Tootanellup Wetland suite

Ecological Investigation of Boggy Lake and Tootanellup Lagoon with comments on adjacent wetlands

Report prepared for Green Skills Inc, Denmark WA.

by Steve & Geraldine Janicke

March 2022

This project is supported by

Australian Government | National Landcare Programme
SOUTHCOAST Natural Resource Management Inc
Green Skills Inc
lotterywest supported
birdlife Western Australia
Denmark Bird Group
Janicke Environmental Assessments
gondwana link
The Koorabup Trust – A private fund for environmental and sustainability projects

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For bibliographical purposes this report should be cited as:

Janicke S. and Janicke, G. (2022) *Tootanellup Wetland Suite; Ecological Investigation of Boggy Lake and Tootanellup Lagoon with comments on adjacent wetlands.* Report prepared for Green Skills Inc., Denmark WA.

Cover photo: Students from South Regional TAFE and volunteers learning about water quality at the edge of Boggy Lake, 10 February 2022.

All photos are by Steve and Geraldine Janicke or Basil Schur.

Acknowledgements

The authors would like to thank the following for their support: Basil Schur of Green Skills Inc., citizen science volunteers and Sylvia Leighton and Harriet Paterson with their students from South Regional TAFE, Birdlife WA, Denmark Bird Group, and individual volunteers including Loxley Fedec, David Wettenhall, Sarah Pozzi, Robyn Pickering, Angela and Andrew Dickinson, John and Kirsty Anderson, Brad Kneebone, Mike Oakley and others.

The Green Skills' program involving a Climate Change related assessment of the Tootanellup wetlands is supported by South Coast Natural Resource Management Inc., through funding from the Australian Government's National Landcare Programme as well as Janicke Environmental Assessments. Gondwana Link Ltd, Birdlife Western Australia, the Denmark Bird Group and the Koorabup Trust. It also formed part of Green Skills' and BirdLife WA's Festival of Birds & Biodiversity 2022 program supported by Lotterywest and Birdlife WA. Green Skills also acknowledges the technical and scientific information and advice provided on wetlands by Ruhi Ferdowsian and Don McFarlane.

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Introduction

In October 2020 Green Skills Inc. purchased Lot 2249 Rocky Gully Road, which is between Rocky Gully and Frankland River, in the Upper Kent catchment in Western Australia. The 49.5 ha (122 acres) property has about 18ha of remnant bush and 31.5ha of cleared land. The property is a strategic link between the Tootanellup Nature Reserve, and a WA Department of Water (DWER) reserve which encompasses Boggy Lake, which in turn is part of a group of 3 freshwater wetlands of very high conservation value.

Green Skills saw the opportunity to be involved in improved management of adjoining Boggy Lake reserve, which is land held by the WA Government for water catchment protection, and other bushland reserves and remnant vegetation on farmland in the area. Permission had been granted to Green Skills to undertake bird and other environmental surveys, and seed collecting on the adjoining Boggy Lake property. In particular, Green Skills is partnering with BirdLife Western Australia and the Denmark Bird Group to undertake regular surveys at Boggy Lake and adjacent wetlands to ascertain the presence of Australasian Bitterns. To assist with planning and management of these wetlands in a time of climate change, a range of investigative surveys and projects were undertaken for the Boggy Lake/Tootanellup area.

A preliminary survey of Boggy Lake and the adjacent wetlands on the DWER reserve was conducted on 24 October 2021 with the help of Basil Schur and several citizen science volunteers. Locations and names of the wetlands surveyed are shown in Figure 1 and Table 1: Locations and names of wetlands surveyed.

The preliminary survey for six wetlands included:

- Water quality parameters (salinity, pH, temperature, turbidity). The other water bodies or wetlands encountered were also be measured.
- Macroinvertebrate sweep of six wetlands preserved with specimens in 75% ethanol and identified to the lowest taxonomic level possible.
- Riparian assessment with respect to and wetland condition.

The preliminary survey was preparation for the wetland BioBlitz in February 2022. The aims of the wetland BioBlitz were to document the biodiversity of the site and to assess what risks the wetlands may be under from salinity etc and to consider possible management action.

The BioBlitz was conducted on 10 February 2022 and included:

- Water quality parameters (salinity, pH, temperature, turbidity) for Boggy Lake and Tootanellup Lagoon
- Macroinvertebrate sweep of the two wetlands with specimens preserved in 75% ethanol and identified to the lowest taxonomic level possible.
- Sharing data and understanding of the wetlands with the Great Southern TAFE students and other volunteers.

Other activities conducted on the day included mapping *Macrozamia riedliei* (Zamia cycad), potential Cockatoo nesting tree locations, recording of biota on iNaturalist and monitoring of marsupial nest boxes on the Green Skills Tootanellup property.

Location

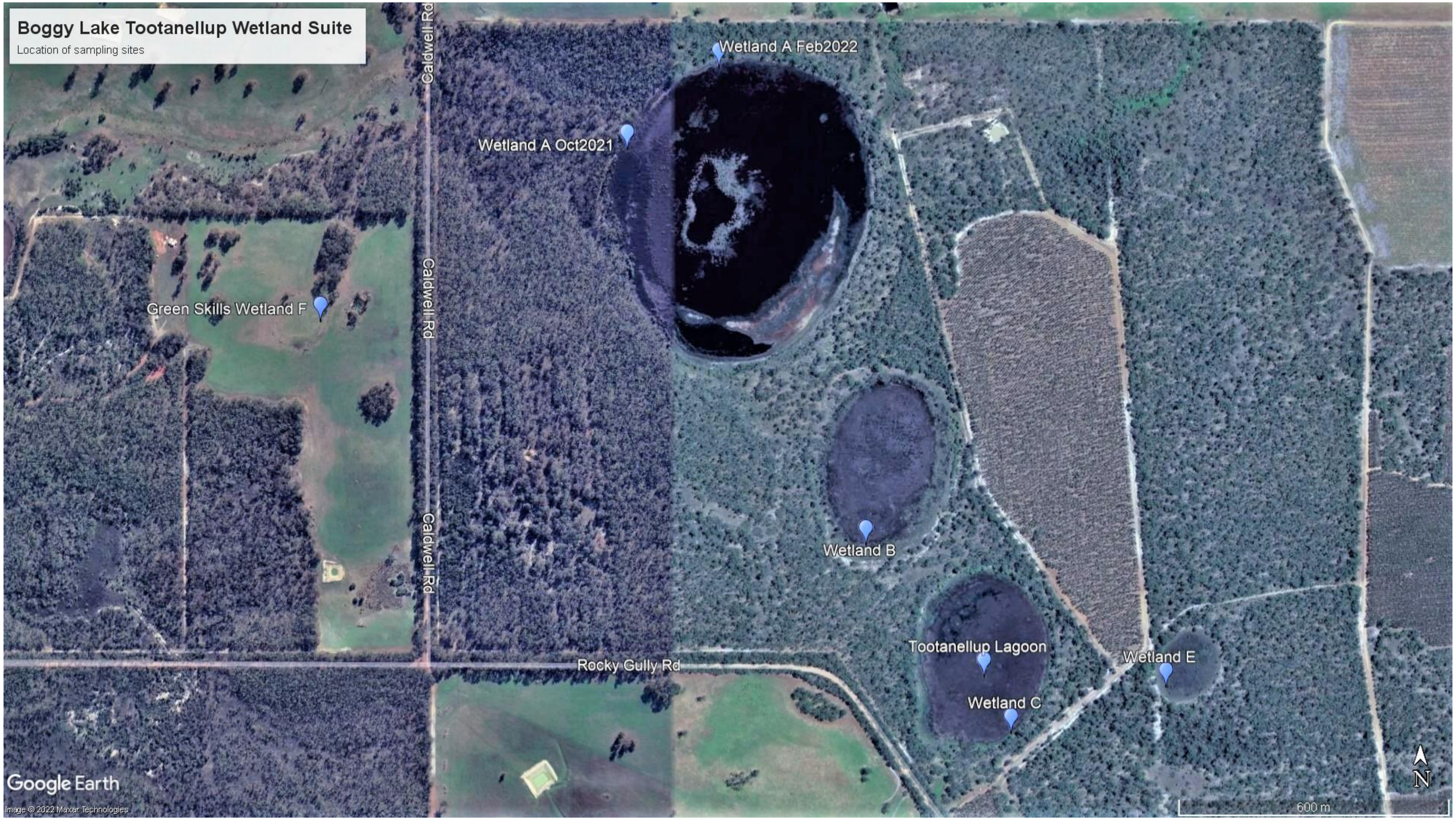


Figure 1: Locations and names of wetlands surveyed.

Figure 2: Boggy Lake and Tootanellup Lagoon suit of wetlands with 2m interval contours.

