					0				0	0
	Kia Ora	Patch 7	S:25°01'11.92" E:150°06'43.67"	Amec (2013)					0				0	0
	Kia Ora	Patch 8	S:25°01'13.88" E:150°06'42.85"	Amec (2013)		2			2				0	2
Nardoo	Carnarvon Palm Woodland	12-4	S: 25°5'29.6", E: 150°7'38.7"	ECOSM (2012)	6	1			1				0	1
	Nardoo	DH10		SKM (2009)	1				0				0	0
	Nardoo	Patch 1	S: 25°05'22.96" E: 150°07'31.66"	Amec (2013)	32*	3	10		13				0	13
	Nardoo	Patch 2	S: 25°05'23.28" E: 150°07'32.62"	Amec (2013)					0				0	0
	Nardoo	Patch 3	S: 25°05'22.76" E: 150°07'36.01"	Amec (2013)		4	12	20	36				0	36
	Nardoo	Patch 4	S: 25°05'23.35" E: 150°07'40.21"	Amec (2013)		1	4		5				0	5
	Nardoo	Patch 5	S: 25°05'26.97" E: 150°07'37.83"	Amec (2013)		8	16	4	28		2		2	30
	Nardoo	Patch 6	S: 25°05'26.76" E: 150°07'38.82"	Amec (2013)		9	34		43		1		1	44
	Nardoo	12-5		ECOSM (2012)	6				0				0	0
Southend	Southend	D14	S: 25°7'34.5", E: 150°8'13.2"	SKM (2009)	2	2	4		6	12			12	18
	Southend (northern portion)	D15	S: 25°07'01.9" E: 150°08'27.6"	SKM (2009)	1	1			1				0	1
	Southend (northern portion)	D16	S: 25°06'42.5" E: 150°08'18.9"	SKM (2009)	1	1			1	3			3	4
	Southend	VH24	S: 25°7'34.5", E: 150°8'13.2"	SKM (2009)	2			2 (H)	2	5			5	5
	Southend	VH25	S: 25°7'9.06", E: 150°8'34.3"	SKM (2009)	1	2			2	2			2	4

Regional Location	Property Name / Site	Site Reference Number	Coordinates	Survey: Organisation (Year)	Survey Intensiveness (person hours)	Adult	Sub-Adult	Juvenile	Total (live)	Adult (dead)	Sub-Adult (dead)	Juvenile (dead)	Total (dead)	Total (combined)
Southend (continued)	Anabranch of Dawson River on Southend	Ad9	S: 25°6'54.12", E: 150°7'40.7"	JKR (2010)	4	1			1				0	1
	Southend (ephemeral wetland)	Ss12	S: 25°6'51.6", E: 150°7'57.8"	JKR (2010)	4	5	1		6	2	2		4	10
	Southend	12-6		ECOSM (2012)	6				0				0	0
	Southend	Patch 1	S: 25°7'1.68", E: 150°8'27.51"	Amec (2013)	32*	3	3	1	7		1		1	8
	Southend	Patch 2	S: 25°7'0.60", E: 150°8'27.18"	Amec (2013)		1	1	1	3				0	3
	Southend	Patch 3	S: 25°7'4.21", E: 150°8'29.56"	Amec (2013)					0				0	0
	Southend	Patch 4	S: 25°7'9.18", E: 150°8'32.97"	Amec (2013)					0				0	0
	Southend	Patch 5	S: 25°7'9.98", E: 150°8'32.93"	Amec (2013)		1			1				0	1
	Southend	Patch 6	S: 25°7'16.87", E: 150°8'39.65"	Amec (2013)			2		2				0	2
	Southend	Patch 7	S: 25°7'32.02", E: 150°8'14.23"	Amec (2013)				1	1				0	1
	Southend	Patch 8	S: 25°7'43.92", E: 150°8'22.91"	Amec (2013)					0				0	0
South of South End		D13	S: 25°08'21.5" E: 150°08'35.2"	SKM (2009)	1				0	1	1		2	2
		JR16	S: 25°09'03", E: 150°09'08"	SKM (2009)	1	1			1				0	1
		D12, VH15		SKM (2009)	2				0				0	0
Isla Delusion	Dawson River crossing on the Isla-Delusion Rd: Known Boggomoss Snail locality	AD4	S: 25°10'52.1394", E: 150°11'0.1674"	Ingram and Stanisic (1997)	4	2	4		6		4		4	10
	Dawson River environs upstream of stock and camping reserve	8	S: 25°12'29.16", E: 150°12'9.3594"	BAAM (2009)	90		1		1		4		4	5
	Dawson River crossing on the Isla-Delusion Rd: Known Boggomoss Snail locality	11	S: 25°10'52.1394", E: 150°11'0.1674"	BAAM (2009)	16		3		3				0	3
	Isla Delusion: Livistona woodland on Dawson River	JR18	S: 25°10'31", E: 150°10'42"	SKM (2009)	1	2	1		3	5			5	8
	Isla Delusion: Livistona nitida woodland on anabranch of Dawson River	JR19	S: 25°05'38" E: 150°09'07"	SKM (2009)	14	8			8	13			13	21
	Isla-Delusion Crossing	12-7	S: 25°10'27", E: 150°10'37.3"	ECOSM (2012)	25	1			1		1		1	2
	Isla-Delusion camping reserve	Not stated	Unkown	BAAM (2012)	6	0	0	0	0	0	0	0	0	0
	Isla-Delusion	Patch 1	S: 25°10'48.71" E: 150°11'2.84"	Amec (2013)	52*				0				0	0
	Isla-Delusion	Patch 2	S: 25°10'42.73" E: 150°10'57.30"	Amec (2013)		1		1 (H)	2					2
	Isla-Delusion	Patch 3	S: 25°10'45.27" E: 150°10'58.90"	Amec (2013)		1	1		2				0	2
	Isla-Delusion	Patch 4	S: 25°10'46.02" E: 150°11'1.89"	Amec (2013)		1	2		3				0	3
	Isla-Delusion	Patch 5	S: 25°10'47.19" E: 150°11'0.97"	Amec (2013)		1			1				0	1
	Isla-Delusion	Patch 6	S: 25°10'49.85" E: 150°11'5.98"	Amec (2013)					0				0	0

