Biodiversity and Conservation Science

Muir-Byenup peat wetland acid release investigation design and initial monitoring results

Prepared for the South West Catchments Council (SWCC) Project No. 022LM.5640 – Milestones 1 and 2

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Cover image reference

Tordit-Gurrup Lagoon depth gauge (left) Byenup Lagoon peat cores (centre) and Tordit-Gurrup Lagoon – desiccation within the northern peat shelf (right), February-May 2015 (photograph by Jasmine Rutherford)

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Acknowledgments

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1 Background

Many wetlands and damplands in southwest Western Australia possess carbon-rich peaty substrates that have potential to acidify lake water due to their high entrained concentrations of sulfate minerals, metals and metalloids. Acidification of lake water can occur through both natural and anthropogenic induced changes where water availability is reduced. Prolonged periods of drying can produce physical changes within the substrate, such as desiccation, followed by geochemical changes that sequentially exhaust the capacity of the soil and entrained water to buffer reductions in pH.

Repeated drying and acidification of soil and water will alter the ecological character of a wetland system. In 2012 reductions in pH (between 2 and 3) were noted in the southern water body of Tordit-Gurrup Lagoon prior to the lake drying for the first time in recorded history (last 40 years).

Tordit-Gurrup is one of the larger wetlands within the internationally important (RAMSAR) listed Muir-Byenup wetland complex. The Muir-Byenup wetlands are located around 290 km south-east of Perth and around 60 km east of Manjimup (Figures 1 and 2). The wetlands are located on top of a Neogene palaeovalley and drainage basin that contains a continuous suite of variably connected wetlands. The wetlands provide important habitat and food sources for a high diversity of waterbirds, including breeding sites for the threatened Australasian bittern (e.g. Storey 1998 and Farrell and Cook 2009). The wetlands support particularly diverse and restricted communities, with at least 32 short-range endemic aquatic invertebrates, the threatened Balston's pygmy perch (and 5 other endemic fish species, out of 8 in the south-west) and 21 priority flora species.

The wetlands are managed by the Department of Biodiversity, Conservation and Attractions (DBCA; the Department) and the Muir-Byenup RAMSAR site is seen as priority asset (see Warren Region Nature Conservation Plan). Hydrological monitoring has been undertaken by the Department since the 1980's. In the late 1990's and early 2000's it was reported that rising groundwater levels was the cause of vegetation stress due to water logging and water and soil salinisation (Gibson and Keighery 1999 and Smith 2003). In 2010 acidity was identified as another important threat to the biodiversity within the lake with work by Smith (2010) concluding it was widespread in the Muir-Byenup RAMSAR site. A follow up water balance investigation of Noobijup Swamp in 2011, reported that the near-surface presence of groundwater was critical in maintaining high moisture levels and preventing sediments oxidising and acidic conditions developing (Wroe 2011).

The decline in average rainfall in the southwest of Western Australia since the 1970's has reduced surface water flows, lake hydro-periods and groundwater recharge. Peat wetlands are particularly sensitive to change as when saturated their high porosities and low permeabilities tend to limit their interactions with other water sources. As a result, when they do experience prolonged drying it can result in deleterious changes in their physical and chemical character.

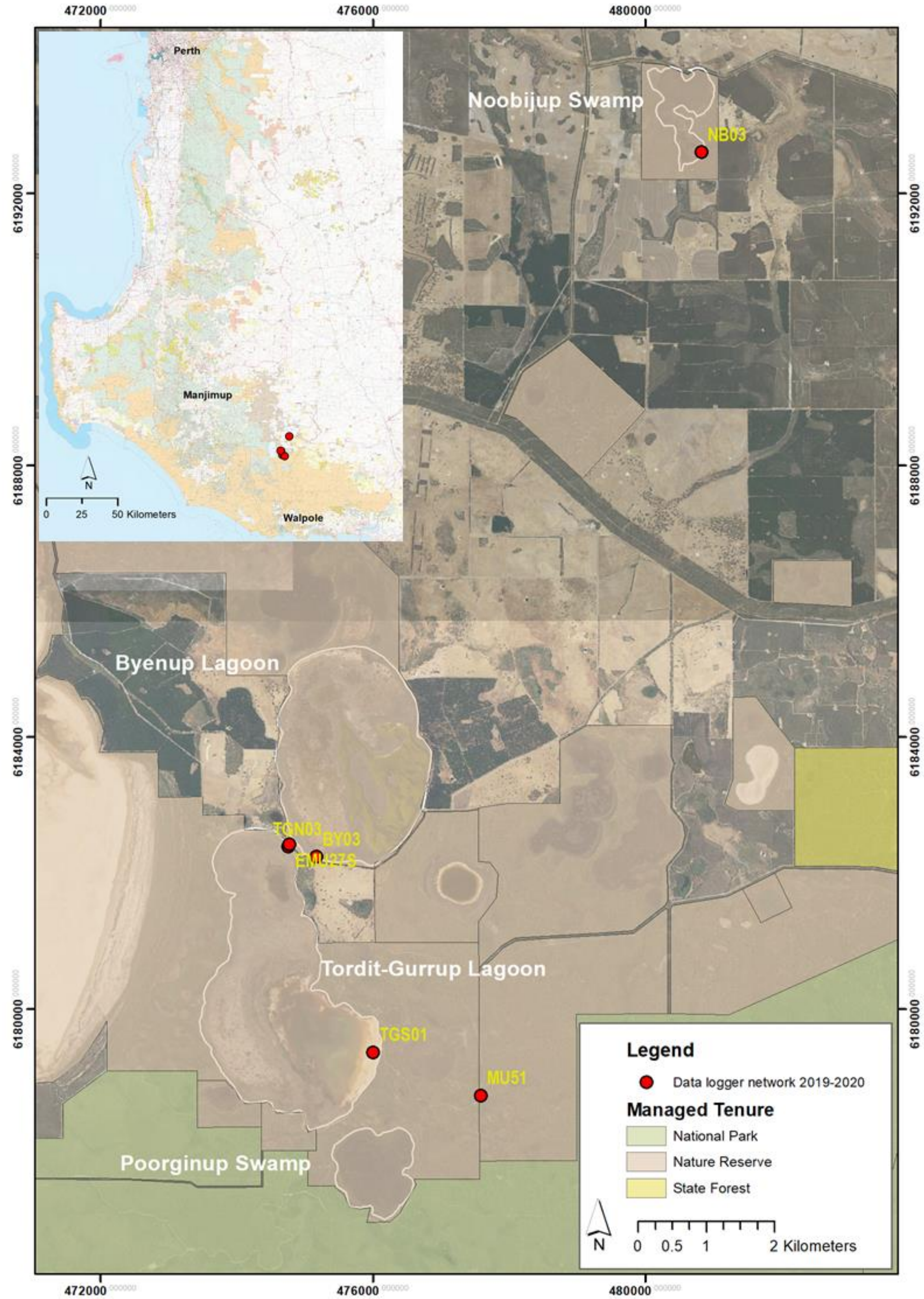


Figure 1: Map showing the location of DBCA managed tenure in relation to the Muir-Byenup RAMSAR listed peat wetlands investigated in the DBCA peat wetlands study (2015-2018); groundwater data logger sites are in red on both the main and coarse scale inset map.

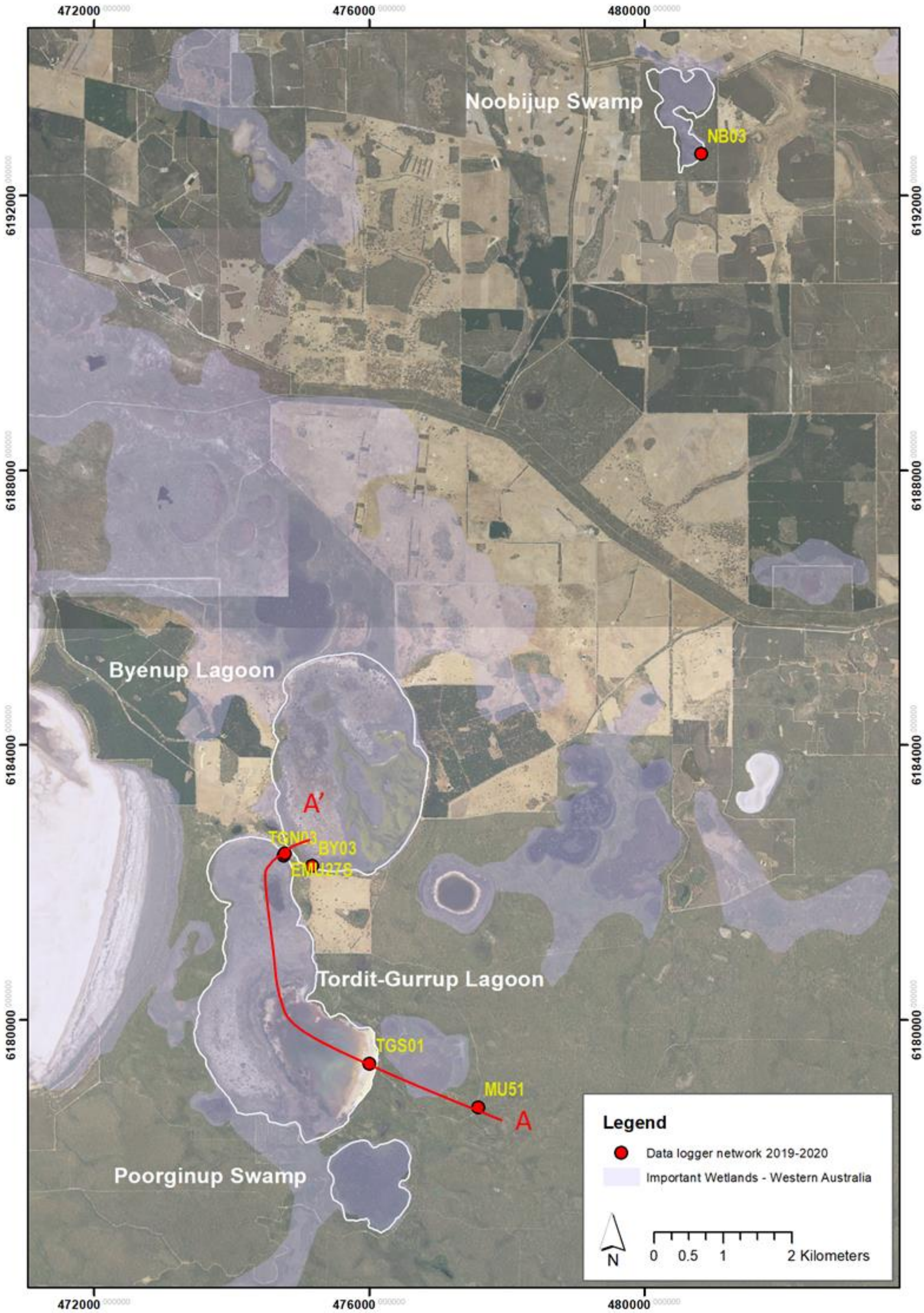


Figure 2: Map showing the location of Muir-Byenup peat wetland study sites in relation to current land use and boundaries of important wetlands. See Figure 4 for Cross Section A-A'.

Drying induced chemical reactions change water retention, permeability and the pH of peat soil water. As a result, the re-wetting of dry peat requires more water which due to the changed permeability releases more acid.

How optimal water balance conditions can be maintained under a drying climate is the subject of work undertaken in this study. In the Muir-Byenup RAMSAR site some wetlands continue to sustain a peat substrate and show little change in relation to these physico-chemical changes. However, there is a delay in the lake substrates and vegetation showing the effects of moisture loss and once they do it is generally too late to implement effective management actions. A lack of hydrological infrastructure and sampling within the lakes currently prohibits an accurate assessment of current groundwater condition and trends.

In 2015 the Department invested in the development of a 3yr project to assess peat wetland resilience (BCS project SP 2014-24). The project involved installing groundwater monitoring bores in lake/wetland shorelines and developing auger transects to sample the peat substrate from the shoreline into the centre of the lake. Data collected showed the different wetland groundwater responses to winter and summer rainfall and the spatial distribution of acid generating soils in relation to wetland open water bodies.

Project SP 2014-24 has entered its reporting phase and has been extended to assess seasonal acid fluxes into the Tordit-Gurrup southern water body (near TGS01 in Figure 1). The project extension has been facilitated through funding provided by the South West Catchments Council – Project number 022LM.5640 and the aims and anticipated outcomes from the project extension are discussed in the following section of this report.

2 Project aims and major tasks

The main project aims are to improve understanding of peat wetland water balances, quantify peat acid stores, determine hydrological processes that encourage acid generation and assess acid fluxes (e.g. vertical and lateral movement, seasonal changes and recycling).

This will be achieved through undertaking the following activities over 24 months;

- <u>Data collection</u>: collection of augered peat soil and water data at Tordit-Gurrup south and installation of data loggers in monitoring bores to collect groundwater level and quality data at Tordit-Gurrup Lagoon, Byenup Lagoon and Noobijup Swamp.
- <u>Results:</u> interpretation and data integration (including DBCA SP 2014-24 (2015-2018) peat wetland study) and Tordit-Gurrup (southern water body) literature review to assess the seasonal acid flux as a percentage of current acid storages, identify the main hydrological processes driving acid release and recommend appropriate methods for on ground trials (e.g. extension to small scale laboratory/mesocosms scale trials at Tordit-Gurrup Lagoon (south),

- Modelling and verification trials; geochemical and water balance modelling and Tordit-Gurrup south laboratory/mesococms scale trial update and
- Reporting; including current and predicted acid resilience of Muir-Byenup wetlands and recommendations for the rehabilitation of Tordit-Gurrup south.

As there continues to be debate on the most appropriate remediation activities at this site, we recommend the investigation into acid stores in Tordit-Gurrup Lagoon be undertaken to enable the potential longevity of the acid problem to be understood and appropriate sites and strategies for rehabilitation be identified.

This will be followed by a peer reviewed analysis of remediation options, in consideration of the field results, with recommendations of suitable laboratory/mesocosm scale investigations to verify the assessment and identify the most appropriate sites and methods for rehabilitation. The investigation design follows best practice and the project is supported by Dr Grant Douglas (Geochemist and Senior Principal Research Scientist CSIRO) and Dr Steve Appleyard (Senior Principal Geochemist and hydrogeologist, Department of Water and Environmental Regulation (DWER)).

The project proposes to deliver the following;

- An improved understanding (conceptual model) of the key regional and local scale hydrological and hydrochemical processes that sustain the physical and chemical character of peat and organic rich substrate material within the Muir-Byenup wetlands, delivered as improved conceptual and numerical models that characterise the physical and geochemical behaviour of peat wetlands
- A risk assessment of the frequency and duration of current and future acidification events in Tordit-Gurrup and other Muir-Byenup peat wetlands

A basis on which to prioritise the conservation of peat wetlands within the Muir-Byenup system based on the likely resilience of wetlands to hydrological change (Perup Management Plan Hydrology and Altered Hydrology Regime Objective), An assessment of strategies for remediation of acidified Muir-Byenup wetlands, including lab/mesocosm scale investigations.

2.1 Report structure

The report presents a conceptual hydrological model and reports on the installation of monitoring infrastructure to assess peat wetland acid fluxes and the interpretation of initial monitoring results. Section one, two and three provide project background information, project aims and the conceptual model. Section four explains the acid flux investigation design and installation (Milestone 1: South West Catchments Council – Project number 022LM.5640). Section 5 interprets monitoring data collected in October and November 2019 (Milestone 2: South West Catchments Council – Project number 022LM.5640), with Section 6 discussing the significance of the results.

3 Hydrological conceptual model

This section contains a brief summary of our current hydrological understanding of water and solute movement in the Muir-Byenup RAMSAR site.

3.1 Rainfall

The majority of hydrological studies in Muir-Byenup RAMSAR site refer to rainfall data from the Bangalup Bureau of Meteorology (BOM) Station No. 9506, located approximately 25km east of Tordit-Gurrup Lagoon. Average annual rainfall has decreased with the rainfall deficit since the late 1960's to early 1970's, with some wet years in the 2000's produced from episodic rainfall in summer (e.g. 2005) and in winter (e.g. 2016) (Figure 3).

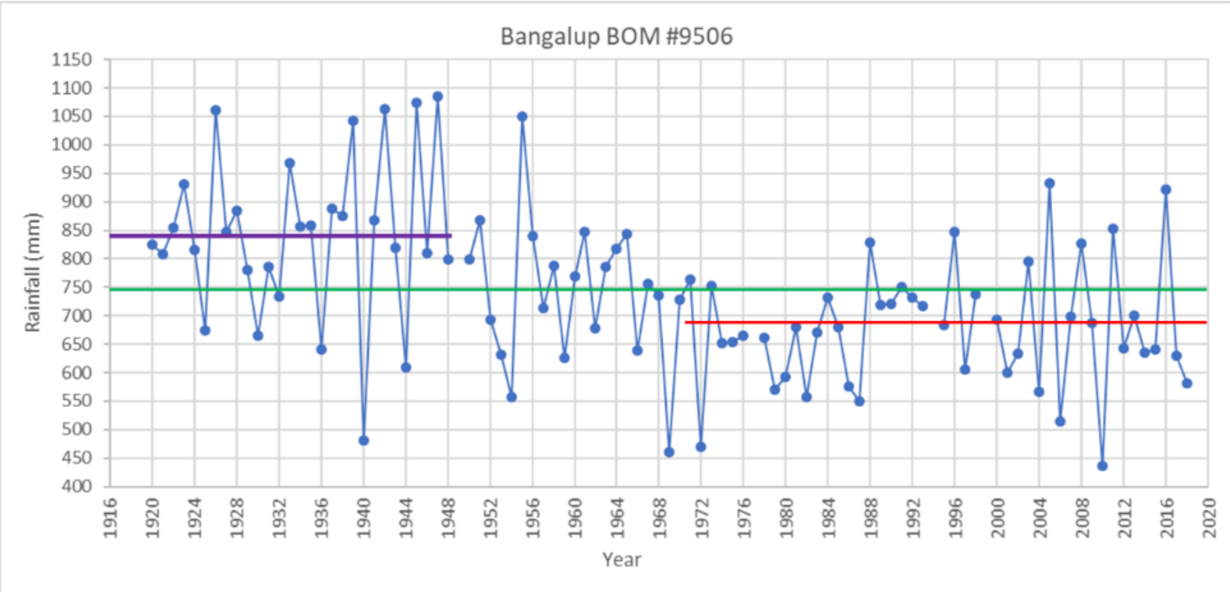


Figure 3: Annual rainfall BOM Station No. 9506; mean annual rainfall (1920-2018) represented by the green line at ~743mm; (1920-1948) by the purple line at ~841mm and (1970-2018) by the red line at ~680mm.

3.2 Groundwater and lakes

Reductions in average annual rainfall since the 1970's result in declines in streamflow, lake hydro-periods and groundwater recharge. At a coarse scale groundwater flow follows topography and this was the preferred conceptualisation for investigations into the mining of the peat wetlands (e.g. Env Res Aust 1971 and Martin 1982) (Figure 4).

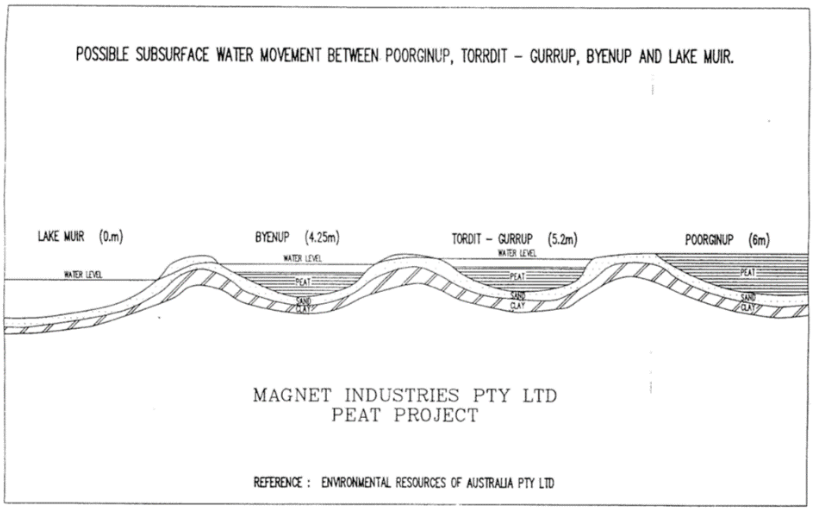


Figure 4: Conceptual model of groundwater movement between four southern lakes in the Muir-Byenup RAMSAR site.

The hydrogeology and groundwater flow have been investigated and reported by the Department at a sub-catchment and catchment scale (e.g. Smith 2003 and Smith 2011). Results of these studies indicate Archaean to Recent aged saprolite, and sediments form a multi-layered aquifer with coarse scale flow supporting hypotheses developed by researchers in the 1970's and 1980's (e.g. Figure 4). Recent research into fine, wetland scale groundwater behavior has shown these trends are more complex. Groundwater flow from the topographically higher Tordit-Gurrup Lagoon towards Byenup Lagoon reverses following above average winter rainfall in 2016 (Figures 5 and 6).

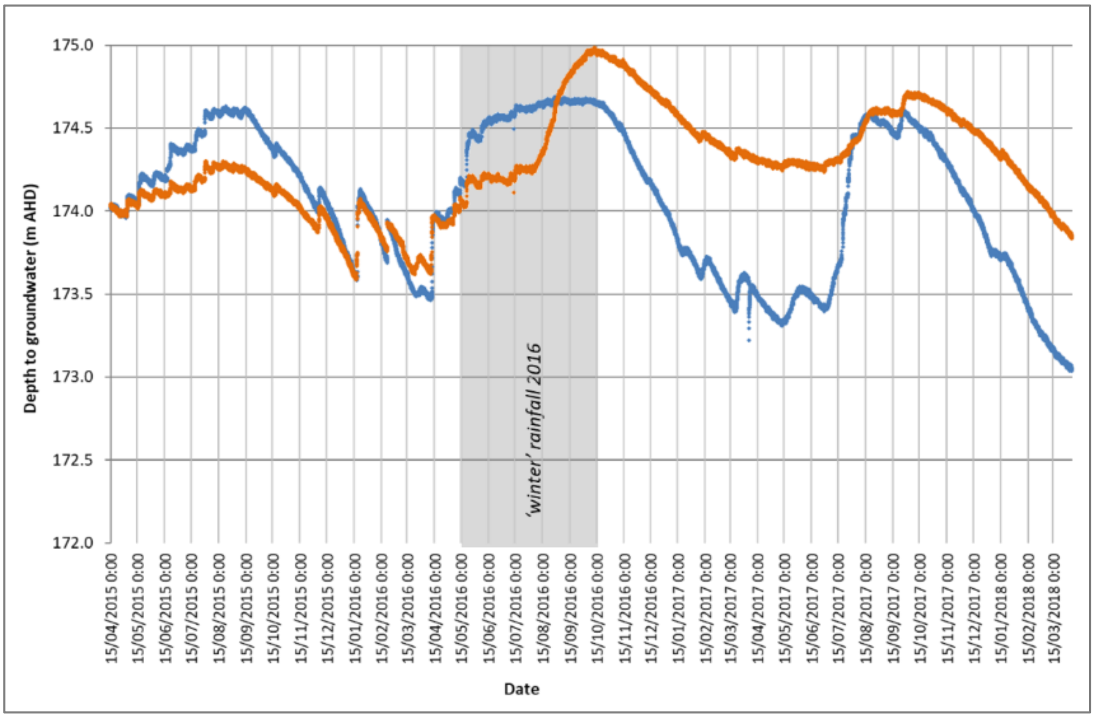


Figure 5: Hourly groundwater level data collected for lake shoreline bores; Byenup Lagoon (orange linework, BY01/03) and Tordit-Gurrup Lagoon (blue linework, TGN01/03) between April 2015 to March 2018.

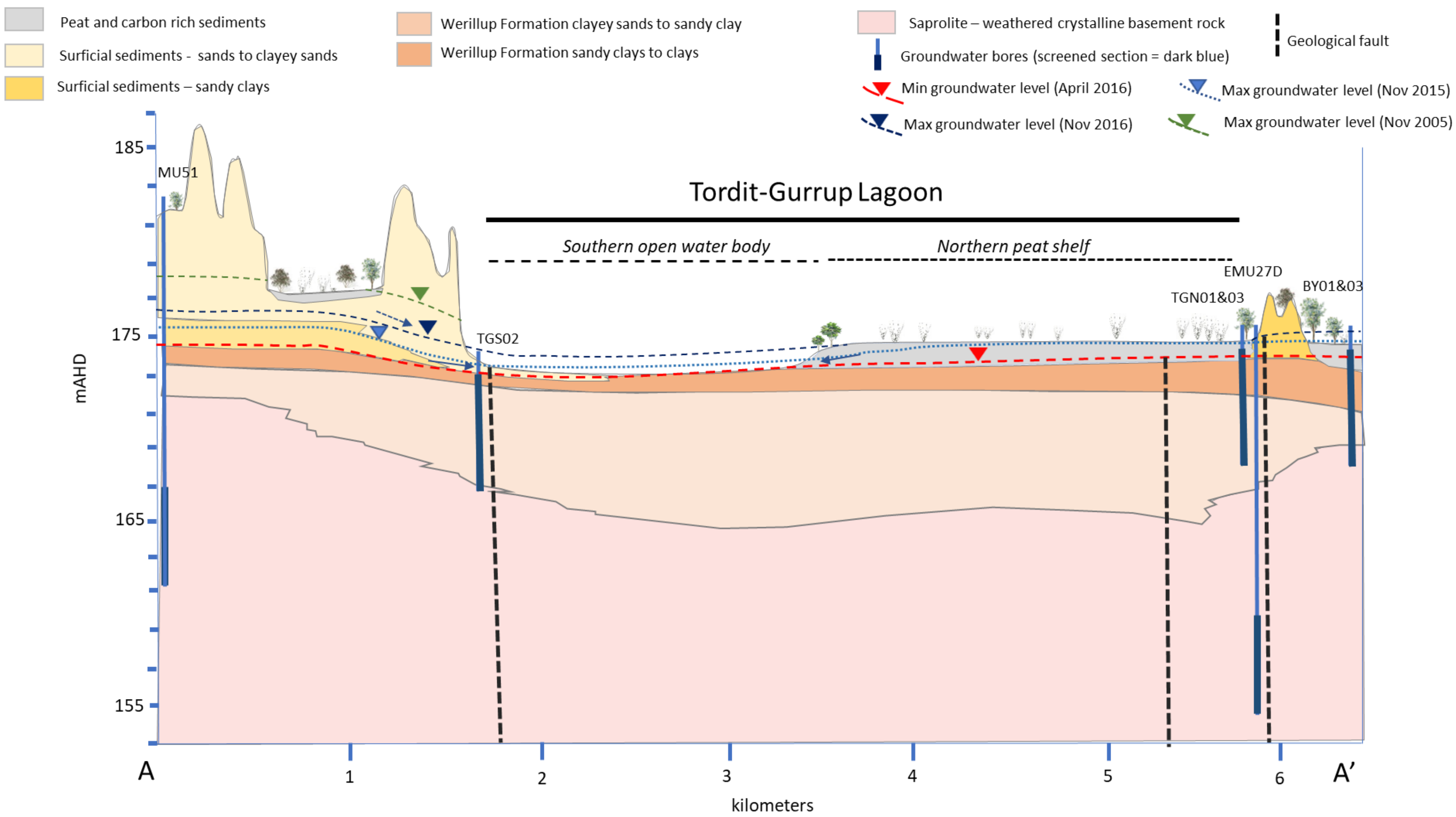


Figure 6: Geological Cross section A-A' following the direction of decreasing landscape elevation and showing local scale controls on groundwater gradients.

Further hydrological complexity occurs where there is heterogeneity in the wetland substrate, particularly where water bodies develop. This is evident in the southern water body in Tordit-Gurrup Lagoon where over time previous carbon-rich sediments have been removed. This low-lying area is likely to have been subjected to deflation, resulting in the removal of surficial sandy clays and broadening and deepening of the lagoon base. These fine-scale changes in geomorphology alter rainfall-runoff, surface water flow, interflow and groundwater flow at a range of scales. This disrupts the south-east to north-west flow trends and encourages aquifers to discharge into the lake's open water bodies (Figure 6).

The deficit in the lake water balance has been exacerbated by reductions in groundwater recharge, in response to lower average annual rainfall. This has affected groundwater levels in aquifers screened to depths of around 20 meters below ground level to the south-east of Tordit-Gurrup Lagoon. In this area, groundwater levels in the saprolite aquifer have been decreasing since 2010 (Figure 6 and bore MU51; Figure 7). In contrast, groundwater levels 6 km downgradient, at the same depth and within the same aquifer, have remained relatively constant, showing a small decline (e.g. bore EMU27D; Figure 7).

The thickness of unsaturated sediments at EMU27D is thin compared to MU51, allowing rainfall recharge to occur relatively promptly, which at this stage is reducing the impacts of rainfall reductions (Figure 7).

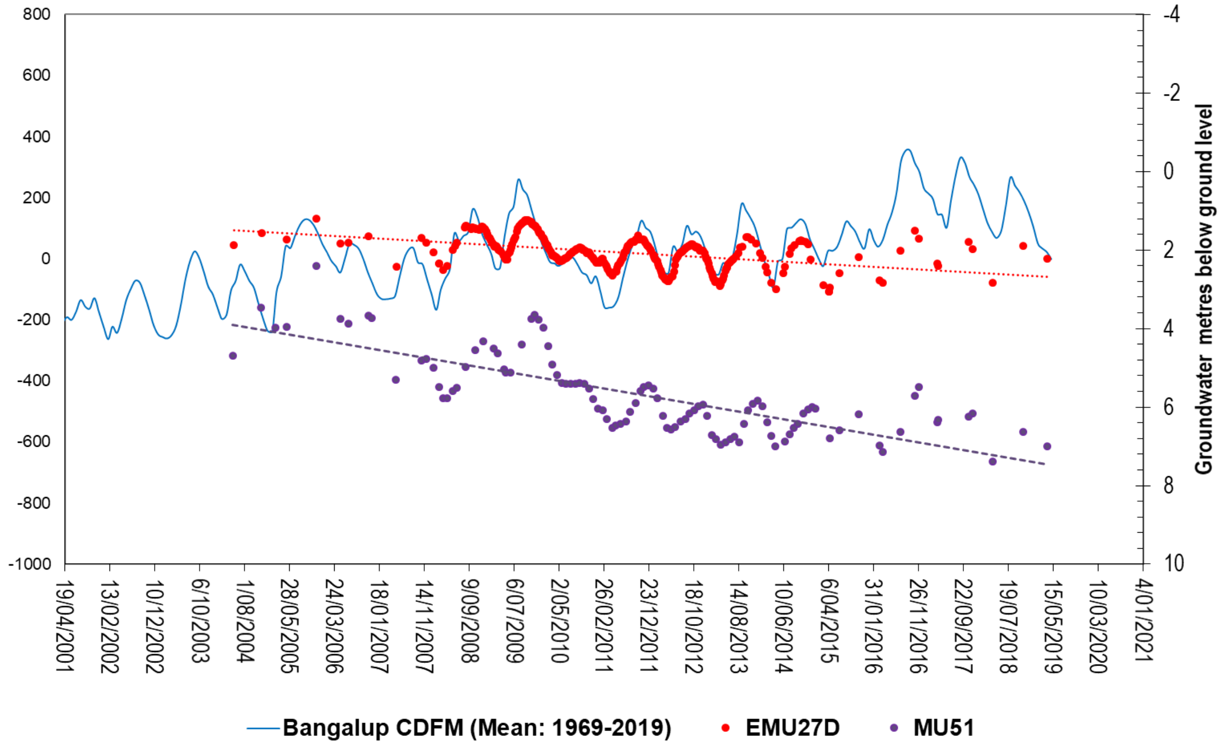


Figure 7: Manual (weekly and biannual) groundwater level data collected between 2004 and 2019 for saprolite aquifer bores screened at depths of around 20 metres below ground level in the vicinity of Tordit-Gurrup Lagoon (see Table 1 for bore construction).

