Appendix P - Pit Lake Water Quality Assessment Report

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Mine Lakes CONSULTING

17 September 2021

PRIMARY GOLD LTD

Rustlers Roost Pit lake water; quality and trends

Submitted to:

Andrew Thomas

CDM Smith

Fortitude Valley

Queensland

AUSTRALIA

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Distribution: 1 Electronic Copy – CDM Smith

1 Electronic Copy – Mine Lakes Consulting

cmccullough@minelakes.com
+61 417 840 596
www.minelakes.consulting
PO Box 144,
Joondalup DC WA 6919

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EXECUTIVE SUMMARY

Primary Gold Ltd (Primary Gold) is proposing to recommence open-cut gold mining across the brownfields Rustlers Roost (RRPA) project area located in the Top End of the Northern Territory. The area is in the Mount Bundey region, approximately 100 km southeast of Darwin, via the Arnhem Highway. There is a single historic pit void at RRPA that has formed a lake since dewatering ceased.

Pit lake water quality was assessed by EcOz Consulting in two sampling campaigns in November 2020 and June 2021. Field physico-chemistry and water quality samples were collected every 5 m from surface to bottom (maximum 27 m) pit lake depth.

Temperature stratification was apparent with 2021 dry season sampling but not in 2020 wet season sampling. An epilimnion formed in 2021 at around 10 m and a hypolimnion at around 15 m.

Pit lake water quality as aquatic ecosystem habitat for the RRPA pit lake was moderately poor, with high nutrient concentrations and low oxygen concentrations. However, pit lake water quality as COPC concentrations for the RRPA pit lake was surprisingly good, with only slight exceedances of ecosystem values for total Fe and NH_4 and drinking water for NH_4.

Pit lake water quality often reflects surface water inflow during the early dry/late wet season and groundwater inflow during the late dry/early wet season. Tropical pit lakes may be shallow but may still thermally stratify for a short period when rains have ceased (Kumar *et al.*, 2013). Shallow mine lakes are likely to destratify readily just by wind forces (Huber *et al.*, 2008; Hipsey *et al.*, 2017).If the pit lake has not mixed and remains stratified it is likely that the water quality discharging from overtopping of the pit would be similar to site run off (CDM Smith, 2019).

Although not considered herein, ingestion of food items from aquatic biota may also present a COPC pathway to humans through bioaccumulation of pit lake aquatic fauna. For example, through Traditional Owners or other people eating aquatic foods from the pit lakes such as fish. If considered a potentially significant contaminant pathway, and once long-term pit lake water quality is well understood, human ingestion risk should be considered in future pit lake assessments.

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GLOSSARY OF TERMS AND ACRONYMS

ARD: Acid Rock Drainage. Also known as acid mine drainage and more properly as acid and metalliferous drainage (AMD) to account for non-acid contamination.

AMD: Acidic and metalliferous drainage. Also known as acid rock drainage and acid mine drainage.

BGL: Below ground level

COPC: Contaminants of potential concern.

CSM: Conceptual site model.

EC: Electrical conductivity.

EIS: Environmental Impact Statement.

ERA: Environmental Risk Assessment.

FoS: Factor of safety.

HHERA: Human Health and Environmental Risk Assessment.

LOD: limit of detection.

MCP: Mine closure plan.

PMF: Probable maximum flood.

PMLU: Post mining land use.

Q29PA: Project Area.

RCP: Representative Concentration Pathway.

RL: Relative level.

RRPA: Rustler's Roost Project Area.

SPR: Source-pathway-receptor model.

TDS: Total dissolved solids.

TEM: Electromagnetic Transient Profiles.

TER: Terms of Reference.

WRD: Waste rock dump.

ZoS: Zone of stability.

1.0 INTRODUCTION

Primary Gold Ltd (Primary Gold) is proposing to recommence open-cut gold mining across the brownfields Rustlers Roost (RRPA) project area located in the Top End of the Northern Territory. The area is in the Mount Bundey region, approximately 100 km southeast of Darwin, via the Arnhem Highway. There is a single historic pit void at RRPA that has formed a lake since dewatering ceased. RRPA has been in care and maintenance since 2004 with Primary Gold acquiring the site in 2013, simultaneously with other historic sites of Toms Gully and Quest 29.

A Mining Management Plan (MMP) was submitted by Primary Gold to the Northern Territory to the Department of Industry, Tourism and Trade (DITT) in February 2018. Primary Gold have also recently submitted a referral document – Rustlers Roost and Quest 29 Open-Cut Mine Redevelopment for a proponent initiated Environmental Impact Statement (EIS) and are now looking to address the Terms of Reference (TOR) for the draft EIS.

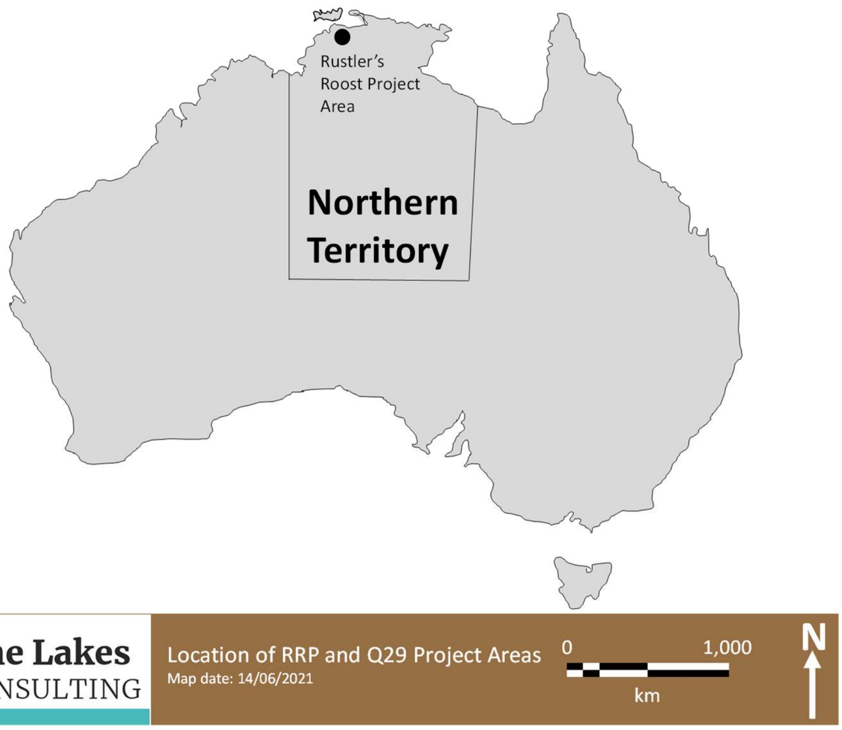

Figure 1. Location of RRP and Q29 Project Areas in the Northern Territory of Australia.

