Central Queensland Coal Project

Appendix 10h – Preliminary Isotope Study

Central Queensland Coal

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Terms and Abbreviations

Cl	Chlorine
GDE	Groundwater Dependant Ecosystem
GMWL	Global Meteoric Water Line
HCO3	Bicarbonate
LMWL	Local Meteoric Water Line
MWL	Meteoric Water Line

1 Connectivity Assessment Results Using Isotope Analysis

1.1 Overview

A preliminary isotope study was undertaken by CDM Smith between 16 and 18 July 2018 to provide an initial indication of water sources supporting the watercourse pools, which are hypothesised to be supported to some extent by groundwater discharge (i.e. Type 2 GDEs, see SEIS Chapter 10 - Groundwater). This study formed part of the works to assist in improving the understanding of the water requirements of the GDEs and potential impacts arising from mining operations, which will in turn enable appropriate management objectives and approaches to be developed to manage these GDEs during and post-mining.

To better understand the relationship between the surface water and groundwater, the stable isotopes of water (δ^2H and δ^{18}O) and radon isotope (^{222}Rn) were analysed from surface water samples collect from pools in both Tooloombah and Deep Creeks, coupled with six groundwater monitoring wells located close to the surface water sampling points. The methods and results are outlined below.

1.2 Environmental (Stable) Isotopes

1.2.1 Methods

Craig (1961) observed that when stable isotopes of water (δ^2H and δ^{18}O) have not undergone evaporation, they would have a linear relationship which can be represented by:

$\delta^2H = 8\ \delta^{18}O + 10$

This equation is referred to as the Global Meteoric Water Line (GMWL) and was developed based on precipitation data from across the globe. A Local Meteoric Water Line (LMWL) is usually developed from precipitation data collected from either a single location or a set of locations within a localised area of interest (USGS 2018), noting that there are limited data available in the Project area to construct this trend, thus there is some uncertainty in the LMWL derived.

The stable isotopes of water can be used to discriminate between different sources of water. The method relies on the distinct isotopic compositions which can arise as a result of isotopic fractionation caused mainly by transportation processes (i.e. mixing) and phase transitions (i.e. evaporation) through the atmosphere, lithosphere and biosphere (Barnes and Allison 1988).

Six grab water samples were collected from Tooloombah Creek in-stream pools (two sampling points each from three pools within the creek – pools To1, To2 and To3) and another three from Deep Creek in-stream pools (a sampling point from each of three pools within the creek – De2, De3 and De5) between 16 and 18 July 2018. Groundwater samples were collected from six monitoring wells located close to the surface water sampling points (WMP02, WMP04, WMP04D, WMP05, WMP06 and WMP10), using a low-flow groundwater sampling pump.

The locations are shown in Figure 1-1.