Table 1: Locations and names of wetlands surveyed. (UTM zone 50)

Label	Wetland name	Easting	Northing	Latitude	Longitude	Altitude	Depth at sampling (m)	General comments
Wetland A	Boggy Lake	513554	6185500	34° 28' 19.1"	117° 08' 51.3"	221 m	0.8	Sampling site in October 2021
		513559	6185481	34°28' 19.72"	117° 8' 51.56"		0.4	Sampling site in February 2022
Wetland B	Wetland B	514076	6184565				0.3	Similar to Tootanellup Lagoon. The lunette with a well-defined wetland edge.
Wetland C	Tootanellup Lagoon	514425	6184190				0.5	Bank gradient relatively steep at sampling site.
Wetland D	Wetland D	514750	6184288	34° 28' 58.4	117° 09' 38.3"	235 m	0.2	Ephemeral playa wetland
Wetland E	Wetland E	514703	6183878	34° 29' 11.7"	117° 09' 36.5"	240 m	0.2	Ephemeral playa wetland
Wetland F	Green Skills Tootanellup	512907	6185144	34° 28' 30.7"	117° 08' 26.0"	220 m	0.3	Within a cleared paddock being revegetated

General Observations

Table 2: Observations during the preliminary survey 24 October 2021

	Wetland A Boggy Lake	Wetland B Wetland B	Wetland C Tootanellup Lagoon	Wetland D Wetland D	Wetland E Wetland E	Wetland F Green Skills Tootanellup
Animals	Purple swamphen, Musk duck calling. 2 spp frog observed 3 spp Odonates		2 leaches, one released. large tadpole released	3 tadpoles released	5 small and 1 large tadpole released	Large number of ducks dominated by black ducks but including Shoveler, Grebe, Mtn Duck, Black duck
Plants	Patches of *B. articulata* within lake B. juncea and other sedges around edges E rudis, Flooded Gum dominant tree around edges. Healthy saplings Large Cotula and Triglochin seen.	Dense B. articulata appears to cover whole wetland B. juncea and other sedges around edge. Scattered E. rudis, flooded gum with seedlings in waters edge E. calophylla dominant tree around upslope edge Cycads (not very large) on lunette Banksia littoralis scattered around edge Several Viminea swish bushes in water's edge	Dense B. articulata appears to cover whole wetland Baumea juncea and Cotula asiatica around edge Scattered Melaleuca preissii around the edge Occasional cycads upslope Banksia littoralis scattered around edge	Melaleuca lateritica and M. viminea within wetland basin, inundated. Dominated by Baumea juncea with some B. vaginalis but a range of other sedge spp. Present Scattered Melaleuca preissiana and Banksia littoralis around edge E. calophylla dominant tree around upslope edge Scattered Triglochin in the water	M. preissiana, M. rhaphiophylla and M. lateritica scattered throughout wetland or in clumps Many species of sedges within wetland Patches of E. occidentalis around edge Several species of Utricularia (Bladderworts) and various small herbs and grass like plants inundated Seems to be floristically most diverse.	Juncus pallidus in occasional around edge unknown sedge in loose patches within wetland surrounded by pasture grasses
Algae	Patches of filamentous algae around edges				Small amount of filamentous algae throughout wetland area sampled	Filamentous algae in wetland but not very dense.
Weeds	Conyza sp. Visible in photos.	Negligible weeds	Conyza sp. Visible in photos.	None noticed	None noticed	Pasture weeds

Water Quality

Water quality measurements were made in-situ using Horriba Compact Conductivity and pH Meters (LAQUAtwin-EC-33 and pH33). Turbidity was determined using a turbidity tube.

Seasonality

The sampling events represent a pre-summer to end-of-summer comparison following a very wet year with subsequent hot weather in January and February. This provides an indication of how water conditions can fluctuate in a short period of time due to seasonal variations rather than longer term trends.

Suggestion: Any future water sampling events be done in pairs, 2 to 4 months apart, Spring-Summer for example. These may be useful to help distinguish seasonal fluctuation in conditions from long term trends.

Electrical conductivity/ salinity variation

Table 3: Water quality of wetlands in the Boggy Lake Tootanellup suite.

	Boggy lake (Wetland A)		Wetland B	Tootanellup Lagoon Wetland C		Wetland D	Wetland E
	24-Oct-21	10-Feb-22	24-Oct-21	24-Oct-21	10-Feb-22	24-Oct-21	24-Oct-21
EC mS/cm	4.5	12.5	0.38	1.35	2.65	0.32	1.48
Salinity ppt	2.26	6.4	0.19	0.67	1.32	0.16	0.22
pH	6.5	7.3	6.3	5.9	6.1	6.1	5.9
Temp (C)	25.5	30	26	19	23	24	27
Turbidity	30	50	50	30	30	30	5
Tannins	Slight	Strong	Strong	Present	Strong	Present	Slight

The EC difference between October and February shows an increase from 4.5 to 12.5 mS/cm in Boggy Lake and in Tootanellup Lagoon almost doubling from 1.35 to 2.65 mS/cm. Given the expected drop in water level, a measurable increase in salt concentration was expected.

However, the February site in Boggy Lake was shifted spatially (240 metres) from that in October and there are some indications that if groundwater is discharging into the lake, it may be patchy across the lake bed and likewise freshwater seeping from lunettes. The shallowness of the lake waters and the dense areas of sedges indicate that water circulation around the lake is likely to be slight, in dense sedge areas even in windy conditions, circulation and mixing of the top and bottom waters may be greater in open water areas.

Suggestion: Investigating variations in salinity at various sites around and across Boggy Lake at low to moderate water levels to assess habitat diversity.

Notes on salinity

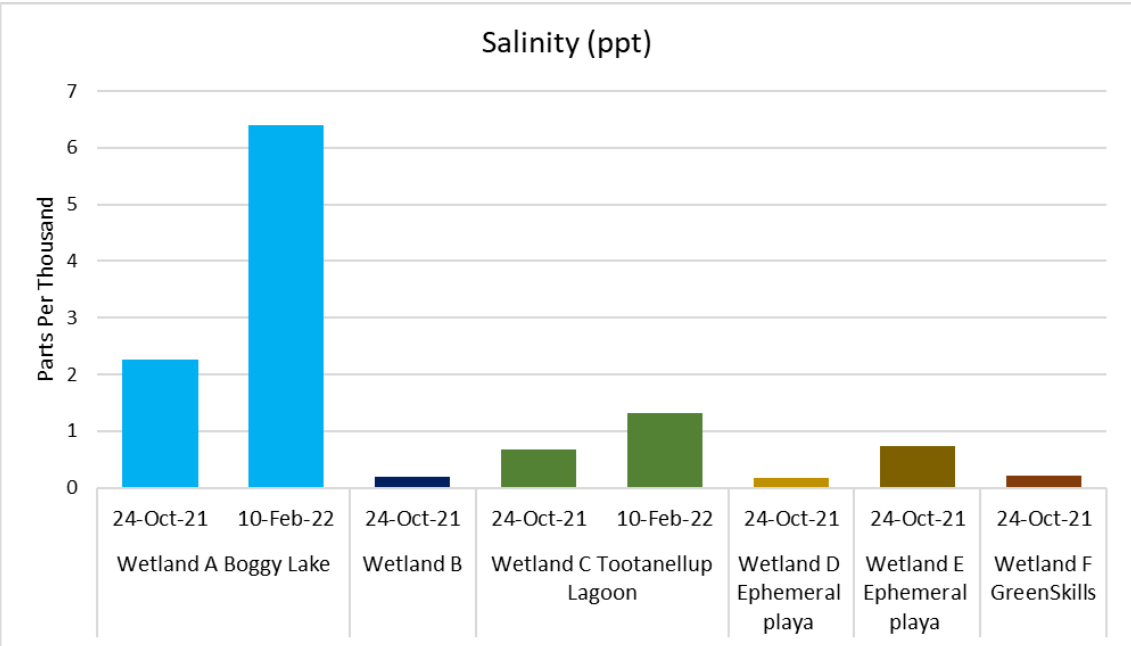
There are different ways of categorising water salinity: fresh, brackish, saline and hypersaline depending on the focus or reason for making the categories.

Table 4: Mayer et al (2005) Classification based on agricultural/industrial usage of water.

Salinity status	Salinity (mg/L)	Salinity (ppt)	Description and use
Fresh	< 500	0.5	Drinking and all irrigation
Marginal	500 –1 000	0.5 - 1	Most irrigation, adverse effects on ecosystems become apparent
Brackish	1 000 – 2 000	1 - 2	Irrigation certain crops only; useful for most stock
Saline	2 000 – 10 000	2 - 10	Useful for most livestock
Highly saline	10 000–35 000	10 - 35	Very saline groundwater, limited use for certain livestock
Brine	>35 000	>35	Seawater: some mining and industrial uses exist
Classifications from Mayer, XM, Ruprecht, JK & Bari, MA 2005, Stream salinity status and trends in south-west Western Australia, Department of Environment, Salinity and land use impacts series, Report No. SLUI 38			

Table 5: Wetland salinity categories based on macroinvertebrate tolerance (Pinder et al, 2005).