1.1 Background

A Request for Quote was sent from Andrew Thomas of CDM Smith to Dr Cherie McCullough of Mine Lakes Consulting (MLC) on 20 May 2021, to provide professional advice services for pit lake risk assessment for the proposed Rustlers Roost and Quest 29 open cut mines.

The scope of work was to prepare a pit lake risk assessment that aligns with the WA Mine Closure Plan Guidance – Appendix 8 Guidance on Pit Lake Assessment Through a Risk-Based Approach (DMIRS, 2020) and other best-practice guidance. Primary Gold are referring to this WA guidance document in the absence of any NT guidance. However, CDM Smith also requested expert assistance in guideline advice from MLC as experts in this field, that should inform the approach taken to assessing the environmental impacts and risks associated with the pit lakes.

2.0 SCOPE OF WORK

Pit lake closure planning will be required for all expanded and new pit lakes on closure. Although the total mine closure will be for the entire project area, this current study is intended to provide advice for final closure planning to more fully account for the pit lake landform. Several studies were requested by CDM Smith to better inform and plan pit lake closure of the sites. The assessment was requested by CDM Smith to help meet the Primary Gold stated TOR of understanding pit lake water quality risk.

This report represents a study targeted toward addressing analysis and reporting of RRPA water quality data as a proxy for potential future pit lake water quality.

2.1 Approach

2.1.1 Sampling

Water quality as physico-chemistry was recorded in the field and collected as water samples for laboratory analyses by EcOz on 18 November 2020 and on 17 June 2021. Methods summarised by EcOz (2020) are presumed for both sampling campaigns.

Water quality depth profile samples were taken at four locations within the current pit lake (Figure 2). These four sampling locations were selected to measure the deepest sections of the former four individual pits within the pit lake, with the objective to capture stratification of water quality from surface to depth. From north to south the locations according to the former pit names are: Sweat Ridge, Dolly Pot, Beef Bucket and Backhoe. At both sampling dates, the Sweat Ridge location was 12 m deep, whilst the deepest points at the other three locations was 27 m. Samples were taken of physico-chemistry and water quality at every 5 m.

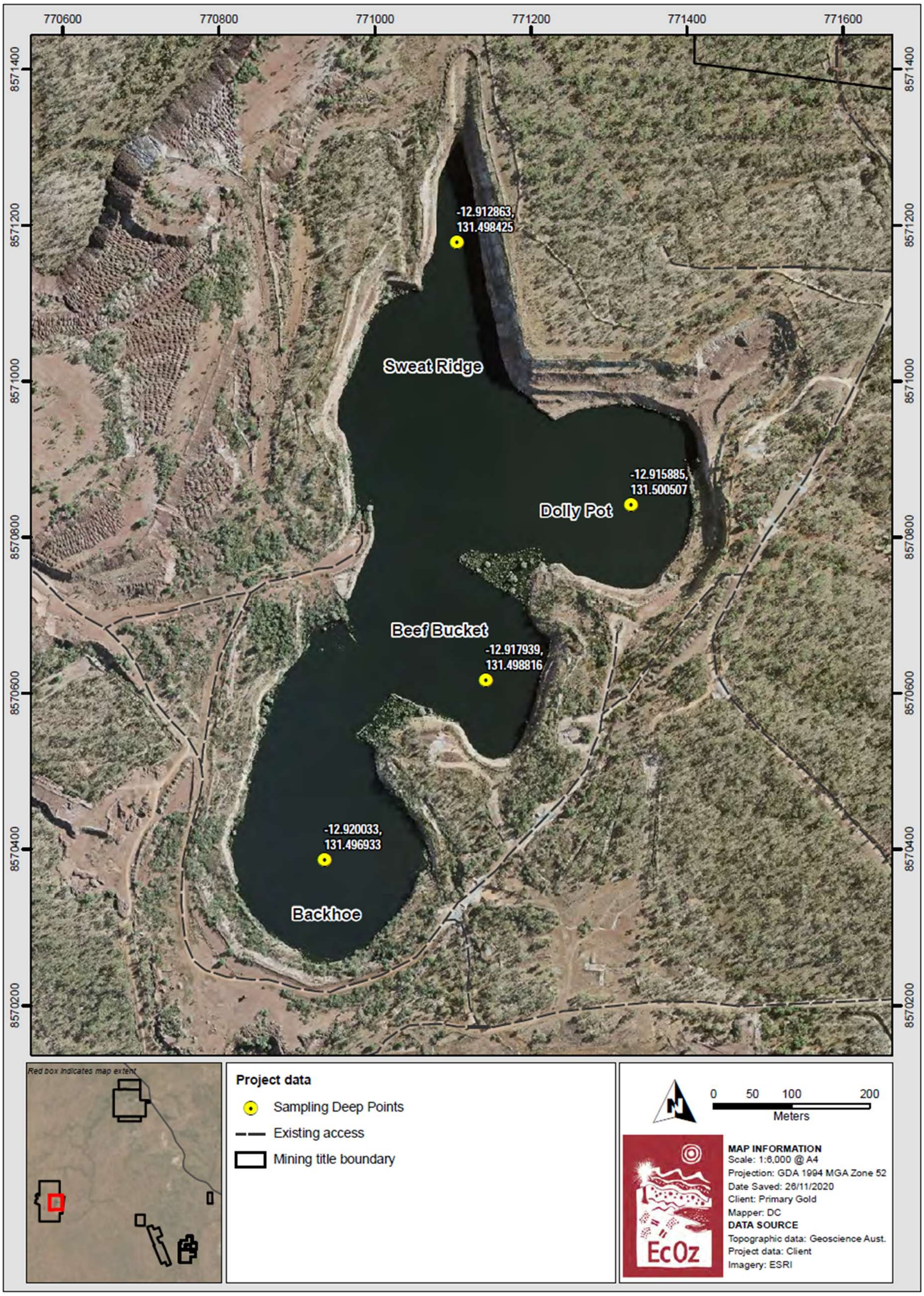

Figure 2. Water sampling locations for RRPA pit lake water quality.

2.1.2 Data analysis

Profile analysis was undertaken with SigmaPlot profile imaging software (Systat Software Inc., 2014). Spline-smoothed lines were used to connect data points from sampling.