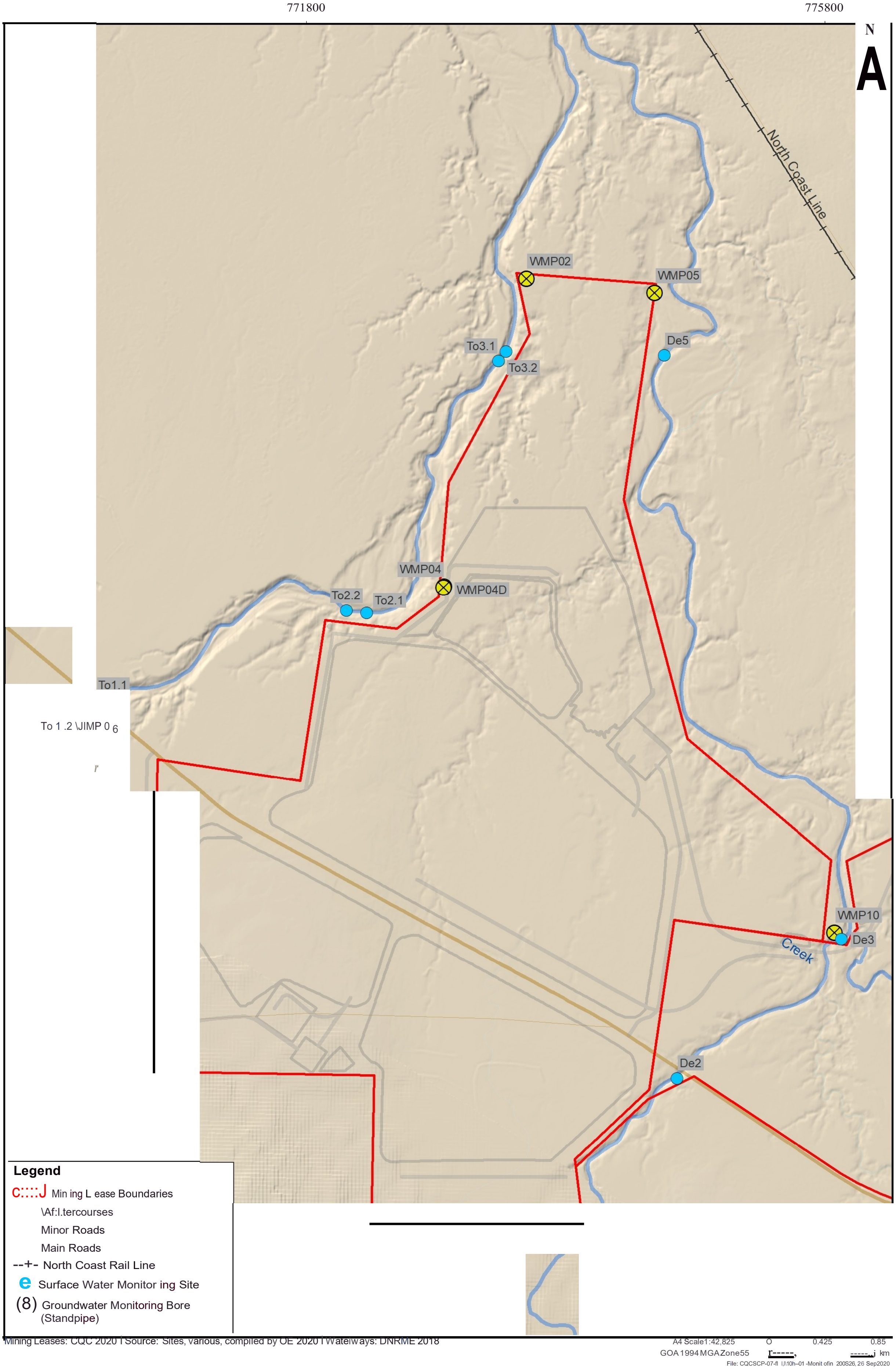

Figure 1-1: Location of sampling sites

Water samples were analysed by Environmental Isotopes (contracted via Australian Laboratory Services, ALS). The hydrogen and oxygen isotope ratios were measured using a Wavelength Scanned-Cavity Ring-down Spectrometer (Picarro L2120) based on Munksgaard *et al* (2011). Lake Eacham and Cairns Tap water were used as reference waters to develop localised water standards.

1.2.2 Results

Laboratory results are presented in Table 1-1 while the results and water standards along with the relevant MWLs are plotted in Figure 1-2.