• <3 ppt, freshwater	Note: seawater is approximately 35 ppt (52ms/cm).
• 3 to 12 ppt, sub-saline or brackish	
• 12 to 35 ppt, saline	
• >35 ppt, hypersaline.	



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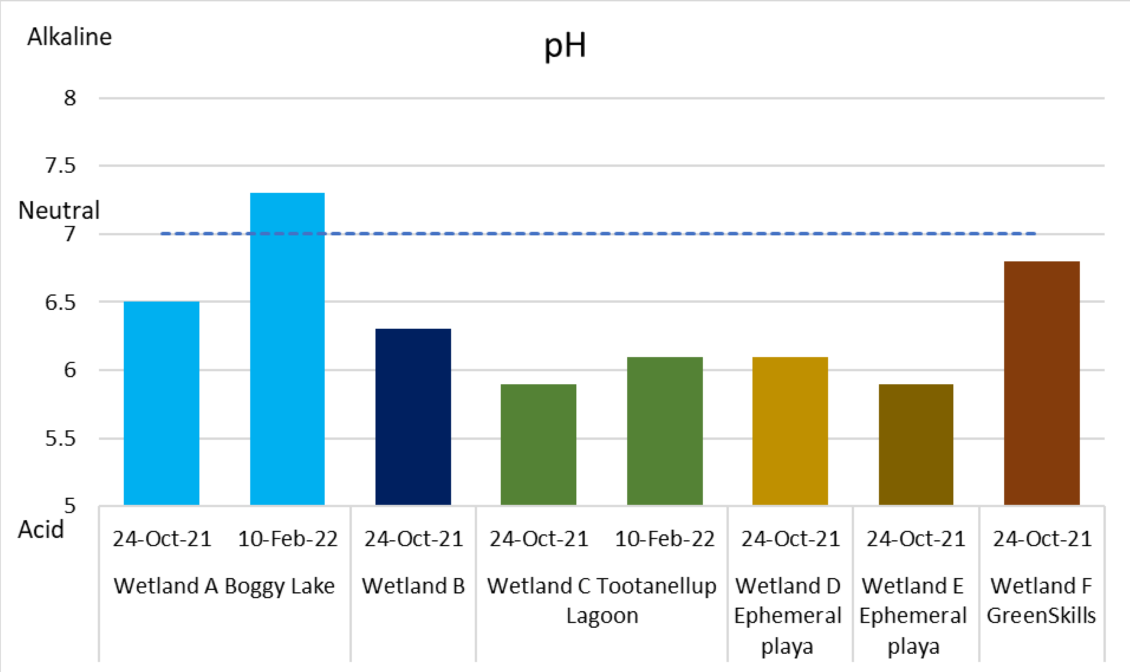

pH, turbidity and temperature

pH readings increased slightly, and this might be expected given the increase in salt concentrations.

The turbidity level had increased nominally in Boggy Lake but had remained unchanged in Tootanellup.

A seasonal increase in water temperature was expected, and Tootanellup (am) ranged from 19 to 23 degrees C whereas Boggy Lake (pm) ranged from 25.5 to 30 degrees, but allowances must be made for the different sampling times for both October and February.

Speculation: The uniform sedge cover in Tootanellup would provide shade across the entire water body and moderate temperature variations whereas the large areas of open water in Boggy Lake are exposed to full sunlight and an increase in temperature would theoretically encourage increased growth of micro-organisms in the water column and this in turn would increase the turbidity. Another factor to consider is that wind would likely stir up more sediment in open waters and this in turn would explain higher turbidity levels.

Water levels

Water levels in Boggy Lake and Tootanellup Lagoon were both down approximately 300 mm and given their generally shallow depth this is a significant portion of the total volume of water seen in October.

Suggestion: water level datum be established at Boggy Lake, Tootanellup Lagoon and wetland B and linked together.

Wetlands D and E are shallow depressions, filled with fresh storm water which can quickly disappear.

Suggestion: Should water table levels be rising below these depressions and on the adjacent properties to the south, they can be examined occasionally to determine if there is any emerging surface expression of groundwater and changes in vegetation cover, but otherwise periodic water sampling when there is water, would not yield further useful information.

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Macroinvertebrates

With the help of volunteers, macroinvertebrates were sampled from all six wetlands in October 2021 and only from Boggy Lake and Tootanellup Lagoon in February 2022. This discussion will focus on Boggy Lake and Tootanellup Lagoon results. Results from the other four wetlands will be reported if the opportunity arises.

Table 6: Number of taxa from each sampling occasion.

Boggy Lake		Tootanellup Lagoon	
24-Oct-21	10-Feb-22	24-Oct-21	10-Feb-22
38	37	23	19

Boggy Lake – Wetland A

Boggy Lake has a variety of habitats including areas of jointed rush and open water. The suite of macroinvertebrates collected reflect the diversity of habits. Boggy Lake had the highest number of species on both sampling occasions. When the data from both sampling occasions was combined, Boggy Lake also had the highest combined species diversity with 60 different species observed.

Table 7: Number of taxa within Macroinvertebrate groups found in Boggy Lake on both sampling occasions.

CLASSIFICATION		Boggy Lake	
		24-Oct-21	10-Feb-22
Arachnida	Acarina – mites	1	3
	Araneae - terrestrial spiders	3	1
Crustacea	Amphipoda Chiltoniidae - scuds	1	1
	Cladocera – water fleas	4	
	Copepoda - plankton	2	2
	Decapoda Parastacidae - koonac		1
	Ostracoda – seed shrimp	3	3
Insecta	Coleoptera Curculionidae - weevil	1	
	Coleoptera Dytiscidae – diving beetle	5	3
	Coleoptera Hydrophilidae – scavenger beetle	1	2
	Coleoptera Scirtidae – marsh beetles	1	
	Diptera Culicidae – mosquito larvae	1	1
	Diptera Chironominae – midge larvae	2	3
	Diptera Orthocladiinae – midge larvae	2	1
	Diptera Tanypodinae – midge larvae	2	1
	Diptera Other – fly larvae	2	
	Hemiptera Corixidae – water boatmen	2	3
	Hemiptera Nepidae – aquatic stick insect		1
	Hemiptera Notonectidae - backswimmers	2	2
	Hemiptera Veliidae – small water striders		1
	Odonata Anisoptera - dragonflies	1	3
	Odonata Zygoptera - damselflies	1	3
	Trichoptera Leptoceridae - caddisflies		2
Vertebrata	Tadpole species 2	1	
	Total number of taxa	38	37

As could be expected, there were more insect larvae present in the October sampling and more adult insects in the following February sampling. Especially noticeable were the high density of Hemiptera (water boatmen and backswimmers) in the open water areas in February. There was also a high diversity (6 species) of Odonates (dragonfly and damselfly larvae), and many adults were observed flying around the Rushes.

Of interest is the presence of the salt water tolerant scud, *Austrochiltonia subtenuis* in contrast to the freshwater scud *Perthia acutitelson* found in Tootanellup Lagoon and Wetland B. Their presence in high numbers seems to imply that Boggy Lake has been brackish to saline for at least a few decades. The salinity of 2.26ppt in October after a very wet year puts Boggy Lake in the fresh category and of 6.4ppt in February in the sub-saline or brackish category. Perthia has been recorded from wetlands with a maximum of 3.6ppt. For many freshwater-only macroinvertebrates, the salinity cut-off is around 3ppt.