Muir-Byenup wetland and lagoon surface water bodies are more responsive to seasonal and longer-term rainfall trends. Higher monitoring frequency lake water level data have been collected by the DBCA Warren Region on a weekly and monthly basis since 2006 (Figure 8).

Data for the wetlands examined in this project show similar responses indicating that incident rainfall across this broad area is relatively consistent and under the current climate wetlands are less sensitive to discrete channel flow into and out of wetlands. Lake water depths that have 'filled' Tordit-Gurrup Lagoon have occurred in 2006, 2009 and 2016 and these events appear to have been short-lived with groundwater gradients reversing the following winter.

Important lake water depths for Tordit-Gurrup Lagoon are 273 mAHD (Lagoon is dry) and 274.5 mAHD (northern peat shelf is close to being fully inundated and potentially fully saturated).

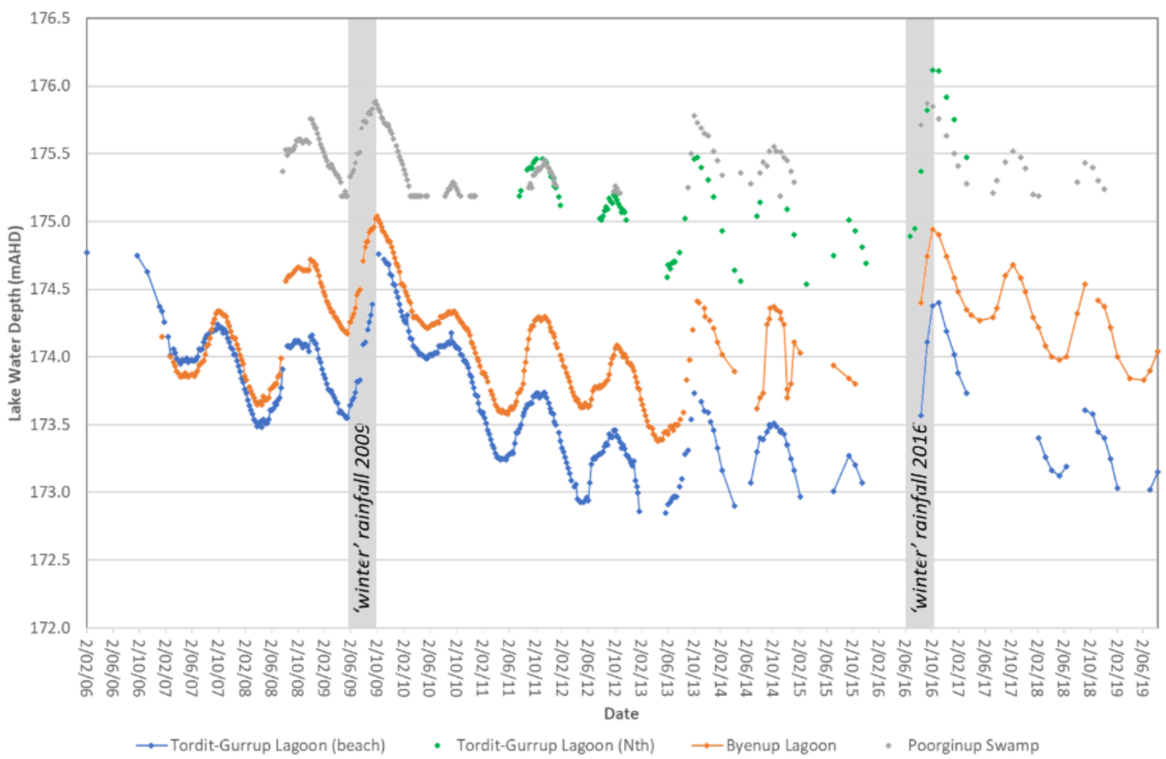


Figure 8: Manual (weekly and monthly) Poorginup Swamp and Tordit-Gurrup and Byenup Lagoon lake water depths (NB Tordit-Gurrup Lagoon (beach) is the southern water body).

3.3 Peat wetland soil water retention and geochemistry

The Muir-Byenup Catchment is located on top of a Neogene palaeovalley that has a long history of supporting peat wetlands. This is supported from the results of studies on spores and pollen in palaeovalley drill core (e.g. Smith 2010 and Yew 2011).

Of particular interest to this study are results from drill core from bore MU46, located on the south-eastern margin of Poorginup Swamp (Figure 1), where carbon-rich sediments are intersected at around 12 to 20 metres below ground level (~165m AHD). A study of the palynology of these sediments confirm they are early Oligocene in age (27.8 to 33.9 Ma yrs), with species characteristic of a mesothermal rainforest grading into a drier, more woodland type vegetation with arid-adaptive features (Yew 2011).

Carbon-rich sediments in the contemporary peat wetlands are Holocene in age (~7,000 yrs BP) and carbon isotope data indicates they developed primarily from Melaleuca species, a species which tends to now fringe the shoreline rather than occupy large areas of the lake (Rutherford in prep). Sedge species occupy larger areas of the peat wetland substrates and root to depths of around 10 to 15cm. Carbon isotopic work indicating that the sedge root systems are important in stabilising sediments, rather than contributing to the peat carbon store. This uppermost zone is termed fibric peat and this is underlain by a 1 to 2-metre-thick 'competent' peat generally characterised by both high porosity and water retention, but low permeability (Rutherford in prep).

Based on this evidence peat wetland survival and resilience is linked to their location and the underlying hydrogeology. A thick sequence of palaeovalley sediments, where the uppermost sediments have a lower permeability, helps minimise the gravity induced drainage of peat soil water (e.g. Werrilup Fm. sandy clays to clays, Figure 6).

Smith (2010) proposed the base beneath the peat could be important geochemically, where it contained alkaline groundwater that could regularly mix with, and buffer, peat soil water (e.g. sulfate and hydroxide ions sourced from oxidised pyrite in dry peat being "flushed' through moist peat in winter"). However, Smith (2010) noted this doesn't occur in the vicinity of lakes that have mined for peat, such as Cowerup Swamp. In this area, the groundwater geochemical fingerprint indicates peat soil water conveyed from the Cowerup Swamp to Lake Muir isn't buffered prior to it recharging deeper aquifers (e.g. is $Na\text{-}Mg\text{-}SO_4$ type water) (Smith 2010).

The competency and chemistry of the sediments underlying the peat is an important research question. It is likely that in some areas of Muir-Byenup Catchment, the substrate beneath the peat leaks and resultant mixing helps buffer acidic water. Understanding where and why this occurs is an important part of the work undertaken in this study as it will help manage the fate and transport of acidic water.

Information gained to date from the collection and analysis of wetland peat in project BCS SP 2014-24 demonstrates a commonality exists between the four wetlands sampled (Figure 2). Initial results indicating there is limited mixing between the peat soil water and underlying groundwater.

This project commenced in May 2015. Approximately 54 meters of core was collected across four peat wetlands using a Geoprobe 7822DT push probe drill rig and a Dormer split tube sampler (Figures 9 and 10; Table 1). Groundwater monitoring bores were constructed and instrumented with data loggers to measure groundwater levels (Rockwater 2015) (Figure 9; Table 1).

Geochemical analyses undertaken on peat wetland core samples, included EC1:5, pH, particle size, water retention, bulk density, volumetric and gravimetric water content, X-Ray fluorescence (XRF), X-Ray diffraction (XRD), SWIR-NIR analysis, scanning electron microscopy (SEM), pHfox and chromium reducible sulphur (CRS).

Preliminary results show peat contains on average 20 to 40% carbon, and 2% pyrite (e.g. data obtained from X-Ray diffraction, isotopic and scanning electron microscope (SEM) analyses) (Figure 11) (Rutherford in prep). Geochemically the peat soil sample profiles in Transect 1 (Figure 9) show similarity indicating that vertical processes across the transect have a common process. In this case it is seasonal evaporation, with the drying of the peat initiating pH driven changes. For example, semi-quantitative XRD results show gypsum occurs at depth and its dominance decreases towards the upper part of the profile where pyrite is the sink for sulfate.

In contrast changes in relief across the transect yield different results that demonstrate evaporation is the dominant lateral geochemical process. The major trends in this direction are depicted in Figure 12, showing the geochemical changes as you move from the shoreline to the northern open water body at Tordit-Gurrup Lagoon. The quality of water draining into the water body changing markedly at the discharge point (e.g. sample site TGN06a_b in Figure 9); characterised by lower pH and increased salinity and acidity (sulphides and metals). This abrupt change is important to understand as it limits the area and volume of peat contributing to seasonal acid fluxes into Tordit-Gurrup's northern water body.

Beneath the peat, the geochemistry of water and sediments are both alkaline. The substrate contains a higher percentage of clay minerals, including high cation exchange capacity clays (e.g. montmorillonite and nontronite) indicating it has potential to buffer peat soil water. However, these sediments also contain a high percentage of iron oxides and oxyhydroxides (e.g. goethite and hematite), which adds to the total potential acidity. The mineralogy and high percentage of clay sized material suggests these materials have a low permeability and don't readily interact/mix with peat soil water (Rutherford in prep).

Under the current climate the peat wetland substrates are more responsive to vertical near-surface processes such as rainfall and local runoff and evaporation. Where there are changes in micro-topography (e.g. water body margin) and/or porosity/permeability (e.g. desiccation) peat soil water discharges and evapo-concentrates entrained solutes (e.g. NaCl and metals) (Figure 12).

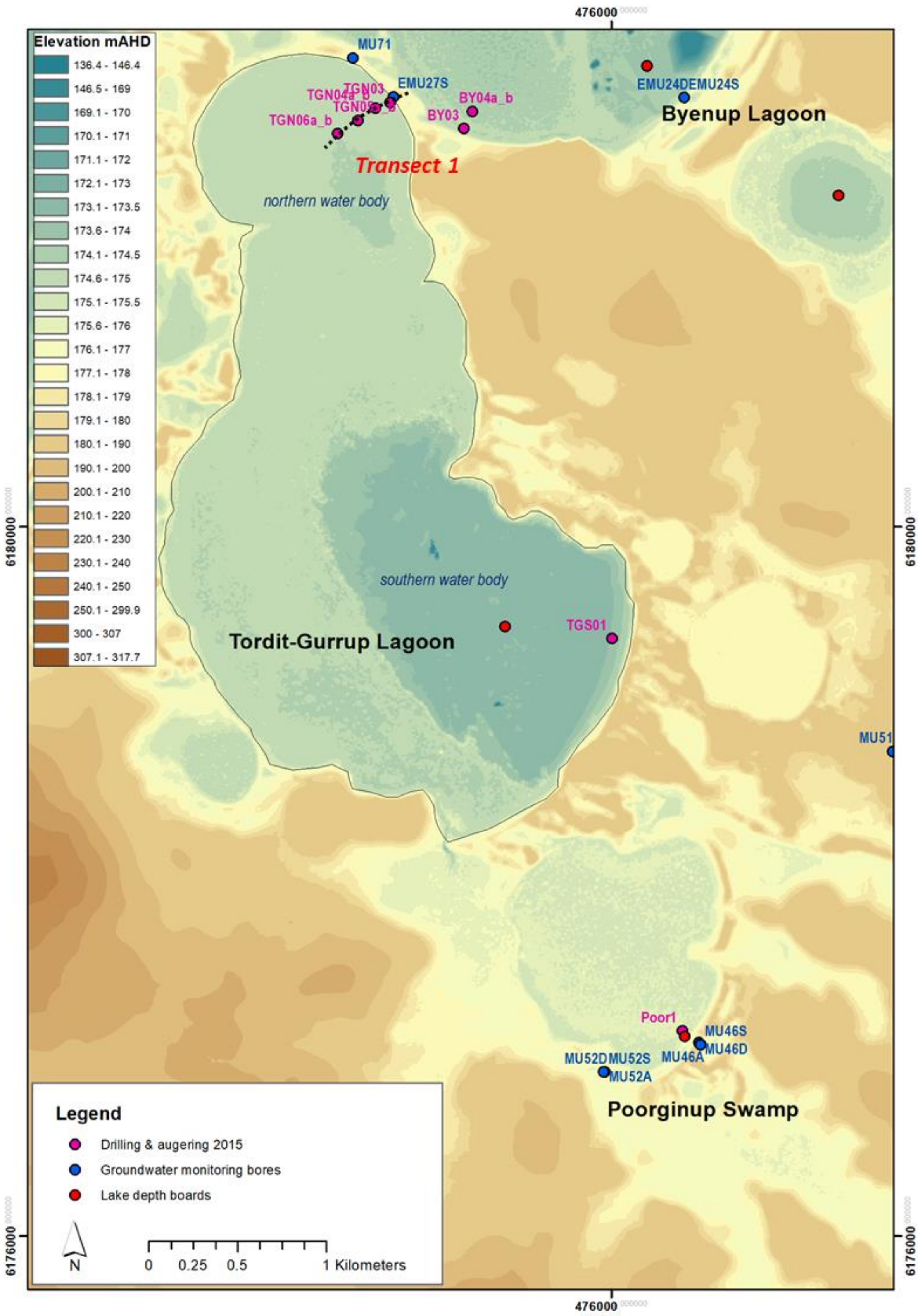


Figure 9: Landscape elevation change across Poorginup Swamp and Tordit-Gurrup and Byenup Lagoons (sourced from LiDAR data) showing the location of pre 2019 infrastructure.

Figure 10: Geoprobe 7822DT push-probe drill rig used to construct lake shoreline bores; Byenup BY01/03 construction (left and centre) and geophysical logging with VistaClara Dart NMR tool in May 2015.

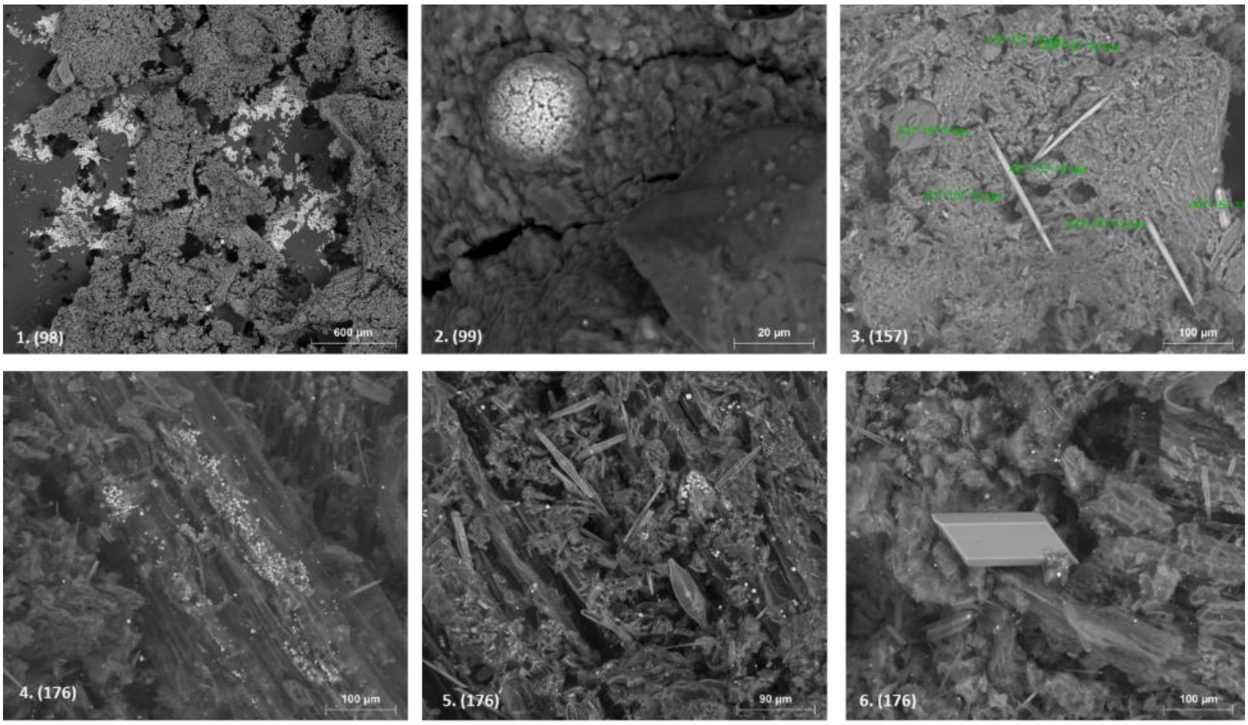


Figure 11: Scanning electron microscopy (SEM) analysis of core from Transect 1 (Figure 9); fine bright material represents disseminated sulfides (1, 4, 5 & 6), framboidal pyrite is common (2), gypsum is present in varied crystalline forms (6) and sponge spicules and other microfossils are ubiquitous (3-6).

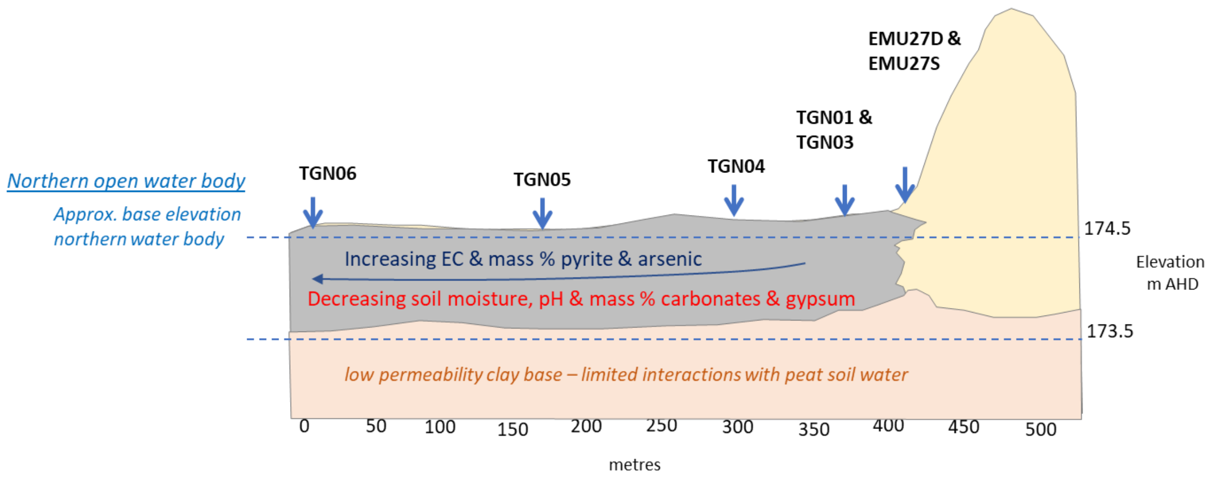


Figure 12: Conceptual model of peat soil water, groundwater and solute movement; northern Tordit-Gurrup Lagoon shown here as an example (Transect 1; Figure 9).

This conceptual model (Figure 12) will now be tested by extending the study to Tordit-Gurrup Lagoon's southern water body. The instrumentation and initial monitoring results are discussed in the following sections.

4 Investigation program design and installation (Oct-Nov 2019)

One of the main outcomes from work undertaken in the northern area of Tordit-Gurrup Lagoon is that the geochemical stratification within the peat can be resolved and mapped along a transect (Figure 12). This is important as it also provides information on the scale of the different hydrological processes that are controlling the lake water balance.

For example, zones exhibiting deleterious geochemical changes (e.g. low pH and elevated metals and metalloids) occur where peat experiences greater seasonal drying. This occurs in the upper 20cm to 50cm of the peat profile, dependent on the vegetation root depth, seasonal temperatures and peat water retention. Deeper zones also exhibit change where the peat profile is desiccated or eroded. These settings are likely to yield acidic water, where gravity induced drainage can take place.

The area with the most prominent peat erosion in Transect 1 is the margin of northern lake water body. The dynamics of seasonal wetting and drying here is different to those on, or close to, the lake shoreline. The northern lake shoreline receives more groundwater, or peat soil water, recharge, which is sourced from local runoff and throughflow from shallow seasonal aquifers.

To the south, the spatial density of desiccation appears greater based on observations made at the ground surface. The eroded margin of the southern lake water body is also larger in extent compared with the northern lake water body, indicating acid fluxes should be higher.

As Tordit-Gurrup lagoon is large in its spatial extent it requires significant incident rainfall, supported by local runoff and shallow aquifer throughflow, to maintain high peat moisture conditions. The western and northern margins of the southern lake water body are located towards the central part of the lake, which reduces the likelihood that they receive runoff and throughflow. The southern lake water body is therefore likely to be more reliant on incident rainfall, and be sensitive to reductions, as evident by the recent acidification of the southern lake water body.

This study is designed to gain a better understanding of spatial and temporal controls on the release of peat acid stores into the southern lake water body. The degree of interaction (mixing) between the lake water body and aquifers beneath the lake in response to declines in groundwater levels will also be assessed.

Intrinsic to answering these questions is determining the volume of water released from storage as the water levels decline. However, this is complicated due to the heterogeneity of the peat, at both a vertical and horizontal scale. Water retention within the peat profile is generally high, which means not all water will be removed, either via evapotranspiration or gravity induced drainage. This introduces a hysteretic response, where summer or winter rainfall rewet the peat profile before it drains and becomes dry. This complicates developing a robust quantitative water balance and has been considered in the investigation design outlined below.

The competency of the Tordit-Gurrup Lagoon southern peat shelf doesn't support the weight of a push probe rig, which limits the investigation to hand augering methods. The initial proposal design explored the use of moisture meters, provided sufficient sites could be selected to characterise the spatial variability and yield enough data to adopt a statistical approach. As the success of this plan was thought to be low, the decision was made to build on the information gained in Transect 1. Focus on monitoring and measuring peat fillable porosity (e.g. volume of water required to saturate/rewet the profile) through the installation of mini-piezometers (see Section 3.3). As well as subsequent acid fluxes, where the profile dries and yields acidic water.

Two transects (Transect 2 and Transect 3) were planned and are aligned to topographic and groundwater gradients (Figure 13). Transect 2 was thought to intersect between 1-2 metres of peat in the north, decreasing to less than 0.5 metre of peat to the south. The presence of peat in Transect 3 was uncertain but was tested to reduce uncertainty. The coring plan was to auger peat to depths of around 1.5 metres below ground level and complete monitoring infrastructure in the peat layer.

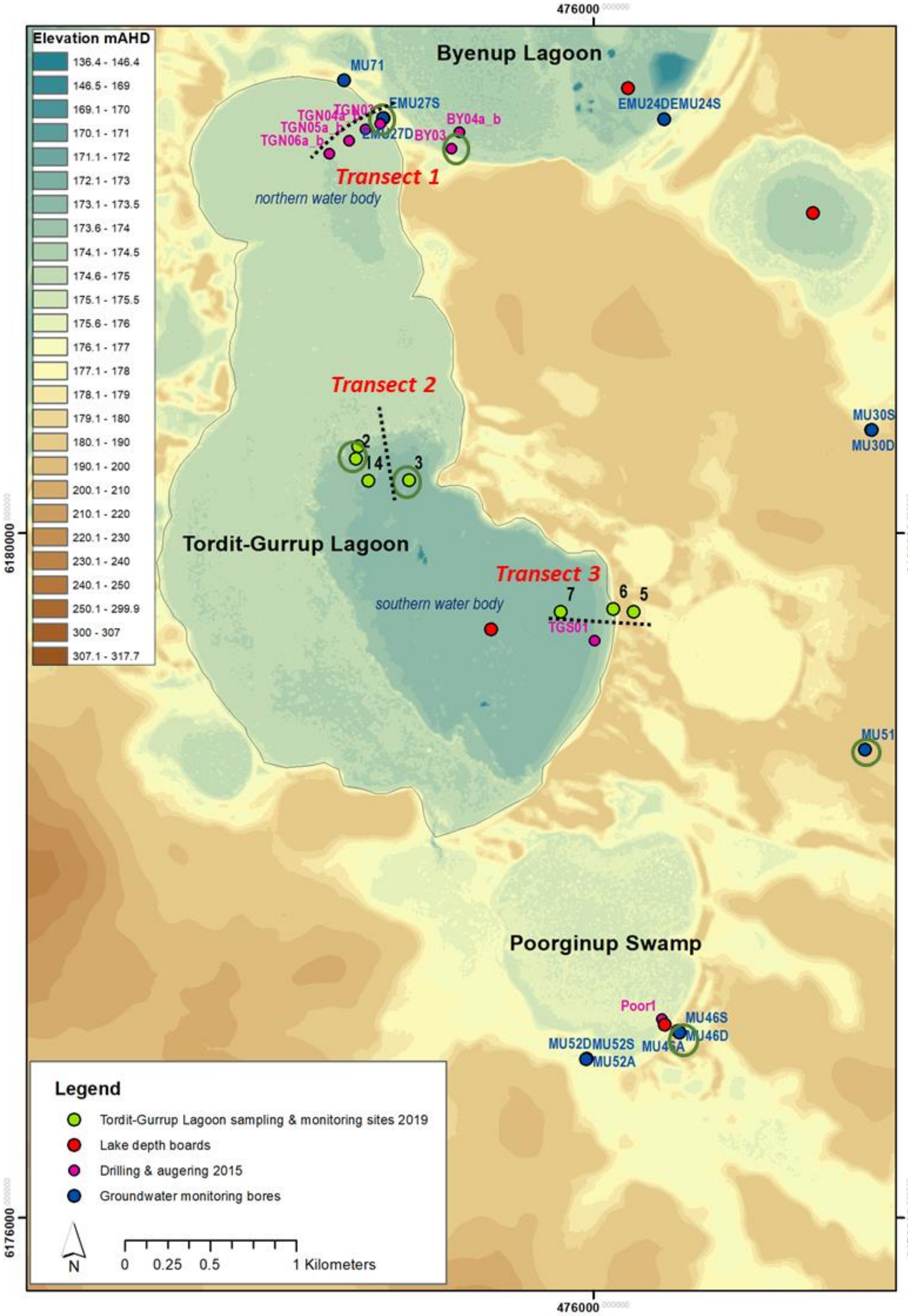


Figure 13: New investigation sites measuring hydrological and geochemical change across Poorginup Swamp and Tordit-Gurrup and Byenup Lagoons; (e.g. transects 2 and 3 and groundwater level, temperature and electrical conductivity data logger sites circled in green (Noobijup Swamp not shown) (see Table 1 for details).

Map ID	Site ID	Location Monitoring Sites		Excavation Depth & Bore Construction								On-going monitoring post Oct/Nov 2019 (Aprox dates/frequency)	Installation & monitoring Program
		Easting_MGA50	Northing_MGA50	Aprox Depth (mbgl)	Top of casing (m)	Top of bore Screen (mbgl)	Base of bore Screen (mbgl)	PVC Casing & backfill	Field water quality analyses	***Volume sample required - lab analyses	Data logger (water level, temp & EC)		
1	TGN08a	474627	6180509	0.6				N/A			N		Auger
	TGN08b	474629	6180511	0.6				N/A			N		Auger
2	*TGN09b	474614	6180436	0.95	1.1	0.1	0.95	Y - 40mm perferated	Field pH,Temp, EC & alkalinity (as CaCO3)	~1100mL	Y (CTD Diver)	1/20; 3/20; 5/20; 7/20; 9/20	Auger, mini piezo & data logger
	TGN09c	474608	6180431	1.0				N/A			N		Auger
3	*TGN10b	474922	6180311	1.0	1.1	0.1	1.00	Y - 40mm perferated	Field pH,Temp, EC & alkalinity (as CaCO3)	~1100mL	Y (CTD Diver)	1/20; 3/20; 5/20; 7/20; 9/20	Auger, mini piezo & data logger
	TGN10c	474922	6180321	0.95				N/A			N		Auger
4	**TGN11a&b	474687	6180305	N/A				N/A	Field pH,Temp, EC & alkalinity (as CaCO3)	~1100mL	N	1/20; 3/20; 5/20; 7/20; 9/20	Soil/lake water grab sample
5	TGS03a	476234	6179540	0.31				N/A			N		Auger
	TGS03b	476240	6179567	0.6				N/A			N		Auger
6	TGS04a	476116	6179556	0.56				N/A			N		Auger
	TGS04c	476131	6179536	0.5				N/A			N		Auger
7	**TGS07a&b	475808	6179541	N/A				N/A	Field pH,Temp, EC & alkalinity (as CaCO3)	~1100mL	N	1/20; 3/20; 5/20; 7/20; 9/20	Soil/lake water grab sample
	TGS01/02	476005	6179371	6	0.86	0.5	5	Existing bore			Y (CTD Diver)	1/20; 5/20; 9/20	Data logger
	TGN01/03	474754	6182394	6	0.71	0.5	6	Existing bore			Y (CTD Diver)	1/20; 5/20; 9/20	Data logger
	TGN04a_b	474670	6182361	1.9				N/A			N		N/A
	TGN05a_b	474572	6182293	1.9				N/A			N		N/A
	TGN06a_b	474458	6182218	1.8				N/A			N		N/A
	EMU27s	474773	6182424	2	0.54	1	2	Existing bore			Y (CTD Diver)	1/20; 5/20; 9/20	Data logger
	EMU27D	474773	6182426	20	0.61	14	20	Existing bore			Y (CTD & Baro Diver)	1/20; 5/20; 9/20	Data logger
	MU51	477584.0	6178735.0	20	0.63	17.8	19.8	Existing bore			Y (CTD Diver)	1/20; 5/20; 9/20	Data logger
	MU46S	476500.2	6177082	27	0.62	20	26	Existing bore			Y (CTD Diver)	1/20; 5/20; 9/20	Data logger
	BY01	475170.0	6182247.0	6	0.63	0.5	6	Existing bore			Y (CTD Diver)	1/20; 5/20; 9/20	Data logger
	NB01	480825.0	6192604.0	6	0.75	0.5	6	Existing bore			Y (CTD Diver)	1/20; 5/20; 9/20	Data logger

*if conditions are suitable a spear/mini piezometer with a vaccum pump or shallow excavation may be used if piezometer is dry or there is insufficient sample

**spatial locations of lake shoreline water and soil substrate grab samples (10cm depth) will change with extent of the open water body

***major ions (500 mL, unfiltered); minor ions and REE (125mL, filtered & pre-acidified); nutrients (125mL, unfiltered); nutrients (125mL, filtered); ferrous iron (60ml; unfiltered); reactive silica (125 mL, filtered); stable water isotopes (20ml, unfiltered (clear glass or HDPE))

Table 1 Muir-Byenup peat wetland acid release investigation and monitoring program

Investigations and installations were carried out in October 2019 (14th–15th & 29-30th October 2019). Appendices 1 and 2 have information on site and soil descriptions, installation methods and standard operating procedures followed and site photographs. The locations of sites are shown on cross sections in Figures 14 to 17 and key information tabulated in Table 1.