Multivariate data analyses were made using PRIMER software (PRIMER-E Ltd, 2006) and followed a procedure of data transformation and then graphical exploration (Clarke, 1993). Environmental data were $\log_{10}$ transformed and normalised.

Principal components analysis (PCA) was then used to produce ordinations of water quality solute concentrations data. PCA is a statistical technique that is used to analyse the interrelationships among a large number of variables and to explain these variables in terms of a smaller number of variables, called principal components, with a minimum loss of information. PCA is especially useful at making large datasets more interpretable. The spread of samples on the plot show the relationships to each other in terms of physico-chemistry. The vectors show the gradients that the samples are plotted along.

Stratification level as epilimnion/hypolimnion was defined from thermal and EC profile data. Analysis of similarity (ANOSIM) was used to statistically test for differences between sampling site locations, years and depths with 9,999 iterations.

2.1.3 Guidelines screening

Water quality maximum solute concentrations were conservatively screened against guidelines relevant to identified potential end uses. Filtered metals are more representative of the bioavailable fraction (Clearwater *et al.*, 2002) and were used in screening assessments over total metals (where relevant).

Livestock proposed to graze on and around the project area following closure are Brahman cattle (*Bos indicus* from India hybridised with *Bos Taurus* from the United Kingdom) for beef production. The Brahman has developed as a major beef breed in hotter humid and dry areas of northern Australia (Blackshaw & Blackshaw, 1994). There is a high likelihood of stock contacting and/or drinking water from the pit lakes as cattle will graze terrestrial vegetation within pit catchments as well as both freshwater and salt meadow vegetation (Hodder & Low, 1978). Stock drinking water guidelines (ANZECC/ARMCANZ, 2000b) for young beef cattle were used in addition to protecting grazing stock as a proxy screening tool for regular contacting and ingestion of pit lake water by terrestrial native wildlife and avifauna.

Flora can be receptors of pit lake waters in their own right, e.g., through decant, but often more importantly determine wildlife distribution as habitat and food items. Although the pit lake is recognised as an artificial waterbody (sensu Water and Rivers Commission, 2000; McCullough & Lund, 2006), default aquatic freshwater ecosystem protection (95%) guidelines were used to determine risk of wildlife ingesting pit lake aquatic biota, or other wildlife that had been feeding upon pit lake biota (ANZG, 2018).

Humans may enter pit voids and make contact with lake waters for swimming and other primary contact activities and drinking (Doupé & Lymbery, 2005; McCullough & Lund, 2006). Pit lakes have afforded local populations with both passive and active recreational opportunities in a number of case studies. Pit lake recreation may be water-based, terrestrial only when water quality or access is poor or significant safety issues remain, or a mixture of both (Gerner & McCullough, 2018). As a result, human drinking water guidelines were applied to pit lake water quality.

3.0 RESULTS

3.1 Climate

Climate is the most important factor of the hydrologic processes associated with a pit lake (Castendyk, 2009). In general, surface hydrologic processes (e.g., direct precipitation, evaporation, and surface water runoff, including occasional stream or river inflows) are defined by regional climate to form a simple water balance budget for the pit lake (Sawatsky *et al.*, 2011).

A historical record of daily rainfall and evaporation is available in the form of a patched point data set from the Scientific Information for Land Owners (SILO) database. SILO patched point data is based on observed historical data from a particular Bureau of Meteorology (BOM) station with missing data 'patched in' by interpolating with data from nearby stations. The SILO patched point data was collected from station 14091 Middle Point Rangers. For this assessment, temperature and rainfall data was obtained for the site for the period from 1957 to 2021 (total 64 years).

The climate of the Darwin-Katherine region is tropical monsoonal and experiences two distinct seasons. The monsoonal wet season occurs from November to April and is typified by high humidity, temperature and evaporation. The cooler, less humid dry season occurs from May to October (BOM, 2021). Annual rainfall totals vary from about 1,000 mm to about 2,300 mm, with an average of about 1,430 mm. Annual pan evaporation totals are about 2,180 mm.

Figure 3 shows monthly rainfall totals and minimum/maximum temperatures near RRPA over the two sampling occasions from July 2019 to June 2021. 2019/2020 wet season rainfall was around1,294 mm whilst the 2020/2021 wet season had a very similar 1,344 mm of rain. However, 2020 sampling occurred in the middle of the wet season, whilst 2021 sampling occurred in the middle of the dry season.