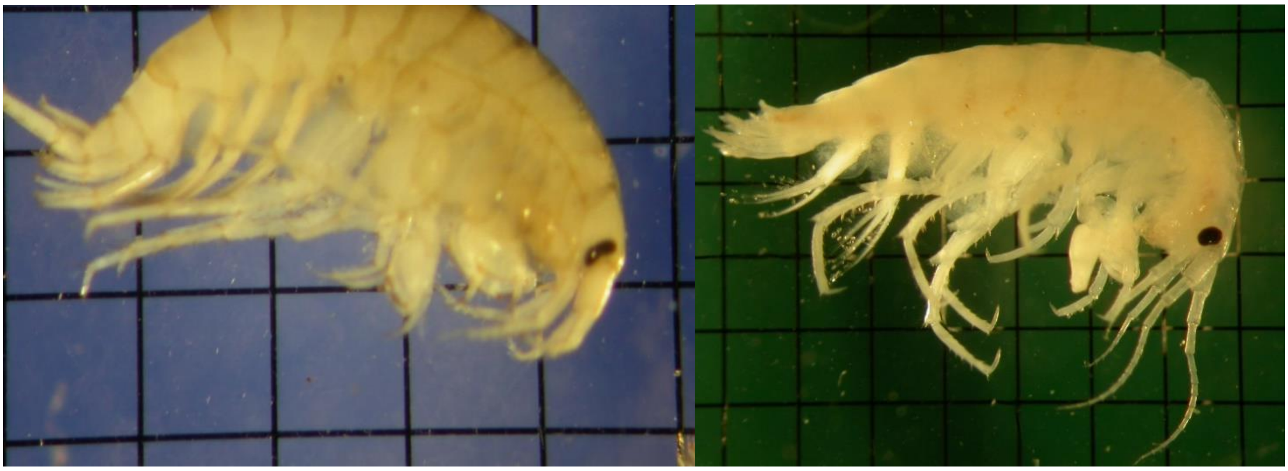

Figure 3: Left. *Perthia acutitelson* is a freshwater only scud. Right, *Austrochiltonia subtenuis* tolerates fresh and saline water.

Boggy Lake has large areas of open water with Jointed Rush (formally known as *Baumea articulata* but the name has recently changed to *Machaerina articulata)* around the edges and in patches in the middle. Jointed Rush can tolerate low levels of salinity but requires fresh water for active growth. In Lake Nunijup, there are several patches of Jointed Rush, and these were looking very sick when the salinity had increased to 22ppt in February 2019. With last winter's high rainfall, many of the patches have started growing again, and were looking healthy with the salinity at about 11ppt.

Jointed Rush is also known to grow in patches where there is fresh groundwater upwelling in otherwise ephemeral wetlands.

The salinity at Boggy Lake in February was still only at 6.4ppt and within the growing tolerance of Jointed Rush. Previous dry years and increased saline ground water inputs may have produced the patchiness of Jointed Rush within Boggy Lake. It is not known what seasonal salinity level would result in death of Jointed Rush in Boggy Lake.

Figure 4: Boggy Lake sampling sites. Above sampling in October 2021, and below sampling about 250 further northeast in February 2022.

Figure 5: Left, Boggy Lake aerial image from 2010 and above, Boggy Lake drone image October 2021.

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Tootanellup Lagoon – Wetland C

Figure 6: Drone image of Tootanellup Lagoon taken on 24 October 2021

Tootanellup Lagoon is a freshwater wetland completely covered in Jointed Rush with minimal open water. The covering of this dense tall rush means the water is well shaded and protected from wind and this reduces evaporation. Sampling for macroinvertebrates required pushing a path through the dense tall rush and sampling the open water thus produced. Jointed Rush grows happily in depths over one metre. The suite of macroinvertebrates collected was much lower than for Boggy Lake which possibly reflects the Jointed Rush habitat and difficulty in obtaining a good sample.

When the data from both sampling occasions was combined, Tootanellup Lagoon also had half combined species diversity of Boggy Lake with 31 different species. This may reflect the shaded habitat and/or the difficulty in sampling.

Of note was the collection on both occasions of the leach *Habeobdella stagni* of the Richardsoniidae family. Ecological information about this leach is limited although it is endemic to fresh water river pools and wetlands in the lower south west of Western Australia.

Figure 7: Left: The leach RICHARDSONIIDAE, Habeobdella stagni

The endemic freshwater scud *Perthia acutitelson* was collected in Tootanellup Lagoon but not in Boggy Lake (See Figure 3).

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Table 8: Number of taxa within Macroinvertebrate groups found in Tootanellup Lagoon on both sampling occasions.

CLASSIFICATION		Tootanellup Lagoon	
		24-Oct-21	10-Feb-22
Annelida	Hirudinea Richardsoniidae - leach	1	1
Arachnida	Acarina - -mites	1	1
	Aranae - spiders	1	
Crustacea	Amphipoda Perthidae - scuds	1	1
	Cladocera – water fleas	1	2
	Copepoda - plankton	1	1
	Decapoda - koonac	1	1
	Ostracoda seed shrimp	2	3
Insecta	Coleoptera Curculionidae - weevil	1	
	Coleoptera Dytiscidae – diving beetle	1	3
	Coleoptera Noteridae - crawling beetle	1	
	Diptera Ceratopogonidae – midge larvae	1	
	Diptera Chironominae- midge larvae	1	
	Diptera Orthocladiinae - midge larvae	2	1
	Diptera Tanypodinae - midge larvae	1	1
	Diptera Culicidae – mosquito larvae	3	2
	Diptera Other – fly larvae	2	
	Hemiptera Veliidae – small water striders		1
	Lepidoptera Glossata – moth larvae	1	
	Odonata Anisoptera - dragonflies	0	1
	Total number of taxa	23	19

Figure 8: Tootanellup Lagoon sampling site in October 2021.



Figure 9: Left: Geraldine sampling within the dense Jointed Rush. Right: sharing insights in the ecology of Jointed Rush wetlands with students and volunteers.


Figure 10: Steve sharing insights into the water quality and hydrology of these wetlands.

Wetland B

This wetland is situated between Boggy Lake and Tootanellup lagoon and is similar in appearance to Tootanellup Lagoon. The suite of macroinvertebrates collected from Wetland B in October 2021 is similar to that in Tootanellup Lagoon.

Figure 11: Drone image of Wetland B with Tootanellup Lagoon in the background taken on 24 October 2021.

Figure 12: Sampling location for Wetland B on October 2021

Wetland D

Figure 13: Sampling location for Wetland D.

The following three ephemeral wetlands are discussed here in general terms. Although macroinvertebrate sweeps were collected, they were not processed at the time of this report.

Wetland D is an ephemeral wetland with fresh water perched above the water table. *Melaleuca lateritica* and *M. viminea* were growing within the inundated wetland along with *Baumea juncea* with some *B. vaginalis.* A range of other sedge species and *Triglochin* sp. were also present. Scattered around the edge were *Melaleuca preissiana* and *Banksia littoralis* while *Corymbia calophylla* was the dominant tree around upslope edge

Ephemeral wetlands are known be highly diverse in flora and aquatic biota. They are highly vulnerable to degradation as their diversity is not seen for much of the year when they are dry pans. However, they are potentially becoming a threatened ecological community. See comments under Wetland E.

Figure 14: Geraldine sampling around the Baumea sp. and Melaleuca lateritica plants in Wetland D

Figure 15: Left: Processing the macroinvertebrate sample. Right: Hibbertia stellaris giving a delightful show of colour.

Wetland E

Wetland E was another ephemeral wetland with shallow water covering a large area. This wetland seemed to be the most diverse floristically. A macroinvertebrate sample was collected and will be processed as opportunity arises.

Figure 16: Sampling location on Wetland E

Figure 17: Left, the bladderwort, Utricularia paulineae. Right, Swamp Bee orchid, Diuris laxiflora

There has been research[1] in recent years on the high diversity seen in ephemeral wetland and threats to their survival. Gibson *et* al (2005) estimated that over 90% seasonal clay-based wetlands of south-west Western Australia have been cleared for agriculture and the remaining areas, despite largely occurring in conservation reserves, are threatened by weed invasion and rising saline groundwater. Gibson *et al* (2019) commented many are currently listed as critically endangered. Threats include weed taxa invading the wetland, rising saline groundwater reduced rainfall in the region and climate change.

Neil Gibson (2010) concludes a DEC Science Division Information Sheet with "Despite the management challenges, the ephemeral clay-based wetlands of south-western Western Australia remain one of the biodiversity jewels in one of the world's biodiversity hotspots."

[1] N. Gibson, K. Brown and G. Paczkowska (2019) *Temporal changes in threatened ephemeral claypans over annual and decadal timescales in south-west Australia* Australian Journal of Botany 66(8) 609-617
Gibson, N., G.J Keighery, M.N Lyons, and B.J. Keighery (2005) *Threatened plant communities of Western Australia. 2 The seasonal claybased wetland communities of the South West* Article in Pacific Conservation Biology
Gibson, N (2010) *Ephemeral clay-based wetlands of the South West* Information Sheet 32 / 2010 DEC Science Division

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Wetland F

Wetland F probably represents the clearing of an ephemeral wetland like Wetland D or E. Although eutrophic and favoured by ducks, there was limited floristic and macroinvertebrate diversity.