Table 1-1 Stable isotopes of water measured in groundwater and surface water samples

Location	Sample type	δ2H (‰, VSMOW)	δ18O (‰, VSMOW)
WMP02	Groundwater	-23.11	-3.94
WMP04		-27.23	-4.42
WMP04D		-25.12	-4.23
WMP05		-34.07	-5.44
WMP06		-11.77	-1.69
WMP10		-24.06	-4.04
De2	Surface water: Deep Creek	2.34	1.28
De3		-14.4	-1.71
De5		0.37	0.92
To1.1	Surface water: Tooloombah Creek	2.04	0.9
To1.2		0.49	0.65
To2.1		-0.07	0.76
To2.2		-7.98	-0.61
To3.1		-1.87	0.45
To3.2		1.51	1.07

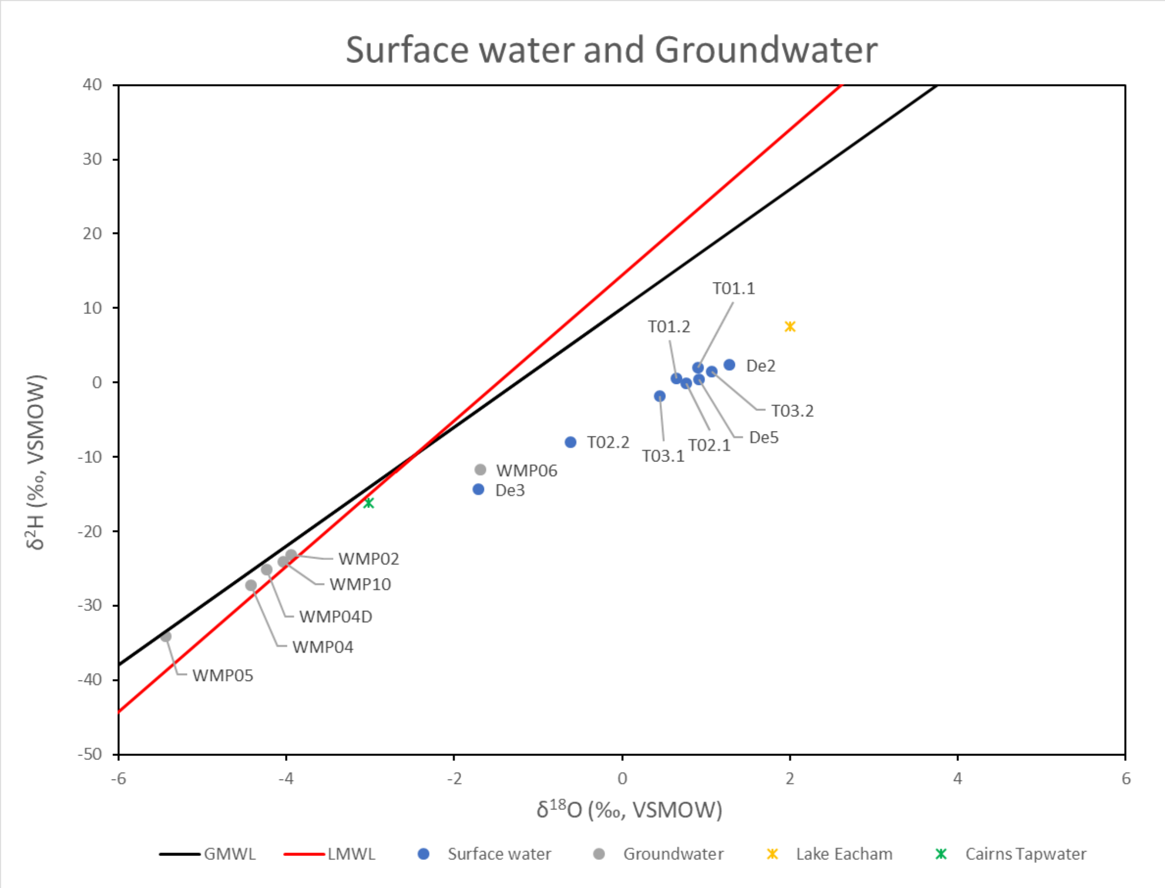

Figure 1-2 Environmental (stable) isotopes

The GMWL is based on precipitation data from numerous locations across the globe while the LMWL was developed from data collected by CSIRO between February and March 2010 in Rockhampton, Queensland (Crosbie *et al*. 2010).