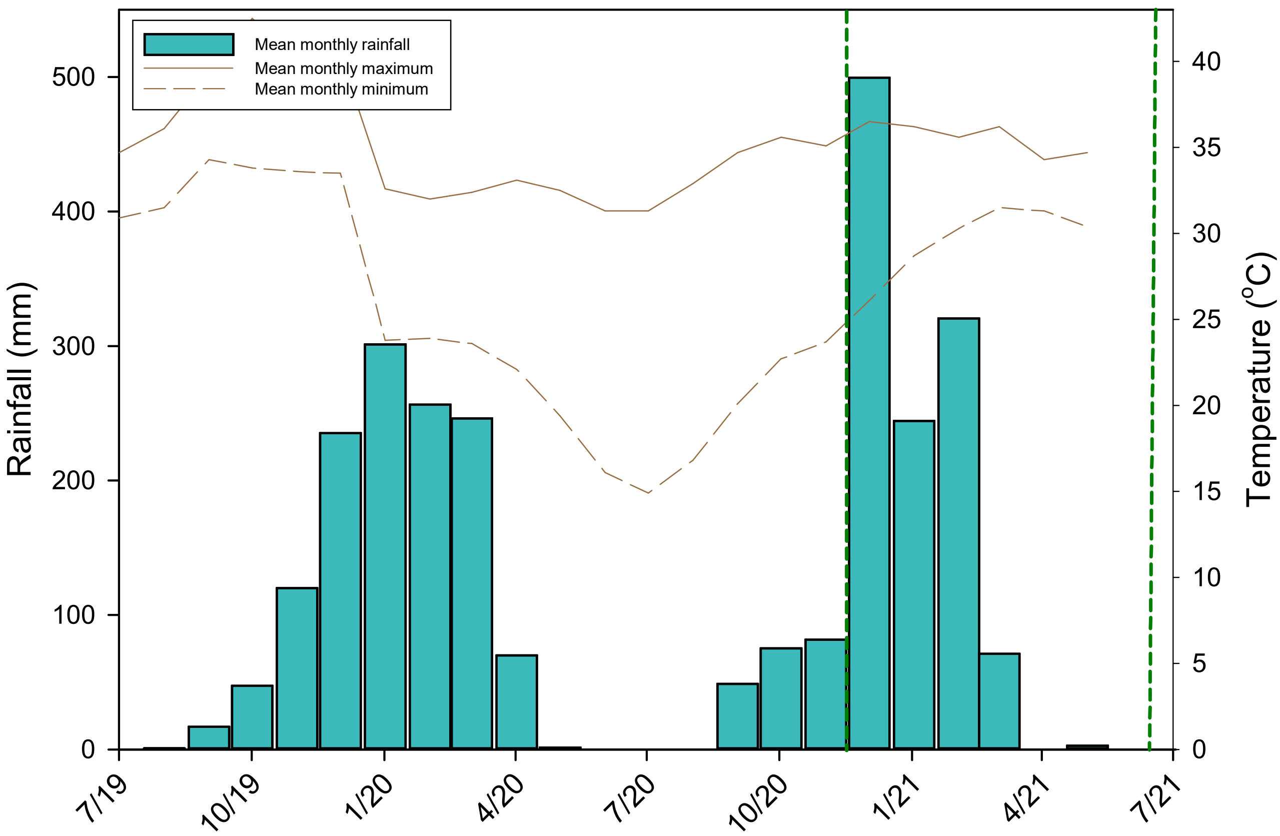

Figure 3. Mean monthly climate for nearby Middle Point Rangers Aerodrome (BOM, 2021) (2019–2021).

Sampling times shown in green doted vertical lines.

3.2 Water Quality

3.2.1 Profiles

Electrical conductivity (EC) showed very low salinity water of only around 25–40 µS/cm across all sampling times and sites (Figure 4). Mean 2020 water was around 10 µS/cm more saline than 2021 water (32 µS/cm–27 µS/cm), likely reflecting the effects of evapoconcentration in the intervening dry season months before rainfall of the 2020/2021 wet season over the 2019/2020 wet season that was finished upon sampling in that year. Sampling sites showed very similar EC to each other. However, 2021 sites also showed stratification with increased EC at depth. This increase is likely indicative of groundwater being pervasive in the stratified water column conditions of this time. Backhoe pit also showed high EC at depth; this may be due to a fracture or similar, introducing more saline groundwater at depth at this site.

pH showed a trend of decline across all times and sites (Figure 5). 2021 samples were also more acidic than circumneutral 2020; about 0.5 pH (7.1–6.6). As with EC, stratification was more pervasive in 2021 sampling than in 2020. This may again be due to more groundwater flow at this time while the lake is functioning as a terminal sink over the dry season. The lowest pH of 2021 Backhoe pit lake at depth supports a groundwater inflow at this point along a fracture or similar.

Temperature was very constant in 2020 sampling but showed marked stratification in 2021 (Figure 6). 2020 samples were also around 1°C warmer in 2020 than 2021 (29.6°C–28.8°C). This temperature stratification was apparent with 2021 dry season sampling but not in 2020 wet season sampling. An epilimnion formed at around 10 m and a hypolimnion beginning after a 5 m pycnocline at around 15 m. Thermal stratification of the lake is expected to occur only during warmer dry season and early wet season months, before cyclonic thunderstorm activity introduces forcing in the form of surface inflow and wind that are both important in deteriorating water column stabilisation (Hipsey *et al.*, 2017).

Turbidity was very consistent through the water column and between sites in 2021 (Figure 7). Turbidity at 2021 sites was also generally slightly lower than 2021 sites (bar the shallow Sweat Ridge site) (0.75–1.2 NTU). Higher turbidity in 220 wet season sampling is expected from surface flow inputs containing suspended solids (Lund *et al.*, 2020).

Oxidation-reduction potential (ORP) was much higher in 2021 than in 2020 (234 mV–32mV) (Figure 8). However, largely constant values until around 20 m depth where ORP values suddenly decreased. In 2020 these values also became negative and anoxic. These values indicate sediments are very likely anaerobic which may reduce some metal species (Luek *et al.*, 2017) but would mobilise any phosphorus nutrients (Roden & Edmonds, 1997). Higher ORP in 2021 may indicate higher concentrations of oxidised metal species in these samples from surface inflows across disturbed ground and a dominance of surface water inflows from 2020 groundwater inflows.

Oxygen was low at both sampling times and much lower in 2020 than in 2021 (mean 46% saturation compared to 87%) (Figure 9). These 2020 data may not be accurate as these are extremely low levels for pit lake (or even lakes in general). DO data data be checked for consistency with future data to confirm accuracy of the oxygen saturation levels. Nevertheless, there was a significant trend of oxygen decrease over depth in both years; with this trend beginning at 15 m in 2020 and at 20 m in 2021.

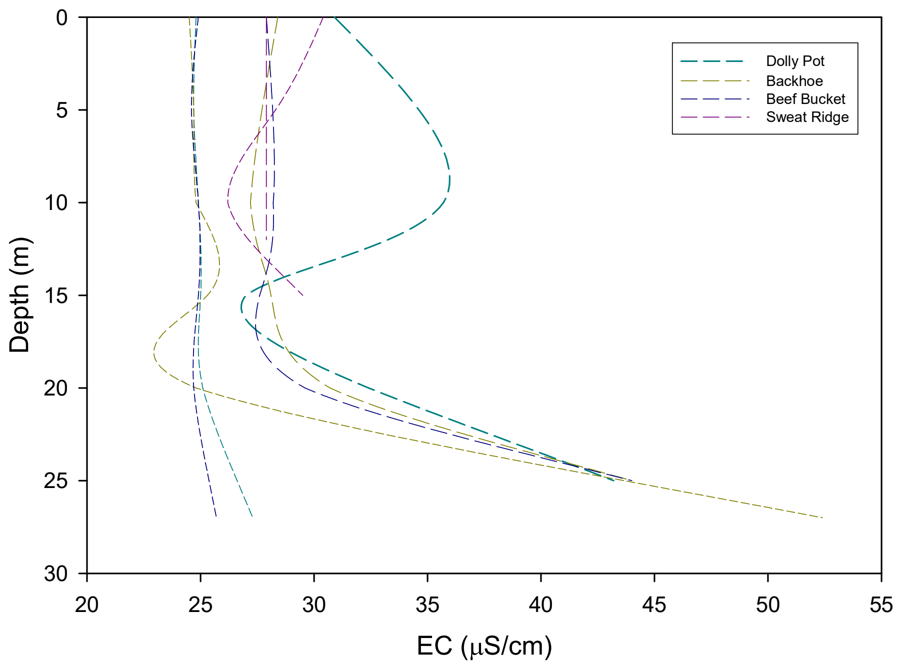

Figure 4. Electrical conductivity of RRPA pit lake by site and time.