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Bird Observations

Australasian Bittern

Quote from: Robyn Pickering,

February 2022 Review *of audio files from Boggy Lake Spring 2021 for Australasian Bittern calls.*

> ***Summary***
>
> *This report summarises audio file processing from Boggy Lake for Australasian Bittern calls. The recordings reviewed and processed were from 14/10/2021 to 7/1/2022.*
>
> *The recordings from Boggy Lake that were processed showed a distant Australasian Bittern called pre-dawn on 28/11/2021, 29/11/202, 10/12/2021 and 20/12/2021. It is likely that this bird was in the range of 1 to 5 kilometres (possibly 10 km) from the recorder, so it is unlikely to have been within Boggy Lake but also unlikely to be at wetlands where other recorders have been placed by BirdLife and the Department of Biodiversity, Conservation and Attractions during this period. This record, therefore, is significant to the Australasian Bittern Recovery Team. It is particularly important as it appears there are no records of Australasian Bittern utilising wetlands in this area.*
>
> *One Australian Little Bittern or Black-backed Bittern was recorded loudly and regularly on the morning of 15/12/2021 and two called regularly on 24/12/2021.*
>
> *In total 24.5 hours of audio were processed over the recording range. Other species noted while processing the audio files were: Slender Tree Frogs, Pobblebonk Frogs, Motorbike Frogs, Australian Shelduck, Pacific Black Duck, Tawny Frogmouth, Australasian Swamphen, Australian Boobook, Laughing Kookaburra, Australian Magpie and Willie Wagtail. Cows, dogs and probably foxes were also noted. Note that there are likely to have been other species recorded but the focus of the processing is to look in the lower frequency for Australasian Bittern or Australian Little Bittern records.*

Robyn commented via email that:

> *This is a significant record as, as far as I am aware, there have been no records from the Rocky Gully area. I am very keen to have more surveys done in that area this spring and have made several recommendations in the attached report about this. As Chair of the BirdLife WA Australasian Bittern Committee, I will ensure that the Rocky Gully/Boggy Lake area has a priority for survey equipment this coming spring as it will be very useful for future conservation measures, that we determine which wetland/wetlands are being utilised by the species. Obviously, we will still be prioritising equipment at our other important sites too.*

Denmark Bird Group Report of Wetland Surveys

The following is as reported by Andrew Dickinson

Introduction

Surveys of five wetlands were conducted on the 8th of December 2021 by members of the Denmark Bird Group. Participating members were Brad Kneebone, Jill Williams, John and Kirsty Anderson, and Andrew Dickinson.

Weather conditions were warm and becoming increasingly warmer with strong NE winds.

Wetland A (Boggy Lake)- Water bird observations

Bird Species	Abundance	Location on/around wetland	Bird Activity
Purple Swamp hen	1	In reeds on western edge	Unseen

The survey for this wetland was conducted from the western side, accessed from Caldwell Road. Only the limited area visible from the western side was surveyed. Time survey commenced was 10.30am. GPS coordinates are 34.2819.1S -117 08 51.3E.

Bush birds recorded in the area adjacent to the wetland were; Weebill, Grey Fantail, Little Grassbird, Spotted Scrub wren, Western Rosella, Silvereye, Splendid Fairy wren, Western Gerygone, Red Wattlebird, Inland Thornbill, Australian reed warbler, Rufous Treecreeper, Striated Pardalote, Western Whistler.

Wetland B (South of Boggy Lake)- Water bird observations

Bird Species	Abundance	Location on/around wetland	Bird Activity
Nil			

This wetland was accessed from Rocky Gully Road. Survey was conducted along the southern edge. No water was visible on this wetland due to thick Baumea sp. this survey commenced at 13.30. No coordinates were recorded.

Bush birds recorded in the area near the wetland were; Western Gerygone, Striated Pardalote, Grey Shrike-thrush, Black-faced Cuckoo Shrike, Silvereye.

Wetland C (Tootanellup Lagoon)- Water bird observations

Bird Species	Abundance	Location on/around wetland	Bird Activity
Nil			

This wetland was accessed from Rocky Gully Road. Survey was conducted along the SW edge. No water was visible on this wetland due to thick Baumea sp. this survey commenced at 11.45. No coordinates were recorded.

The only bush birds recorded in the area was Black-faced Cuckoo Shrike.

Wetland E- Water bird observations

Bird Species	Abundance	Location on/around wetland	Bird Activity
Nil			

This wetland was accessed from Rocky Gully Road into the SW corner. Two members of the group walked east through the wetland in water that was about 20cm deep. This survey commenced at 12.30. GPS Coordinates are 34.29 11.7S- 117. 09 36.5E

Bush birds recorded in the area near the wetland were; Spotted Scrub wren, Inland Thornbill, Yellow-rump Thornbill, Shining Bronze Cuckoo, Grey Fantail, Brown Honeyeater, Australian Magpie.

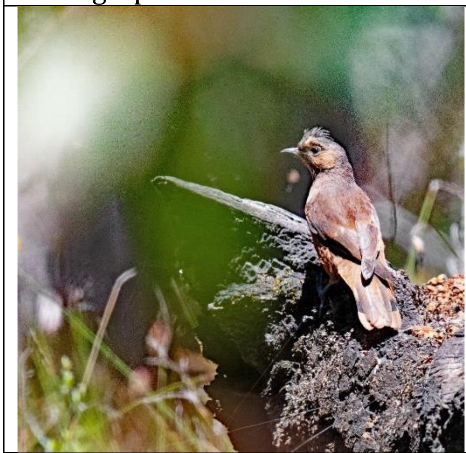
Wetland F (Tootanellup-Green Skills)- Water bird observations

Bird Species	Abundance	Location on/around wetland	Bird Activity
Grey Teal	74	Central, amongst vegetation	Loafing
Chestnut Teal	3	Central, with Grey Teal	Loafing
Pacific Heron	1	Flying, landing on edge	Feeding
Pacific Black Duck	3+6 young	Central, slightly away from Teal	Feeding
Black-fronted Dotterel	5	Edge, on drying mud	Feeding

This wetland was accessed from Caldwell Road and the survey conducted from eastern side of wetland where trees provided cover. This survey commenced at 09.45. GPS coordinates are 34. 2830. 7S -117. 08 26E

Other birds recorded in the area were; Emu, Willy Wagtail, Tree Martin, Striated Pardalote.

Photographs taken by John Anderson during Denmark Bird Group's outing to Tootanellup on 8th December 2022

Photograph	Notes
	Tootanellup Bio Blitz Bird Survey 8 Dec 2021 Ph John Anderson Rufous Treecreeper
	Tootanellup Bio Blitz Bird Survey 8 Dec 2021 Ph John Anderson White-necked Heron
	Wood Duck & Grey Teal Tootanellup 8Dec21 Ph John Anderson

Janicke Environmental Assessments

	Black-fronted Dotterel Tootanellup Ph John Anderson
	Black-fronted Dotterel Tootanellup 8Dec21 Ph John Anderson
	Grey & Chestnut Teal P Black Duck Tootanellup 8Dec21 Ph John Anderson
	DSCN9940 Boggy Lake Ph John Anderson

Janicke Environmental Assessments

	DSCN9960 wetland E 8 Dec 2021 Ph John Anderson
	Tootanelllup Bio Blitz Bird Survey 8 Dec 2021 Ph John Anderson DSCN9936 Boggy Lake
	Tootanelllup Bio Blitz Bird Survey 8 Dec 2021 Ph John Anderson
	DSCN9933 Small Lake Ph John Anderson

Janicke Environmental Assessments

	DSCN9959 Wetland E Ph John Anderson
	DSCN9976 Wetland B Ph John Anderson
	DSCN9949 Wetland B Ph John Anderson
	DSCN9964 Wetland E Ph John Anderson

Appendix 1: Discussion on hydrology of wetlands

The following series of quotes form part of an ongoing discussion on the hydrology of the Tootanellup wetland.

Quote from Hopkinson (2003) Wetlands of the Upper Kent Catchment

Precise statements about individual wetland hydrology are difficult to make without conducting drilling around each site to determine the geology and groundwater profile. It is becoming clear, however, that some of the Kent wetlands have been captured by the rising regional watertable.

An example of this is Lake Nunijup, where recent drilling has shown the groundwater levels to be above the level of the bottom of the lake basin. Management decisions now need to be made in an effort to control the levels of water within the lake so there is enough water in the lake to put a positive pressure on the basin sediments to prevent further discharge of saline groundwater.

In general, the water balance of the Kent wetlands is determined by:

- *Surface runoff from the catchment via the waterways that feed the wetlands*
- *Ground water discharging into the wetlands. This flow may be considerable in comparison to total inflow, due to the high hydraulic conductivities and low hydraulic gradients of the tertiary sediments containing the groundwater. Recent studies on salt and water balances carried out for Lakes Nunijup and Carabundup indicate the interaction between the lake and groundwater has become an important component of the water and salt balance for these lakes (DeSilva J, 2002).*
- *Rainfall percolates through the sands of the dunes that fringe many basins and recharges the watertable within the dune system. This sandy lens of fresh water discharges through the interface with dune and wetland and will seasonally flow into the wetland system.*
- *Direct rainfall on the wetland,*

Water is lost from the wetlands due to:

- *Evaporation from summer heat and wind*
- *Evapotranspiration from fringing wetland vegetation*
- *Discharge of wetland into ground water.*
- *Overflow, either along low-lying flats or discreet channels linking wetlands.*

The wetlands' main water loss is through evaporation with minimal loss from discharge through base sediments. In most years this means dissolved salts are unable to leave the system and are concentrated as the wetland evaporates. Infrequent episodic high rainfall events may allow some salts to be exported from wetlands in outflow water.