Regional Location	Property Name / Site	Site Reference Number	Coordinates	Survey: Organisation (Year)	Survey Intensiveness (person hours)	Adult	Sub-Adult	Juvenile	Total (live)	Adult (dead)	Sub-Adult (dead)	Juvenile (dead)	Total (dead)	Total (combined)
Isla Delusion (continued)	Isla-Delusion	Patch 7	S: 25°10'51.07" E: 150°11'11.26"	Amec (2013)					0				0	0
	Isla-Delusion	Patch 8	S: 25°10'53.65" E: 150°11'22.91"	Amec (2013)					0				0	0
	Isla-Delusion	Patch 9	S: 25°10'42.97" E: 150°10'39.78"	Amec (2013)					0				0	0
	Isla-Delusion	Patch 10	S: 25°10'41.25" E: 150°10'36.78"	Amec (2013)					0				0	0
	Isla-Delusion	Patch 11	S: 25°10'55.27" E: 150°11'2.60"	Amec (2013)					0				0	0
	Isla-Delusion	Patch 12	S: 25°10'57.41" E: 150°11'8.22"	Amec (2013)					0				0	0
	Isla-Delusion	Site 9, 10, 12, 13, 19		BAAM (2009)	34				0				0	0
Gyranda	Gyranda (east bank)	D2	S: 25°18'07.5" E: 150°09'46.8"	SKM (2009)	1				0	1			1	1
	Gyranda (west bank)	D3	S: 25°18'27.6" E: 150°09'35.1"	SKM (2009)	1				0	2			2	2
	Gyranda (west bank)	D4	S: 25°18'55.7" E: 150°10'12.2"	SKM (2009)	2	1			1	3			3	4
	Gyranda (east bank north of weir)	D5	S: 25°16'14.8" E: 150°10'27.6"	SKM (2009)	1				0	1			1	1
	Gyranda	Patch 1	S: 25°18'32.92" E: 150°09'43.23"	Amec (2013)	18*				0				0	0
	Gyranda	Patch 2	S: 25°18'20.37" E: 150°09'34.36"	Amec (2013)					0				0	0
	Gyranda	Patch 3	S: 25°18'17.00" E: 150°09'29.11"	Amec (2013)					0				0	0
	Gyranda	Patch 4	S: 25°18'20.37" E: 150°09'31.05"	Amec (2013)					0				0	0
	Gyranda	D1, D6, D7		SKM (2009)	3				0				0	0
Nathan Gorge	Nathan Gorge (Cabbagetree Creek)	D11	S: 25°25'42" E: 150°10'14.8"	SKM (2009)	1	3	1		4	2			2	6
		D19, D20		SKM (2009)	5				0				0	0
				Ingram and Stanisic (1997)	2				0				0	0
		1		BAAM (2012)	8				0				0	0
		Not stated	Unkown	BAAM (2012)	1	0	0	0	0	0	0	0	0	0
Mt Rose Boggomoss		BS17	S: 25°27'8.4594", E: 150°1'42.528"	Ingram and Stanisic (1997)	20	2	10		12	2	45	7	54	66
		14	S: 25°27'8.4594", E: 150°1'42.528"	BAAM (2009)	12		2	20	22	41	130	38	209	231
		15	S: 25°27'7.92", E: 150°1'14.88"	BAAM (2009)	4		1	2	3				0	3
		16	S: 25°27'22.6794", E: 150°1'16.3194"	BAAM (2009)	4		2	2	4				0	4
		12-10	S: 25°27'8.4594", E: 150°1'42.528"	ECOSM (2012)	14				0	20			20	20
		Not stated	Unkown	BAAM (2012)	13	0	0	0	0	80	0	0	80	80
		Patch 1	S: 25°27'8.36", E: 150°1'44.87"	Amec (2013)	96*	3			3				0	3
		Patch 2	S: 25°27'5.59", E: 150°1'12.93"	Amec (2013)					0				0	0

Regional Location	Property Name / Site	Site Reference Number	Coordinates	Survey: Organisation (Year)	Survey Intensiveness (person hours)	Adult	Sub-Adult	Juvenile	Total (live)	Adult (dead)	Sub-Adult (dead)	Juvenile (dead)	Total (dead)	Total (combined)
Mt Rose Boggomoss (continued)		Patch 3	S: 25°27'27.20", E: 150°1'18.16"	Amec (2013)					0				0	0
		Patch 4	S: 25°27'32.86", E: 150°1'43.33"	Amec (2013)					0				0	0
		Patch 5	S: 25°27'15.94", E: 150°1'40.97"	Amec (2013)					0				0	0
		Patch 6	S: 25°27'12.95", E: 150°1'34.86"	Amec (2013)					0				0	0
		Site 12-12, 12-11		ECOSM (2012)	3.5				0				0	0
		BS 8, 17, 18, 20, 21, 22, 23, 60		Ingram and Stanisic (1997)	8				0				0	0
20km (approx) south of Mt Rose Boggomoss	Tributary of the Dawson River located upstream of the proposed dam wall.	BS40	S: 25°34'3.864", E: 150°4'15.5634"	Ingram and Stanisic (1997)	4				0		1		1	1
Total					**612**	74	115	52	**244**	200	192	45	**437**	**679**

H - Hatchling
* survey intensiveness across patches