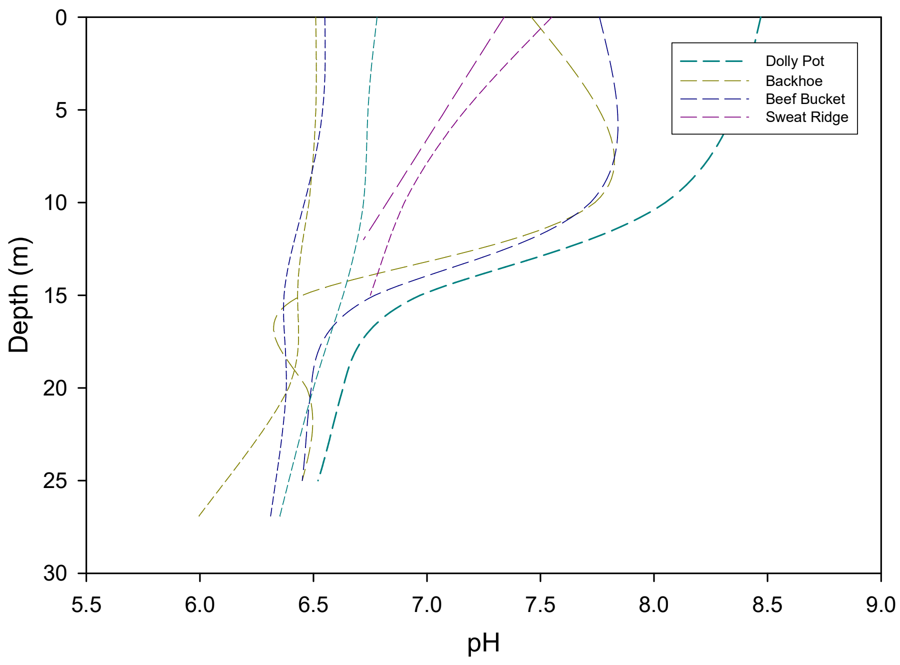

Figure 5. pH of RRPA pit lake by site and time.

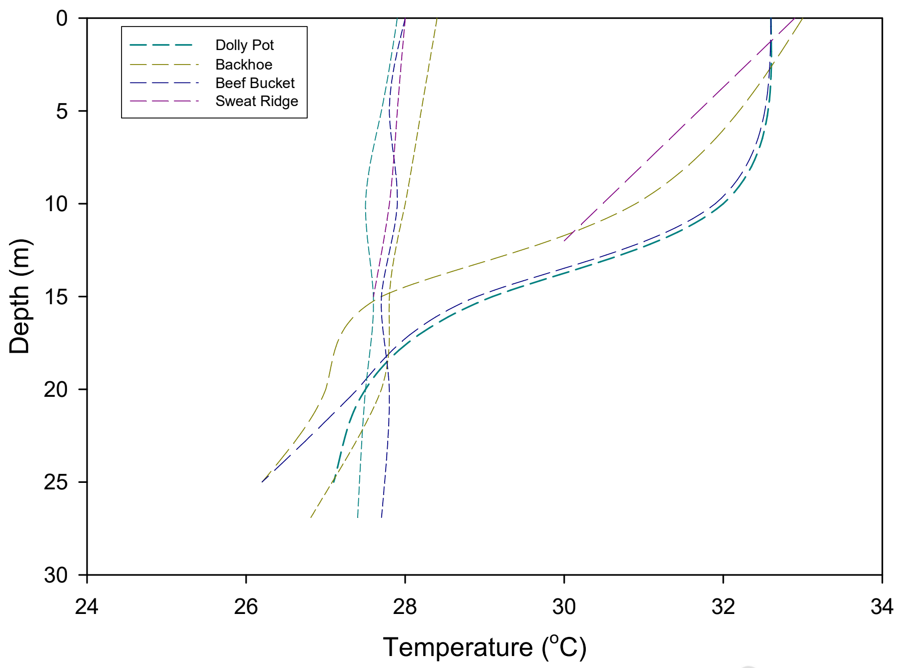

Figure 6. Temperature of RRPA pit lake by site and time.

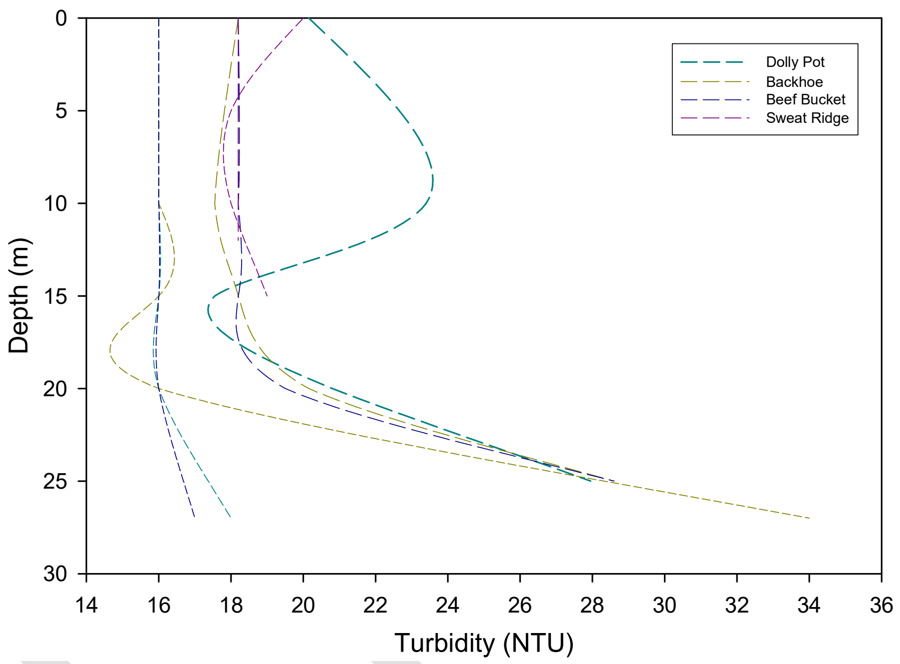

Figure 7. Turbidity of RRPA pit lake by site and time.