Ruhi Ferdowsian comments on Boggy Lake hydrology 29 October 2021

A preliminary assessment of Boggy Lake done pro bono by Ruhi Ferdowsian for Green Skills, commissioned by Basil Schur.

Here are a few dot points describing salinity and hydrology of Boggy Lake catchment and nearby wetlands.

Geology and aquifers

- The low hills are remnants of the ancient granite hills. The valleys and flats are infilled depressions containing Tertiary sediments. Very likely, the regolith in the valleys, have coarse material at depth. A semi-regional aquifer may be flowing in the more conductive coarse material.
- The low hills have shallow local aquifers that flow from hilly areas towards the valleys and feed the deeper semi-regional aquifer.

Soil-Salinity and salinity of the wetlands

- Groundwaters are saline (>2000mg/L). The deeper aquifer has higher salinity than the local aquifers. The salinity of deeper groundwater may be more that 5000mg/L.
- High salinity level in Poorarecup Lake is due to saline runoff from the northern parts of its large catchment as well as concentration of salt due to evaporation.
- Very likely the wetlands are perching over the semi-regional aquifer, but they are not affected by its salinity.
- The main contributor to the salinity of the wetlands are the local aquifers close to and around the wetlands. This means that high rate of recharge in the cleared areas around the wetlands may cause/increase salinity in the wetlands.
- The attached map indicates the local scale groundwater flow directions.

Salinity treats to the wetlands

- The attached map and the flow passes indicate that the biggest treats to the wetlands are the cleared area to the north and the recently cleared area to the east.
- The cleared area to the south has also some impact. Salinity of wetlands E and C are due to groundwater coming from the southern and south-western areas.
- It is likely that salinity of wetlands D and F do not increase significantly.
- In two to three years' time, the two recently cleared areas may increase the salinity of Boggy Lake. The biggest treat is from the area immediately to the east of the lake.
- Wetland B also may be impacted by groundwater and recharge from recently cleared area to its east.
- The natural vegetation in the catchment can extract some freshwater from the saline aquifer and reduce groundwater levels. In the absence of the natural vegetations, the lakes would be or would become saline.

Comments on the present salinities

- The reasonably fresh waters are due to recent heavy rainfall. At the moment freshwater is perching over the wetland including the lakes. The salinity of these lakes will increase during the dry period. It may be useful to measure salinity of the wetlands later in the summer time.

Future salinities

- The salinity of the lakes and wetland may increase in the future. Boggy lake may experience high salinity (> 3000mg/L). Salinity of the other lakes and wetlands my remain slightly higher than the present levels.
- I expect the excessive salinity may affect the composition of the natural vegetation in the Boggy Lake.
- It is likely that the natural vegetation in the other wetlands and lakes may tolerate the changes in water salinity.

Disclamation

- I have tried my best to write my opinion and my comments with care. I do not accept responsibility for any mistakes. You may like to consult other scientists if you like.

Regards

Rouhulah Ferdowsian

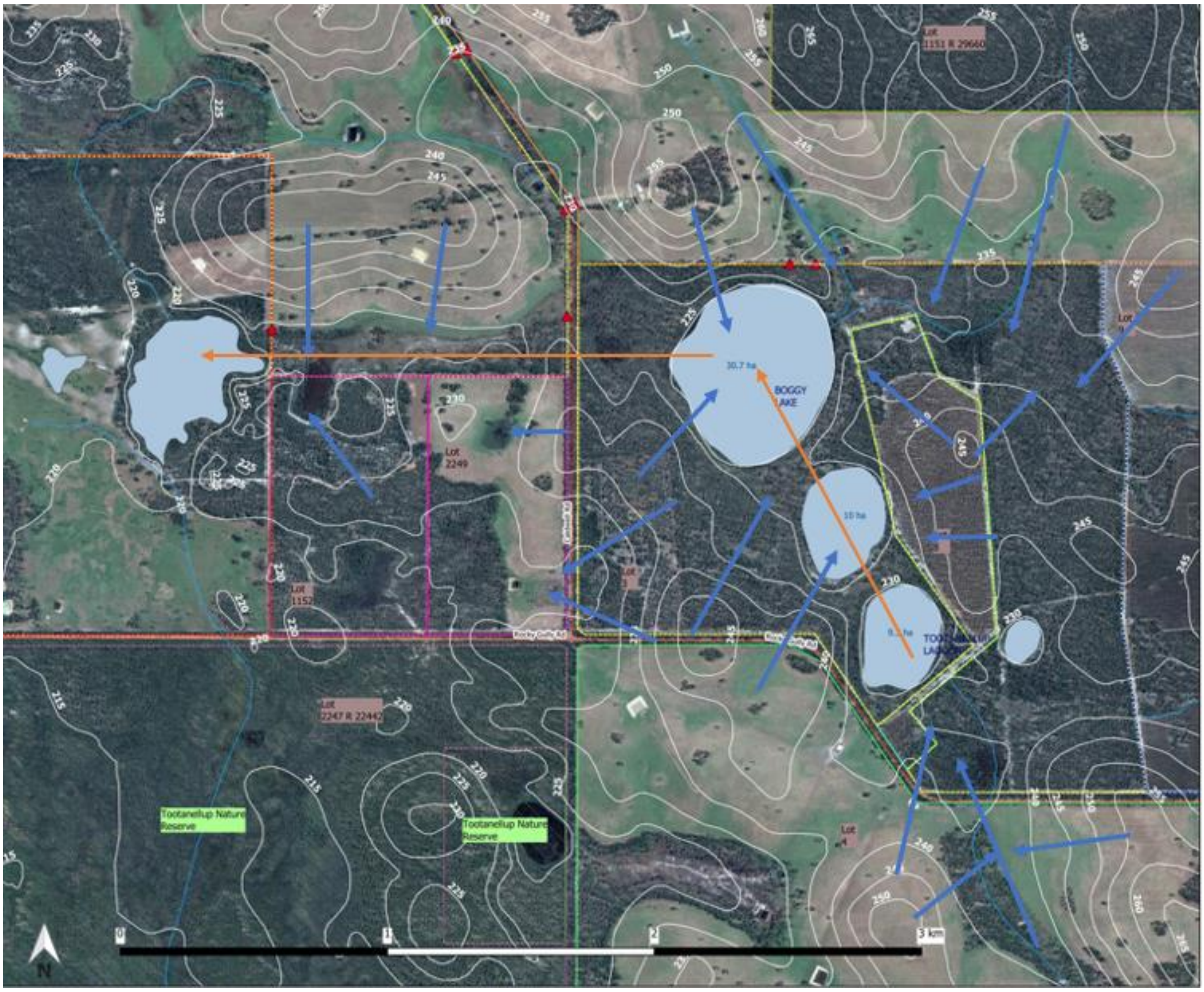


Figure 18:: The Boggy Lake and wetlands around it. The blue arrows show the flow directions and their possible discharge zones.

Ruhi Ferdowsian Revegetation suggestions. Nov 2021

Ruhi Ferdowsian's response to questions from Basil.

What is involved in calculated what proportion of Boggy Lake catchment that is currently cleared would need to be revegetated/reforested to prevent environmentally damaging salinity rises in Boggy Lake (i.e. in particular to keep the Baumea reed beds in place) I think if we can intercept the shallow groundwater, we can save the lake.

What is involved in deciding on which are the priority areas in the Boggy Lake catchment that need to be focussed on for revegetation or other catchment treatments

Two areas: Cleared areas to the east and
The areas that collect the shallow groundwater.

What proportion of the other two wetland cleared catchments would you recommend to keep their salinity levels from rising adversely? I have suggested the areas in priority order (see Figure 20: Ruhi Ferdowsian's suggested revegetation areas and priority.).