The laboratory reported Lake Eacham and Cairns Tapwater are reference standards that the samples can be compared with. There is clear distinction between the isotopic values of samples from the surface water and groundwater, indicating different processes have affected the two sample groups. Gonfiantini (1986) noted that when water undergoes evaporation, the residual isotopes become progressively enriched in heavier isotopes of δ^2H and $\delta^{18}O$, and the ratio of $\delta^{18}O$ to δ^2H increases. However, when isotopic composition of a water sample plots close to the MWL, it is indicative of its meteoric origin.

The groundwater samples plot on or near the GMWL and LMWL, indicating that groundwater is derived mainly from rainfall recharge and that they underwent little to no evaporation prior to recharge. Surface water samples collected from in-stream pools plot well below the GMWL and LMWL, indicating that they have been affected by evaporation (heavier isotopes, relative to the groundwater samples), which is not unexpected.

1.3 Radioactive Isotopes – Radon

1.3.1 Methods

Radon-222 (^{222}Rn) is a radioactive daughter isotope of Radium-226 and is the longest-lived and most-studied isotope of radon (it has a half-life of 3.82 days). Radon is a gas and will tend to seek a gaseous phase. This means that the natural waters that come into contact with the atmosphere will readily lose radon to the atmosphere, which has very low radon concentrations (USGS 2018). For this reason, groundwater usually has a much higher concentration of ^{222}Rn than surface water.

^{222}Rn is often used in groundwater and surface water interaction studies because the surface water will have a very low natural ^{222}Rn due to degassing and any elevated concentrations can be used to indicate local discharges of groundwater.

Six grab water samples were collected from the Deep and Tooloombah Creeks (three each) between 16 and 18 July 2018. Groundwater samples were not collected for radon analysis during this preliminary assessment as the current monitoring bores are not in proximity to surface water bodies. Radon was extracted from the samples into a 20 mL mineral oil scintillant based on the method proposed by Leaney and Herczeg (2006).

Water samples were analysed on 26 July 2018 at the Australian Nuclear Science and Technology Organisation (ANSTO) laboratory.

1.3.2 Results

Table 1-2 provides a summary of the radon results. Notably, the holding period between the sampling and analysis was between 8 and 10 days, and given ^{222}Rn has a 3-day half-life, corrections have been required to account for this using a correction equation described by Dawood *et al*. (2012).

Table 1-2 ^{222}Radon data

Date of sample collection	Date of sample analysis	Holding time (in days)	Sample ID	Lab result (Bq/L)	Corrected values (Bq/L)
16-07-18	26-07-18	10	DE3	0.19	1.17
17-07-18	26-07-18	9	De5	0.06	0.30
18-07-18	26-07-18	8	DE2	0.11	0.48
18-07-18	26-07-18	8	To1	0.65	2.75
18-07-18	26-07-18	8	To2	0.83	3.54
18-07-18	26-07-18	8	To3	0.45	1.93

The ranges of observed ^{222}Rn concentrations in the pools at Tooloombah Creek indicate that there is a likely connection between the creek and the groundwater while the concentrations from Deep Creek indicate low connectivity during the time of sampling (July 2018, which is dry season).

With the understanding that radon, bicarbonate and chloride are higher in groundwater than in surface water and that long residence time would facilitate the loss of radon from water to the atmosphere, O'Grady *et al*. (2007) plotted ^{222}Rn isotopes against chloride and ^{222}Rn against bicarbonate / chloride to determine the amount of groundwater inflow into wetlands. Comparing the ^{222}Rn and Cl^- present in different locations, the authors noted that sites with:

- low ^{222}Rn and low Cl^- concentrations are considered to have short residence times and low groundwater input

- high ^{222}Rn and medium Cl^- concentrations are considered to have short residence times and a reasonable input of groundwater
- high ^{222}Rn and very low Cl^- concentrations are considered to be unlikely as low chloride concentration indicates surface water is predominant, which would have negligible radon concentration and
- high ^{222}Rn and high Cl^- concentrations are also considered to be unlikely as high concentrations of Cl^- would indicate long residence time resulting in high evaporation which would have led to the loss of ^{222}Rn to the atmosphere, exceptional cases include where groundwater is rich in chloride.