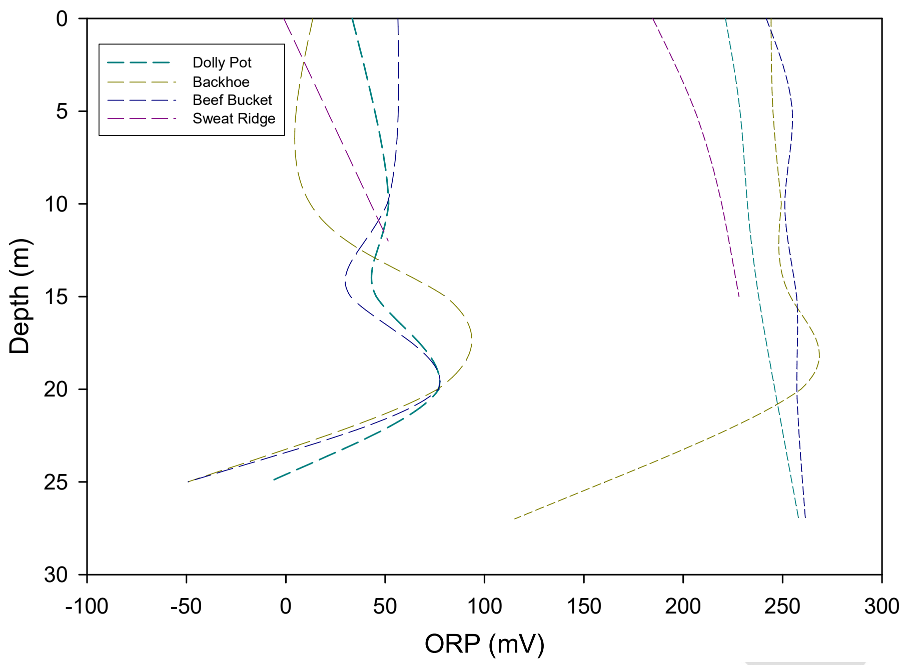

Figure 8. Oxidation-reduction potential of RRPA pit lake by site and time.

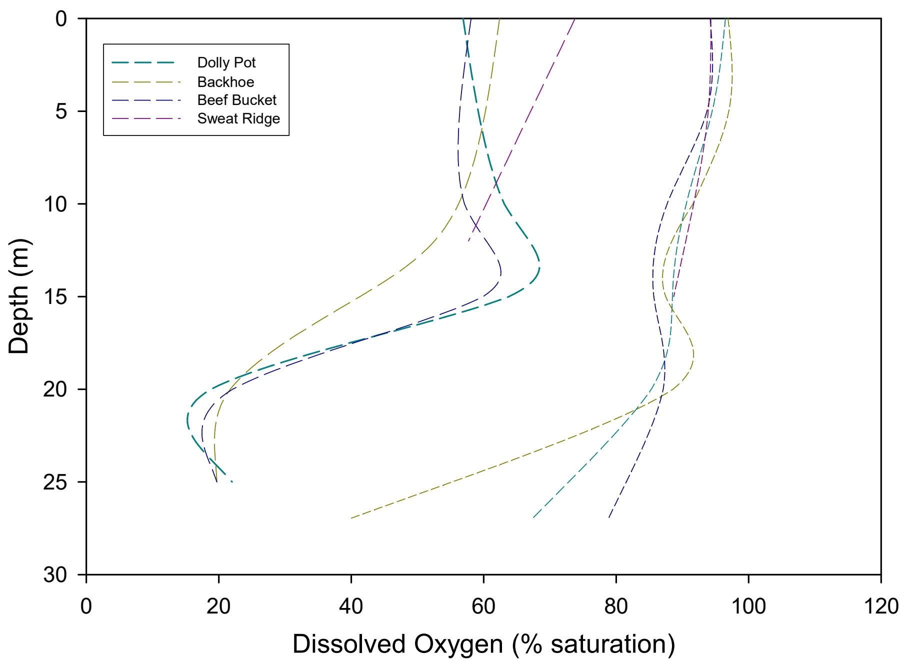

Figure 9. Dissolved oxygen percentage saturation of RRPA pit lake by site and time.

Note: Long dashed line indicates 2020 and dotted line indicates 2021 sampling.

3.2.2 Multivariate analysis

PCA plots separated water samples into three main groups with the PC1 axis explaining 39.2% of total variation and PC2 explaining 18.0% for a total of 57.3% variation explained as a low-reliability plot (Figure 10).

The water quality of sampling sites did not separate from each other with a scatter of all sites intermingled with each other. Sites were not statistically significantly different (Global R -0.036, p = 83.1%) (Figure 10, top). Sampling sites also did not appear to be along a water quality gradient along the pit strike from a north to south order of pits with Beef Bucket being the most different pit for water quality (Figure 11).

There was clear separation between mean samples between 2020 and 2021 (Figure 10, middle). Sampling years were also not statistically significantly different (Global R: 0.191, p = 0.07%). However, 2021 water quality demonstrated a difference primarily along PC2 with higher NO_x and Ni. Conversely, 2020 water quality had higher TP, Al, Cl, Cu, Zn and pH which may represent surface water inflow with loadings of some metals.

Mean stratification level was not statistically significant different between samples (Global R 0.049, p = 14.7%) (Figure 10, bottom). However, shallow water was generally higher pH with lower nitrogen as NH_3 and TKN nitrogen fractions (likely due to primary production (Tittel & Kamjunke, 2004; Kumar *et al.*, 2016)) and deeper waters were typically higher alkalinity, Ni and NOx potentially representing groundwater inflow (including NOx from blasting residue (Reevey, 1996)).