The October 2019 field program achieved the following;

1. Collecting peat and soil core for lab analyses: **7 sites** (TGN08a_b, TGN09a_b, TGN10a_b, TGN11a&b, TGS03a_b, TGS4a_c, TGS07a&b).
2. Installing PVC housings (mini-piezometers) and data loggers to measure peat soil water depth levels, temperature and electrical conductivity: **2 sites** (TGN09b & TGN10b).
3. Installing data loggers in existing bores: **7 sites** (TGS02, TGN01, EMU27s, EMU27D, MU51, MU46s & NB01).
4. Identifying and constructing peat soil water and surface water collection sites: **4 sites** (TGN09b, TGN10b, TGN11 & TGS07)

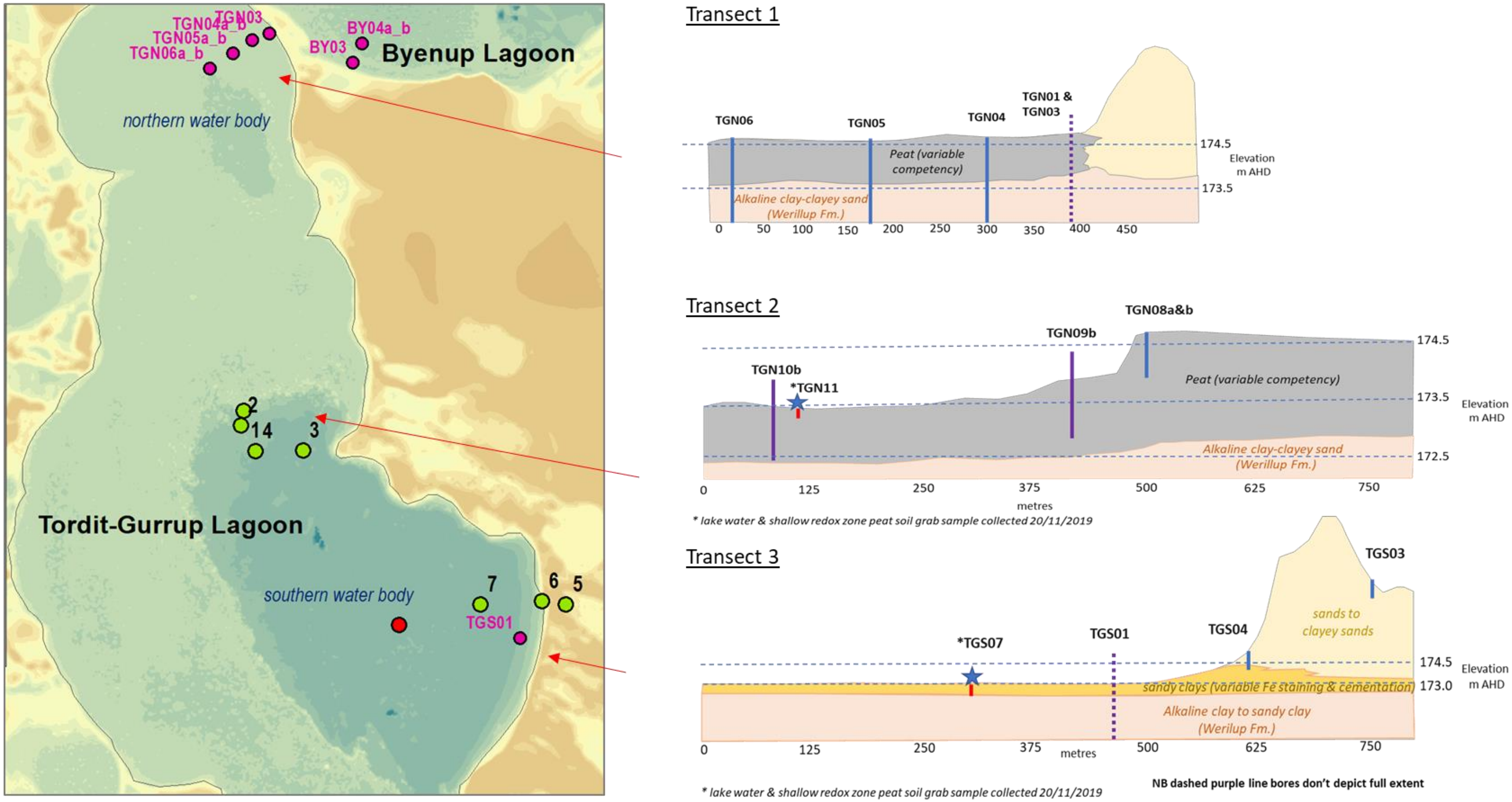
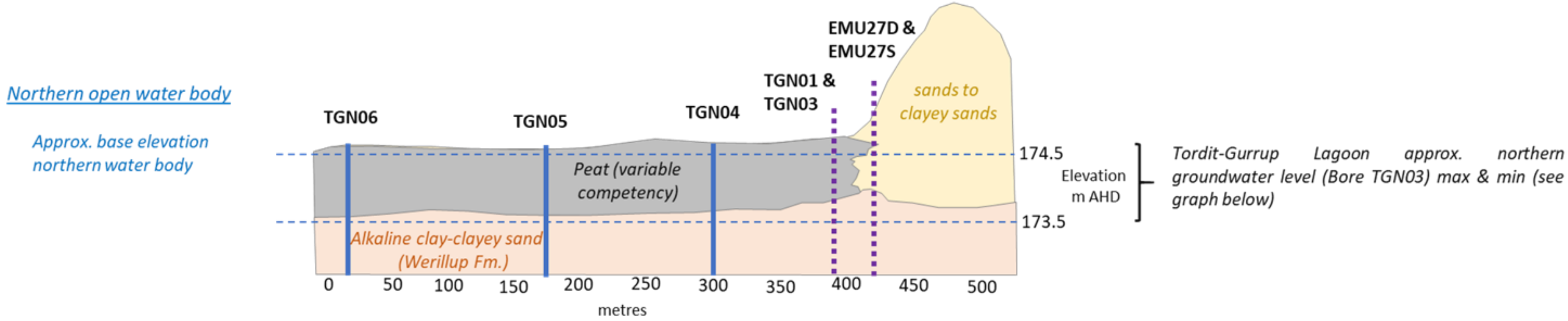


Figure 14: Perspective view map of acid release investigation sites and cross sections of the three main transects showing the different regolith materials sampled and their geometries (see Table 1 and Figures 15 to 17 for details).

Transect 1



NB dashed purple line bores don't depict full extent

Map ID	Site ID	Location monitoring sites		Approx depth	PVC casing &
		Easting_MGA50	Northing_MGA50	(m bgl)	data logger
	TGN01/03	474754	6182394	6	Y (CTD Diver)
	TGN04a_b	474670	6182361	1.9	N
	TGN05a_b	474572	6182293	1.9	N
	TGN06a_b	474458	6182218	1.8	N
	EMU27D	474773	6182424	20	Y (Baro Diver)
	EMU27S	474773	6182426	N/A	Y (CTD Diver)

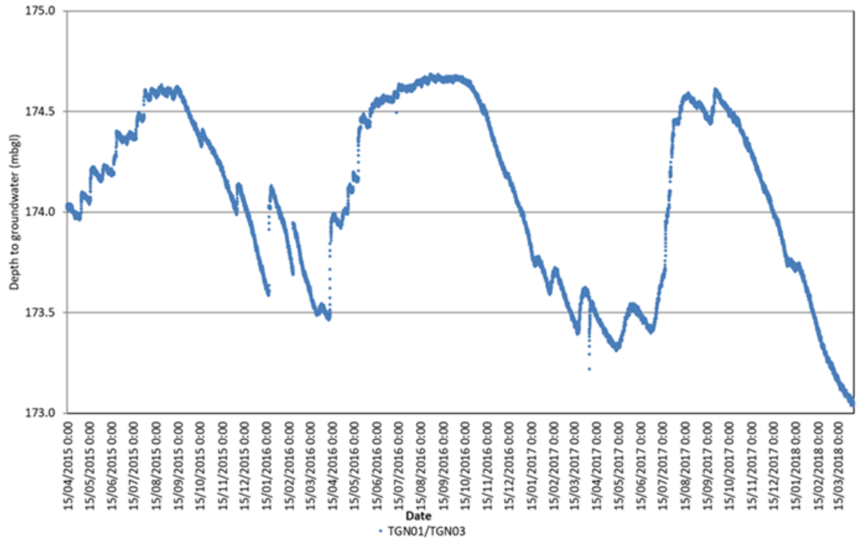
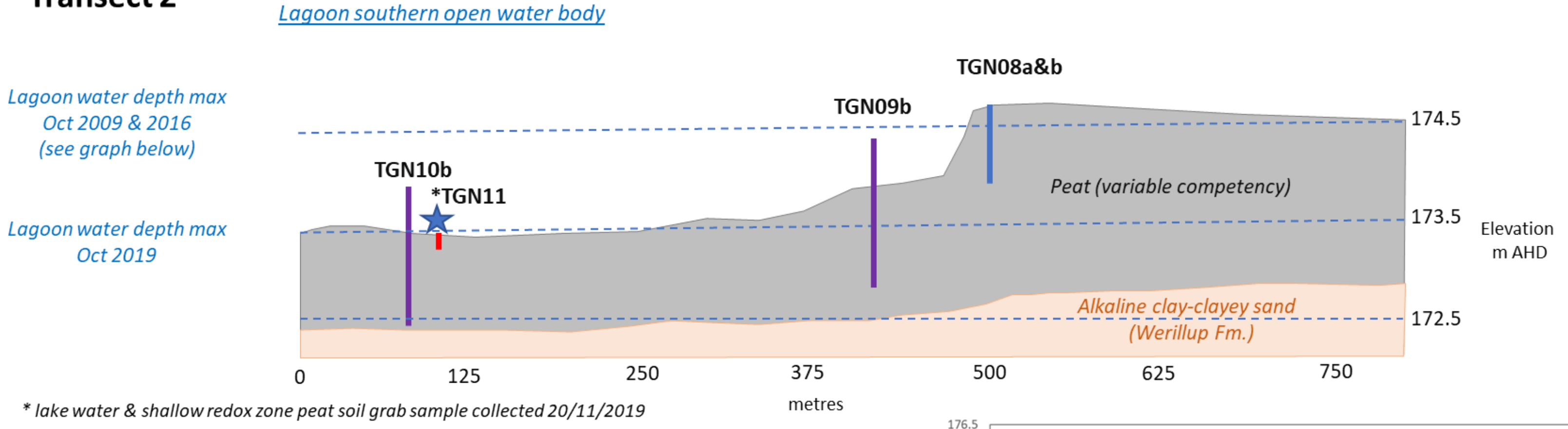


Figure 15: Tordit-Gurrup Lagoon acid release investigation design – Transect 1 geological cross section with monitoring infrastructure locations and graphed groundwater level data for TGN01 (2015 to 2017).

Transect 2



Map ID	Site ID	Location Monitoring Sites		Aprox Depth (mbgl)	PVC Casing & data logger
		Easting_MGA50	Northing_MGA50		
1	TGN08a	474627	6180509	0.6	N/A
	TGN08b	474629	6180511	0.6	N/A
2	*TGN09b	474614	6180436	0.95	Y (CTD Diver)
	TGN09c	474608	6180431	1.0	N/A
3	*TGN10b	474922	6180311	1.0	Y (CTD Diver)
	TGN10c	474922	6180321	0.95	N/A
4	**TGN11a&b	474687	6180305	N/A	N/A

**surface water and shallow grab (10cm depth) sampling site (grab sample at shoreline)

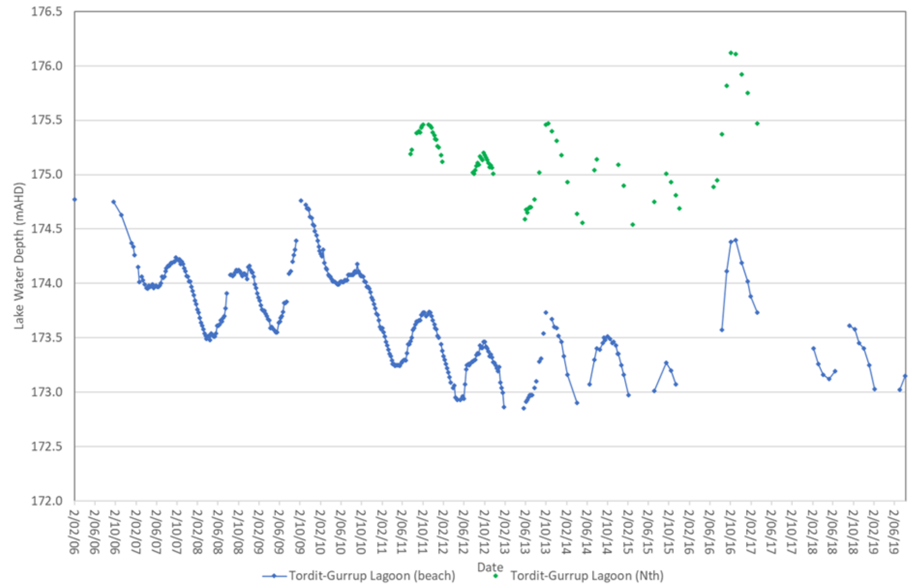


Figure 16: Tordit-Gurrup Lagoon acid release investigation design – Transect 2 geological cross section with monitoring infrastructure locations and graphed surface water level data for Tordit-Gurrup Lagoon's southern and northern water body.

Transect 3

Map ID	Site ID	Location Monitoring Sites		Aprox Depth (mbgl)	PVC Casing & data logger
		Easting_MGA50	Northing_MGA50		
5	TGS03a	476234	6179540	0.31	N/A
	TGS03b	476240	6179567	0.6	N/A
6	TGS04a	476116	6179556	0.56	N/A
	TGS04c	476131	6179536	0.5	N/A
7	**TGS07a&b	475808	6179541	N/A	N/A
**surface water and shallow grab (10cm depth) sampling site (grab sample at shoreline)					

Tordit-Gurrup Lagoon approx. southern groundwater level (Bore TGS01) max & min ranges from 173 to 174.5 m AHD (graph not shown)

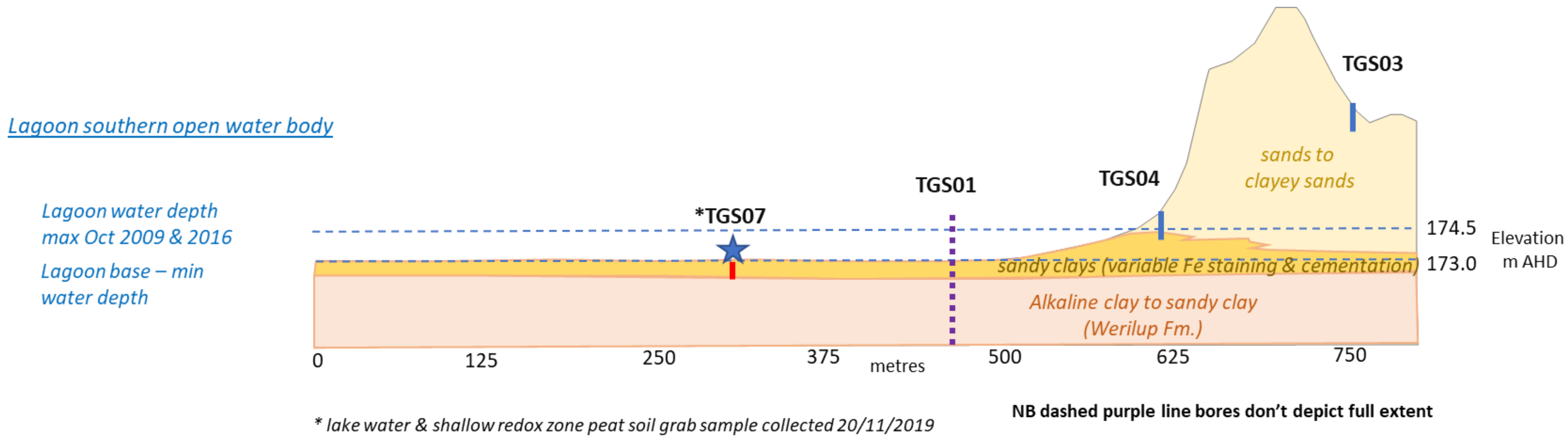


Figure 17: Tordit-Gurrup Lagoon acid release investigation design – Transect 3 geological cross section with monitoring infrastructure locations.

5 Monitoring data interpretation – initial results; Oct-Nov 2019

Sampling and monitoring commenced in October 2019, following the installation of new sites and re-commissioning of data loggers in existing bores (Table1). On the 19th to 21st November the first round of post installation monitoring was undertaken. This included downloading data loggers and sampling peat soil water (2 sites) and surface water in the Tordit-Gurrup southern water body (2 sites) (Table 1).

Water samples were tested in the field (Appendix 1) and delivered to laboratories to undertake analyses detailed in Table 1. Chain of custody documentation for different laboratory water analyses and peat core are in Appendix 3.

5.1 Mapping peat and fingerprinting water quality

Minor fibric peat was only identified in core TGS03 in Transect 3. This was at a depth of around 10cm and no underlying competent peat layer was evident. Combining with existing data from TGS02, this indicates the area sampled by Transect 3 doesn't provide a significant source of acid to the southern surface water body.

Transect 2 coring intersected around one metre of core at the margin and 300 metres upgradient of the surface water body. Access was difficult further north due to thicker vegetation, which limited hand coring success to around 0.6 metres depth (Figure 16).

Field physico-chemistry results show peat soil water have a similar pH and electrical conductivity (EC) to samples collected in Transect 1. Peat soil water pH between 4 and 5 and decreasing to 3 to 4 in laboratory analyses (TGN09 & TGN10 Table 2). In contrast surface water samples are lower at the time of collection (e.g. between 2.8 and 2.9 for TGN12 and TGS06) and increase to around 3 in the laboratory (Table 2). This is a common problem with low pH waters as post sampling the unacidified samples no longer interact with the soil matrix and gases, which drives chemical reactions and mineral dissolution and precipitation. The magnitude of this problem will continue to be assessed and will be considered in subsequent interpretations.

Site ID	Date Sampled	Temperature (field) ^{o}C	Electrical conductivity (EC) (lab) (mS/cm)	Electrical conductivity (EC) (field) (mS/cm)	EC change (field-lab)	% change EC	pH (lab)	pH (field)	pH change (field-lab)	% change pH
GN09c	16/10/2019	17.9		6.9				3.97		
GN09c	20/11/2019	17.9	14.8	15.2	0.4	2.6	4.1	4.86	0.76	15.6
GN10b	29/10/2019	18.9		19.6				4.1		
GN10b	20/11/2019	21.7	22.3	21.8	-0.5	2.3	3.2	3.88	0.68	17.5
GN12	29/10/2019	19.5		22.9				2.95		
GN12	20/11/2019	19.1	22.4	23.0	0.6	2.6	3	2.8	-0.2	-7.1
GS06	30/10/2019	18.0		16.9				2.79		
GS06	19/11/2019	21.3	20.2	21.0	0.8	3.8	2.9	2.76	-0.14	-5.1

Table 2: Comparison of field and laboratory physico-chemistry measurements

5.2 Identifying groundwater and surface water mixing and interactions

Groundwater surface water interactions for data collected in October and November 2019 are assessed by plotting the data within the broader dataset collected between 2015 and 2017. Quality assured October and November 2019 laboratory data for major and minor ion analyses are compiled in Appendix 4.

5.2.1 Major ion chemistry

Major ion interpretations are shown in Appendix 5 as bivariate plots of different major ion concentrations (mmol/L) against the conservative (tends to stay in solution) ion chloride.

Surface water trends were first examined and compared to lake water sampled in different Muir-Byenup lakes between 1998 and 2019. Sampling was generally undertaken in the months of September and October and bivariate plot results indicate the lakes have individual geochemical fingerprints and most show little change over the past 20 years Appendix 5. The only exception being historical sampling of Lake Muir and the October and November 2019 sampling at Tordit-Gurrup. Both displaying elevated SO_4 and Ca, while Tordit-Gurrup also shows elevated total N and dissolved Fe (Appendix 5).

Similar trends are present when groundwater and peat soil water data are plotted with surface water data collected in lakes present in Figure 10. However, there is a higher degree of scatter/variation within and between the peat soil water and groundwater groups.

5.2.2 Metals, metalloids and REE

Bivariate plots of metal, metalloid and rare earth element (REE) concentrations were examined against chloride and pH to assess preliminary trends, sampling gaps and identify dominant hydrological processes (Appendices 6 and 7).

Results and a preliminary interpretation show that some metals and metalloids are correlated with one or both increases in chloride (e.g. evaporation) and pH (e.g. redox changes), particularly when groundwater and peat soil water were treated as separate populations. Evaporation appearing to be an important process in concentrating As, B, Fe, Li, Mn, Pb Rb, Se and Sr, (Appendix 6). Reductions in pH driving geochemical changes that increase Al, B, Co, Li, Mn, Ni and Rb (Appendix 6).

There are some gaps in distributions with the more recent October and November 2019 sampling often forming a separate population. These gaps are likely to be closed with the autumn – winter 2020 sampling when the peat soil water and surface water will mix with rainfall and local runoff.

REE concentrations generally increase with decreasing pH, apart from Re (Appendix 7). Normalising and comparing 2019 REE data with previous data collected in 2015 fills data gaps and will help interpret future REE results (Figure 18).

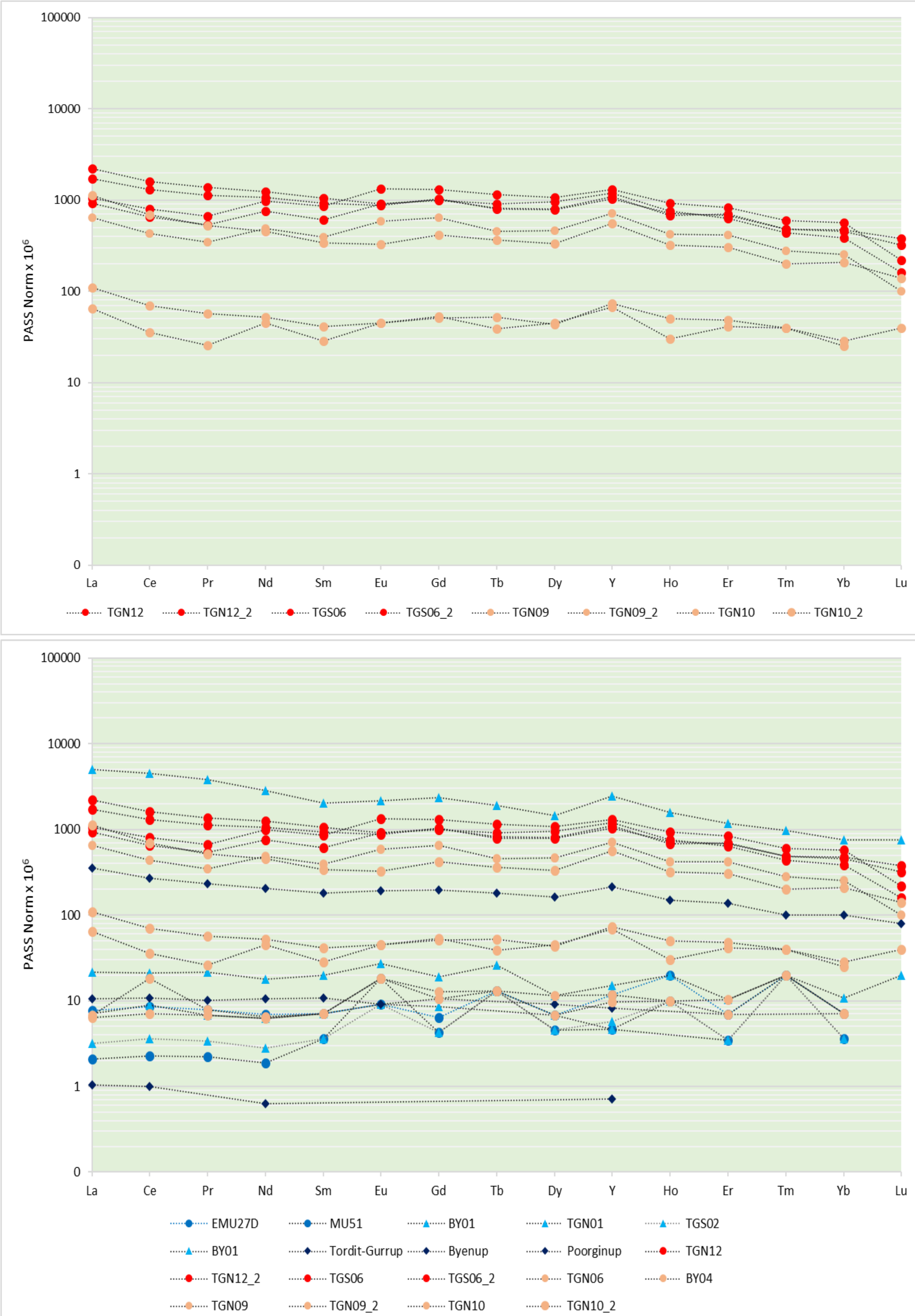


Figure 18: REY plots of Post Archaean Australian Shale (PAAS) normalized data sampled in October and November 2019 (top) and data sampled between 2015 and 2019 (bottom); (Note that the highest values occur in shallow groundwater collected in 2015 from TGN01).

Correlation matrices for the full datasets were prepared (Appendix 8) to compare with individual population graphs and design future multivariate statistical analyses.

5.2.3 Stable water isotopes (δ^2H vs $\delta^{18}O$)

Stable water isotope analyses were undertaken to provide an independent environmental tracer dataset to assess evaporation and mixing. Results are plotted in Figure 19, with trends similar to bivariate plot trends. This reaffirms the importance of evaporation in concentrating solutes, including metals, in the Muir-Byenup peat wetlands.

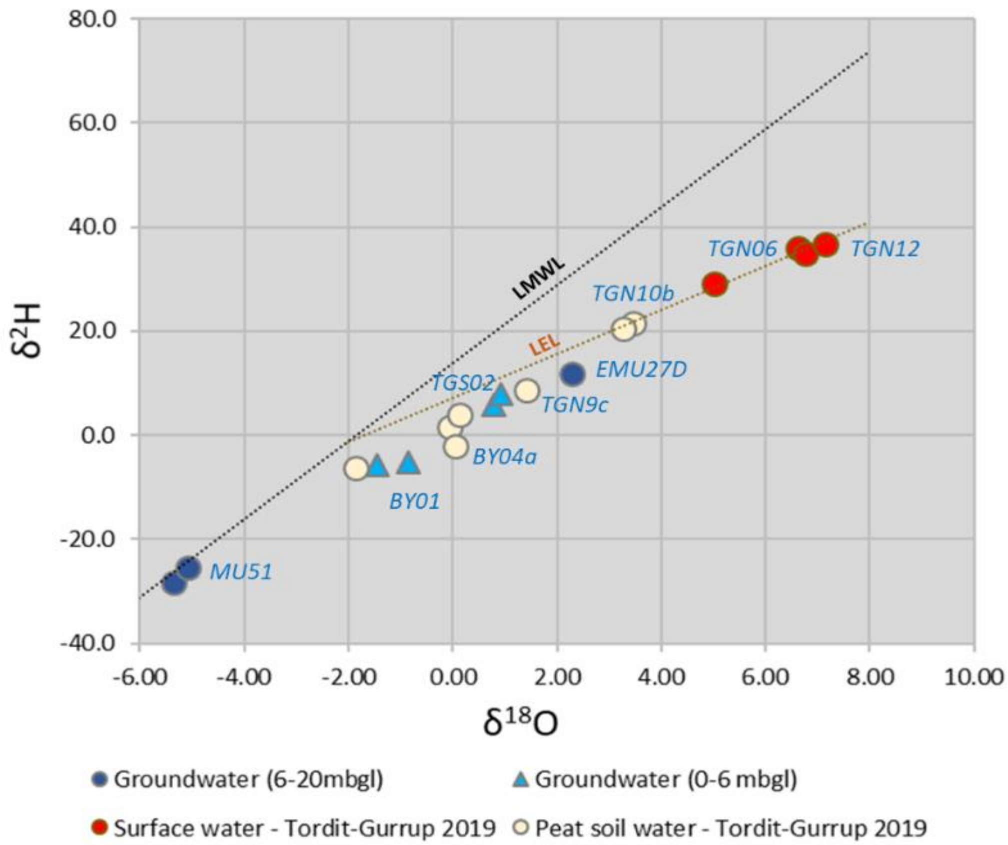


Figure 19: Bivariate plot of of a. δ^2H vs $\delta^{18}O$, showing local meteroic water line (LMWL) from Hearn (2011) unpublised data and local evaporation line (LEL) derived from data interpreted in this report.

5.3 Verifying groundwater and water quality gradients

Groundwater level and water quality data collected from data loggers in November 2019 was interpreted to assess flow directions proposed in conceptual models presented in Figures 4, 6 and 12.

Information in major ion data is also assessed to understand the evolution of geochemical evolution of groundwater along flow paths, as well as fine-scale water-rock/soil interactions that occur within peat wetlands.

5.3.1 Geochemical modelling

Bivariate plots show an increase in salinity from Poorginup to Byenup (Appendix 5). Groundwater quality generally increases along its flow path, so these results are aligned with the simple model presented in Figure 4.

Major ion data were imported into the AquaChem™ 2014.2 software programme to undertake data reliability checking, determine water type/facies and produce Piper Trilinear Diagrams. Saturation indices (SI) were then modelled using the WATEQ4F thermodynamic database within PHREEQC, with mineralogical outputs including, albite, anhydrite, chalcedony, goethite, gypsum, halite, haematite and quartz.

Piper diagrams and PHREEQC output tables with station ID and date, key chemistry data, modelled water type and mineralogical saturation indices and percentage error (charge balance error) are tabled in Appendix 9.

Piper diagrams display the same geochemical flow trend as the bivariate plots (Appendix 9). PHREEQC outputs confirm charge balance errors are generally small with only two samples (Nov surface water samples) exceeding the acceptable ± 5% range (Appendix 9).

Outputs from the PHREEQC model indicate that most minerals are more stable in solution (e.g. have negative SI values). A notable exception is the subtle variation in iron oxide and oxyhydroxide minerals haematite and goethite. Both appear stable as precipitates in peat soil water but not in nearby surface water. This preliminary interpretation verifying the presence of an abrupt change in geochemical gradients in Transect 2.

5.3.2 Groundwater level and quality (data loggers)

Groundwater level and water quality data from Diver CTD data loggers were downloaded, processed to compensate for barometric pressures and graphed to quality assured against past data collected between 2015 and 2017 (Appendix 10).

Preliminary results presented in Tables 3 and 4 show groundwater level gradients (mAHD) conform to the conceptual model in Figure 6. Groundwater levels in the Tordit-Gurrup southern water body forming a groundwater sink, or local low point along the flow path (e.g. TGN10b and TGN09b in Table 3).

Site ID	Easting MGA50	Northing MGA50	Date: Data logger installed	Date: last manual groundwater level measurement	Time: last manual groundwater level measurement	Ground elevation (mAHD)	Depth drilled (mbgl)	Top of bore screen (mbgl)	Base of bore screen (mbgl)	Top of casing height (TOC) (stick-up) (m)	Groundwater level (mTOC)	Groundwater level (mbgl)	Groundwater level (mAHD)	Diver CDT/Baro data Logger Serial No	Frequency Data Logger Measurements	Battery (Nov 2019) (%)
NB01	480825.0	6192604.0	15/10/2019	20/11/2019	16:40	219.90	6.00	0.50	6.00	0.75	0.76	0.01	219.89	V9849	Hourly	97
MU51	477584.0	6178735.0	15/10/2019	20/11/2019	14:42	181.40	20.00	17.80	19.80	0.63	7.12	6.49	174.91	K6618	Hourly	69
MU46S	476500.2	6177082	19/11/2019	19/11/2019	13:29	177.32	27.00	20.00	26.00	0.62	3.27	2.65	174.67	X0055	Hourly	98
TGS02	476005.0	6179371.0	15/10/2019	15/10/2019	12:30	173.60	5.00	0.50	5.00	0.86	1.43	0.57	173.03	K5037	Hourly	69
*TGN10b	474922.3	6180310.6	29/10/2019	20/11/2019	10:37	173.50	0.95	0.10	1.10	1.10	1.23	0.13	173.37	V9883	Hourly	97
*TGN09b	474613.8	6180435.7	29/10/2019	20/11/2019	10:13	174.00	0.10	0.10	1.10	1.10	1.33	0.23	173.77	V9179	Hourly	96
TGN01	474754.0	6182394.0	16/10/2019	20/11/2019	7:57	174.61	6.00	0.50	6.00	0.71	1.07	0.36	174.25	V8794	Hourly	96
EMU27D	474773.0	6182424.0	14/10/2019	20/11/2019	7:52	176.10	20.00	14.00	20.00	0.61	2.72	2.11	173.99	K6593	Hourly	69
EMU27S	474773.0	6182426.0	30/10/2019	20/11/2019	7:54	176.15	2.00	1.00	2.00	0.54	dry	dry	dry	V5452	Hourly	93
BY01	475170.0	6182247.0	14/10/2019	20/11/2019	8:30	174.18	6.00	0.50	6.00	0.63	0.66	0.03	174.15	V6918	Hourly	95
BARO (EMU27S)	474773.0	6182426.0	14/10/2019	20/11/2019	8:00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	BN998	Hourly	100
*Note TGN09b and TGN10b have not been surveyed																

Table 3: Groundwater level and electrical conductivity data logger compliance data

Comparing data logger measured electrical conductivity data with the laboratory analyses of electrical conductivity (EC) produce a reasonable relationship (correlation coefficient of around 0.7) (Table 4).