Comparing the ^{222}Rn and the ratio of bicarbonate and chloride values (HCO_3^-/Cl^-) present in different locations, the authors also noted that sites with:

- low ^{222}Rn concentration and low ratio of HCO_3^-/Cl^- are considered to have low groundwater input
- low ^{222}Rn concentration and high ratio of HCO_3^-/Cl^- are considered to have higher groundwater input and long residence
- high ^{222}Rn concentration and high ratio of HCO_3^-/Cl^- are considered to have higher groundwater input and short residence and
- high ^{222}Rn concentration and low ratio of HCO_3^-/Cl^- are considered to be unlikely as a low ratio of bicarbonate to chloride indicates that groundwater input is negligible, meaning radon should not be present.

Figure 1-3 and Figure 1-4 show the plots of radon vs. chloride concentrations and radon vs. bicarbonate / chloride ratios, respectively. Figure 1-3 indicates that groundwater contributes only a limited amount of water to Deep Creek (very low chloride and ^{222}Rn) while Tooloombah Creek receives relatively higher amount of groundwater inflow (higher amounts of chloride and ^{222}Rn). Deep Creek also has longer residence time relative to Tooloombah Creek due to lower ^{222}Rn values. This is further buttressed by Figure 1-4, which indicates that groundwater contributes to some extent in both creeks (medium values for the bicarbonate / chloride ratio, 0.4 – 1.8) at the time of sampling.

Overall, both creeks appear to be connected to groundwater to some extent and undergo evaporation.