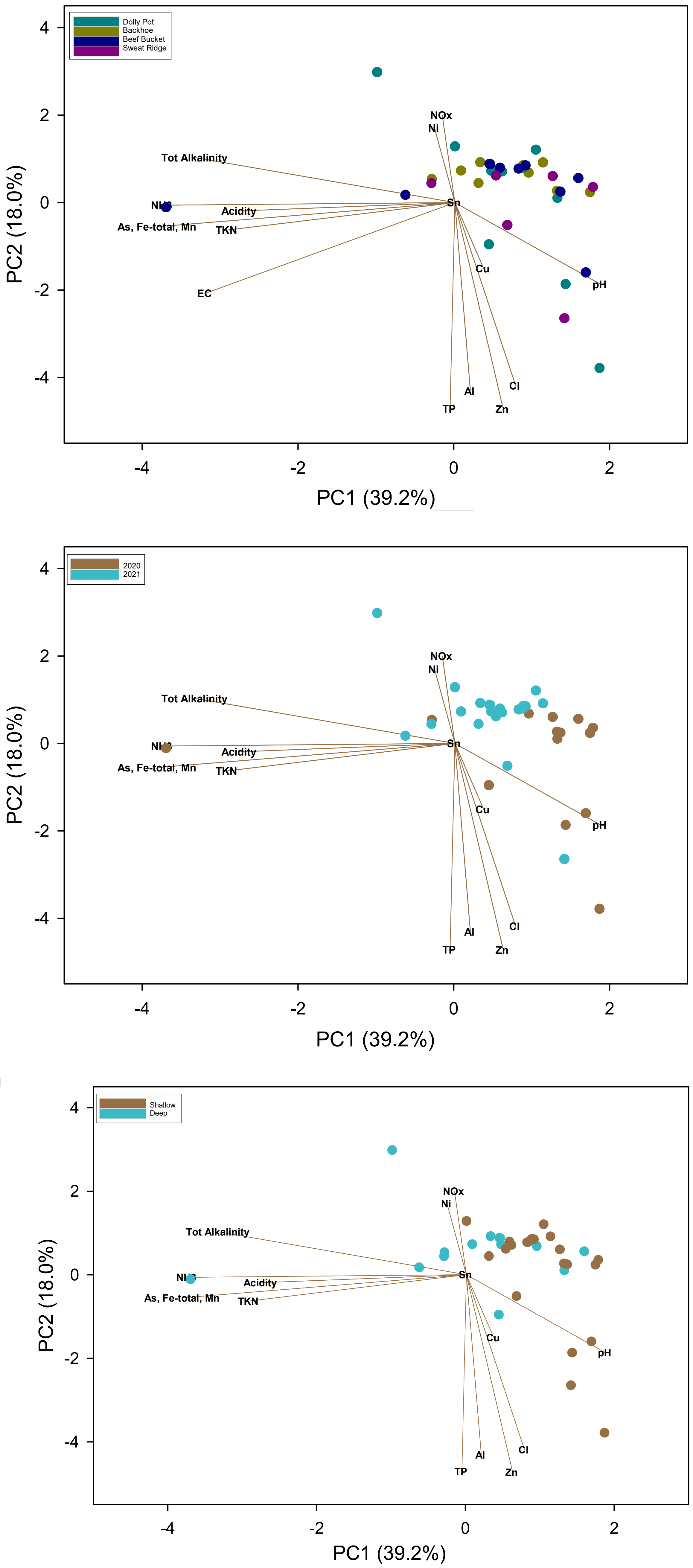

Figure 10. PCA ordinations of water quality by sampling site (top), date (middle) and depth (bottom).

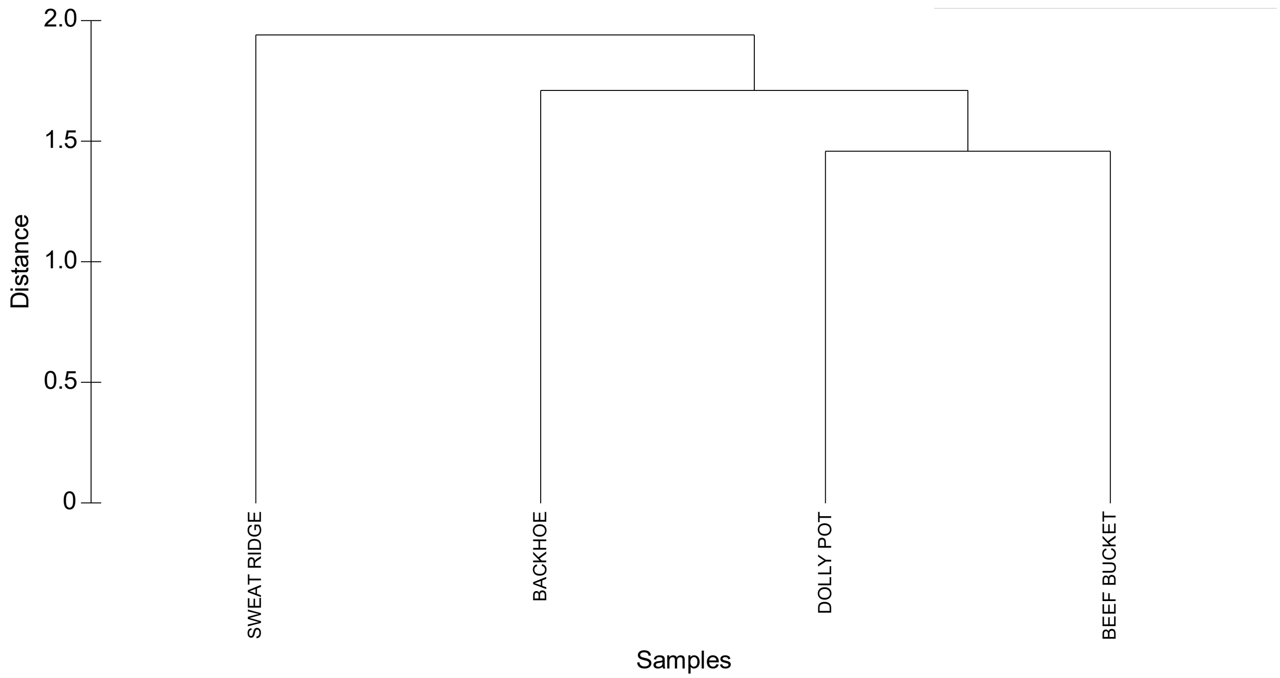

Figure 11. Cluster dendrogram for Rustlers Roost pit lake water quality by mean site.

3.2.3 Guidelines

3.2.3.1 Regional guideline trigger values

RRPA pit lake water quality did not meet guidelines for freshwater aquatic ecosystem protection for tropical lakes and reservoirs for (Table 1) TP, NO_3, NH_4, DO, pH, salinity and turbidity for both 2020 and 2021. Guidelines were also exceeded for TN for 2021 only. Curiously, exceedances for salinity and turbidity were because the water was too fresh and too clear, respectively.

Low pH exceedance in 2021 was very minor and within instrument precision range at 5.99 with the pH maximum in 2020 quite alkaline at 8.47.

Table 1. Pit lake water quality against regional guideline trigger values for freshwater aquatic ecosystem protection: tropical lakes and reservoirs (ANZECC/ARMCANZ, 2000a).

		TP	TN	NO_3	NH_4	DO	pH	Salinity	Turbidity
		µg/L	µg N/L	µg N/L	µg N/L	% saturation		µS/cm	NTU
Date	**Guideline**	**10**	**350**	**5**	**10**	**90-110**	**6.0-8.0**	**90-900**	**2-200**
	Mean	18	147	10	46	46	7.09	32	0.8
2020	Minimum	10	100	10	10	19	6.45	27	0.4
	Maximum	80	300	10	270	74	8.47	44	2.3
	Mean	13	217	12	66	86	6.60	27	1.2
2021	Minimum	10	100	10	10	40	5.99	25	0.1
	Maximum	30	700	40	570	97	7.55	52	4.1

3.2.3.2 COPC

Maximum solute concentrations of COPCs were compared to potential end uses guidelines (Table 2). Exceedances were only noted for the draft guidelines for total Fe and NH_4 However, data gaps exist for COPC of Hg and Mo.