Data presented in Table 4 also provide a separate line of evidence that groundwater electrical conductivity generally increases along a flow path from MU51 to BY01 (Figure 10).

Site ID	Date sampled	Total Dissolved Solids (TDS) (lab) (mg/L)	Electrical Conductivity (EC) (lab) (mS/cm)	Electrical Conductivity (EC) mS/cm (ave Oct-Nov 2019)
MU51	15/04/2015	10300	16.0	3.0
*TGS02	15/04/2015	3940	5.8	5.0
TGN10b	20/11/2019	15000	22.3	12.5
TGN09c	20/11/2019	9900	14.8	8.3
TGN01	14/04/2015	6450	6.7	13.4
EMU27D	14/04/2015	51800	67.6	40.9
BY01	14/04/2015	28600	35.4	38.7
NB01	15/04/2015	5760	7.9	11.9
*ave EC calculated for period 9/11 to 19/11				

Table 4: Groundwater electrical conductivity data calibration

6 Summary and discussion

The work undertaken to date has complemented previous data collected in DBCA project SP 2014-24 and extended the conceptual model by broadening understanding on the following;

- Mapped extent of peat (fibric and competent material).
- Geochemical fingerprints and mixing of peat soil water, groundwater and surface water.
- Limited mixing that occurs between peat soil water and underlying groundwater in peat wetlands and
- Dominant hydrological processes that concentrate solutes including metals that contribute to peat wetland acidity.

6.1 Further work

Detailed lithological logging and selection of peat materials for laboratory analyses will be undertaken in January and February 2020. Geochemical analyses undertaken will at a minimum include the analyses carried out on peat core samples in DBCA project SP 2014-24 (see Section 3).

Other activities will include;

- Continue monitoring as outlined in Table 1.
- Assess data gaps (e.g. the need to sample the sediments/substrate beneath peat near TGN09 and TGN10).
- Interpret peat soil geochemistry data within full peat soil database.
- Review and interpret groundwater logger data to ensure they are delivering fit for purpose data to develop a water balance and
- Review and interpret water quality data to identify hydrological process boundaries.

7 References

Environmental Resources of Australia Pty. Ltd (1971) Environmental effect of the proposed peat removal from lagoons in the Lake Muir area, W.A. A report to Cladium Mining Pty. Ltd.

Farrell C. & Cook B. (2009) Ecological character description of the Muir-Byenup System RAMSAR site south-west Western Australia. Report prepared for the Department of Environment and Conservation. Centre of Excellence in Natural Resource Management, University of Western Australia.

Gibson, N. & Keighery, G.J. (1999) Assessment of the nature conservation values of the Byenup-Muir peat swamp system, south western Australia: flora and vegetation, Unpublished report for Environment Australia prepared by Department of Conservation and Land Management.

Martin, M.W., and Daetwyler, N.A. (1980) Saline river diversion studies, Tone and Kent Rivers geological investigation. GSWA File Number 338/1979, Hydrogeology Report No. 2110, Engineering geology report No. EG. 211

Martin, M.W. (1982) Byenup, Tordit-Gurrup and Poorginup Lagoons: water quality criteria in relation to peat mining. GSWA File Number 231/1979, Hydrogeology Report No. 2433.

Rockwater (2015) Muir-Byenup peat wetland investigation – bore completion and wetland analyses report. Report for Department of Parks and Wildlife.

Rutherford, J.L., (in prep). Resilience of Muir-Byenup peat wetlands under a changing climate.

Smith, R.A. (2003) Hydrogeology of the Muir–Unicup catchments, Western Australia, Water and Rivers Commission, Salinity and Land Use Impacts Series Report SLUI 22, 34p.

Smith, M. (2010) Hydrogeology of the Lake Muir–Unicup Catchment, Western Australia: an ecologically important area experiencing hydrologic change. Curtin University Department of Applied Geology, unpublished Doctor of Philosophy Thesis 274p

Storey A.W. (1998) Assessment of the Nature Conservation Values of the Byenup-Muir Peat Swamp System, South-western Australia: Physico-chemistry, Aquatic Macroinvertebrates and Fishes. An Unpublished Report for the Department of Conservation and Land Management. Wetland Research and Management, Perth.

Wroe, R. (2011) Hydrogeology of Noobijup Lake, Muir-Unicup Catchment, Western Australia: Implications for environmental water requirements. University of Western Australia School of Earth and Environment unpublished Honours Thesis 60p

Yew, E. (2011) Palynology of Eocene sediments from the Muir-Unicup Catchment, south Western Australia. Curtin University Department of Applied Geology, unpublished Honours Thesis 151p

Appendices

Appendix 1 Field procedures and notes: Oct/Nov 2019

Authored by Rachel Hamilton (Managed Recharge)

Water Quality Equipment

Water quality equipment utilised during October fieldwork and respective calibration procedures are described herein. All equipment was triple rinsed with deionised water after each use to ensure no contamination between samples. Correct operation of all equipment was checked prior to fieldwork using a 'dummy' tap water sample.

A YSI Professional Digital Sampling System (ProDSS) was used to measure pH (pH units), electrical conductivity (mS/cm), dissolved oxygen (%) and oxygen redox potential (mV). The instrument was calibrated by ECO Environmental on 23/07/2019 with all probes passing calibration checks.

A Nalgene vacuum flask with a hand operated pump was used to filter water samples through (individually wrapped) 0.45µm cellulose nitrate 47mm diameter filters. Due to filters clogging up more than one filter paper was required per sample to get the adequate sample volume. Replacing a filter within the vacuum flask was done with carefully with clean hands to avoid any contamination between the filtered and unfiltered sample.

A Hach Alkalinity Test Kit (10-400 mg/L, Model AL-DT) was used to test field alkalinity. All reagents and consumables in the kit were newly purchased and within their expiry dates. The low pH nature of the water samples resulted in all samples having unmeasurable alkalinity values.

A Heron Water Level Meter was used for measuring the depth to groundwater in bores prior to installation of dataloggers.

Standard Open Water Body Sampling Collection Procedure

Open water body samples were collected along the analysis transect line in 20 cm deep water. Samples were collected by lowering an inverted clean sample bottle 10cm deep in the lake and then displacing the air trapped inside the bottle with water. During sampling turbidity was minimised by taking careful footsteps in order to reduce suspending the lake-bed sediments into the open water body. Samples were taken from an area where sediments had not been disturbed from accessing the locating.

Sample bottles that did not require filtration were filled at the sample location and immediately put into an insulated 'cooler' bag with ice bricks. Samples requiring filtration were put in the same insulated bag and carried immediately to the vehicle for filtration and field analyses. A volume of ~3L of sample was collected to ensure adequate sample volume for all analyses.

Standard Vadose Zone Sampling Collection Procedure

Vadose zone water samples were taken adjacent to vadose zone logger housing sites (TGN09b and TGN10b). Samples were collected by hand excavating a hole to ~40cm depth, ~10cm below the saturated zone, to enable enough vadose zone water flow into the hole for a sample to be collected.

Sample bottles that did not require filtration were filled at the sample location and immediately put into an insulated 'cooler' bag with ice bricks. Samples requiring filtration were put in the same insulated bag and carried immediately to the vehicle for filtration and field analyses. A volume of ~2-3L of sample was collected to ensure adequate sample volume for all analyses.

Coring Hygiene

Augering equipment was handled carefully between samples to eliminate cross contamination. When cores where dry the augering equipment was wiped down with a clean rag to remove any sediments and then rinsed with tap water. Following rinsing with tap water the equipment was double rinsed with deionised water.

When cores where wet the augering equipment was initially washed with nearby lake water to remove sediments, clay and peat. The equipment was then rinsed with tap water and wiped down with a clean rag to dry. Following rinsing with tap water the equipment was double rinsed with deionised water

Physical variations between sites

Hole ID	General area description	Materials description	Degree of saturation/ Ability to make water
TGS03a	Located within the forest along the transect line from TGS beach	Brown/orange, sandy clay, minor loam and organics (0-12cm) overlying a grey, sandy loam, sand is fine to medium	Dry
TGS03b		Grey/brown, sandy loam, minor fibrous peat, ants in top 10cm (0-43cm) overlying a grey fine to medium sand	Dry
TGS04a	Located ~10m into the forest vegetation that encircles the beach at TGS. Site is just within the forest.	Beige/white sandy clay (0-10cm) overlying a white clayey sand, white heavy clay at very base of hole	Dry, NB: white heavy clay is slightly damp
TGS04c		Brown, sandy loam, organics and fine roots (0-9cm) overlying a white/beige sandy clay that is fine to very coarse, poorly sorted and moderately consolidated, below 40cm an orange sandy clay that is fine to very coarse, poorly sorted and moderately consolidated with minor organics, heavily iron stained, hematite and goethite mottling present	Dry, NB: orange sandy clay is slightly damp

Hole ID	General area description	Materials description	Degree of saturation/ Ability to make water
TGN08a	Located on northern peat shelf, in competent peat, ground is very spongy/bouncy to walk on	Black spongy peat with abundant fine root matter (0-12cm) overlying a brown, clayey peat with minor large pieces of fibrous material	Wet, water flows slowly into very base of auger hole
TGN08b		Dark brown, fibrous peat (0-10cm) overlying a brown, clayey peat with minor fine roots	Wet, water flows slowly into very base of auger hole
TGN09b	Located on northern peat shelf, some areas have large desiccation cracks through the peat (~20-30cm deep) that have open water within them. ground is spongy/bouncy to walk on	Dark brown, fibrous peat, abundant large pieces of Baumea articulata debris (0-30cm) overlying a dark brown, peaty clay that is puggy and has minor fine roots, green sandy clay at very base of hole	Wet, water flows readily into auger hole
TGN09c		Dark brown, fibrous clayey peat that is reductive smelling (0-30cm) overlying a dark brown, peaty clay that is puggy, and has minor fine roots, green sandy clay in basal 10cm of hole	Wet, water flows readily into auger hole, dry between 20-30cm, suggests some lenses/pockets of water within the peat
TGN10b	Located on edge of northern peat shelf adjacent to lake open water body, abundant desiccation cracks through the peat, ground is very soggy to walk on	Red/brown fibrous peat, salt crystals and iron staining present (0-10cm) overlying a brown/dark grey clayey peaty	Wet, water flows readily into auger hole
TGN10c		Red/brown fibrous peat, salt crystal and iron staining present (0-10cm) overlying a brown/dark grey clayey peaty, green sandy clay at very base of hole	Wet, water flows readily into auger hole
TGS06	Lake sediments are made of yellow sand	N/A	N/A
TGN12	Located on edge of northern peat shelf adjacent to lake open water body. Adjacent to thick Baumea articulata vegetated area located to the north, in completely desiccated peat with large	N/A	N/A

Hole ID	General area description	Materials description	Degree of saturation/ Ability to make water
	cracks, peat groundlevel is at the surface water level and is spongy/bouncy to walk on		

Water Sampling Protocols

Water sampling protocols for the various analysis are listed in the table below.

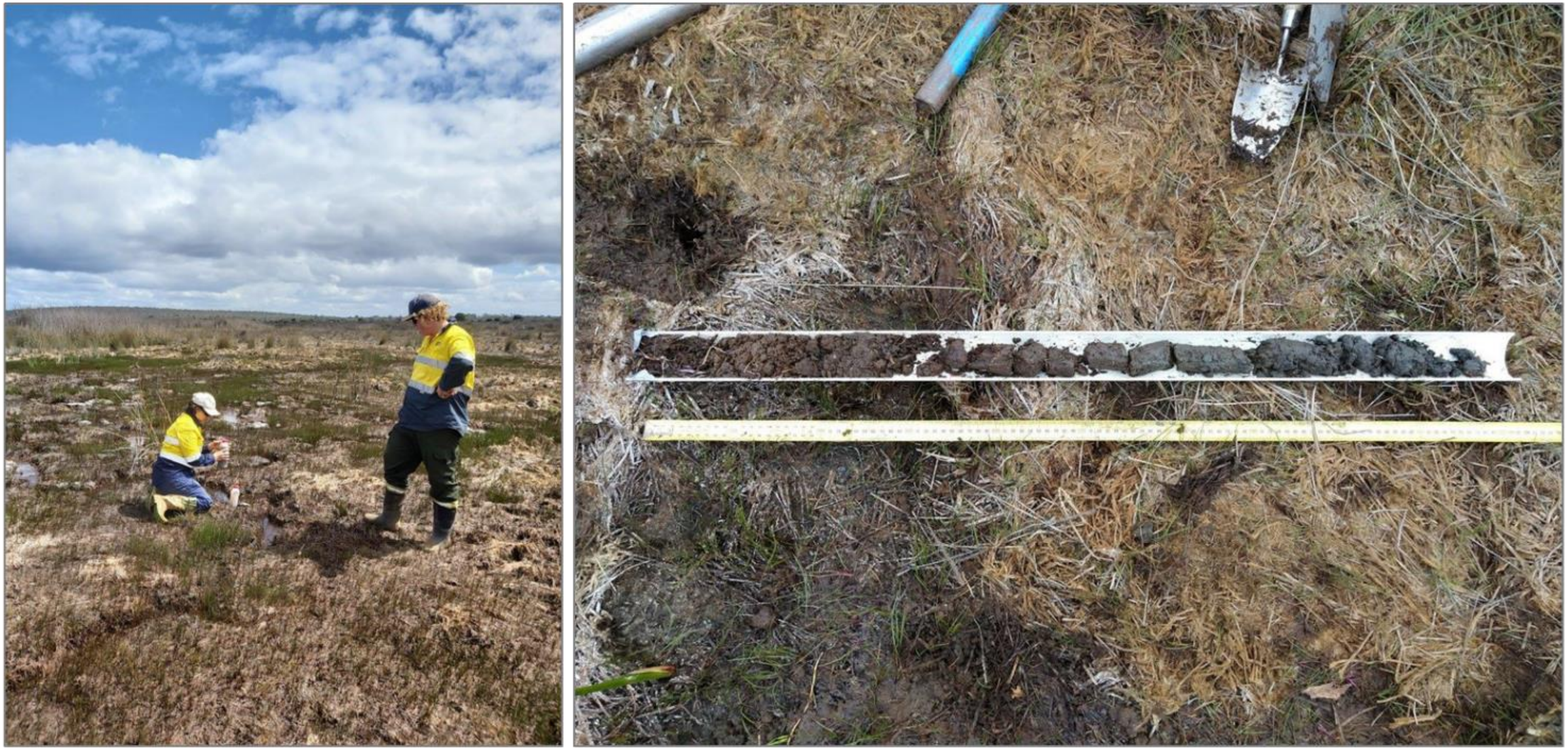
Analyses Description	Laboratory Provider	Volume at bottle type	Preservation method	Field Filtered/Unfiltered	Storage
Major Ions	Chem Centre	500mL plastic bottle	Not preserved	Unfiltered	On ice or in fridge
Ferrous Ion (Fe2+)	Chem Centre	60mL plastic bottle	Preserved with HCl	Field filtered	On ice or in fridge
Reactive SiO_2	Chem Centre	125mL plastic bottle	Not preserved	Field filtered	On ice or in fridge
Nutrients	Chem Centre	2 x 125mL plastic bottles	Not preserved	1 x 125mL field filtered, 1 x 125mL unfiltered	On ice then in freezer if storing overnight
Minor Ion and REE's	LabWest	125mL plastic bottle	Preserved with HNO_3	Field filtered	On ice or in fridge
Isotopes	UWA	20mL glass vial	Not preserved	Unfiltered	On ice or in fridge

Site ID	Sample type	Easting MGA50	Northing MGA51	Date	Time	Field physico-chemistry results - Oct and Nov 2019								Sample notes
						EC (mS/cm)	pH	Temp (°C)	ORP	DO (%)	DO (mg/L)	Turbidity (NTU)	Alkalinity	
TGN09b	Peat (vadose) zone	474613.8	6180435.7	16/10/2019	13:35	6.852	3.97	17.9	341.1	100.7	9.27	0	0	Water sampled from hand dug hole adjacent to bore (~5m NNW), next to dessication cracked peat area in peat
TGN10b	Peat (vadose) zone	474922.3	6180310.6	29/10/2019	14:30	19.57	4.11	18.9	205.7	61.2	8.67	0	0	Water sampled from hand dug hole adjacent to bore (~1m SE), site is in peat near the edge of the water body which lies to the W, couldn't wade further west safely
TGS06	open water body	475807.9	6179540.7	30/10/2019	9:30	16.85	2.79	18	487.4	97.1	8.92	0	0	windy day, water well mixed, sampled from ~10cm depth in ~20cm of water
TGN12	open water body	474686.6	6180305.5	29/10/2019	14:30	19.55	2.95	22.9	486	104.7	8.03	0	0	Adjacent to thick baumea just to the north, in dessicated peat area, peat is spongy, too dangerous to wade further S, sampled from ~10cm depth in ~20cm of water
TGN09b	Peat (vadose) zone	474613.8	6180435.7	20/11/2019	12:15	15.19	4.86	17.9	213.4	79.8	8.83	852	0	water sampled from hand dug hole adjacent to bore (~2m SSE), hole dug at ~10:15 and left open for water to seep in the allow sampling, next to dessication cracked peat area in peat
TGN10b	Peat (vadose) zone	474922.3	6180310.6	20/11/2019	12:30	21.8	3.88	21.7	273.1	79	8	314	0	water sampled from hand dug hole adjacent to bore (~3m SE), hole dug at ~10:45 and left open for water to seep in the allow sampling, site is in peat near the edge of the water body which lies to the W, couldn't wade further west safely
TGS06	open water body	475792.9	6179540.7	19/11/2019	14:30	21	2.76	21.3	486.1	91.9	8.03	2.04	0	windy and smoke haze around, water well mixed, sampled from ~10cm depth in ~20cm of water General site comments - beach sand is light orange (in Oct it was more biege), shoreline sediments are black and algae is present
TGN12	open water body	474709.8	6180287.0	20/11/2019	10:00	23.13	2.8	19.1	480.7	102.2	8.35	5.89	0	In dessicated peat area, peat is very spongy, too dangerous to wade further S, sampled from ~10cm depth in ~20cm of water

Appendix 2 Field photographs: Oct/Nov 2019

Authored by Rachel Hamilton (Managed Recharge)

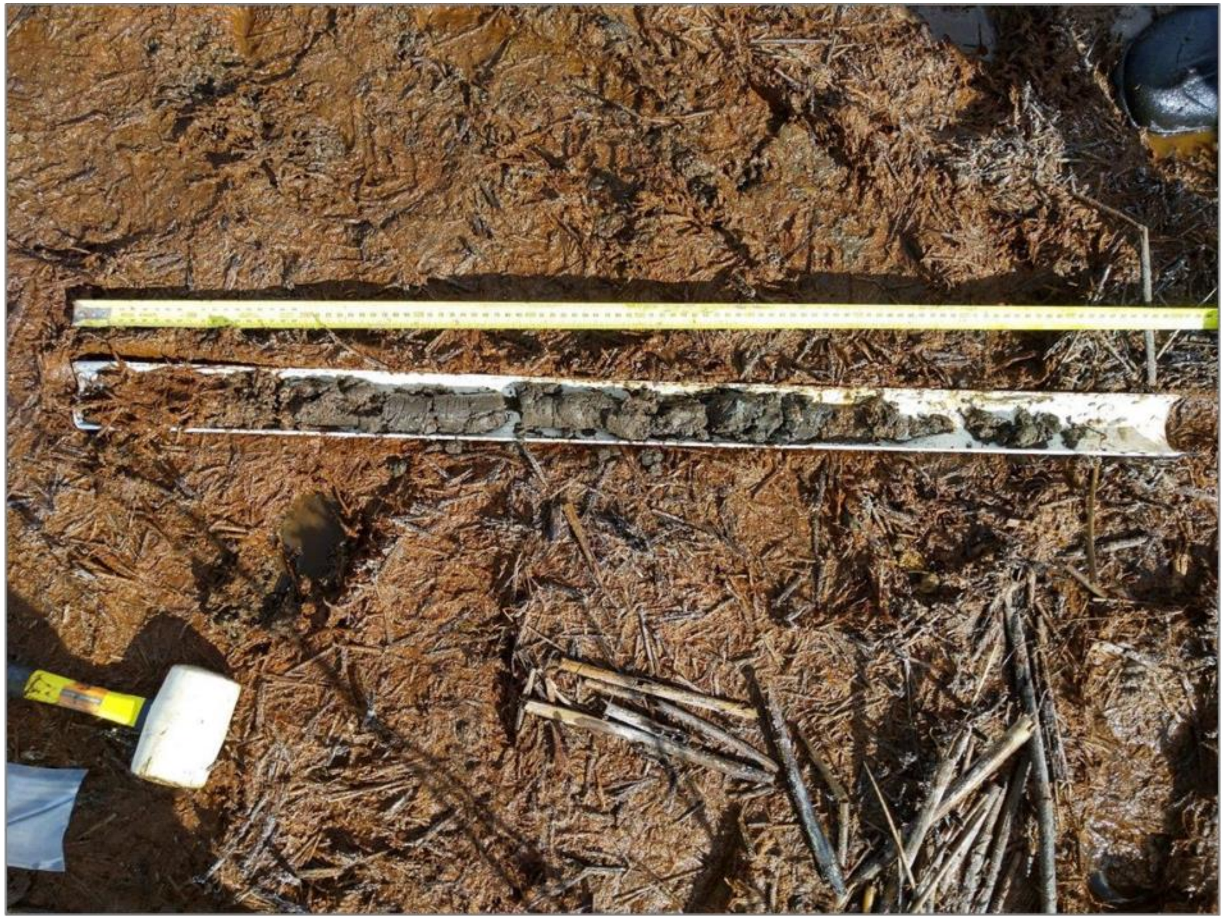
Transect 2 site TGN9b – mini piezometer construction, showing stick-up and screen slots



Transect 2 site TGN9b – water sampling and peat core (fibric peat grading to competent peat (higher carbon and clay material content); left to right)

Transect 2 site TGN9b – peat desiccation and presence of light hydrocarbons in ponded soil/surface water

Transect 2 site TGN10b – mini piezometer construction, showing location in relation to the southern surface water body, stick-up and screen slots with filter sock



Transect 2 site TGN10b – soil water sampling and peat core (fibric peat stained by iron oxyhydroxide - sulphide minerals grading to competent peat (higher carbon and clay material content); left to right)

Transect 2 site TGN10b – mini piezometer construction, showing stick-up and data logger installation to measure hourly groundwater level, temperature and electrical conductivity

Left to right; Transect 2 site TGN12 water sample site, Transect 3 TGN6 water sample site (two photos) and Tordit-Gurrup southern water body depth gauge

Appendix 3 Chain of custody documentation

CHAIN OF CUSTODY DOCUMENTATION	COC # : MUIR_Oct_2019	DATE RESULTS REQUIRED:	Samples analysis (samples may contain hazardous substances)

LABORATORY: DBCA soil laboratory Kensington Attn Jasmine Rutherford	Container: Volume (mL) / Type	FOR LABORATORY USE ONLY
CLIENT: Department of Biodiversity, Conservation and Attractions		COOLER SEAL (circle appropriate)
POSTAL ADDRESS: C/- Ecosystem Science, Locked Bag 104 BENTLEY DELIVERY CENTRE WA 6983	Treatment: Preserved / Preserved with / Filtered (0.47uM)	Intact: Yes No N/A
Delivery Address: 17 Dick Perry Ave, Technology Park, Kensington WA 6151		SAMPLE TEMPERATURE
PROJECT: Muir-Byenup (Tordit-Gurrup) — P.O.#: N/A		CHILLED: Yes No N/A
PROJECT MANAGER: Jasmine Rutherford — QUOTE NO.: N/A	Storage: Temp	
SAMPLER: Rachel Hamilton	Field measurements	Notes: e.g. Highly contaminated samples
MOBILE:		e.g. "High PAHs expected".
PHONE: 9219 9505 0407 722 635		Extra volume for QC or trace LORs etc.
EMAIL REPORT TO: jasmine.rutherford@dbca.wa.gov.au		
EMAIL INVOICE TO: jasmine.rutherford@dbca.wa.gov.au		

COMMENTS / SPECIAL HANDLING / STORAGE OR DISPOSAL:

SAMPLE INFORMATION

LAB ID	SAMPLE ID	MATRIX	DATE	Time	Site name	Total bottles	EC mS/cm	Temp	pH	Total Alkalinity (mg/L)	Notes
	TGS04a	1	15-10	830	Muir-Byenup	1					0-56cm, sandy clay.
	TGS04c	1	15-10	900	"	1					0-50cm, (★ iron from 40-50cm)
	TGS03a	1	15-10	940	"	1					0-31cm
	TGS03b	1	15-10	1015	"	1					0-60cm (2 lengths PVC)
	~~TGS05a~~	1	~~15-10~~	~~1100~~	~~"~~	1					~~0-10cm~~
	~~TGN10a~~	1	~~15-10~~	~~1400~~	~~"~~	1					~~0-10cm~~
	~~TGN09a~~	1	~~16-10~~	~~1030~~	~~"~~	1					~~0-15cm +~~
	TGN09c	1	16-10	1330	"	1					0-100cm
	TGN09b	1	16-10	1300		1					0-95
	TGN08a	1	16-10	1100		1					0-60

RELINQUISHED BY:		RECEIVED BY		METHOD OF SHIPMENT
Name:	Date:	Name:	Date:	Con' Note No: Dropped off by DPaW
Of: DPaW	Time:	Of:	Time:	
Name:	Date:	Name:	Date:	Transport Co: N/A
Of:	Time:	Of:	Time:	

Matrix: 1 = Water; 2 = Soil; 3 = Sediment; 21 = Regolith

Water Container Codes: P = Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; CG = Clear glass unpreserved
V = VOA Vial HCl Preserved; VS = VOA Vial Sulphuric Preserved; SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

Department of Parks and Wildlife **COC Page 1 of 2**

TGN08b 16-10, 1250, 0-60cm.
TGN10b 16-10, 1430, 0-100cm
TGN10c 16-10, 1450, 0-95cm

	CHAIN OF CUSTODY DOCUMENTATION	COC # : MUIR_~~Oct~~ Nov_2019	DATE RESULTS REQUIRED:	Samples analysis (samples may contain hazardous substances)

LABORATORY: DBCA soil laboratory Kensington Attn Jasmine Rutherford

CLIENT: Department of Biodiversity, Conservation and Attractions

POSTAL ADDRESS: C/- Ecosystem Science, Locked Bag 104 BENTLEY DELIVERY CENTRE WA 6983

Delivery Address: 17 Dick Perry Ave, Technology Park, Kensington WA 6151

PROJECT: Muir-Byenup (Tordit-Gurrup) | P.O.#: N/A

PROJECT MANAGER: Jasmine Rutherford | QUOTE NO.: N/A

SAMPLER: Rachel Hamilton

MOBILE: 0408012647

PHONE: 9219 9505 0407 722 635

EMAIL REPORT TO: jasmine.rutherford@dbca.wa.gov.au

EMAIL INVOICE TO: jasmine.rutherford@dbca.wa.gov.au

COMMENTS / SPECIAL HANDLING / STORAGE OR DISPOSAL:

Container: Volume (mL); Type
Treatment: Preserved; Preserved with; Filtered (0.47uM)
Storage: Temp
Field measurements: EC mS/cm; Temp; pH; Total Alkalinity (mg/L)

FOR LABORATORY USE ONLY
COOLER SEAL (circle appropriate)
Intact: Yes No N/A
SAMPLE TEMPERATURE
CHILLED: Yes No N/A

Notes: e.g. Highly contaminated samples
e.g. "High PAHs expected".
Extra volume for QC or trace LORs etc.

SAMPLE INFORMATION

LAB ID	SAMPLE ID	MATRIX	DATE	Time	Site name	Total bottles	EC mS/cm	Temp	pH	Total Alkalinity (mg/L)							Notes
	TGN11a	1	20-11	1150	Tordit-Gurrup	1											10cm shoreline grab sample core
	TGN11b	1	20-11	1152	↓	1											↕
	TGS07a	1	20-11	1510	↓	1											↓
	TGS07b	1	20-11	1512	↓	1											
		1				1											
		1				1											
		1				1											
		1				1											
		1				1											
		1				1											
		1				1											

RELINQUISHED BY:		RECEIVED BY		METHOD OF SHIPMENT
Name: Rachel Hamilton	Date:	Name:	Date:	Con' Note No: Dropped off by DPaW
Of: Merged Rechage DPaW	Time:	Of:	Time:	
Name:	Date:	Name:	Date:	Transport Co: N/A
Of:	Time:	Of:	Time:	

Matrix: 1 = Water; 2 = Soil; 3 = Sediment; 21 = Regolith

Water Container Codes: P = Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; CG = Clear glass unpreserved
V = VOA Vial HCl Preserved; VS = VOA Vial Sulphuric Preserved; SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

CHAIN OF CUSTODY DOCUMENTATION	COC # : MUIR_Oct_2019	DATE RESULTS REQUIRED:	Samples analysis (samples may contain hazardous substances)

LABORATORY: Chem Centre WA

CLIENT: Department of Biodiversity, Conservation and Attractions

POSTAL ADDRESS: C/- Ecosystem Science, Locked Bag 104 BENTLEY DELIVERY CENTRE WA 6983

Delivery Address: 17 Dick Perry Ave, Technology Park, Kensington WA 6151

PROJECT: Muir-Byenup (Tordit-Gurrup) P.O.#: N/A

PROJECT MANAGER: Jasmine Rutherford QUOTE NO.: N/A

SAMPLER: Rachel Hamilton

MOBILE: rachel.hamilton@managedrecharge.com.au ↳ please "cc" !!

PHONE: 9219 9505 0407 722 635

EMAIL REPORT TO: jasmine.rutherford@dbca.wa.gov.au

EMAIL INVOICE TO: jasmine.rutherford@dbca.wa.gov.au

COMMENTS / SPECIAL HANDLING / STORAGE OR DISPOSAL:

		Ions (Ca, Fe, K, Mg, Na, Si, Cl, Br, SO4)		Ferrous Iron (Fe2+)	Si O2 (reactive	Nutrients (Ammonia as N, Nitrate as N, Nitrite as N, Nox, Total Soluble Reactive Phosphorus)	Total N, Total P, Total kjeldahl N
Container	Volume (mL)	500		60	125	125	125
	Type	P		P	P	P	P
Treatment	Preserved	No		Yes	No	No	No
	Preserved with	N/A		HCl	N/A	N/A	N/A
	Filtered (0.47uM	No		Yes	Yes	Yes	No
Storage	Temp	4°C		4°C	4°C	Frozen	Frozen

FOR LABORATORY USE ONLY

COOLER SEAL (circle appropriate)

Intact: Yes No N/A

SAMPLE TEMPERATURE

CHILLED: Yes No N/A

Notes: e.g. Highly contaminated samples

e.g. "High PAHs expected".

Extra volume for QC or trace LORs etc.