Quote from Don McFarlane email 5 Nov 2021

Subject: RE: for Don from Basil re Boggy Lake DWER site and salinity
Hi Basil,

Increasing lake salinities could come from one or a combination of three processes:

1. *Saline runoff, if catchments feeding the lakes are salt affected*
2. *Concentration of salts by evaporation over the summer- autumn period*
3. *Rising saline groundwater*

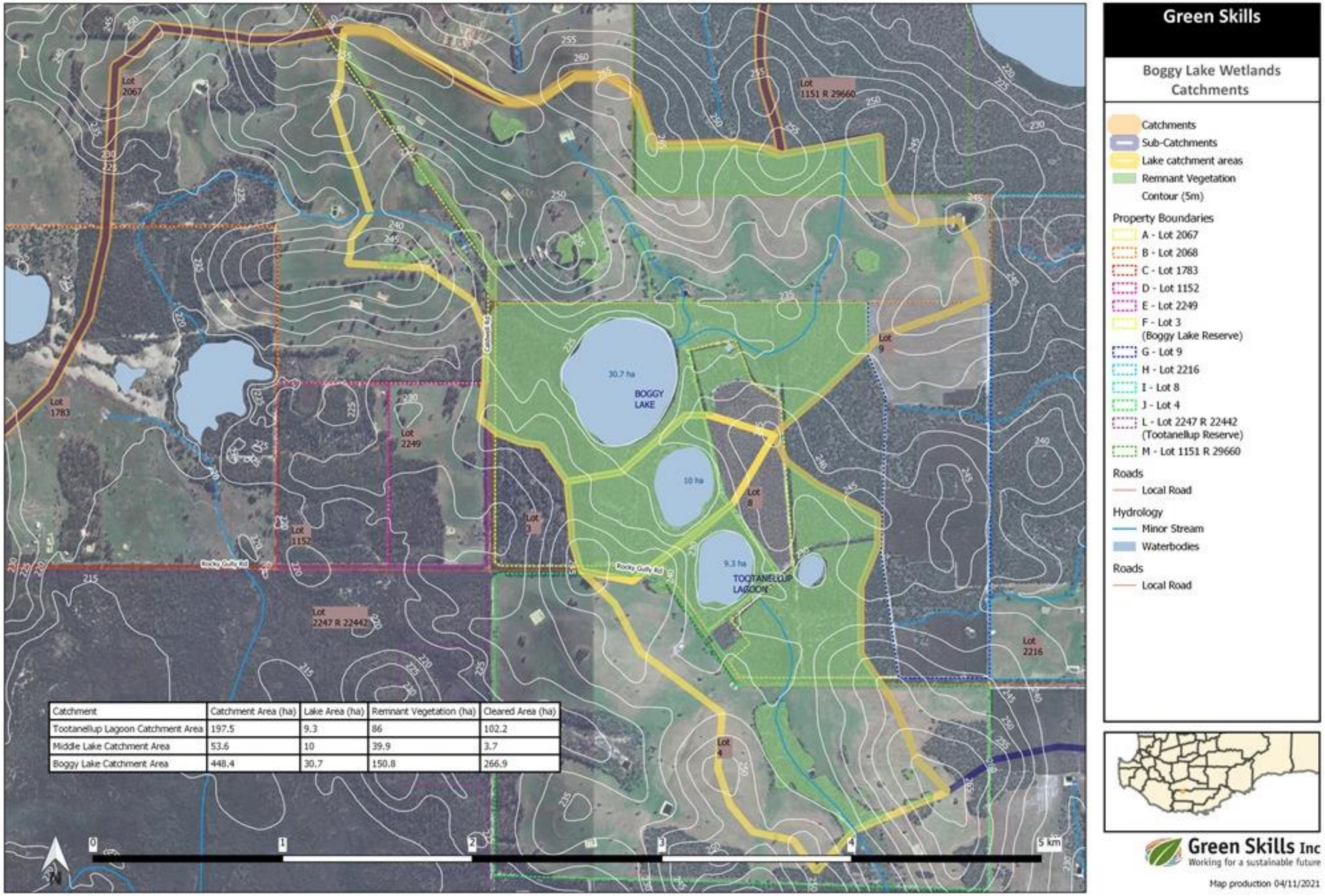
From memory we were surprised when Lake Poorarecup's salinity, which had been gradually rising for about 20 years, overflowed during a wet period and salinities dropped back to what they had been 15 years earlier. This showed that the salt must have been building up by mechanism 2 above. Basically, these internally drained areas underlain by Tertiary sediments are poorly flushed. This is a feature we want to explore in the Albany Forum in March. As well as salt, nutrients will build up if the lakes are terminal drainages for 99% of their lives

As for revegetation, it could help if processes 1 and 3 are dominant. But if the lakes are recharged by rain falling on surrounding dunal system and winter seepage into the lakes, this will exacerbate process 2. Even returning the surrounding areas to pre-European cover will reduce recharge of fresh water in a drying climate. Lake Forrestfield in Perth is perched and recharged by rain falling on the surrounding dunes. It helps in dry years to have sparse vegetation on these dunes. This may seem wrong when you want to restore the original vegetation. But we don't have the original climate and it will get much drier and hotter, so we need to adapt.

On the Swan Coastal Plain, we have found that perennial vegetation interception (in the canopy and in the root zone) is now much larger It can be 100% with wetting fronts under trees only getting to 3-5m deep. Groundwater levels are in decline, even under undisturbed Banksia woodlands. The current vegetation is not equilibrated with the new climate.

Ironically, when there is little salt storage in the soil profile, dryland agriculture enable fresh water to recharge and helps groundwater fed wetlands.

Groundwater levels in areas with high water tables are buffered against falls (ET and surface drainage losses reduce) as well as against rises (ET and drainage increase). When groundwater levels fall below about 3-4m the winter recharge can't replace all of the lost storage over summer and levels start to cumulatively fall.



Catchment	Catchment Area (ha)	Lake Area (ha)	Remnant Vegetation (ha)	Cleared Area (ha)
Tootanellup Lagoon Catchment Area	197.5	9.3	86	102.2
Middle Lake Catchment Area	53.6	10	39.9	3.7
Boggy Lake Catchment Area	448.4	30.7	150.8	266.9

Figure 19: Catchment boundaries and areas for Boggy Lake, Tootanellup Lagoon and Middle Lake.

Figure 20: Ruhi Ferdowsian's suggested revegetation areas and priority.

I am unsure which of the above 3 processes are dominant in your catchment. Ideally bores would help identify the level and salinity of groundwater in perched and regional aquifers. If you can calculate lake water storage changes, monitoring salt concentrations will show whether the salt increase can be attributed to evaporation by itself, or if there needs to be an external source of salt (runoff or groundwater discharge).

As I mentioned on the phone Lake Nunijup went from fresh to saline as farmers emptied it during a drought. Black ooze appeared in the base as saline groundwater (no longer held back by hydraulic pressure) entered the lake. Emptying the lake may have only accelerated the salinisation process if regional groundwater levels were rising after clearing.

The blue gums will have dried the regolith under them but may not have affected much further away from the plantation. This is why Richard George has stopped recommending selective revegetation as a whole-of-catchment solution to dryland salinity caused by process 3 above. A lot of water movement is vertical and what happened locally is very important. We described this is the following paper:

Pannell, D. J., D. J. McFarlane and R. Ferdowsian (2001), "Rethinking the Externality Issue for Dryland Salinity in Western Australia", Australian Journal of Agricultural and Resource Economics, Vol. 45, No. 3, pp. 459-475.

The reversal of salinity in the Kent is in the paper: https://research-repository.uwa.edu.au/en/publications/freshwater-tributaries-provide-refuge-and-recolonization-opportun: If you know Paul Close, he may be able to send you a copy

If this is confusing, I am happy to talk by phone.

Kind regards

Don
Dr Don McFarlane Mobile: 0407 476 026 email: don.mcfarlane@outlook.com
Adjunct Professor, School of Agriculture and Environment, University of Western Australia

Quote from Don McFarlane email 8 November 2022

In response to questions from Basil Schur

The water and salt balance questions you are asking are the same we need to address at the Albany Forum, so it is timely. With climate change and clearing, the hydrology of the catchments have been greatly disturbed. Even uncleared catchments may need adaptive management given they are not in equilibrium with the current and future climate. If we can identify what water regime is needed for key species, then it may be possible to do continuous adaptation and provide refugia when other areas are lost

1. Is there a way of determining which of your 3 stated processes are operating for Boggy Lake through using existing historical bore data from the Kent catchment and by planned water sampling of both the wetland itself and the tributaries that feed it?

- The lake salinity will rise more slowly if it is by evaporation compared with a rising saline watertable under the lake. If it is concentration by evaporation, halving of the water in storage will double salinity assuming there is negligible outflow. Groundwater salinities don't vary much compared with stream salinities (which may have a first flush of salt). So, you may only need to measure groundwater salinities every year of two and see that it is steady. Stream salinities need more measurements. While concentrations are important (mg/L), if there isn't much discharge from the lakes then the amount of salt (tonnes/year) is important (concentration x volume). This is often the case for nutrients as well. Ideally you should measure lake levels and convert these to lake volume using a bathymetry map. This may require someone with surveying skills as the current digital terrain models only measure to the nearest metre, assuming you can see the bottom.