Both 2020 and 2021 sampling maximums for total Fe were around an order of magnitude higher than the aquatic ecosystem protection guideline of 0.3 mg/L.

NH_4 exceeded aquatic ecosystem protection guidelines by around an order of magnitude. Furthermore, NH_4 also slightly exceeded potable guidelines.

Table 2. Pit lakes historical water quality against freshwater aquatic ecosystem protection (95% DGV unless otherwise stated) (ANZG, 2018), stock drinking (DWAF, 1996; ANZECC/ARMCANZ, 2000b) and potability guidelines (NHMRC/NRMMC, 2018).

Analyte	DGV	LOD	Stock drinking	Potability	2020	2021
Al	0.055	0.01	-	-	0.02	0.01
As	0.013	0.001	-	-	0.008	0.009
Cd	0.0002[H,B]	0.0001	**0.01**	0.002	0.0001	0.0001
Co	0.0014	0.001	**1**	0.006[ϴ]	0.001	0.001
Cr	0.0031[t,D,B]	0.001	-	-	0.001	0.001
CrVI	0.001[H,B]	0.001	-	-	0.001	0.001
Cu	0.0014[B]	0.001	**0.4**	2	0.001	0.002
Fe	0.3[t,A]	0.05	-	-	2	4
Hg	0.0006[B]	–	-	-	-	-
Mg	3[∞]	1	**1,000***	-	1	1
Mn	1.9	0.001	**10**	0.5	0.62	0.78
Mo	0.034	–	**0.15**	0.05	-	-
NH_4	0.012	0.01	**0.61**	-	0.33	**0.69**
Ni	0.011[H,B]	0.001	**1**	0.02	0.001	0.002
NOx	10.6	0.04[m]	**400**	50[m]	0.04	0.18
Pb	0.0034[H,B]	0.001	**0.1**		0.001	0.001
Se	0.005[t,B]	0.01	**0.02**	0.01	0.01	0.01
SO_4	-	1	**1,000***	500[1]	1	1
U	0.008[B]	0.001	-	-	0.001	0.001
Zn	0.008[H]	0.005	**20**	3	0.006	0.006

All values as filterable concentrations and in mg/L unless otherwise stated.
Red shading = exceeds ANZG (2018) default guideline (DGV) criteria for freshwater aquatic ecosystem protection, green = no exceedance of guideline values, blue = unknown.
ϴ USEPA regional screening levels for tap water (https://semspub.epa.gov/work/HQ/199646.pdf)
ø Tropical Australian reservoirs and lakes.
A After ANZECC (1992).
H ite-specific hardness modified trigger value (HMTV) as per Warne et al. (2018) as hardness calculated from [Ca] + [Mg] <30 mg/L as $CaCO_3$.
B Potentially bioaccumulating.
D Draft guideline from https://www.waterquality.gov.au/anz-guidelines/guideline-values/default/draft-dgvs#draft-default-guideline-values
t As total.
m As NO_3.
∞ Soft waters only (Van Dam et al. 2010).
* Protective of young beef cattle in hot climates.
1 Purgative effects may occur above this level.

4.0 SUMMARY AND CONCLUSIONS

Pit lake water quality as aquatic ecosystem habitat for the RRPA pit lake was moderately poor, with high nutrient concentrations and low oxygen concentrations. However, pit lake water quality as COPC concentrations for the RRPA pit lake was surprisingly good, with only slight exceedances of ecosystem values for total Fe and NH_4 and drinking water for NH_4.

Pit lake water quality seemingly reflects surface water inflow during the early dry/late wet season and groundwater inflow during the late dry/early wet season. Tropical pit lakes may be shallow but may still thermally stratify for a short period when rains have ceased (Kumar *et al.*, 2013). Shallow mine lakes are likely to destratify readily just by wind forces (Huber *et al.*, 2008; Hipsey *et al.*, 2017).If the pit lake has not mixed and remains stratified it is likely that the water quality discharging from overtopping of the pit would be similar to site run off (CDM Smith, 2019).

Although not considered herein, ingestion of food items from aquatic biota may also present a COPC pathway to humans through bioaccumulation of pit lake aquatic fauna. For example, through Traditional Owners or other people eating aquatic foods from the pit lakes such as fish (McCullough & Lund, 2006; McCullough *et al.*, 2009; Miller *et al.*, 2013). If considered a potentially significant contaminant pathway, and once long-term pit lake water quality is well understood, human ingestion risk should be considered in future pit lake assessments.

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Closing

Thank you for this opportunity to provide to provide professional services to you and your organisation. If you have any questions regarding this document, please feel free to contact the undersigned.

Authorisation

Dr Cherie D. McCullough, PhD

Director, Principal Environmental Scientist

BSc, MSc (Hons), PhD, FAusIMM CP(Env), OMCPPA

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ABN 53 970 913 800

Why choose Mine Lakes Consulting?

We are a highly experienced and internationally active environmental consultancy specialising in mine closure and particularly mine water and the environment. We have an excellent understanding of pit lake closure and compliance guidance, having developed much of this under contract to regulators. Our scientific work has provided underpinned the global understanding of pit lake environmental management.

Our staff are the globally recognised experts for all aspects of mine pit lakes and mine closure planning. We are the trusted advisors of both leading multi-national mining houses and governments across a range of jurisdictions. Our reputation precedes us.

- Mine pit lakes are typically not well managed in closure planning. However, Mine pit lakes are Mine Lakes Consulting core business. As such, we have a much deeper understanding of the science and policy surrounding these key closure landforms.
- Dr Cherie McCullough is PhD qualified in the ecotoxicology of mine waters; the key discipline critical to understanding environmental risk and contaminated sites issues surrounding pit lakes.
- We have a broad project experience of general and other landform-specific mine closure planning, enabling us to assist with inclusion of mine pit lakes into broader closure planning and approval documents.
- Our work and advice is well-regarded by stakeholders and the scientific community through regular leading-practice industry presentation and an extensive breadth and depth of peer-reviewed industry and academic publications of the state-of-the-art of multi-disciplinary science underpinning mine pit lakes.

APPENDIX A. STUDY ASSUMPTIONS AND LIMITATIONS

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