SAMPLE INFORMATION / Field measurements

LAB ID	SAMPLE ID	MATRIX	DATE	Time	Site name	Total bottles	EC mS/cm	Temp	pH	Total Alkalinity (mg/L)	Ions		Ferrous Iron	Si O2	Nutrients	Total N, Total P, Total kjeldahl N	Notes
9S1659/001	TGN09C	1	16-10	1335	Tordit-Gurrup	1	6.85	17.9	3.97	0	✓		✓*	✓	✓	✓	* filtered but not
		1				1											preserved as I didn't
		1				1											have correct bottle,
		1				1											low pH sample anyway
		1				1											so it could be worth
		1				1											analysing??
		1				1											
		1				1											
		1				1											
		1				1											

RELINQUISHED BY:				RECEIVED BY				METHOD OF SHIPMENT
Name:		Date:		Name: Kevin Robins		Date:	17-10-19	Con' Note No: Dropped off by DPaW
Of:	DPaW	Time:		Of: ChemCentre		Time:	13:15.	
Name:		Date:		Name:		Date:		Transport Co: N/A
Of:		Time:		Of:		Time:		

Matrix: 1 = Water; 2 = Soil; 3 = Sediment; 21 = Regolith

Water Container Codes: P = Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; CG = Clear glass unpreserved

V = VOA Vial HCl Preserved; VS = VOA Vial Sulphuric Preserved; SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;

Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

CHAIN OF CUSTODY DOCUMENTATION	COC # : MUIR_Oct_2019	DATE RESULTS REQUIRED:	Samples analysis (samples may contain hazardous substances)

LABORATORY: ~~ARS~~ Chem Centre — 19S1852

CLIENT: Department of Biodiversity, Conservation and Attractions

POSTAL ADDRESS: C/- Ecosystem Science, Locked Bag 104 BENTLEY DELIVERY CENTRE WA 6983

Delivery Address: 17 Dick Perry Ave, Technology Park, Kensington WA 6151

PROJECT: Muir-Byenup (Tordit-Gurrup) P.O.#: N/A

PROJECT MANAGER: Jasmine Rutherford QUOTE NO.: N/A

Container	Volume (mL)	500		60	125	125	125
	Type	P		P	P	P	P
Treatment	Preserved	No		Yes	No	No	No
	Preserved with	N/A		HCl	N/A	N/A	N/A
	Filtered (0.47uM	No		Yes	Yes	Yes	No
Storage	Temp	4°C		4°C	4°C	Frozen	Frozen

FOR LABORATORY USE ONLY
COOLER SEAL (circle appropriate)
Intact: Yes No N/A
SAMPLE TEMPERATURE
CHILLED: Yes No N/A

SAMPLER: Rachel Hamilton
MOBILE: 0408012647
PHONE: 9219 9505 0407 722 635
EMAIL REPORT TO: jasmine.rutherford@dbca.wa.gov.au
EMAIL INVOICE TO: jasmine.rutherford@dbca.wa.gov.au

COMMENTS / SPECIAL HANDLING / STORAGE OR DISPOSAL: please "CC" rachel.hamilton@managedrecharge.com.au COC & results.

Notes: e.g. Highly contaminated samples e.g. "High PAHs expected". Extra volume for QC or trace LORs etc.

LAB ID	SAMPLE ID	MATRIX	DATE	Time	Site name	Total bottles	EC mS/cm	Temp	pH	Total Alkalinity (mg/L)	Ions (Ca, Fe, K, Mg, Na, Si, Cl, Br, SO4)		Ferrous Iron (Fe2+)	Si O2 (reactive	Nutrients (Ammonia as N, Nitrate as N, Nitrite as N, Nox, Total Soluble Reactive Phosphorus)	Total N, Total P, Total kjeldahl N	Notes
001	TGN10B	1	29-10	14 30	Tordit-Gurrup	1	19.58	18.7	4.1	0	✓		✓	✓	✓	✓	low pH samples
002	~~TGN09~~	1				1					✗						
003	TGN12	1	29-10	14 30	Tordit-Gurrup	1	22.9	19.5	2.93	0	✓		✓	✓	✓	✓	11
	TGS06	1	30-10	930	Tordit-Gurrup	1	~~[illegible]~~										
		1				1	16.7	18.0	2.79	0	✓		✓	✓	✓	✓	11
		1				1											
		1				1											
		1				1											
		1				1											
		1				1											

RELINQUISHED BY:		RECEIVED BY		METHOD OF SHIPMENT
Name: Rachel Hamilton	Date:	Name: Cate	Date: 30-10-19	Con' Note No: Dropped off by DPaW
Of: DPaW	Time:	Of: ChemCentre	Time: 3-15pm.	
Name:	Date:	Name:	Date:	Transport Co: N/A
Of:	Time:	Of:	Time:	

Matrix: 1 = Water; 2 = Soil; 3 = Sediment; 21 = Regolith

Water Container Codes: P = Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; CG = Clear glass unpreserved
V = VOA Vial HCl Preserved; VS = VOA Vial Sulphuric Preserved; SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

CHAIN OF CUSTODY DOCUMENTATION

COC # : MUIR_~~Oct~~ Nov _2019

DATE RESULTS REQUIRED:

Samples analysis (samples may contain hazardous substances)

LABORATORY: Chem Centre WA		
CLIENT: Department of Biodiversity, Conservation and Attractions		
POSTAL ADDRESS: C/- Ecosystem Science, Locked Bag 104 BENTLEY DELIVERY CENTRE WA 6983		
Delivery Address: 17 Dick Perry Ave, Technology Park, Kensington WA 6151		
PROJECT: Muir-Byenup (Tordit-Gurrup)	P.O.#: N/A	
PROJECT MANAGER: Jasmine Rutherford	QUOTE NO.: N/A	
SAMPLER: Rachel Hamilton	COMMENTS / SPECIAL HANDLING / STORAGE OR DISPOSAL:	
MOBILE: 0408012647	→ Please "CC" COC/SRN & results	
PHONE: 9219 9505 0407 722 635		
EMAIL REPORT TO: jasmine.rutherford@dbca.wa.gov.au		
EMAIL INVOICE TO: jasmine.rutherford@dbca.wa.gov.au		

		Ions (Ca, Fe, K, Mg, Na, Si, Cl, Br, SO4)	Physio Chem & TDS by grav.	Ferrous Iron (Fe2+)	Si O2 (reactive	Nutrients (Ammonia as N, Nitrate as N, Nitrite as N, Nox, Total Soluble Reactive Phosphorus)	Total N, Total P, Total kjeldahl N
Container	Volume (mL)	500	500	60	125	125	125
	Type	P	P	P	P	P	P
Treatment	Preserved	No	No	Yes	No	No	No
	Preserved with	N/A	N/A	HCl	N/A	N/A	N/A
	Filtered (0.47uM	No	No	Yes	Yes	Yes	No
Storage	Temp	4°C	4°C	4°C	4°C	Frozen	Frozen

FOR LABORATORY USE ONLY

COOLER SEAL (circle appropriate)

Intact: Yes No N/A

SAMPLE TEMPERATURE

CHILLED: Yes No N/A

Notes: e.g. Highly contaminated samples

e.g. "High PAHs expected".

Extra volume for QC or trace LORs etc.

SAMPLE INFORMATION / Field measurements

LAB ID	SAMPLE ID	MATRIX	DATE	Time	Site name	Total bottles	EC mS/cm	Temp	pH	Total Alkalinity (mg/L)	Ions	Physio Chem & TDS	Ferrous Iron	Si O2	Nutrients	Total N, Total P, Total kjeldahl N	Notes
001	TGS06	1	19-11	1430	Tordit-Gurrup	1	21.0	21.3	2.76	0	✓	✓	✓	✓	✓	✓	All Acidic
002	TGN12	1	20-11	1000	Tordit-Gurrup	1	23	19.1	2.80	0	✓	✓	✓	✓	✓	✓	Samples
003	TGN10b	1	20-11	1230	Tordit-Gurrup	1	21.8	21.7	3.88	0	✓	✓	✓	✓	* ✓	✓	*please filter, very hard to filter
004	TGN09c	1	20-11	1215	Tordit Gurrup	1	15.2	17.9	4.86	0	✓	✓	✓	✓	✓	✓	
		1				1											
		1				1											
	19S2195	1				1											
		1				1											
		1				1											
		1				1											

RELINQUISHED BY:		RECEIVED BY		METHOD OF SHIPMENT
Name: Rachel Hamilton	Date:	Name:	Date:	Con' Note No: Dropped off by DPaW
Of: Managed Recharge DPaW	Time:	Of:	Time:	
Name:	Date:	Name:	Date:	Transport Co: N/A
Of:	Time:	Of:	Time:	

Matrix: 1 = Water; 2 = Soil; 3 = Sediment; 21 = Regolith

Water Container Codes: P = Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; CG = Clear glass unpreserved

V = VOA Vial HCl Preserved; VS = VOA Vial Sulphuric Preserved; SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;

Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

CHAIN OF CUSTODY DOCUMENTATION

COC # : MUIR_Oct_2019

DATE RESULTS REQUIRED:

Samples analysis (samples may contain hazardous substances)

LABORATORY: LabWest Attn Andrew Day, 28 Bolulder Road, Malaga WA 6090 ph 9248 9321

CLIENT: Department of Biodiversity, Conservation and Attractions

POSTAL ADDRESS: C/- Ecosystem Science, Locked Bag 104 BENTLEY DELIVERY CENTRE WA 6983

Delivery Address: 17 Dick Perry Ave, Technology Park, Kensington WA 6151

PROJECT: Muir-Byenup (Tordit-Gurrup) | P.O.#: N/A

PROJECT MANAGER: Jasmine Rutherford | QUOTE NO.: N/A

SAMPLER: Rachel Hamilton

MOBILE:

PHONE: J Rutherford 9219 9505 mob 0407 722 635

EMAIL REPORT TO: jasmine.rutherford@dbca.wa.gov.a

EMAIL INVOICE TO: jasmine.rutherford@dbca.wa.gov.a

COMMENTS / SPECIAL HANDLING / STORAGE OR DISPOSAL:

Container	Volume (mL)	125
	Type	P
Treatment	Preserved	Yes
	Preserved with	HNO3
	Filtered (0.47uM	Yes
Storage	Temp	4°C

FOR LABORATORY USE ONLY

COOLER SEAL (circle appropriate)

Intact: Yes No N/A

SAMPLE TEMPERATURE

CHILLED: Yes No N/A

Notes: e.g. Highly contaminated samples

e.g. "High PAHs expected".

Extra volume for QC or trace LORs etc.

SAMPLE INFORMATION

LAB ID	SAMPLE ID	MATRIX	DATE	Time	Site name	Total bottles	EC mS/cm	Temp	pH	Total Alkalinity (mg/L)
	TGN09c	1	16/10/2019	1:35:00 PM	Tordit-Gurrup Nth	1	6.9	18	3.97	0
	TGN10b	1	29/10/2019	2:30:00 PM	Tordit-Gurrup Nth	1	19.6	19	4.10	0
	TGN12	1	29/10/2019	2:30:00 PM	Tordit-Gurrup Nth	1	22.9	20	2.95	0
	TGS06	1	30/10/2019	9:30:00 AM	Tordit-Gurrup Sth	1	16.9	18	2.79	0
		1				1				
		1				1				
		1				1				
		1				1				
		1				1				
		1				1				

RELINQUISHED BY:		RECEIVED BY		METHOD OF SHIPMENT
Name:	Date:	Name:	Date:	Con' Note No: Dropped off by DPaW
Of: DPaW	Time:	Of:	Time:	
Name:	Date:	Name:	Date:	Transport Co: N/A
Of:	Time:	Of:	Time:	

Matrix: 1 = Water; 2 = Soil; 3 = Sediment; 21 = Regolith

Water Container Codes: P - Plastic; N - Nitric Preserved Plastic; ORC - Nitric Preserved ORC; SH - Sodium Hydroxide/Cd Preserved; S - Sodium Hydroxide Preserved Plastic; AG - Amber Glass Unpreserved; CG - Clear glass unpreserved

V - VOA Vial HCl Preserved; VS - VOA Vial Sulphuric Preserved; SG - Sulfuric Preserved Amber Glass; H - HCl preserved Plastic; HS - HCl preserved Speciation bottle; SP - Sulfuric Preserved Plastic; F - Formaldehyde Preserved Glass;

Z - Zinc Acetate Preserved Bottle; E - EDTA Preserved Bottles; ST - Sterile Bottle; ASS - Plastic Bag for Acid Sulphate Soils; B - Unpreserved Bag.

Department of Biodiversity, Conservation and Attractions	**CHAIN OF CUSTODY DOCUMENTATION**	COC # : MUIR_Nov_2019	DATE RESULTS REQUIRED:	Samples analysis (samples may contain hazardous substances)

LABORATORY: LabWest Attn Andrew Day, 28 Bolulder Road, Malaga WA 6090 ph 9248 9321	Container	Volume (mL)	125	FOR LABORATORY USE ONLY
CLIENT: Department of Biodiversity, Conservation and Attractions		Type	P	COOLER SEAL (circle appropriate)
POSTAL ADDRESS: C/- Ecosystem Science, Locked Bag 104 BENTLEY DELIVERY CENTRE WA 6983	Treatment	Preserved	Yes	Intact: Yes No N/A
Delivery Address: 17 Dick Perry Ave, Technology Park, Kensington WA 6151		Preserved with	HNO3	SAMPLE TEMPERATURE
PROJECT: Muir-Byenup (Tordit-Gurrup) P.O.#: N/A		Filtered (0.47uM	Yes	CHILLED: Yes No N/A
PROJECT MANAGER: Jasmine Rutherford QUOTE NO.: N/A	Storage	Temp	4°C	

SAMPLER: Rachel Hamilton	COMMENTS / SPECIAL HANDLING / STORAGE OR DISPOSAL:	Field measurements	Notes: e.g. Highly contaminated samples
MOBILE:			e.g. "High PAHs expected".
PHONE: 9219 9505 0407 722 635			Extra volume for QC or trace LORs etc.
EMAIL REPORT TO: jasmine.rutherford@dbca.wa.gov.a			
EMAIL INVOICE TO: jasmine.rutherford@dbca.wa.gov.a			

SAMPLE INFORMATION

LAB ID	SAMPLE ID	MATRIX	DATE	Time	Site name	Total bottles	EC mS/cm	Temp	pH	Total Alkalinity (mg/L)
	TGS06	1	19/11/2019	2:30:00 PM	Tordit-Gurrup Lagoon	1	21.0	21	2.76	0
	TGN12	1	20/11/2019	10:00:00 AM	Tordit-Gurrup Lagoon	1	23.0	19	2.80	0
	TGN10b	1	20/11/2019	12:30:00 PM	Tordit-Gurrup Lagoon	1	21.8	22	3.88	0
	TGN09c	1	20/11/2019	12:15:00 PM	Tordit-Gurrup Lagoon	1	15.2	18	4.86	0
		1				1				
		1				1				
		1				1				
		1				1				
		1				1				
		1				1				

RELINQUISHED BY:		RECEIVED BY		METHOD OF SHIPMENT
Name:	Date:	Name:	Date:	Con' Note No: Dropped off by DPaW
Of: DPaW	Time:	Of:	Time:	
Name:	Date:	Name:	Date:	Transport Co: N/A
Of:	Time:	Of:	Time:	

Matrix: 1 = Water; 2 = Soil; 3 = Sediment; 21 = Regolith

Water Container Codes: P - Plastic; N - Nitric Preserved Plastic; ORC - Nitric Preserved ORC; SH - Sodium Hydroxide/Cd Preserved; S - Sodium Hydroxide Preserved Plastic; AG - Amber Glass Unpreserved; CG - Clear glass unpreserved
V - VOA Vial HCl Preserved; VS - VOA Vial Sulphuric Preserved; SG - Sulfuric Preserved Amber Glass; H - HCl preserved Plastic; HS - HCl preserved Speciation bottle; SP - Sulfuric Preserved Plastic; F - Formaldehyde Preserved Glass;
Z - Zinc Acetate Preserved Bottle; E - EDTA Preserved Bottles; ST - Sterile Bottle; ASS - Plastic Bag for Acid Sulphate Soils; B - Unpreserved Bag.

CHAIN OF CUSTODY DOCUMENTATION

COC # : MUIR_Oct_2019

DATE RESULTS REQUIRED:

Samples analysis (samples may contain hazardous substances)

LABORATORY: UWA, Western Australian Biogeochemistry Ctr, Attn Douglas Ford

CLIENT: Department of Biodiversity, Conservation and Attractions

POSTAL ADDRESS: C/- Ecosystem Science, Locked Bag 104 BENTLEY DELIVERY CENTRE WA 6983

Delivery Address: 17 Dick Perry Ave, Technology Park, Kensington WA 6151

PROJECT: Muir-Byenup (Tordit-Gurrup) | P.O.#: N/A

PROJECT MANAGER: Jasmine Rutherford | QUOTE NO.: N/A

SAMPLER: Rachel Hamilton

MOBILE:

PHONE: J. Rutherford 9219 9505 mob 0407 722 635

EMAIL REPORT TO: jasmine.rutherford@dbca.wa.gov.a

EMAIL INVOICE TO: jasmine.rutherford@dbca.wa.gov.a

COMMENTS / SPECIAL HANDLING / STORAGE OR DISPOSAL:

Container	Volume (mL)	20
	Type	CG
Treatment	Preserved	No
	Preserved with	N/A
	Filtered (0.47uM	No
Storage	Temp	4°C

FOR LABORATORY USE ONLY

COOLER SEAL (circle appropriate)

Intact: Yes No N/A

SAMPLE TEMPERATURE

CHILLED: Yes No N/A

Notes: e.g. Highly contaminated samples

e.g. "High PAHs expected".

Extra volume for QC or trace LORs etc.

SAMPLE INFORMATION

LAB ID	SAMPLE ID	MATRIX	DATE	Time	Site name	Total bottles	EC mS/cm	Temp	pH	Total Alkalinity (mg/L)
	TGN09c	1	16/10/2019	1:35:00 PM	Tordit-Gurrup Nth	1	6.9	18	3.97	0
	TGN10b	1	29/10/2019	2:30:00 PM	Tordit-Gurrup Nth	1	19.6	19	4.10	0
	TGN12	1	29/10/2019	2:30:00 PM	Tordit-Gurrup Nth	1	22.9	20	2.95	0
	TGS06	1	30/10/2019	9:30:00 AM	Tordit-Gurrup Sth	1	16.9	18	2.79	0
		1				1				
		1				1				
		1				1				
		1				1				
		1				1				
		1				1				

RELINQUISHED BY:				RECEIVED BY				METHOD OF SHIPMENT
Name:		Date:		Name:		Date:		Con' Note No: Dropped off by DPaW
Of:	DPaW	Time:		Of:		Time:		
Name:		Date:		Name:		Date:		Transport Co: N/A
Of:		Time:		Of:		Time:		

Matrix: 1 = Water; 2 = Soil; 3 = Sediment; 21 = Regolith

Water Container Codes: P - Plastic; N - Nitric Preserved Plastic; ORC - Nitric Preserved ORC; SH - Sodium Hydroxide/Cd Preserved; S - Sodium Hydroxide Preserved Plastic; AG - Amber Glass Unpreserved; CG - Clear glass unpreserved

V - VOA Vial HCl Preserved; VS - VOA Vial Sulphuric Preserved; SG - Sulfuric Preserved Amber Glass; H - HCl preserved Plastic; HS - HCl preserved Speciation bottle; SP - Sulfuric Preserved Plastic; F - Formaldehyde Preserved Glass;

Z - Zinc Acetate Preserved Bottle; E - EDTA Preserved Bottles; ST - Sterile Bottle; ASS - Plastic Bag for Acid Sulphate Soils; B - Unpreserved Bag.

CHAIN OF CUSTODY DOCUMENTATION	COC # : MUIR_Nov_2019	DATE RESULTS REQUIRED:	Samples analysis (samples may contain hazardous substances)

LABORATORY: UWA, Western Australian Biogeochemistry Ctr, Attn Douglas Ford

CLIENT: Department of Biodiversity, Conservation and Attractions

POSTAL ADDRESS: C/- Ecosystem Science, Locked Bag 104 BENTLEY DELIVERY CENTRE WA 6983

Delivery Address: 17 Dick Perry Ave, Technology Park, Kensington WA 6151

PROJECT: Muir-Byenup (Tordit-Gurrup) P.O.#: N/A

PROJECT MANAGER: Jasmine Rutherford QUOTE NO.: N/A

SAMPLER: Rachel Hamilton

MOBILE:

PHONE: J. Rutherford 9219 9505 mob 0407 722 635

EMAIL REPORT TO: jasmine.rutherford@dbca.wa.gov.a

EMAIL INVOICE TO: jasmine.rutherford@dbca.wa.gov.a

COMMENTS / SPECIAL HANDLING / STORAGE OR DISPOSAL:

Container	Volume (mL)	20
	Type	CG
Treatment	Preserved	No
	Preserved with	N/A
	Filtered (0.47uM	No
Storage	Temp	4°C

FOR LABORATORY USE ONLY

COOLER SEAL (circle appropriate)

Intact: Yes No N/A

SAMPLE TEMPERATURE

CHILLED: Yes No N/A

Notes: e.g. Highly contaminated samples

e.g. "High PAHs expected".

Extra volume for QC or trace LORs etc.

SAMPLE INFORMATION

LAB ID	SAMPLE ID	MATRI	DATE	Time	Site name	Total bottles	EC mS/cm	Temp	pH	Total Alkalinity (mg/L)
	TGS06	1	19/11/2019	2:30:00 PM	Tordit-Gurrup Lagoon	1	21.0	21	2.76	0
	TGN12	1	20/11/2019	10:00:00 AM	Tordit-Gurrup Lagoon	1	23.0	19	2.80	0
	TGN10b	1	20/11/2019	12:30:00 PM	Tordit-Gurrup Lagoon	1	21.8	22	3.88	0
	TGN09c	1	20/11/2019	12:15:00 PM	Tordit-Gurrup Lagoon	1	15.2	18	4.86	0
		1				1				
		1				1				
		1				1				
		1				1				
		1				1				
		1				1				
		1				1				

RELINQUISHED BY:		RECEIVED BY		METHOD OF SHIPMENT
Name:	Date:	Name:	Date:	Con' Note No: Dropped off by DPaW
Of: DPaW	Time:	Of:	Time:	
Name:	Date:	Name:	Date:	Transport Co: N/A
Of:	Time:	Of:	Time:	

Matrix: 1 = Water; 2 = Soil; 3 = Sediment; 21 = Regolith

Water Container Codes: P - Plastic; N - Nitric Preserved Plastic; ORC - Nitric Preserved ORC; SH - Sodium Hydroxide/Cd Preserved; S - Sodium Hydroxide Preserved Plastic; AG - Amber Glass Unpreserved; CG - Clear glass unpreserved

V - VOA Vial HCl Preserved; VS - VOA Vial Sulphuric Preserved; SG - Sulfuric Preserved Amber Glass; H - HCl preserved Plastic; HS - HCl preserved Speciation bottle; SP - Sulfuric Preserved Plastic; F - Formaldehyde Preserved Glass;

Z - Zinc Acetate Preserved Bottle; E - EDTA Preserved Bottles; ST - Sterile Bottle; ASS - Plastic Bag for Acid Sulphate Soils; B - Unpreserved Bag.

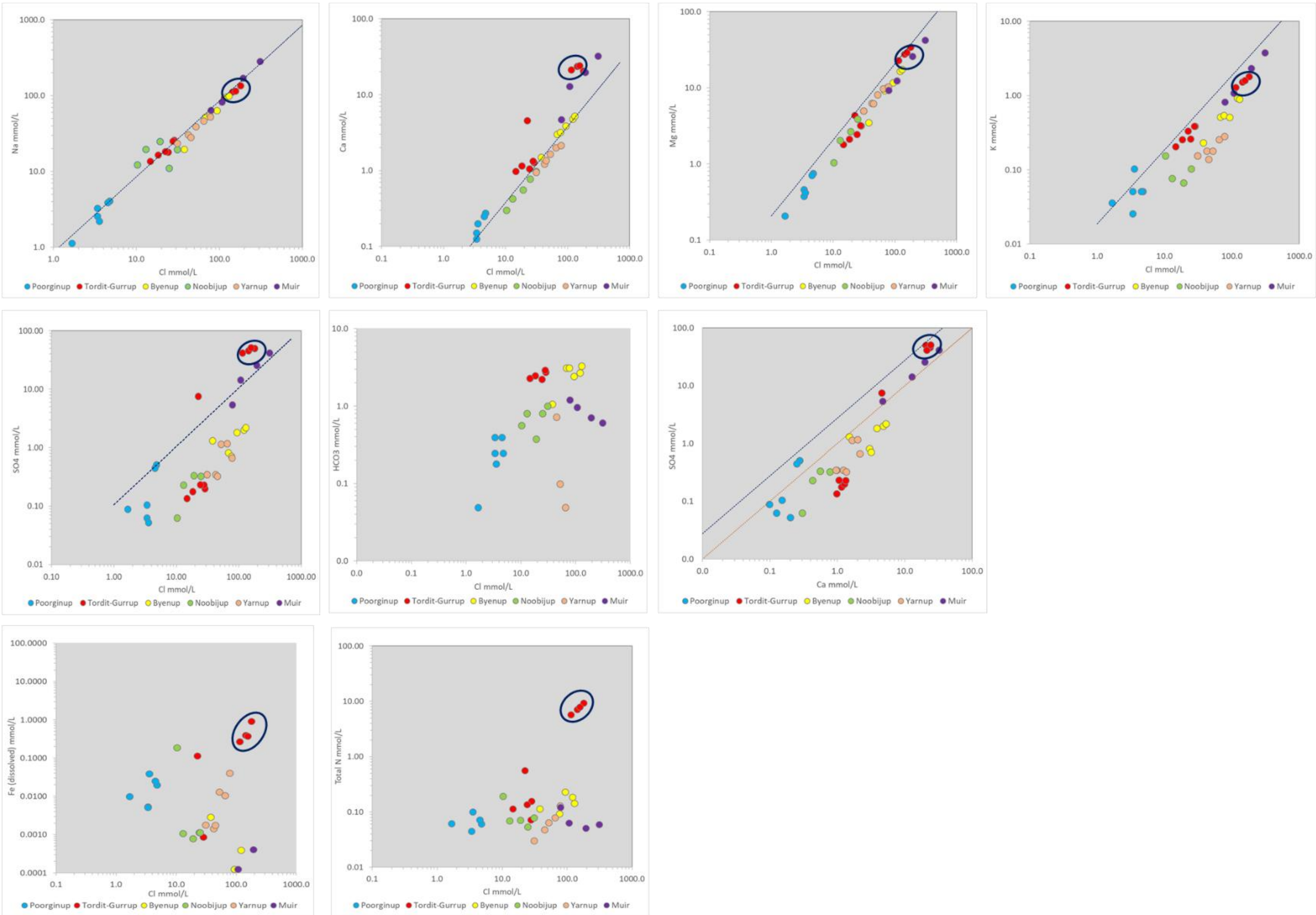
Appendix 4 Laboratory data; quality assured major & minor ions (Oct/Nov 2019)

			Alkalin	Br	Ca	Cl	ECond	Fe	FeII	K	Mg	N_NH3	N_NO2	N_NO3	N_NOx	N_TK	N_total	Na	P_SR	P_total	SO4	Si	SiO2	TDS_gra	TSS	pH
		Method Code	iALK1WATI	iANIO1WAIC	MET1WCICF	iCO1WCDA	iEC1WZSE	MET1WCICF	iCO1WCDA	MET1WCICF	MET1WCICF	iNPSi1SFAA	iNPSi1SFAA	iNPCALC4	iNPSi1SFAA	iNPCALC1	iNPT1SFAA	MET1WCICF	iNPSi1SFAA	iNPT1SFAA	iCO1WCDA	MET1WCICF	iNPSi1SFAA	iSOL1WDGR	iSOL1WPGR	iPH1WASE
		Limits of Reporting	*1*	*0.1*	*0.1*	*1*	*0.2*	*0.005*	*0.05*	*0.1*	*0.1*	*0.01*	*0.01*	*0.01*	*0.01*	*0.025*	*0.025*	*0.1*	*0.005*	*0.005*	*1*	*0.05*	*0.002*	*10*	*1*	*0.1*
		Units	mg/L	mg/L	mg/L	mg/L	mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
Site ID	DateSampled	ChemCentre Id																								
T6N09c	16/10/2019	19S1659/001		3.5	442	2190		13	0.12	20.6	287	41	<0.010	<0.01	0.015	44	44	1160	0.015	0.094	2100	12	27			
TGN09c	20/11/2019	19S2195/004	<1	5.7	660	3910	1480	3.1	3.1	36.2	503	60	<0.010	0.05	0.052	290	290	2020	0.031	2.1	2800	19	43	9900	4500	4.1
TGN10b	29/10/2019	19S1852/001		7.4	738	5330		160	160	58.7	696	110	<0.010	<0.01	0.01	160	160	2650	0.049	0.16	4200	17	43			
TGN10b	20/11/2019	19S2195/003	<1	9.1	730	6310	2230	210	210	69.8	832	130	<0.010	0.06	0.064	170	170	3140	0.024	0.84	4600	22	46	15000	17000	3.2
TGN12	29/10/2019	19S1852/002		6.6	946	5080		22	5.8	59.2	663	99	<0.010	<0.01	<0.010	100	100	2570	0.041	0.12	4400	11	29			
TGN12	20/11/2019	19S2195/002	<1	8.6	817	6370	2240	51	18	70.3	820	120	<0.010	<0.01	<0.010	130	130	3120	<0.005	0.015	4800	16	37	16000	18	3
TGS06	30/10/2019	19S1852/003		5.5	847	4040		15	3.9	50.3	552	80	<0.010	<0.01	<0.010	80	80	2150	0.024	0.038	4000	6.9	17			
TGS06	19/11/2019	19S2195/001	<1	7.1	967	5540	2020	21	5.8	62.5	702	100	<0.010	<0.01	<0.010	110	110	2660	<0.005	0.02	4900	9.5	20	15000	56	2.9