2. What would be involved (costs, feasibility) of drilling test bores in Boggy Lake reserve?

- Bore holes need only be shallow because you need to know if the regional watertable is within 5 m of the lake bed. And perched aquifers will be sitting on clay within the top few metres. I don't know what drilling companies charge. They will have a mobilisation cost and then a per metre drilling cost. You could see if you can borrow Geonics EM 38 and 31 meters from DPIRD. The EM38 picks up salt within the top 1m, and the EM31 within the top 6 m. When we have detected a high apparent conductivity on the EM31 in fresh soil it has foreshadowed salt being at the surface a decade or so later. This could help locate where to drill holes, and if you have an incipient salt problem

Is there a risk that these bores will allow accelerated movement of saline groundwaters to the surface?

- No. there are unlikely to be strong upward gradient and any leakage around the annulus of a drill hole will be minor.

If the rising salinity in Boggy Lake is caused entirely or mainly by Concentration of salts by evaporation over the summer- autumn period, then will not this concentration of salts continue to increase steadily into the future regardless of what is done in the catchment, because there is no overflow from this wetland system?

- Yes. But there is likely to be some groundwater discharge which we can't see. With Poorarecup, it took a very major runoff event to cause an overflow. I don't know enough about Boggy Lake to see if there is a similar 'spillway' outlet. Often perching of lake water is greatest when lake levels are low (thick peat, clay or sapropel in the centre of the lake) but the banks are much more permeable. So, there may be seepage outflow when lake levels are high. The fact that the lake is fresh means that there must have been salt flushing in the past. They are not like the lakes SE of the Stirling Range which are very saline indicating poor flushing

Following on from this question assuming that the lake levels will either dry up or get low in some or increasing number of years, then why would revegetation of part of the catchment make the problem worse?

- The lake needs runoff or seepage of fresh water to maintain levels. The drying climate is reducing runoff and recharge by 3% for every 1% reduction in rainfall. Perennial vegetation reduces runoff and recharge. Rainfall currently can now come in short showers, interspersed with wind and sun. Canopy interception is these showers can be 40-80% before root uptake intercept the soil water. So, revegetation can exacerbate drying. If recharge is occurring through the lake banks, revegetating them will make things worse.

If the rising salinity in Boggy Lake is caused entirely or mainly by Concentration of salts by evaporation over the summer- autumn period, would you be advocating for measures to actually increase run-off to Boggy Lake from the cleared areas of the catchment?

- Yes. Assuming you can direct fresh water and not saline water. In the Perth area we have found that road runoff is maintaining lake levels. Direct recharge (rain percolating through the soil profile) used to contribute quite a lot of recharge, it is now only about 20%. Lakes away from areas with natural or artificial runoff are rapidly drying (Thomson, Forrestdale etc). Shallow drains into the clay sub-soil can pick up perched water in duplex soils. Better defining drainage lines can also increase runoff. We used local data to estimate runoff from different rural catchments with and without defined drainage lines in: McFarlane, D.J., Ferdowsian, R. and Ryder, A.T. (1995). Water Supplies for Horticulturalists in the Lower Great Southern. West Australian Dept of Ag Misc Publ. No. 17/95, 34pp. Updated in 2005 https://www.academia.edu/23258649/Water_supplies_for_horticulture_in_the_Lower_Great_Southern

That do you think of Ruhi's preliminary statement (below) that "The main contributor to the salinity of the wetlands are the local aquifers close to and around the wetlands. This means that high rate of recharge in the cleared areas around the wetlands may cause/increase salinity in the wetlands. "

- I agree. This was covered in the paper I referred to before: Pannell, D. J., D. J. McFarlane and R. Ferdowsian (2001), "Rethinking the Externality Issue for Dryland Salinity in Western Australia", Australian Journal of Agricultural and Resource Economics, Vol. 45, No. 3, pp. 459-475.
  We used to think that recharge was through distant sandy upland areas requiring a catchment solution and multiple farmers' efforts. We now realise that it is more likely to be close to the problem areas. But I am not sure that the regional watertable is close to the surface without looking at bore records or salt-affected land. My apology if you have sent these, I have been a bit busy. Ruhi will know the catchment better than I. We do know that blue gums lowered water tables in the Narrikup and adjacent areas by several metres so their removal may result in a rebound. In which case revegetation of these areas would be a good idea.

Do you know what water regime you want for the lakes – seasonal depths and salinities? You may need a combined engineering – perennial vegetation solution. If you had shallow drains capable to bringing fresh water into the lake even in dry years, and a sluice gate to allow water to exit and flush salts, this would be ideal for adaptive management. And perennial plants where the regional watertable is close to the surface.

After the Albany Forum we may be able to identify key wetlands that can be feasibly managed in a drying climate with rising saline groundwater levels. Some will be too hard to save, others may be OK without a lot of intervention (e.g., Lake Pleasant View). And some may transition from supporting freshwater species to saline ones.

Thanks for this insightful discussion of a real-world wetland
Regards
Don

Comments from Steve Janicke

Don's insight and discussion re the hydrological stuff is interesting and so I thought to join in if I may. The discussions really highlight the complexity of hydrological determinants and interactions that define why a wetland exists where it does and how it functions with respect to annual weather patterns, landform, agriculture and so on. A whole suite of questions spring to my mind for example, I get the impression that these wetland basins were formed in much drier eras judging by the lunettes. Is there much information about those times and conditions? Is the current character of the wetlands a result of leap-frogging' processes over centuries or millennia or was there an initial formation and a sort of linear evolution as vegetation gradually moved in and progressively dominated the systems? Has the fortunes of the wetlands been a matter of unpredictable 'boom and bust' climate events?

I imagine that the complexity of the current influences makes it difficult to apply general principles alone with respect to management. There will need to be some investment into creating an 'identi-kit' likeness of the Boggy Lake system, hydrologically and biologically, and by that, I mean getting more precise topographical data set and a better handle on ground water movement, water quality response to weather patterns, vegetation communities etc in order to build such a model. This information can be gathered bit by bit over time as opportunities arise. The discussion also suggests a division of desirable insight, first clarifying the 'regional' influences and secondly 'local' influences. A better understanding of the boundaries of those influences would be useful. Again, that would be a topographical view to find where surface water flows as well as the more problematic evaluation of subsurface and groundwater pathways.

The BioBlitz event in February could assist here with respect to local topographical levels. In particular I thought it might be useful to get an accurate picture of the relative elevations of wetlands A to F and the cross-sectional elevation profiles of the narrow stretches of land between them. Other bathymetry points can be added. This can be a fairly straightforward level survey in principle as the woodlands seemed to be open enough to offer tolerable lines of sight. A base elevation bench mark could be placed near the entrance of the Green Skills property and an elevation datum at each wetland for future reference, e.g., to tie in piezometers if that happens. [I checked out the Landgate AHD survey data base and there does not appear to be an official altitude bench mark in the vicinity of the wetlands, although there is a point a few kilometres away on the SW side of Tootanellup Reserve]. I would be happy to be involved with that on a volunteer basis and have had experience surveying elevation profiles and cross-sections along creeks

Appendix 2 Comments on vegetation

The value of vegetation in the Boggy Lake reserve would be similar to that of the Tootanellup Reserve as described by Greg Keighery (2003)

Quote from Greg Keighery (2003)

TOOTANELLUP NATURE RESERVE; FLORA AND VEGETATION

GREG KEIGHERY Science Division
Department of Parks and Wildlife
August 2013

SUMMARY

A total of 376 native taxa and 50 weeds were recorded from Tootanellup Nature Reserve. This included six priority taxa: *Eryngium muirii* (P2), *Amblysperma minor* (*Trichocline* sp Treeton (Bk & NG 564)-P2), *Schoenus natans* (P4), *Tribonanthes* sp Lake Muir (GK & NG 2134) (p3), *Hemigenia microphylla* (P3) and *Ornduffia submersa* (P3).

The reserve contains a series of clay flats and claypans typical of those recorded in the Lake Muir Reserves. A potentially new form of Ferricrete community dominated by Melaleuca cuticularis was also recorded.

Introduction

Tootanellup Nature Reserve is located SE of Frankland and approximately 6 km NE of Rocky Gully. The reserve was surveyed over two days in November 2011 with the assistance of Jannine Liddelow of Frankland District as part of the pre controlled burn plans for this reserve and Randall Road Reserve.

Biological Values - Flora

A total of 376 native taxa and 50 weeds were recorded from the reserve (Table 1). This number could be expected to increase with further survey in other seasons. The diversity of soils and wetlands present in the reserve are reflected in the rich diversity of native species recorded. It is expected that we recorded 80% of the expected flora.