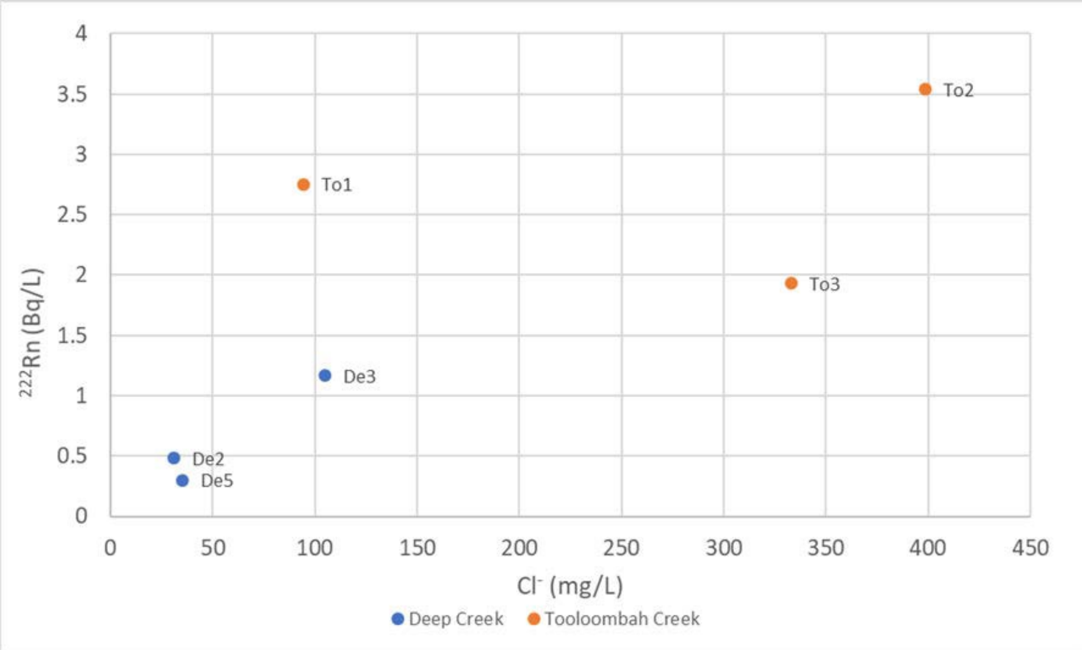

Figure 1-3: Radon versus chloride

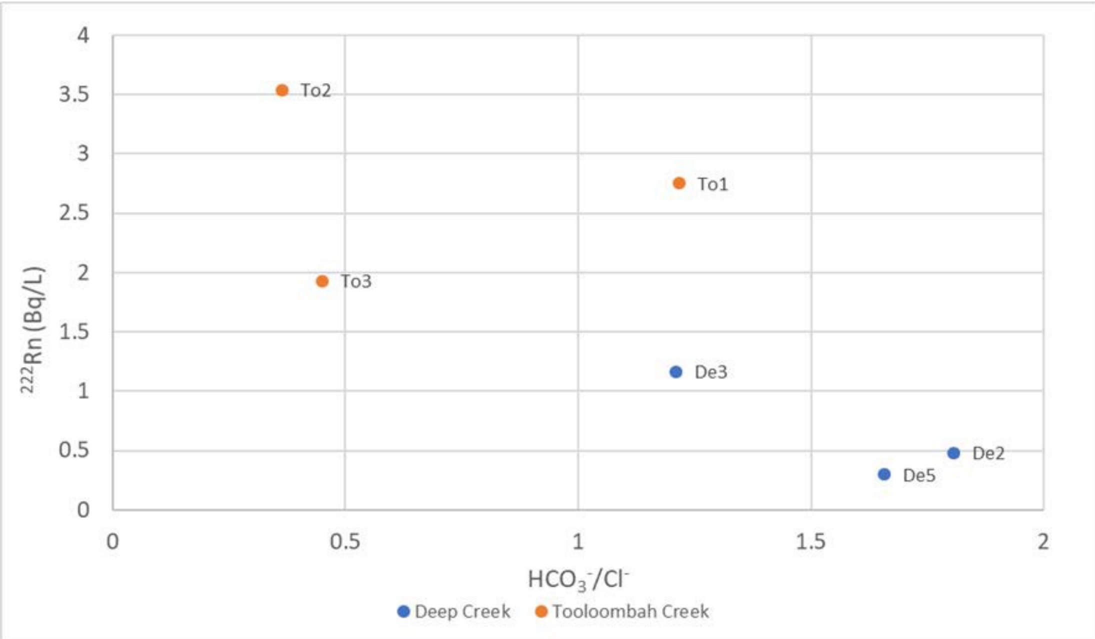

Figure 1-4: Radon versus bicarbonate/chloride ratio

1.4 Results Summary

The environmental isotopes along with the radon isotopes indicate the creeks are, to some extent, connected to groundwater at the time of sampling. The clear distinction between the environmental isotopes of groundwater and the surface water samples indicate surface water has undergone more evaporation (longer residence time) relative to groundwater. The groundwater samples are less depleted and where they plot on the global and local MWL indicate rainfall is the main source of recharge and that the water underwent little to no evaporation prior to recharge.

δ^2H and $\delta^{18}O$ results from the Deep and Tooloombah Creeks pools shows the isotopes have been enriched as a result of evaporation. It also indicates they have higher retention time (relative to the recharge source of the groundwater).

The radon analysis on Deep and Tooloombah Creeks water samples indicate Deep Creek is less connected to groundwater and has longer residence time relative to the Tooloombah Creek (relatively higher chloride and ^{222}Rn). The presence of bicarbonate and chloride in both creeks (HCO_3^- /Cl^- ratio ranging between 0.4 and 1.9) indicate groundwater baseflow supports creek pools, albeit not in significant quantities.

1.5 References

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