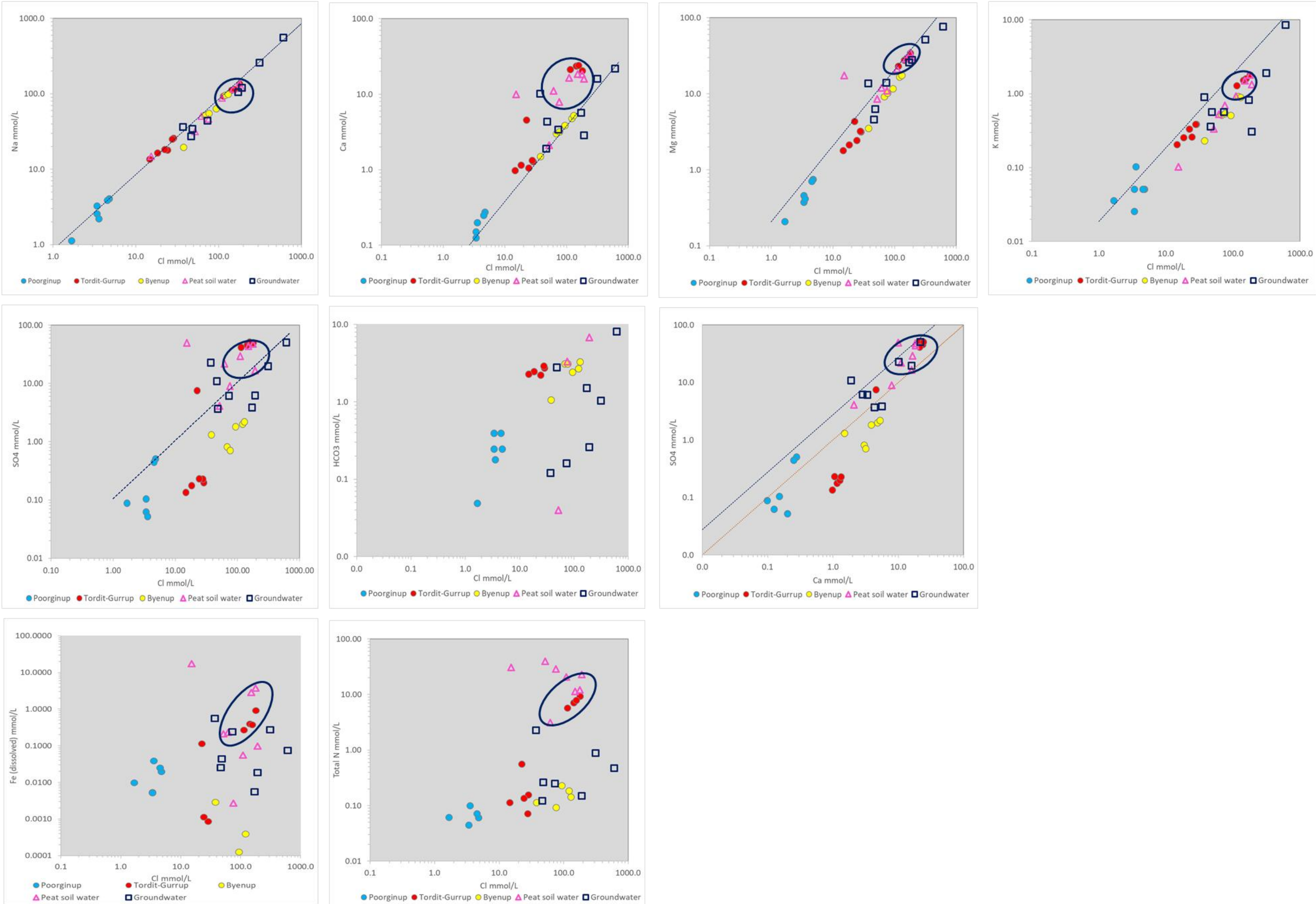
Element	Group	Date sampled	Ag	Al	As	Au	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Cs	Cu	Dy	Er	Eu	Fe	Ga	Gd	Ge	Hf	Hg	Ho	In	K	La	Li	Lu
Units			ug/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	mg/L	ug/L	ug/L	ug/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	mg/L	ug/L	ug/L	ug/L
DL			0.05	0.001	0.5	0.05	5	0.05	0.05	0.05	0.05	0.05	0.01	0.02	0.001	0.01	0.1	0.01	0.01	0.01	0.01	0.05	0.01	0.05	0.02	0.1	0.01	0.01	0.05	0.01	0.1	0.01
Method																																
ClientID/Scheme			ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04
TGN09c	Peat soil water	16/10/2019	0.007	3.72	1.34	< 0.01	758	38.1	0.3	0.47	306	< 0.05	5.59	9.46	< 0.5	0.54	0.7	0.19	0.14	0.05	16.41	0.16	0.24	0.06	< 0.01	0.003	0.05	0.002	20.8	4.18	47.1	0.02
TGN10b	Peat soil water	29/10/2019	0.011	16.4	2.54	< 0.01	1180	44.1	0.91	0.24	604	0.07	55.2	27.1	0.9	1.35	1.7	1.46	0.88	0.36	183.9	0.31	1.96	0.15	0.02	0.011	0.32	0.001	67.6	42.8	124	0.07
TGN12	Surface water	29/10/2019	0.016	40.3	2.52	< 0.01	1250	51.1	2.18	0.94	734	0.11	128	37.5	2.7	1.29	2.7	3.53	2.03	1	26.36	0.48	4.76	0.39	0.01	0.031	0.68	0.005	69.5	83.5	143	0.16
TGS06	Surface water	30/10/2019	0.008	38	3.19	< 0.01	1110	29.2	2.01	0.02	686	0.06	104	41.3	2.2	1.13	1.2	3.44	1.96	0.97	17.08	0.33	4.87	0.37	0.01	0.01	0.72	0.007	55.4	65	118	0.19
TGS06	Surface water	19/11/2019	0.014	44.9	4.54	0.03	1140	31.2	3.47	0.05	692	0.25	63.6	45.2	0.003	0.96	35.4	4.71	2.42	1.45	25	0.63	6.13	1.02	< 0.01	< 0.001	0.93	< 0.001	91.6	39.8	174	0.11
TGN12	Surface water	20/11/2019	< 0.005	42.6	3.14	0.05	1300	35.2	3.4	0.05	590	< 0.05	52.2	32.4	0.004	1.02	18.1	4.18	1.84	1	57.89	0.59	4.7	1.02	< 0.01	0.016	0.75	< 0.001	107	35.3	191	0.08
TGN10b	Peat soil water	20/11/2019	0.005	19.6	3.25	0.04	1190	50.5	1.99	0.06	534	0.31	34.6	19.8	0.002	1.21	4.7	2.03	1.21	0.65	266.7	0.59	3.03	0.85	0.08	< 0.001	0.42	0.001	102	24.6	157	0.05
TGN09c	Peat soil water	20/11/2019	< 0.005	0.706	6.06	0.03	879	53.9	0.39	0.03	425	0.11	2.83	4.24	0.001	0.48	0.5	0.2	0.12	0.05	39.21	0.23	0.25	0.44	< 0.01	< 0.001	0.03	0.029	50.4	2.45	66.7	< 0.01

Element	Group	Date sampled	Mg	Mn	Mo	Na	Nb	Nd	Ni	P	Pb	Pd	Pr	Pt	Rb	Re	S	Sb	Sc	Se	Si	Sm	Sn	Sr	Ta	Tb	Te	Th	Ti	Tl	Tm	U	V	W	Y	Yb	Zn	Zr
Units			mg/L	ug/L	ug/L	mg/L	ug/L	ug/L	ug/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	mg/L	ug/L	ug/L	ug/L	ug/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
DL			0.05	0.05	0.1	0.05	0.01	0.01	0.2	0.02	0.1	0.2	0.01	0.01	0.01	0.01	1	0.05	1	0.5	40	0.01	0.05	0.01	0.02	0.01	0.05	0.05	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.5	0.02
Method																																						
ClientID/Scheme			ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04
TGN09c	Peat soil water	16/10/2019	275	4640	0.07	1250	< 0.005	1.66	6.2	0.14	0.5	< 0.1	0.51	< 0.01	26.2	0.001	747	0.02	0.2	1.4	3090	0.23	0.34	2.98	0.002	0.04	0.95	0.04	2	0.04	0.02	0.05	0.25	0.007	2.06	0.08	15.1	0.1
TGN10b	Peat soil water	29/10/2019	646	12300	< 0.01	3690	0.005	14.5	77.7	0.35	2	< 0.1	4.64	< 0.01	78	0.002	1740	0.03	0.6	7.9	5360	1.89	0.37	6.57	< 0.002	0.28	0.25	0.09	1.2	0.08	0.1	0.04	2.16	0.011	15.6	0.58	99.3	0.52
TGN12	Surface water	29/10/2019	576	10300	0.06	3500	< 0.005	39.8	44.7	0.08	3.3	< 0.1	12.2	< 0.01	77.8	0.003	1800	0.03	1.1	11	3120	5.9	0.46	7.38	0.003	0.63	1.09	0.65	5.6	0.05	0.24	0.31	0.52	0.009	30.7	1.28	34.9	0.15
TGS06	Surface water	30/10/2019	465	8080	0.01	2600	< 0.005	34.1	30.5	0.16	1.9	< 0.1	10	< 0.01	70.5	0.002	1580	0.01	1.4	6.5	2280	5.16	0.16	6.6	< 0.002	0.61	0.78	0.63	5.5	0.05	0.24	0.23	0.17	0.005	28.9	1.33	15.3	0.04
TGS06	Surface water	19/11/2019	765	13300	0.19	3290	0.034	31.5	63.7	0.1	1.6	< 0.1	5.97	< 0.01	65.6	0.001	2840	0.07	1.7	10.7	2870	4.79	0.1	9.38	0.009	0.88	0.42	0.55	< 0.01	0.04	0.3	0.23	0.17	0.016	36.6	1.59	39.3	0.06
TGN12	Surface water	20/11/2019	902	15900	0.11	3830	0.015	24.2	65.3	0.04	1.4	< 0.1	4.78	< 0.01	70.2	0.002	2770	0.08	1.6	5.9	5240	3.42	0.21	9.67	0.003	0.7	0.68	0.48	< 0.01	0.02	0.22	0.19	0.33	0.002	33.5	1.08	29.7	0.17
TGN10b	Peat soil water	20/11/2019	881	16500	0.34	3740	< 0.005	15.6	51.2	0.22	1.9	< 0.1	3.1	< 0.01	65.4	0.001	2650	0.23	0.4	11.8	7450	2.21	0.15	7.61	0.003	0.35	0.48	0.42	0.02	0.07	0.14	0.21	10.7	0.016	19.9	0.71	63.4	0.64
TGN09c	Peat soil water	20/11/2019	503	11700	0.98	2340	0.022	1.44	12	0.28	0.4	< 0.1	0.23	< 0.01	33.2	0.002	1580	0.14	0.4	6.7	6380	0.16	0.06	4.92	0.006	0.03	0.22	0.04	< 0.01	0.02	0.02	< 0.01	3.76	0.015	1.9	0.07	15.1	0.17

Appendix 5 Major ion bivariate plots

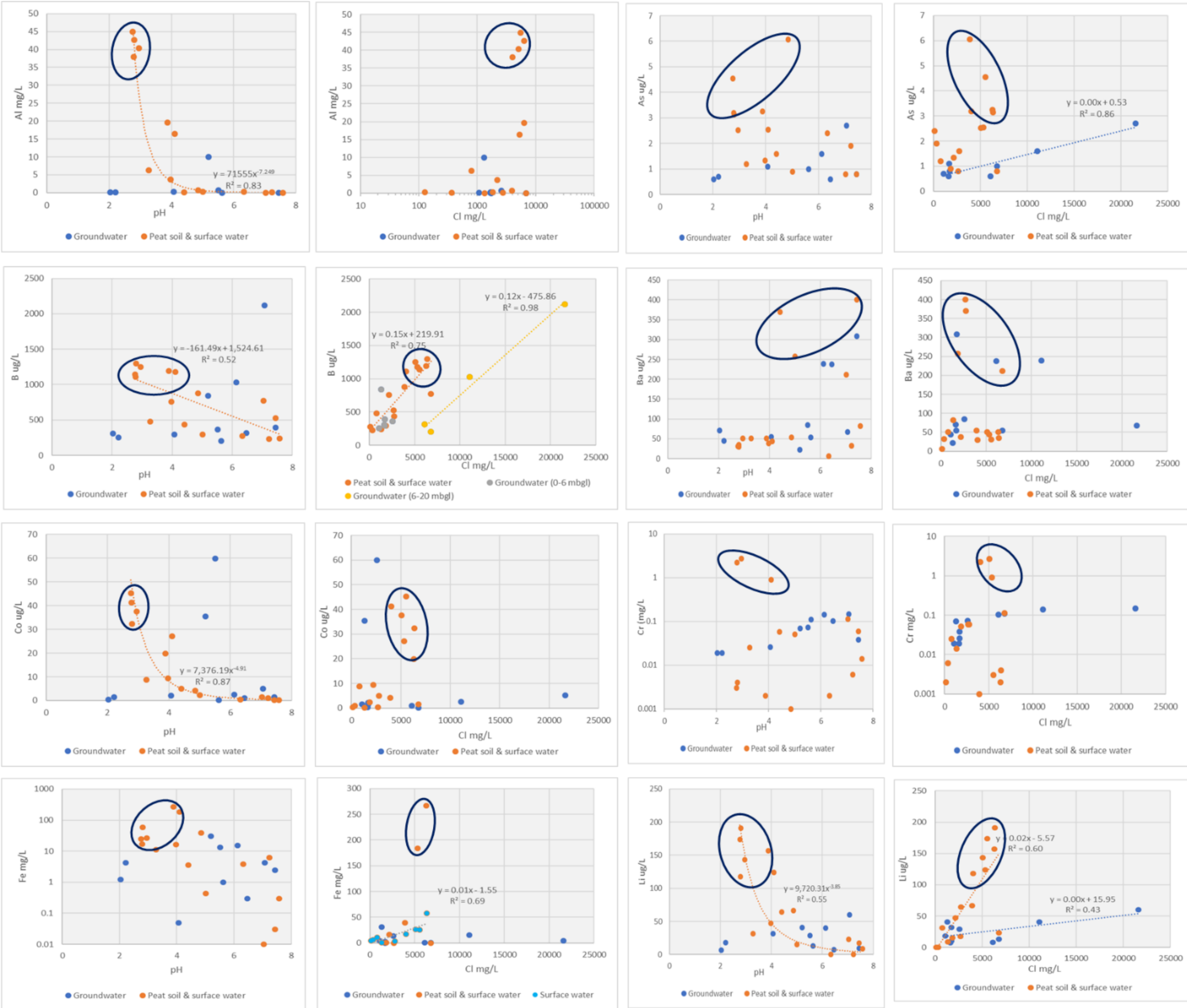


Bivariate plots; concentration (mmol/L) major cations & anions with respect to chloride; surface water data from six lakes in the Muir-Byenup Ramsar site (1998 to 2019) (NB dashed blue line represents seawater evaporation line (chloride plots);SO4/Ca plot orange and blue dashed lines represent respective gypsum & pyrite dissolution); 2019 data are circled in black where they were measured, where measurements were below detection limits there is no circle (e.g. no measurable alkalinity / HCO3 in Oct/Nov 2019)



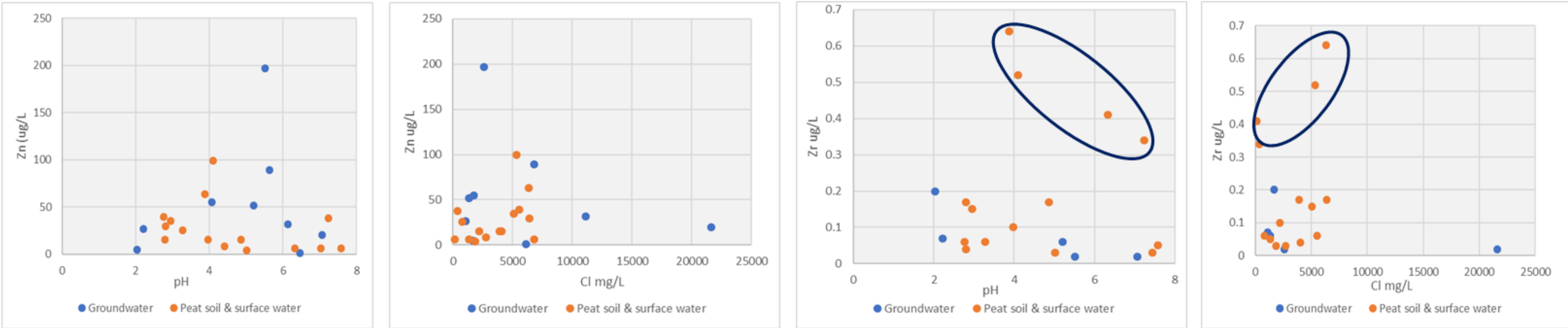
Bivariate plots; changing concentration (mmol/L) major cations & anions with respect to chloride; surface water data from Tordit-Gurrup & Byenup Lagoons & Poorginup Swamp (1998 to 2019); groundwater and peat soil water includes Noobijup Swamp (2015 to 2019) (NB dashed blue line represents seawater evaporation line (chloride plots); SO4/Ca plot orange and blue dashed lines represent respective gypsum & pyrite dissolution); 2019 data are circled in black where they were measured, where measurements were below detection limits there is no circle (e.g. no measurable alkalinity / HCO3 in Oct/Nov 2019)

Appendix 6 Minor ion bivariate plots



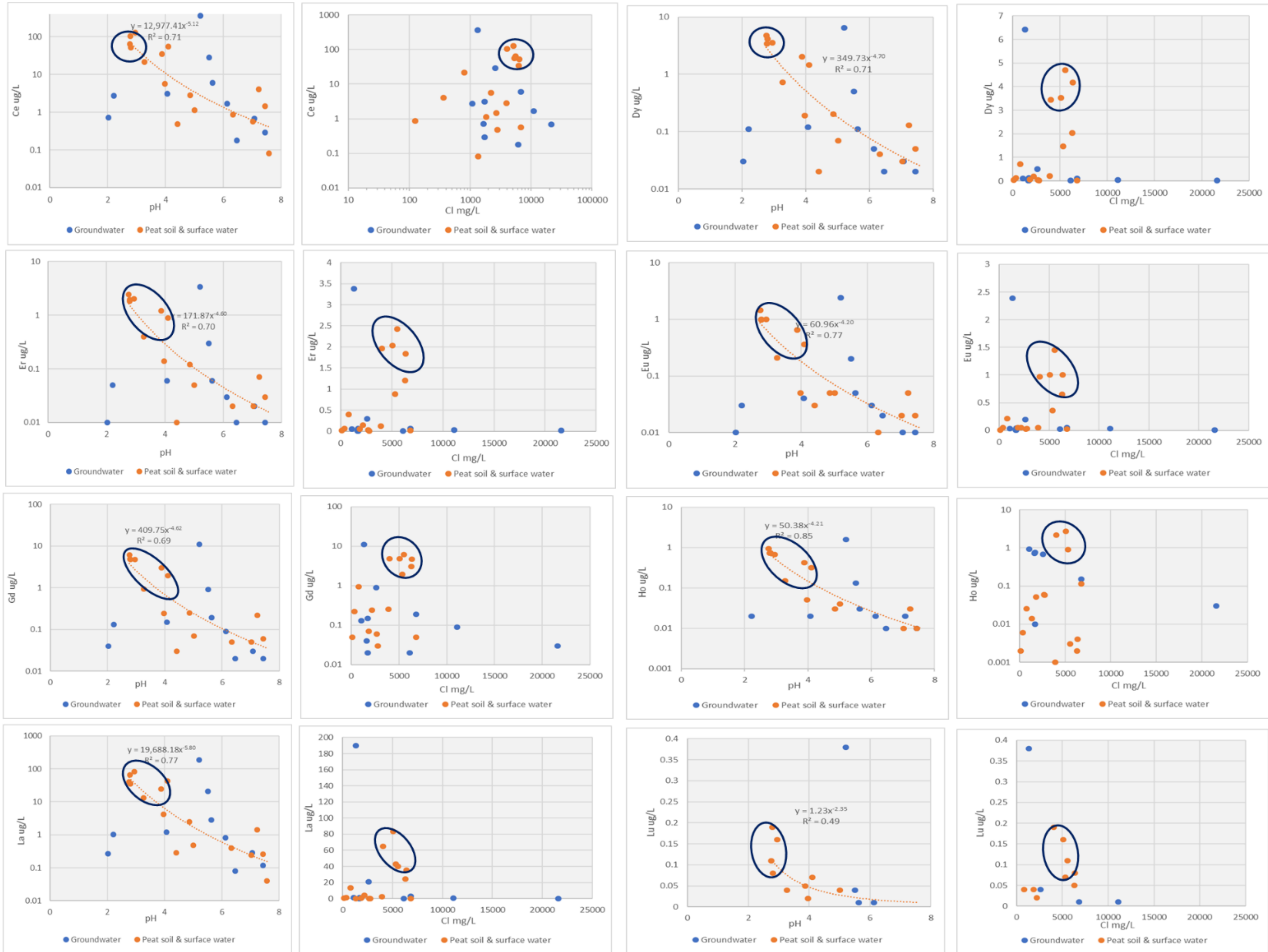
Bivariate plots; concentration (pH units, mg/L or µg/L) minor ions (metals & metalloids) with respect to pH and chloride; surface water data from five lakes and groundwater & peat soil water from four lakes within the Muir-Byenup Ramsar site (2015 to 2019) (NB trendlines & correlation coefficients are present where relationships were observed; 2019 data generally have higher concentrations (see Appendix 3) and are circled in black where they were measured & verify trends or form a population

Bivariate plots; concentration (pH units, mg/L or µg/L) minor ions (metals & metalloids) with respect to pH and chloride; surface water data from five lakes and groundwater & peat soil water from four lakes within the Muir-Byenup Ramsar site (2015 to 2019) (NB trendlines & correlation coefficients are present where relationships were observed; 2019 data generally have higher concentrations (see Appendix 3) and are circled in black where they were measured & verify trends or form a population

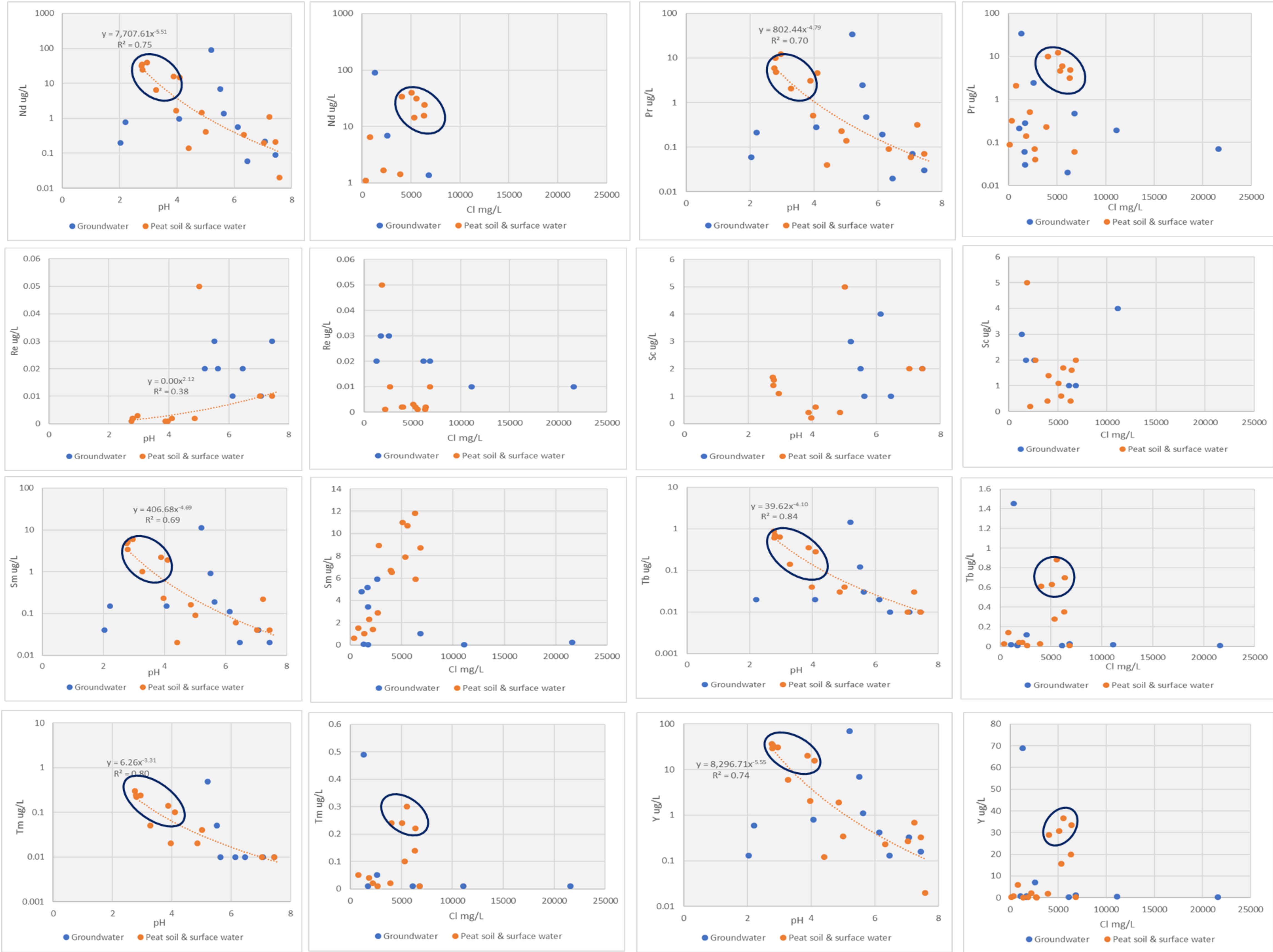


Bivariate plots; concentration (pH units, mg/L or µg/L) minor ions (metals & metalloids) with respect to pH and chloride; surface water data from five lakes and groundwater & peat soil water from four lakes within the Muir-Byenup Ramsar site (2015 to 2019) (NB trendlines & correlation coefficients are present where relationships were observed; 2019 data generally have higher concentrations (see Appendix 3) and are circled in black where they were measured & verify trends or form a population

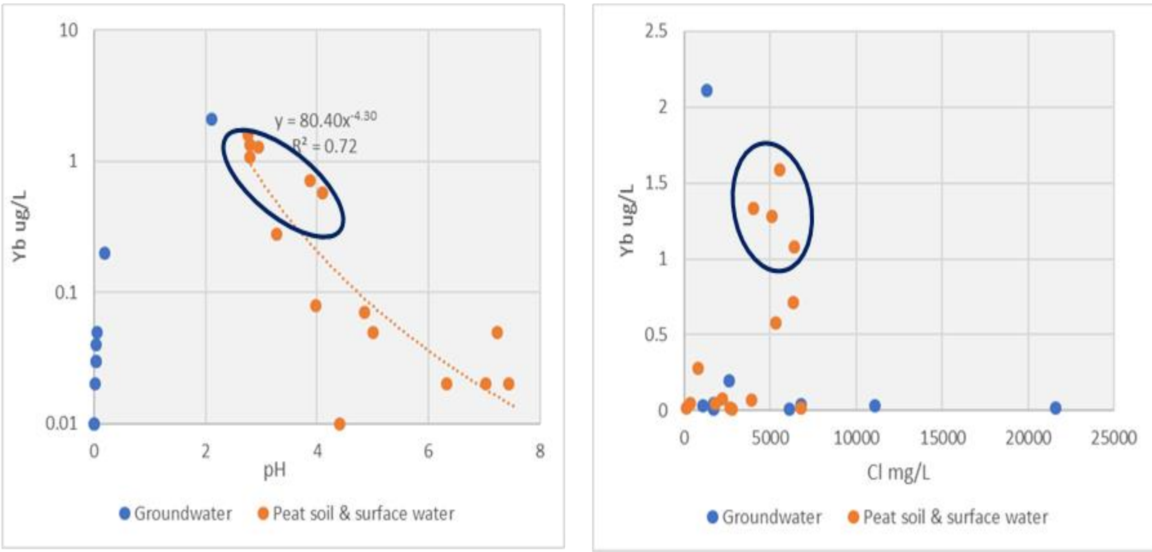
Appendix 7 REE bivariate plots



Bivariate plots; concentration rare earth elements (REE) with respect to pH and chloride; surface water data from five lakes and groundwater & peat soil water from four lakes within the Muir-Byenup Ramsar site (2015 to 2019) (NB trendlines & correlation coefficients are present where relationships were observed; 2019 data generally have higher concentrations (see Appendix 3) and are circled in black where they were measured & verify trends or form a population



Bivariate plots; concentration rare earth elements (REE) with respect to pH and chloride; surface water data from five lakes and groundwater & peat soil water from four lakes within the Muir-Byenup Ramsar site (2015 to 2019) (NB trendlines & correlation coefficients are present where relationships were observed; 2019 data generally have higher concentrations (see Appendix 3) and are circled in black where they were measured & verify trends or form a population



Bivariate plots; concentration rare earth elements (REE) with respect to pH and chloride; surface water data from five lakes and groundwater & peat soil water from four lakes within the Muir-Byenup Ramsar site (2015 to 2019) (NB trendlines & correlation coefficients are present where relationships were observed; 2019 data generally have higher concentrations (see Appendix 3) and are circled in black where they were measured & verify trends or form a population

Appendix 8 Correlation matrices – water chemistry

Variable	Correlations (MajorIonsPhysicalChemInputV2)Marked correlations are significant at p < .05000N=7 (Casewise deletion of missing data)																				
	Means	Std.Dev.	Alk	Ca	Cl	EC	Fe	HCO3	K	Mg	NH3	NO3	TK	Ntotal	Na	Ptotal	SO4	Si	SiO2	TDS	pH
Alk	131.14	177.01	1.00	0.46	0.77	0.71	-0.41	1.00	0.70	0.67	-0.49	0.26	-0.22	-0.21	0.72	-0.18	-0.10	-0.03	-0.04	0.68	0.83
Ca	574.29	203.99	0.46	1.00	0.81	0.82	-0.32	0.46	0.73	0.85	0.39	-0.30	-0.53	-0.53	0.78	-0.49	0.53	0.07	0.07	0.75	0.00
Cl	6166.00	7199.37	0.77	0.81	1.00	0.99	-0.36	0.77	0.98	0.98	-0.07	-0.13	-0.59	-0.59	0.99	-0.50	0.42	0.14	0.13	0.98	0.44
EC	2079.71	2156.94	0.71	0.82	0.99	1.00	-0.28	0.71	0.99	0.99	-0.04	-0.22	-0.60	-0.60	1.00	-0.48	0.51	0.15	0.15	0.99	0.35
Fe	175.25	359.83	-0.41	-0.32	-0.36	-0.28	1.00	-0.41	-0.31	-0.21	-0.06	-0.51	0.47	0.46	-0.31	0.80	0.54	-0.32	-0.34	-0.20	-0.59
HCO3	159.99	215.95	1.00	0.46	0.77	0.71	-0.41	1.00	0.70	0.67	-0.49	0.26	-0.22	-0.21	0.72	-0.18	-0.10	-0.03	-0.04	0.68	0.83
K	79.71	113.97	0.70	0.73	0.98	0.99	-0.31	0.70	1.00	0.97	-0.12	-0.20	-0.66	-0.66	1.00	-0.52	0.46	0.25	0.24	0.99	0.41
Mg	692.57	539.00	0.67	0.85	0.98	0.99	-0.21	0.67	0.97	1.00	0.03	-0.28	-0.60	-0.60	0.98	-0.45	0.59	0.15	0.14	0.98	0.26
NH3	30.36	48.64	-0.49	0.39	-0.07	-0.04	-0.06	-0.49	-0.12	0.03	1.00	-0.07	-0.13	-0.14	-0.08	-0.37	0.35	-0.08	-0.09	-0.11	-0.65
NO3	0.06	0.04	0.26	-0.30	-0.13	-0.22	-0.51	0.26	-0.20	-0.28	-0.07	1.00	0.36	0.37	-0.19	-0.15	-0.75	-0.38	-0.39	-0.26	0.60
TK	234.31	169.70	-0.22	-0.53	-0.59	-0.60	0.47	-0.22	-0.66	-0.60	-0.13	0.36	1.00	1.00	-0.62	0.79	-0.29	-0.85	-0.84	-0.59	-0.11
Ntotal	236.09	170.61	-0.21	-0.53	-0.59	-0.60	0.46	-0.21	-0.66	-0.60	-0.14	0.37	1.00	1.00	-0.62	0.79	-0.30	-0.85	-0.84	-0.59	-0.10
Na	3276.43	4321.36	0.72	0.78	0.99	1.00	-0.31	0.72	1.00	0.98	-0.08	-0.19	-0.62	-0.62	1.00	-0.51	0.47	0.18	0.18	0.99	0.40
Ptotal	2.74	2.69	-0.18	-0.49	-0.50	-0.48	0.80	-0.18	-0.52	-0.45	-0.37	-0.15	0.79	0.79	-0.51	1.00	0.03	-0.54	-0.54	-0.43	-0.23
SO4	3089.86	1646.86	-0.10	0.53	0.42	0.51	0.54	-0.10	0.46	0.59	0.35	-0.75	-0.29	-0.30	0.47	0.03	1.00	0.02	0.00	0.55	-0.56
Si	22.57	7.15	-0.03	0.07	0.14	0.15	-0.32	-0.03	0.25	0.15	-0.08	-0.38	-0.85	-0.85	0.18	-0.54	0.02	1.00	1.00	0.17	0.05
SiO2	48.53	15.18	-0.04	0.07	0.13	0.15	-0.34	-0.04	0.24	0.14	-0.09	-0.39	-0.84	-0.84	0.18	-0.54	0.00	1.00	1.00	0.16	0.05
TDS	15790.00	16154.18	0.68	0.75	0.98	0.99	-0.20	0.68	0.99	0.98	-0.11	-0.26	-0.59	-0.59	0.99	-0.43	0.55	0.17	0.16	1.00	0.34
pH	5.35	1.83	0.83	0.00	0.44	0.35	-0.59	0.83	0.41	0.26	-0.65	0.60	-0.11	-0.10	0.40	-0.23	-0.56	0.05	0.05	0.34	1.00

Color map of correlations (MajorIonsPhysicalChemInputV2)
N=7 (Casewise deletion of missing data)

r>=	-1	-0.80	-0.60	-0.40	-0.20	0	0.20	0.40	0.60	0.80	1

Variable	Alk	Ca	Cl	EC	Fe	HCO3	K	Mg	NH3	NO3	TK	Ntotal	Na	Ptotal	SO4	Si	SiO2	TDS	pH
Alk	1.00	0.46	0.77	0.71	-0.41	1.00	0.70	0.67	-0.49	0.26	-0.22	-0.21	0.72	-0.18	-0.10	-0.03	-0.04	0.68	0.83
Ca	0.46	1.00	0.81	0.82	-0.32	0.46	0.73	0.85	0.39	-0.30	-0.53	-0.53	0.78	-0.49	0.53	0.07	0.07	0.75	0.00
Cl	0.77	0.81	1.00	0.99	-0.36	0.77	0.98	0.98	-0.07	-0.13	-0.59	-0.59	0.99	-0.50	0.42	0.14	0.13	0.98	0.44
EC	0.71	0.82	0.99	1.00	-0.28	0.71	0.99	0.99	-0.04	-0.22	-0.60	-0.60	1.00	-0.48	0.51	0.15	0.15	0.99	0.35
Fe	-0.41	-0.32	-0.36	-0.28	1.00	-0.41	-0.31	-0.21	-0.06	-0.51	0.47	0.46	-0.31	0.80	0.54	-0.32	-0.34	-0.20	-0.59
HCO3	1.00	0.46	0.77	0.71	-0.41	1.00	0.70	0.67	-0.49	0.26	-0.22	-0.21	0.72	-0.18	-0.10	-0.03	-0.04	0.68	0.83
K	0.70	0.73	0.98	0.99	-0.31	0.70	1.00	0.97	-0.12	-0.20	-0.66	-0.66	1.00	-0.52	0.46	0.25	0.24	0.99	0.41
Mg	0.67	0.85	0.98	0.99	-0.21	0.67	0.97	1.00	0.03	-0.28	-0.60	-0.60	0.98	-0.45	0.59	0.15	0.14	0.98	0.26
NH3	-0.49	0.39	-0.07	-0.04	-0.06	-0.49	-0.12	0.03	1.00	-0.07	-0.13	-0.14	-0.08	-0.37	0.35	-0.08	-0.09	-0.11	-0.65
NO3	0.26	-0.30	-0.13	-0.22	-0.51	0.26	-0.20	-0.28	-0.07	1.00	0.36	0.37	-0.19	-0.15	-0.75	-0.38	-0.39	-0.26	0.60
TK	-0.22	-0.53	-0.59	-0.60	0.47	-0.22	-0.66	-0.60	-0.13	0.36	1.00	1.00	-0.62	0.79	-0.29	-0.85	-0.84	-0.59	-0.11
Ntotal	-0.21	-0.53	-0.59	-0.60	0.46	-0.21	-0.66	-0.60	-0.14	0.37	1.00	1.00	-0.62	0.79	-0.30	-0.85	-0.84	-0.59	-0.10
Na	0.72	0.78	0.99	1.00	-0.31	0.72	1.00	0.98	-0.08	-0.19	-0.62	-0.62	1.00	-0.51	0.47	0.18	0.18	0.99	0.40
Ptotal	-0.18	-0.49	-0.50	-0.48	0.80	-0.18	-0.52	-0.45	-0.37	-0.15	0.79	0.79	-0.51	1.00	0.03	-0.54	-0.54	-0.43	-0.23
SO4	-0.10	0.53	0.42	0.51	0.54	-0.10	0.46	0.59	0.35	-0.75	-0.29	-0.30	0.47	0.03	1.00	0.02	0.00	0.55	-0.56
Si	-0.03	0.07	0.14	0.15	-0.32	-0.03	0.25	0.15	-0.08	-0.38	-0.85	-0.85	0.18	-0.54	0.02	1.00	1.00	0.17	0.05
SiO2	-0.04	0.07	0.13	0.15	-0.34	-0.04	0.24	0.14	-0.09	-0.39	-0.84	-0.84	0.18	-0.54	0.00	1.00	1.00	0.16	0.05
TDS	0.68	0.75	0.98	0.99	-0.20	0.68	0.99	0.98	-0.11	-0.26	-0.59	-0.59	0.99	-0.43	0.55	0.17	0.16	1.00	0.34
pH	0.83	0.00	0.44	0.35	-0.59	0.83	0.41	0.26	-0.65	0.60	-0.11	-0.10	0.40	-0.23	-0.56	0.05	0.05	0.34	1.00

Correlations (MinorIons_REEPhysicalChemInputV2)Marked correlations are significant at p < .05000N=7 (Casewise deletion of missing data)

Variable	Means	Std.Dev.	pH	Cl	Al	As	B	Ba	Co	Cr	Cs	Cu	Fe	Li	Mn	Ni	Pb	Rb	Se	Sr	U	V	Zn	Zr	Ce	Dy	Er	Eu	Gd	Ho	La	Lu	Nd	Pr	Re	Sc	Sm	Tb	Tm	Y	Yb
pH	3.47	0.88	1.00	-0.58	-0.99	-0.78	-0.77	0.81	-0.94	-0.37	-0.57	-0.45	0.27	-0.79	-0.55	-0.44	-0.55	-0.72	-0.46	-0.83	-0.80	0.88	0.11	0.29	-0.75	-0.97	-0.98	-0.94	-0.98	-0.98	-0.72	-0.73	-0.92	-0.75	0.77	0.55	-0.92	-0.96	-0.96	-0.98	-0.96
Cl	4930.00	1574.42	-0.58	1.00	0.59	0.73	0.91	-0.84	0.53	-0.12	0.78	0.35	0.55	0.95	0.99	0.86	0.51	0.80	0.72	0.91	0.43	-0.58	0.57	0.54	0.27	0.61	0.59	0.57	0.59	0.59	0.31	0.02	0.43	0.24	-0.87	-0.85	0.39	0.58	0.50	0.69	0.52
Al	28.87	16.92	-0.99	0.59	1.00	0.77	0.75	-0.78	0.93	0.33	0.54	0.52	-0.30	0.80	0.55	0.46	0.54	0.70	0.47	0.85	0.80	-0.88	-0.11	-0.31	0.72	0.99	0.98	0.96	0.98	0.98	0.69	0.69	0.91	0.73	-0.74	-0.51	0.91	0.98	0.97	0.99	0.96
As	2.87	1.10	-0.78	0.73	0.77	1.00	0.73	-0.83	0.81	-0.08	0.57	0.68	0.14	0.84	0.74	0.64	0.34	0.66	0.67	0.88	0.57	-0.68	0.24	0.07	0.37	0.83	0.84	0.88	0.86	0.86	0.35	0.34	0.63	0.36	-0.81	-0.65	0.63	0.85	0.82	0.85	0.84
B	1066.00	347.24	-0.77	0.91	0.75	0.73	1.00	-0.97	0.76	0.27	0.93	0.19	0.35	0.92	0.88	0.81	0.74	0.97	0.71	0.91	0.58	-0.82	0.50	0.37	0.62	0.72	0.75	0.67	0.73	0.72	0.66	0.41	0.71	0.59	-0.98	-0.93	0.67	0.69	0.66	0.81	0.71
Ba	71.33	82.79	0.81	-0.84	-0.78	-0.83	-0.97	1.00	-0.85	-0.28	-0.91	-0.25	-0.29	-0.89	-0.83	-0.78	-0.68	-0.96	-0.69	-0.89	-0.57	0.86	-0.46	-0.29	-0.64	-0.76	-0.80	-0.73	-0.79	-0.78	-0.67	-0.50	-0.74	-0.61	0.99	0.92	-0.71	-0.75	-0.73	-0.84	-0.78
Co	29.38	14.69	-0.94	0.53	0.93	0.81	0.76	-0.85	1.00	0.44	0.66	0.44	-0.22	0.73	0.50	0.53	0.61	0.79	0.53	0.78	0.69	-0.94	0.08	-0.23	0.79	0.91	0.95	0.91	0.94	0.94	0.78	0.77	0.92	0.79	-0.81	-0.61	0.92	0.92	0.93	0.93	0.97
Cr	0.84	1.16	-0.37	-0.12	0.33	-0.08	0.27	-0.28	0.44	1.00	0.44	-0.51	-0.29	-0.03	-0.19	-0.13	0.73	0.43	0.18	-0.02	0.48	-0.46	-0.10	-0.22	0.88	0.19	0.34	0.18	0.28	0.23	0.88	0.84	0.65	0.88	-0.27	-0.28	0.65	0.19	0.31	0.25	0.37
Cs	1.02	0.41	-0.57	0.78	0.54	0.57	0.93	-0.91	0.66	0.44	1.00	-0.10	0.49	0.73	0.75	0.75	0.84	0.97	0.74	0.70	0.45	-0.73	0.66	0.52	0.66	0.48	0.57	0.45	0.54	0.50	0.72	0.42	0.62	0.62	-0.93	-0.98	0.58	0.46	0.46	0.60	0.55
Cu	9.69	12.74	-0.45	0.35	0.52	0.68	0.19	-0.25	0.44	-0.51	-0.10	1.00	-0.26	0.50	0.36	0.38	-0.20	0.07	0.22	0.57	0.23	-0.32	-0.10	-0.31	-0.10	0.64	0.54	0.67	0.57	0.62	-0.14	-0.06	0.24	-0.09	-0.22	0.02	0.25	0.67	0.59	0.55	0.53
Fe	82.48	101.89	0.27	0.55	-0.30	0.14	0.35	-0.29	-0.22	-0.29	0.49	-0.26	1.00	0.28	0.59	0.48	0.17	0.32	0.47	0.19	-0.19	0.17	0.79	0.99	-0.27	-0.28	-0.24	-0.26	-0.24	-0.27	-0.20	-0.48	-0.31	-0.31	-0.37	-0.60	-0.34	-0.30	-0.34	-0.17	-0.28
Li	131.71	57.65	-0.79	0.95	0.80	0.84	0.92	-0.89	0.73	-0.03	0.73	0.50	0.28	1.00	0.94	0.81	0.52	0.82	0.68	0.99	0.60	-0.74	0.36	0.26	0.42	0.83	0.80	0.78	0.80	0.81	0.44	0.24	0.63	0.40	-0.90	-0.78	0.60	0.80	0.73	0.87	0.74
Mn	10957.43	5541.71	-0.55	0.99	0.55	0.74	0.88	-0.83	0.50	-0.19	0.75	0.36	0.59	0.94	1.00	0.85	0.44	0.77	0.70	0.90	0.39	-0.54	0.58	0.57	0.20	0.58	0.56	0.54	0.56	0.56	0.24	-0.03	0.38	0.17	-0.86	-0.84	0.34	0.55	0.47	0.65	0.49
Ni	48.04	25.04	-0.44	0.86	0.46	0.64	0.81	-0.78	0.53	-0.13	0.75	0.38	0.48	0.81	0.85	1.00	0.42	0.79	0.56	0.80	0.09	-0.66	0.77	0.50	0.21	0.49	0.46	0.43	0.45	0.47	0.28	-0.04	0.31	0.16	-0.79	-0.77	0.27	0.48	0.37	0.55	0.42
Pb	1.77	0.89	-0.55	0.51	0.54	0.34	0.74	-0.68	0.61	0.73	0.84	-0.20	0.17	0.52	0.44	0.42	1.00	0.81	0.74	0.49	0.67	-0.63	0.37	0.24	0.86	0.45	0.58	0.45	0.52	0.47	0.89	0.61	0.76	0.84	-0.71	-0.75	0.74	0.44	0.50	0.55	0.57
Rb	62.89	22.71	-0.72	0.80	0.70	0.66	0.97	-0.96	0.79	0.43	0.97	0.07	0.32	0.82	0.77	0.79	0.81	1.00	0.69	0.80	0.52	-0.86	0.56	0.35	0.72	0.65	0.71	0.60	0.68	0.66	0.76	0.51	0.73	0.68	-0.97	-0.94	0.69	0.63	0.61	0.75	0.69
Se	8.01	3.41	-0.46	0.72	0.47	0.67	0.71	-0.69	0.53	0.18	0.74	0.22	0.47	0.68	0.70	0.56	0.74	0.69	1.00	0.65	0.64	-0.42	0.50	0.47	0.47	0.48	0.59	0.57	0.57	0.51	0.49	0.23	0.56	0.45	-0.74	-0.79	0.54	0.49	0.52	0.57	0.57
Sr	6.99	2.63	-0.83	0.91	0.85	0.88	0.91	-0.89	0.78	-0.02	0.70	0.57	0.19	0.99	0.90	0.80	0.49	0.80	0.65	1.00	0.60	-0.78	0.31	0.17	0.44	0.87	0.84	0.83	0.85	0.86	0.45	0.29	0.67	0.42	-0.89	-0.74	0.64	0.85	0.79	0.91	0.79
U	0.18	0.10	-0.80	0.43	0.80	0.57	0.58	-0.57	0.69	0.48	0.45	0.23	-0.19	0.60	0.39	0.09	0.67	0.52	0.64	0.60	1.00	-0.53	-0.26	-0.21	0.74	0.77	0.83	0.80	0.82	0.77	0.69	0.68	0.87	0.76	-0.57	-0.44	0.88	0.75	0.83	0.79	0.81
V	4.51	6.88	0.88	-0.58	-0.88	-0.68	-0.82	0.86	-0.94	-0.46	-0.73	-0.32	0.17	-0.74	-0.54	-0.66	-0.63	-0.86	-0.42	-0.78	-0.53	1.00	-0.22	0.14	-0.78	-0.83	-0.85	-0.77	-0.83	-0.84	-0.79	-0.69	-0.85	-0.76	0.82	0.65	-0.82	-0.83	-0.81	-0.87	-0.85
Zn	40.87	31.84	0.11	0.57	-0.11	0.24	0.50	-0.46	0.08	-0.10	0.66	-0.10	0.79	0.36	0.58	0.77	0.37	0.56	0.50	0.31	-0.26	-0.22	1.00	0.84	-0.02	-0.11	-0.06	-0.12	-0.09	-0.10	0.08	-0.29	-0.09	-0.07	-0.51	-0.69	-0.14	-0.11	-0.17	0.00	-0.08
Zr	0.23	0.25	0.29	0.54	-0.31	0.07	0.37	-0.29	-0.23	-0.22	0.52	-0.31	0.99	0.26	0.57	0.50	0.24	0.35	0.47	0.17	-0.21	0.14	0.84	1.00	-0.22	-0.30	-0.26	-0.30	-0.27	-0.30	-0.14	-0.47	-0.29	-0.26	-0.37	-0.61	-0.34	-0.33	-0.37	-0.19	-0.31
Ce	62.67	42.27	-0.75	0.27	0.72	0.37	0.62	-0.64	0.79	0.88	0.66	-0.10	-0.27	0.42	0.20	0.21	0.86	0.72	0.47	0.44	0.74	-0.78	-0.02	-0.22	1.00	0.62	0.74	0.61	0.69	0.65	0.99	0.92	0.93	1.00	-0.62	-0.53	0.92	0.62	0.70	0.68	0.75
Dy	2.77	1.65	-0.97	0.61	0.99	0.83	0.72	-0.76	0.91	0.19	0.48	0.64	-0.28	0.83	0.58	0.49	0.45	0.65	0.48	0.87	0.77	-0.83	-0.11	-0.30	0.62	1.00	0.98	0.98	0.98	0.99	0.59	0.60	0.86	0.63	-0.72	-0.48	0.86	1.00	0.97	0.99	0.96
Er	1.48	0.82	-0.98	0.59	0.98	0.84	0.75	-0.80	0.95	0.34	0.57	0.54	-0.24	0.80	0.56	0.46	0.58	0.71	0.59	0.84	0.83	-0.85	-0.06	-0.26	0.74	0.98	1.00	0.98	1.00	0.99	0.70	0.70	0.93	0.74	-0.77	-0.56	0.93	0.98	0.99	0.98	0.99
Eu	0.78	0.47	-0.94	0.57	0.96	0.88	0.67	-0.73	0.91	0.18	0.45	0.67	-0.26	0.78	0.54	0.43	0.45	0.60	0.57	0.83	0.80	-0.77	-0.12	-0.30	0.61	0.98	0.98	1.00	0.99	0.99	0.57	0.60	0.86	0.62	-0.70	-0.46	0.86	0.99	0.99	0.97	0.97
Gd	3.65	2.08	-0.98	0.59	0.98	0.86	0.73	-0.79	0.94	0.28	0.54	0.57	-0.24	0.80	0.56	0.45	0.52	0.68	0.57	0.85	0.82	-0.83	-0.09	-0.27	0.69	0.98	1.00	0.99	1.00	1.00	0.65	0.67	0.91	0.69	-0.76	-0.53	0.91	0.99	0.99	0.99	0.99
Ho	0.55	0.31	-0.98	0.59	0.98	0.86	0.72	-0.78	0.94	0.23	0.50	0.62	-0.27	0.81	0.56	0.47	0.47	0.66	0.51	0.86	0.77	-0.84	-0.10	-0.30	0.65	0.99	0.99	0.99	1.00	1.00	0.62	0.65	0.88	0.66	-0.74	-0.50	0.88	1.00	0.99	0.99	0.98
La	41.64	26.85	-0.72	0.31	0.69	0.35	0.66	-0.67	0.78	0.88	0.72	-0.14	-0.20	0.44	0.24	0.28	0.89	0.76	0.49	0.45	0.69	-0.79	0.08	-0.14	0.99	0.59	0.70	0.57	0.65	0.62	1.00	0.88	0.90	0.99	-0.65	-0.59	0.89	0.59	0.66	0.66	0.72
Lu	0.10	0.06	-0.73	0.02	0.69	0.34	0.41	-0.50	0.77	0.84	0.42	-0.06	-0.48	0.24	-0.03	-0.04	0.61	0.51	0.23	0.29	0.68	-0.69	-0.29	-0.47	0.92	0.60	0.70	0.60	0.67	0.65	0.88	1.00	0.87	0.93	-0.45	-0.31	0.89	0.61	0.71	0.62	0.75
Nd	22.87	13.64	-0.92	0.43	0.91	0.63	0.71	-0.74	0.92	0.65	0.62	0.24	-0.31	0.63	0.38	0.31	0.76	0.73	0.56	0.67	0.87	-0.85	-0.09	-0.29	0.93	0.86	0.93	0.86	0.91	0.88	0.90	0.87	1.00	0.93	-0.71	-0.55	1.00	0.86	0.91	0.89	0.94
Pr	5.83	4.09	-0.75	0.24	0.73	0.36	0.59	-0.61	0.79	0.88	0.62	-0.09	-0.31	0.40	0.17	0.16	0.84	0.68	0.45	0.42	0.76	-0.76	-0.07	-0.26	1.00	0.63	0.74	0.62	0.69	0.66	0.99	0.93	0.93	1.00	-0.59	-0.50	0.93	0.63	0.71	0.68	0.76
Re	0.01	0.02	0.77	-0.87	-0.74	-0.81	-0.98	0.99	-0.81	-0.27	-0.93	-0.22	-0.37	-0.90	-0.86	-0.79	-0.71	-0.97	-0.74	-0.89	-0.57	0.82	-0.51	-0.37	-0.62	-0.72	-0.77	-0.70	-0.76	-0.74	-0.65	-0.45	-0.71	-0.59	1.00	0.95	-0.68	-0.70	-0.68	-0.81	-0.74
Sc	1.69	1.54	0.55	-0.85	-0.51	-0.65	-0.93	0.92	-0.61	-0.28	-0.98	0.02	-0.60	-0.78	-0.84	-0.77	-0.75	-0.94	-0.79	-0.74	-0.44	0.65	-0.69	-0.61	-0.53	-0.48	-0.56	-0.46	-0.53	-0.50	-0.59	-0.31	-0.55	-0.50	0.95	1.00	-0.51	-0.46	-0.45	-0.60	-0.53
Sm	3.35	2.08	-0.92	0.39	0.91	0.63	0.67	-0.71	0.92	0.65	0.58	0.25	-0.34	0.60	0.34	0.27	0.74	0.69	0.54	0.64	0.88	-0.82	-0.14	-0.34	0.92	0.86	0.93	0.86	0.91	0.88	0.89	0.89	1.00	0.93	-0.68	-0.51	1.00	0.86	0.92	0.88	0.94
Tb	0.50	0.29	-0.96	0.58	0.98	0.85	0.69	-0.75	0.92	0.19	0.46	0.67	-0.30	0.80	0.55	0.48	0.44	0.63	0.49	0.85	0.75	-0.83	-0.11	-0.33	0.62	1.00	0.98	0.99	0.99	1.00	0.59	0.61	0.86	0.63	-0.70	-0.46	0.86	1.00	0.98	0.98	0.97
Tm	0.18	0.09	-0.96	0.50	0.97	0.82	0.66	-0.73	0.93	0.31	0.46	0.59	-0.34	0.73	0.47	0.37	0.50	0.61	0.52	0.79	0.83	-0.81	-0.17	-0.37	0.70	0.97	0.99	0.99	0.99	0.99	0.66	0.71	0.91	0.71	-0.68	-0.45	0.92	0.98	1.00	0.96	0.99
Y	23.65	12.68	-0.98	0.69	0.99	0.85	0.81	-0.84	0.93	0.25	0.60	0.55	-0.17	0.87	0.65	0.55	0.55	0.75	0.57	0.91	0.79	-0.87	0.00	-0.19	0.68	0.99	0.98	0.97	0.99	0.99	0.66	0.62	0.89	0.68	-0.81	-0.60	0.88	0.98	0.96	1.00	0.96
Yb	0.95	0.53	-0.96	0.52	0.96	0.84	0.71	-0.78	0.97	0.37	0.55	0.53	-0.28	0.74	0.49	0.42	0.57	0.69	0.57	0.79	0.81	-0.85	-0.08	-0.31	0.75	0.96	0.99	0.97	0.99	0.98	0.72	0.75	0.94	0.76	-0.74	-0.53	0.94	0.97	0.99	0.96	1.00

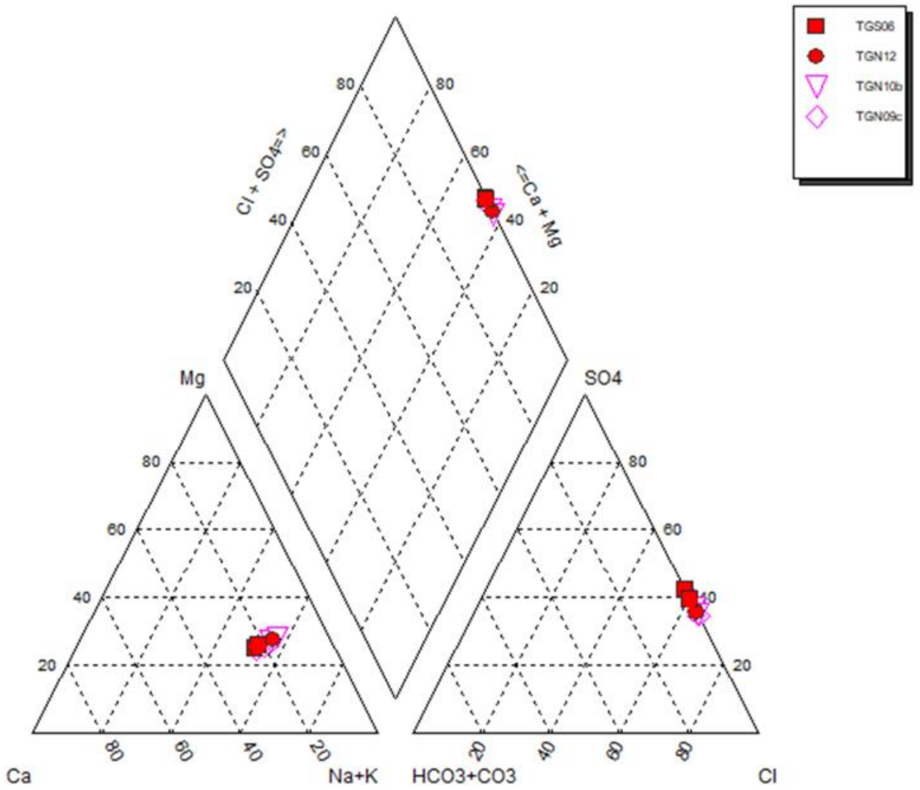
Color map of absolute correlations (MinorIons_REEPhysicalChemInput2)
N=7 (Casewise deletion of missing data)
abs(r)>= 0 | 0.10 | 0.20 | 0.30 | 0.40 | 0.5 | 0.60 | 0.70 | 0.80 | 0.90 | 1

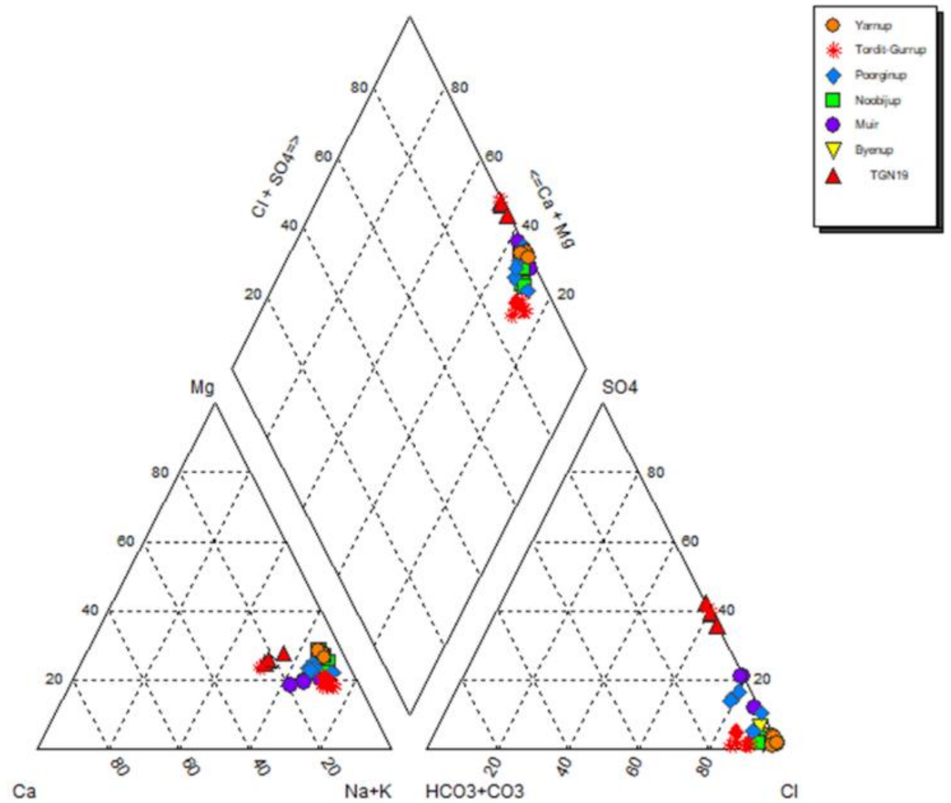
Variable	pH	Cl	Al	As	B	Ba	Co	Cr	Cs	Cu	Fe	Li	Mn	Ni	Pb	Rb	Se	Sr	U	V	Zn	Zr	Ce	Dy	Er	Eu	Gd	Ho	La	Lu	Nd	Pr	Re	Sc	Sm	Tb	Tm	Y	Yb
pH	1.00	0.58	0.99	0.78	0.77	0.81	0.94	0.37	0.57	0.45	0.27	0.79	0.55	0.44	0.55	0.72	0.46	0.83	0.80	0.88	0.11	0.29	0.75	0.97	0.98	0.94	0.98	0.98	0.72	0.73	0.92	0.75	0.77	0.55	0.92	0.96	0.96	0.98	0.96
Cl	0.58	1.00	0.59	0.73	0.91	0.84	0.53	0.12	0.78	0.35	0.55	0.95	0.99	0.86	0.51	0.80	0.72	0.91	0.43	0.58	0.57	0.54	0.27	0.61	0.59	0.57	0.59	0.59	0.31	0.02	0.43	0.24	0.87	0.85	0.39	0.58	0.50	0.69	0.52
Al	0.99	0.59	1.00	0.77	0.75	0.78	0.93	0.33	0.54	0.52	0.30	0.80	0.55	0.46	0.54	0.70	0.47	0.85	0.80	0.88	0.11	0.31	0.72	0.99	0.98	0.96	0.98	0.98	0.69	0.69	0.91	0.73	0.74	0.51	0.91	0.98	0.97	0.99	0.96
As	0.78	0.73	0.77	1.00	0.73	0.83	0.81	0.08	0.57	0.68	0.14	0.84	0.74	0.64	0.34	0.66	0.67	0.88	0.57	0.68	0.24	0.07	0.37	0.83	0.84	0.88	0.86	0.86	0.35	0.34	0.63	0.36	0.81	0.65	0.63	0.85	0.82	0.85	0.84
B	0.77	0.91	0.75	0.73	1.00	0.97	0.76	0.27	0.93	0.19	0.35	0.92	0.88	0.81	0.74	0.97	0.71	0.91	0.58	0.82	0.50	0.37	0.62	0.72	0.75	0.67	0.73	0.72	0.66	0.41	0.71	0.59	0.98	0.93	0.67	0.69	0.66	0.81	0.71
Ba	0.81	0.84	0.78	0.83	0.97	1.00	0.85	0.28	0.91	0.25	0.29	0.89	0.83	0.78	0.68	0.96	0.69	0.89	0.57	0.86	0.46	0.29	0.64	0.76	0.80	0.73	0.79	0.78	0.67	0.50	0.74	0.61	0.99	0.92	0.71	0.75	0.73	0.84	0.78
Co	0.94	0.53	0.93	0.81	0.76	0.85	1.00	0.44	0.66	0.44	0.22	0.73	0.50	0.53	0.61	0.79	0.53	0.78	0.69	0.94	0.08	0.23	0.79	0.91	0.95	0.91	0.94	0.94	0.78	0.77	0.92	0.79	0.81	0.61	0.92	0.92	0.93	0.93	0.97
Cr	0.37	0.12	0.33	0.08	0.27	0.28	0.44	1.00	0.44	0.51	0.29	0.03	0.19	0.13	0.73	0.43	0.18	0.02	0.48	0.46	0.10	0.22	0.88	0.19	0.34	0.18	0.28	0.23	0.88	0.84	0.65	0.88	0.27	0.28	0.65	0.19	0.31	0.25	0.37
Cs	0.57	0.78	0.54	0.57	0.93	0.91	0.66	0.44	1.00	0.10	0.49	0.73	0.75	0.75	0.84	0.97	0.74	0.70	0.45	0.73	0.66	0.52	0.66	0.48	0.57	0.45	0.54	0.50	0.72	0.42	0.62	0.62	0.93	0.98	0.58	0.46	0.46	0.60	0.55
Cu	0.45	0.35	0.52	0.68	0.19	0.25	0.44	0.51	0.10	1.00	0.26	0.50	0.36	0.38	0.20	0.07	0.22	0.57	0.23	0.32	0.10	0.31	0.10	0.64	0.54	0.67	0.57	0.62	0.14	0.06	0.24	0.09	0.22	0.02	0.25	0.67	0.59	0.55	0.53
Fe	0.27	0.55	0.30	0.14	0.35	0.29	0.22	0.29	0.49	0.26	1.00	0.28	0.59	0.48	0.17	0.32	0.47	0.19	0.19	0.17	0.79	0.99	0.27	0.28	0.24	0.26	0.24	0.27	0.20	0.48	0.31	0.31	0.37	0.60	0.34	0.30	0.34	0.17	0.28
Li	0.79	0.95	0.80	0.84	0.92	0.89	0.73	0.03	0.73	0.50	0.28	1.00	0.94	0.81	0.52	0.82	0.68	0.99	0.60	0.74	0.36	0.26	0.42	0.83	0.80	0.78	0.80	0.81	0.44	0.24	0.63	0.40	0.90	0.78	0.60	0.80	0.73	0.87	0.74
Mn	0.55	0.99	0.55	0.74	0.88	0.83	0.50	0.19	0.75	0.36	0.59	0.94	1.00	0.85	0.44	0.77	0.70	0.90	0.39	0.54	0.58	0.57	0.20	0.58	0.56	0.54	0.56	0.56	0.24	0.03	0.38	0.17	0.86	0.84	0.34	0.55	0.47	0.65	0.49
Ni	0.44	0.86	0.46	0.64	0.81	0.78	0.53	0.13	0.75	0.38	0.48	0.81	0.85	1.00	0.42	0.79	0.56	0.80	0.09	0.66	0.77	0.50	0.21	0.49	0.46	0.43	0.45	0.47	0.28	0.04	0.31	0.16	0.79	0.77	0.27	0.48	0.37	0.55	0.42
Pb	0.55	0.51	0.54	0.34	0.74	0.68	0.61	0.73	0.84	0.20	0.17	0.52	0.44	0.42	1.00	0.81	0.74	0.49	0.67	0.63	0.37	0.24	0.86	0.45	0.58	0.45	0.52	0.47	0.89	0.61	0.76	0.84	0.71	0.75	0.74	0.44	0.50	0.55	0.57
Rb	0.72	0.80	0.70	0.66	0.97	0.96	0.79	0.43	0.97	0.07	0.32	0.82	0.77	0.79	0.81	1.00	0.69	0.80	0.52	0.86	0.56	0.35	0.72	0.65	0.71	0.60	0.68	0.66	0.76	0.51	0.73	0.68	0.97	0.94	0.69	0.63	0.61	0.75	0.69
Se	0.46	0.72	0.47	0.67	0.71	0.69	0.53	0.18	0.74	0.22	0.47	0.68	0.70	0.56	0.74	0.69	1.00	0.65	0.64	0.42	0.50	0.47	0.47	0.48	0.59	0.57	0.57	0.51	0.49	0.23	0.56	0.45	0.74	0.79	0.54	0.49	0.52	0.57	0.57
Sr	0.83	0.91	0.85	0.88	0.91	0.89	0.78	0.02	0.70	0.57	0.19	0.99	0.90	0.80	0.49	0.80	0.65	1.00	0.60	0.78	0.31	0.17	0.44	0.87	0.84	0.83	0.85	0.86	0.45	0.29	0.67	0.42	0.89	0.74	0.64	0.85	0.79	0.91	0.79
U	0.80	0.43	0.80	0.57	0.58	0.57	0.69	0.48	0.45	0.23	0.19	0.60	0.39	0.09	0.67	0.52	0.64	0.60	1.00	0.53	0.26	0.21	0.74	0.77	0.83	0.80	0.82	0.77	0.69	0.68	0.87	0.76	0.57	0.44	0.88	0.75	0.83	0.79	0.81
V	0.88	0.58	0.88	0.68	0.82	0.86	0.94	0.46	0.73	0.32	0.17	0.74	0.54	0.66	0.63	0.86	0.42	0.78	0.53	1.00	0.22	0.14	0.78	0.83	0.85	0.77	0.83	0.84	0.79	0.69	0.85	0.76	0.82	0.65	0.82	0.83	0.81	0.87	0.85
Zn	0.11	0.57	0.11	0.24	0.50	0.46	0.08	0.10	0.66	0.10	0.79	0.36	0.58	0.77	0.37	0.56	0.50	0.31	0.26	0.22	1.00	0.84	0.02	0.11	0.06	0.12	0.09	0.10	0.08	0.29	0.09	0.07	0.51	0.69	0.14	0.11	0.17	0.00	0.08
Zr	0.29	0.54	0.31	0.07	0.37	0.29	0.23	0.22	0.52	0.31	0.99	0.26	0.57	0.50	0.24	0.35	0.47	0.17	0.21	0.14	0.84	1.00	0.22	0.30	0.26	0.30	0.27	0.30	0.14	0.47	0.29	0.26	0.37	0.61	0.34	0.33	0.37	0.19	0.31
Ce	0.75	0.27	0.72	0.37	0.62	0.64	0.79	0.88	0.66	0.10	0.27	0.42	0.20	0.21	0.86	0.72	0.47	0.44	0.74	0.78	0.02	0.22	1.00	0.62	0.74	0.61	0.69	0.65	0.99	0.92	0.93	1.00	0.62	0.53	0.92	0.62	0.70	0.68	0.75
Dy	0.97	0.61	0.99	0.83	0.72	0.76	0.91	0.19	0.48	0.64	0.28	0.83	0.58	0.49	0.45	0.65	0.48	0.87	0.77	0.83	0.11	0.30	0.62	1.00	0.98	0.98	0.98	0.99	0.59	0.60	0.86	0.63	0.72	0.48	0.86	1.00	0.97	0.99	0.96
Er	0.98	0.59	0.98	0.84	0.75	0.80	0.95	0.34	0.57	0.54	0.24	0.80	0.56	0.46	0.58	0.71	0.59	0.84	0.83	0.85	0.06	0.26	0.74	0.98	1.00	0.98	1.00	0.99	0.70	0.70	0.93	0.74	0.77	0.56	0.93	0.98	0.99	0.98	0.99
Eu	0.94	0.57	0.96	0.88	0.67	0.73	0.91	0.18	0.45	0.67	0.26	0.78	0.54	0.43	0.45	0.60	0.57	0.83	0.80	0.77	0.12	0.30	0.61	0.98	0.98	1.00	0.99	0.99	0.57	0.60	0.86	0.62	0.70	0.46	0.86	0.99	0.99	0.97	0.97
Gd	0.98	0.59	0.98	0.86	0.73	0.79	0.94	0.28	0.54	0.57	0.24	0.80	0.56	0.45	0.52	0.68	0.57	0.85	0.82	0.83	0.09	0.27	0.69	0.98	1.00	0.99	1.00	1.00	0.65	0.67	0.91	0.69	0.76	0.53	0.91	0.99	0.99	0.99	0.99
Ho	0.98	0.59	0.98	0.86	0.72	0.78	0.94	0.23	0.50	0.62	0.27	0.81	0.56	0.47	0.47	0.66	0.51	0.86	0.77	0.84	0.10	0.30	0.65	0.99	0.99	0.99	1.00	1.00	0.62	0.65	0.88	0.66	0.74	0.50	0.88	1.00	0.99	0.99	0.98
La	0.72	0.31	0.69	0.35	0.66	0.67	0.78	0.88	0.72	0.14	0.20	0.44	0.24	0.28	0.89	0.76	0.49	0.45	0.69	0.79	0.08	0.14	0.99	0.59	0.70	0.57	0.65	0.62	1.00	0.88	0.90	0.99	0.65	0.59	0.89	0.59	0.66	0.66	0.72
Lu	0.73	0.02	0.69	0.34	0.41	0.50	0.77	0.84	0.42	0.06	0.48	0.24	0.03	0.04	0.61	0.51	0.23	0.29	0.68	0.69	0.29	0.47	0.92	0.60	0.70	0.60	0.67	0.65	0.88	1.00	0.87	0.93	0.45	0.31	0.89	0.61	0.71	0.62	0.75
Nd	0.92	0.43	0.91	0.63	0.71	0.74	0.92	0.65	0.62	0.24	0.31	0.63	0.38	0.31	0.76	0.73	0.56	0.67	0.87	0.85	0.09	0.29	0.93	0.86	0.93	0.86	0.91	0.88	0.90	0.87	1.00	0.93	0.71	0.55	1.00	0.86	0.91	0.89	0.94
Pr	0.75	0.24	0.73	0.36	0.59	0.61	0.79	0.88	0.62	0.09	0.31	0.40	0.17	0.16	0.84	0.68	0.45	0.42	0.76	0.76	0.07	0.26	1.00	0.63	0.74	0.62	0.69	0.66	0.99	0.93	0.93	1.00	0.59	0.50	0.93	0.63	0.71	0.68	0.76
Re	0.77	0.87	0.74	0.81	0.98	0.99	0.81	0.27	0.93	0.22	0.37	0.90	0.86	0.79	0.71	0.97	0.74	0.89	0.57	0.82	0.51	0.37	0.62	0.72	0.77	0.70	0.76	0.74	0.65	0.45	0.71	0.59	1.00	0.95	0.68	0.70	0.68	0.81	0.74
Sc	0.55	0.85	0.51	0.65	0.93	0.92	0.61	0.28	0.98	0.02	0.60	0.78	0.84	0.77	0.75	0.94	0.79	0.74	0.44	0.65	0.69	0.61	0.53	0.48	0.56	0.46	0.53	0.50	0.59	0.31	0.55	0.50	0.95	1.00	0.51	0.46	0.45	0.60	0.53
Sm	0.92	0.39	0.91	0.63	0.67	0.71	0.92	0.65	0.58	0.25	0.34	0.60	0.34	0.27	0.74	0.69	0.54	0.64	0.88	0.82	0.14	0.34	0.92	0.86	0.93	0.86	0.91	0.88	0.89	0.89	1.00	0.93	0.68	0.51	1.00	0.86	0.92	0.88	0.94
Tb	0.96	0.58	0.98	0.85	0.69	0.75	0.92	0.19	0.46	0.67	0.30	0.80	0.55	0.48	0.44	0.63	0.49	0.85	0.75	0.83	0.11	0.33	0.62	1.00	0.98	0.99	0.99	1.00	0.59	0.61	0.86	0.63	0.70	0.46	0.86	1.00	0.98	0.98	0.97
Tm	0.96	0.50	0.97	0.82	0.66	0.73	0.93	0.31	0.46	0.59	0.34	0.73	0.47	0.37	0.50	0.61	0.52	0.79	0.83	0.81	0.17	0.37	0.70	0.97	0.99	0.99	0.99	0.99	0.66	0.71	0.91	0.71	0.68	0.45	0.92	0.98	1.00	0.96	0.99
Y	0.98	0.69	0.99	0.85	0.81	0.84	0.93	0.25	0.60	0.55	0.17	0.87	0.65	0.55	0.55	0.75	0.57	0.91	0.79	0.87	0.00	0.19	0.68	0.99	0.98	0.97	0.99	0.99	0.66	0.62	0.89	0.68	0.81	0.60	0.88	0.98	0.96	1.00	0.96
Yb																																							

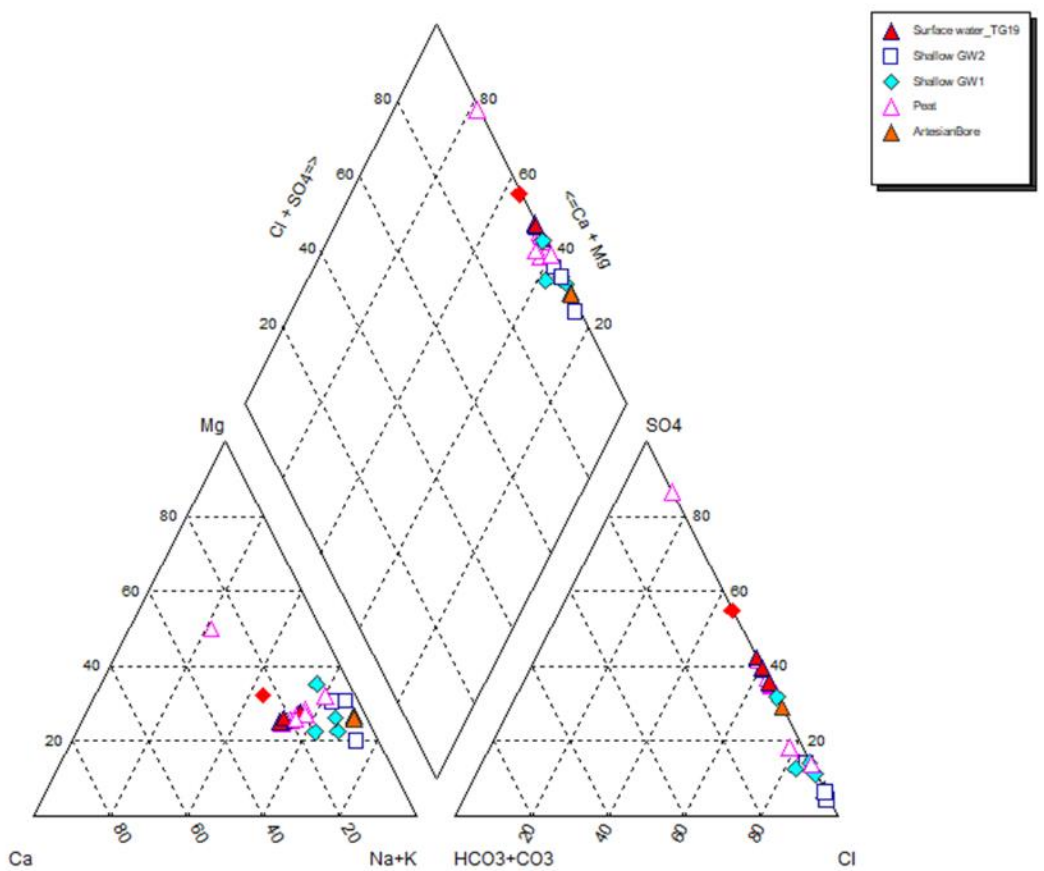
Appendix 9 Piper plots & PHREEQC geochemical modelling (saturation indices)

Station ID	Sampling Date	Water Type	Temperature °C	pH (field)	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	HCO3 mg/l	SO4 mg/l	Al_diss ug/l	As_diss ug/l	Br mg/l	Fe mg/l	SiO2 mg/l	Alkalinity	Ionic Strength	Percent Error
TGN09c	16/10/2019	Na-Mg-Ca-Cl-SO4	17.9	4	442	287	1160	20.6	2190	0	2100	3700	1.3	3.5	16.4	27	-0.0002	0.1200	-4.39
TGN09c	20/11/2019	Na-Mg-Cl-SO4	17.9	4.9	660	503	2020	36.2	3910	0	2800	700	6.1	5.7	39.2	43	0.0000	0.1936	-1.39
TGN10b	29/10/2019	Na-Mg-Cl-SO4	18.9	4.1	738	696	2650	58.7	5330	0	4200	16400	2.5	7.4	183.9	43	-0.0002	0.2608	-4.72
TGN10b	20/11/2019	Na-Mg-Cl-SO4	21.7	3.9	730	832	3140	69.8	6310	0	4600	19600	3.3	9.1	266.7	46	-0.0003	0.2988	-4.12
TGN12	29/10/2019	Na-Mg-Ca-Cl-SO4	19.5	3	946	663	2570	59.2	5080	0	4400	40300	2.5	6.6	26.4	29	-0.0021	0.2593	-3.22
TGN12	20/11/2019	Na-Mg-Cl-SO4	19.1	2.8	817	820	3120	70.3	6370	0	4800	42600	3.1	8.6	57.9	37	-0.0034	0.3013	-5.22
TGS06	30/10/2019	Na-Mg-Ca-Cl-SO4	18	2.8	847	552	2150	50.3	4040	0	4000	38000	3.2	5.5	17.1	17	-0.0033	0.2208	-2.08
TGS06	19/11/2019	Na-Mg-Cl-SO4	21.3	2.8	967	702	2660	62.5	5540	0	4900	44900	4.5	7.1	25	20	-0.0035	0.2752	-6.28

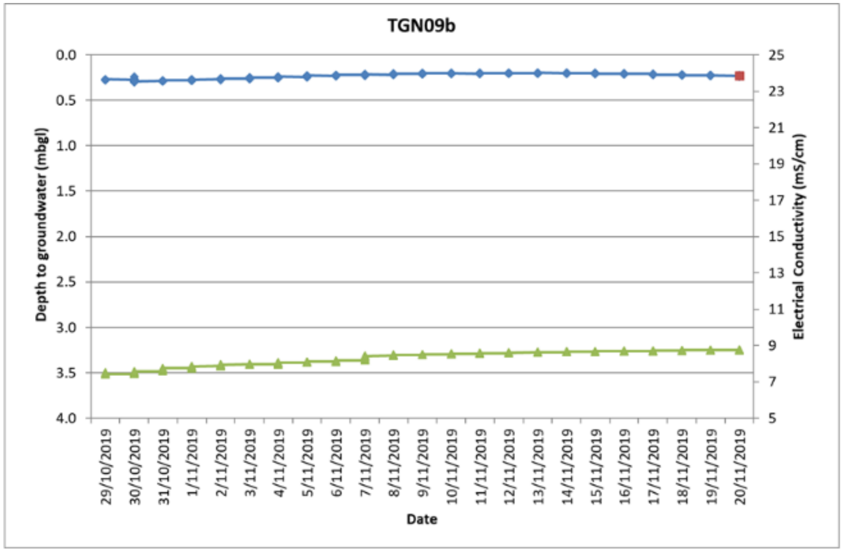
Station ID	Sampling Date	Water Type	log[Al+3] mmol/kg	log[Ca+2] mmol/kg	log[Cl-] mmol/kg	log[Fe+2] mmol/kg	log [Mg+2] mmol/kg	log[Na+] mmol/kg	log[SO4-2] mmol/kg	SI (Albite)	SI (Anhydrite)	SI (Chalcedon	SI (Goethite)	SI (Gypsum)	SI (Halite)	SI (Hematite)	SI (Quartz)
TGN09c	16/10/2019	Na-Mg-Ca-Cl-SO4	-5.37	-2.51	-1.33	-4.09	-2.47	-1.42	-2.29	-5.7	-0.5	0.3	-0.5	-0.2	-4.3	0.9	0.8
TGN09c	20/11/2019	Na-Mg-Cl-SO4	-6.17	-2.38	-1.10	-3.76	-2.26	-1.19	-2.27	-2.1	-0.3	0.5	2.5	-0.1	-3.9	6.9	1.0
TGN10b	29/10/2019	Na-Mg-Cl-SO4	-4.89	-2.38	-0.98	-3.14	-2.17	-1.08	-2.16	-3.8	-0.2	0.5	0.8	0.0	-3.6	3.5	1.0
TGN10b	20/11/2019	Na-Mg-Cl-SO4	-4.83	-2.40	-0.91	-2.99	-2.11	-1.01	-2.17	-4.3	-0.2	0.5	0.5	0.0	-3.5	3.0	1.0
TGN12	29/10/2019	Na-Mg-Ca-Cl-SO4	-4.50	-2.28	-1.00	-3.98	-2.20	-1.09	-2.16	-8.3	-0.1	0.3	-3.3	0.1	-3.7	-4.7	0.8
TGN12	20/11/2019	Na-Mg-Cl-SO4	-4.49	-2.35	-0.90	-3.65	-2.11	-1.01	-2.15	-8.7	-0.2	0.5	-3.6	0.1	-3.5	-5.3	0.9
TGS06	30/10/2019	Na-Mg-Ca-Cl-SO4	-4.51	-2.31	-1.09	-4.15	-2.26	-1.17	-2.17	-10.0	-0.1	0.1	-4.2	0.1	-3.8	-6.4	0.6
TGS06	19/11/2019	Na-Mg-Cl-SO4	-4.49	-2.28	-0.96	-4.02	-2.19	-1.08	-2.13	-9.5	-0.1	0.2	-3.9	0.2	-3.6	-5.7	0.6

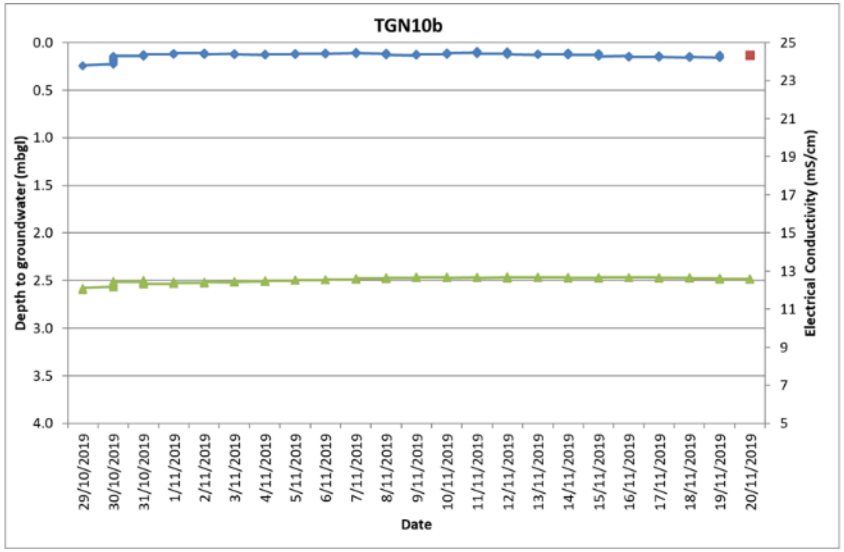

TGS06
TGN12
TGN10b
TGN09c
Cl + SO4=>
<=Ca + Mg
Mg
SO4
Ca
Na+K
HCO3+CO3
Cl


Yarnup
Tordit-Gurrup
Poorginup
Noobijup
Muir
Byenup
TGN19
Cl + SO4=>
<=Ca + Mg
Mg
SO4
Ca
Na+K
HCO3+CO3
Cl

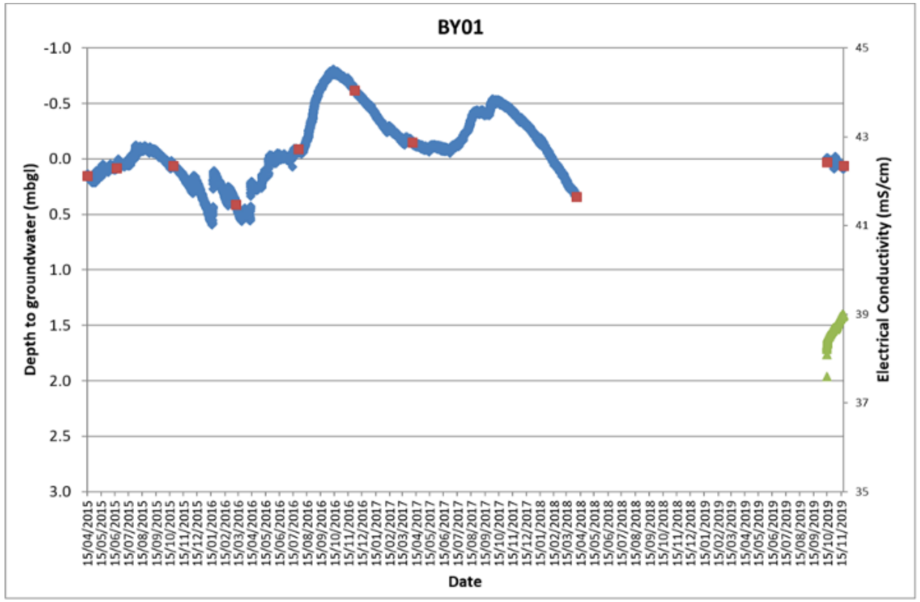

Surface water_TG19
Shallow GW2
Shallow GW1
Peat
ArtesianBore
Cl + SO4=>
<=Ca + Mg
Mg
SO4
Ca
Na+K
HCO3+CO3
Cl

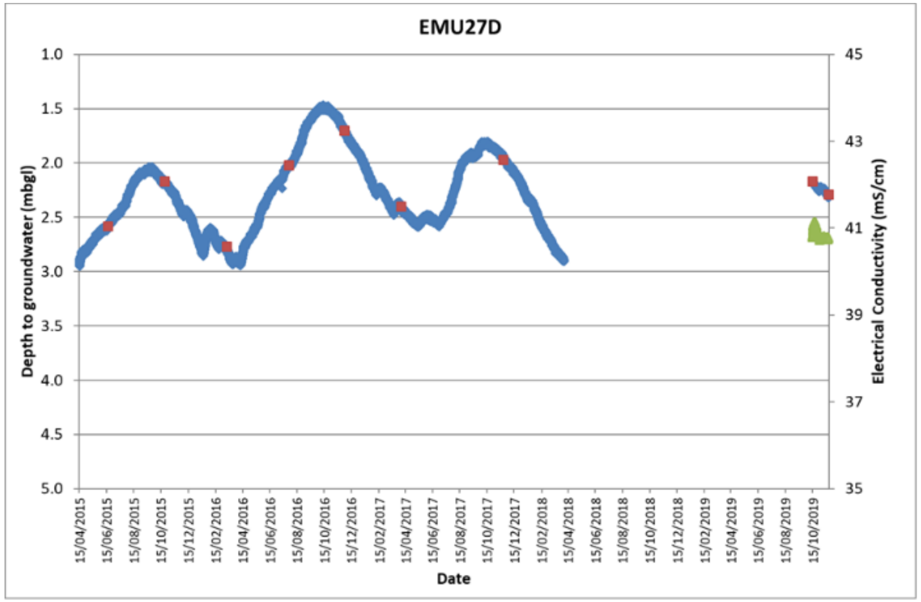
Appendix 10 Groundwater level & electrical conductivity data logger data



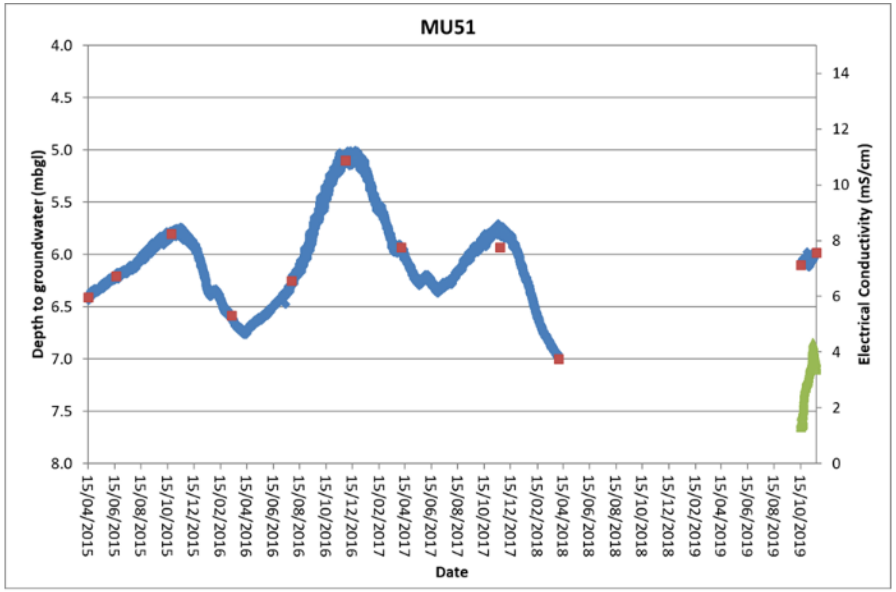


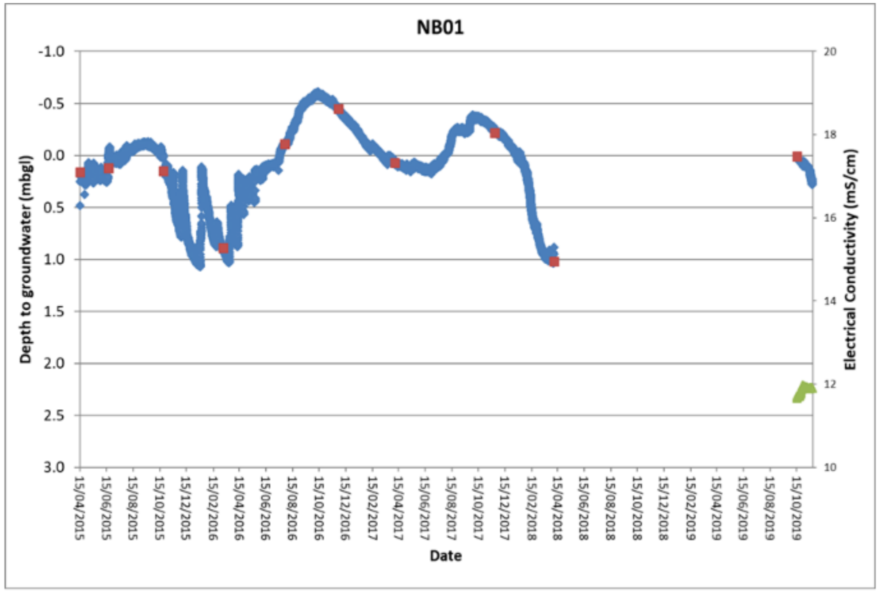
blue=CTD Diver data logger groundwater level; red=manual groundwater level measurements; green=CTD Diver data logger groundwater electrical conductivity



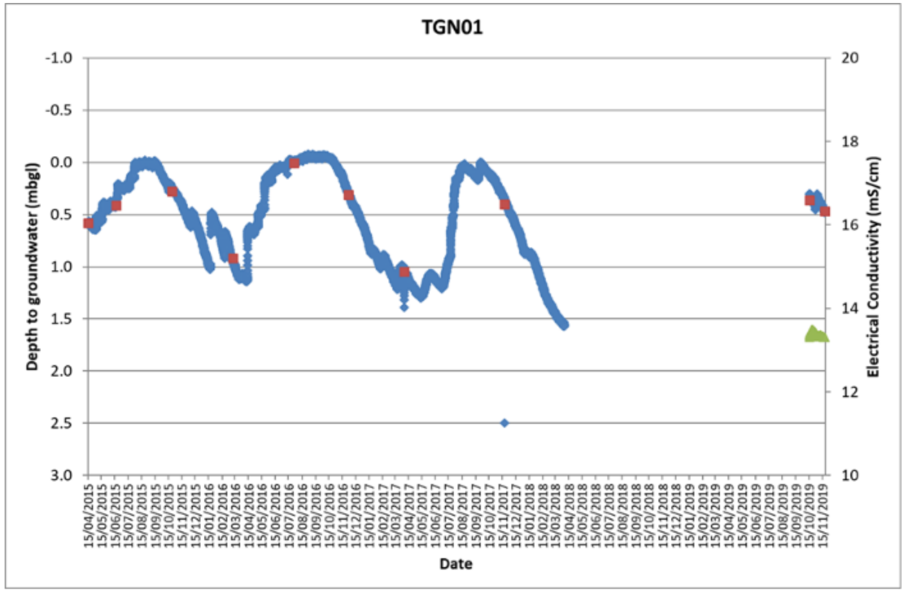


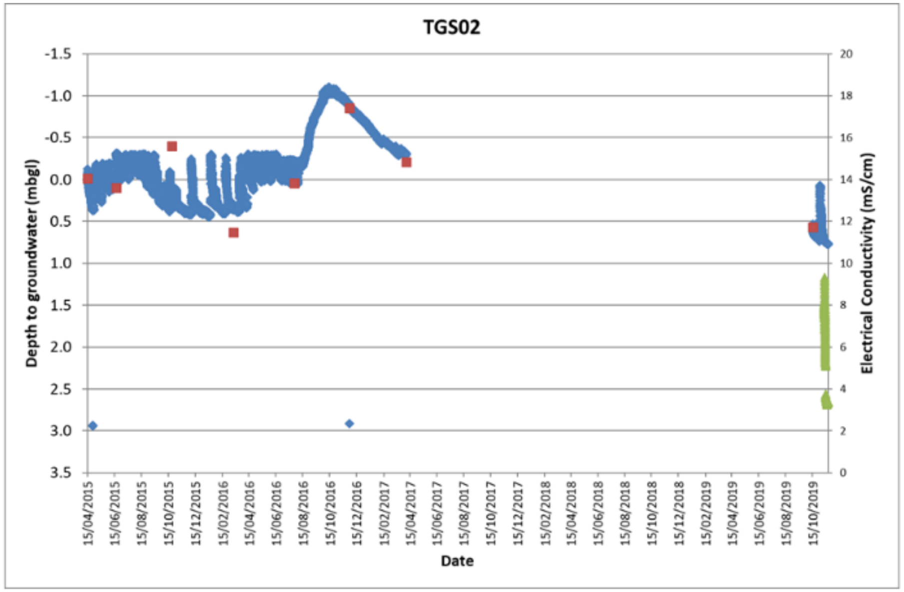
blue=CTD Diver data logger groundwater level; red=manual groundwater level measurements; green=CTD Diver data logger groundwater electrical conductivity





blue=CTD Diver data logger groundwater level; red=manual groundwater level measurements; green=CTD Diver data logger groundwater electrical conductivity





blue=CTD Diver data logger groundwater level; red=manual groundwater level measurements; green=CTD Diver data logger groundwater electrical conductivity