MOUNT RAWDON ENVIRONMENTAL EVALUATION

Stage 1: Characterisation of groundwater resources and identification of potential contaminant sources

Conceptual Hydrogeological Flow Model

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October 2019

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EXECUTIVE SUMMARY

Stage 1 of Environmental Evaluation STAT1264; EPML00712113 requires Mount Rawdon Operations (MRO) to develop a conceptual model that identifies the dominant hydrogeological systems within the Mount Rawdon mine lease, incorporating all available data from groundwater monitoring bores. The sources of all chemicals of potential concern (COPC) that have been released from the TSF, waste rock dumps and processing area and have entered receiving waters were identified.

Hydrogeological Features of the Mine Lease

Mount Rawdon occurs on the Great Dividing Range. The primary hydrogeological feature of the mine lease is a fractured rock aquifer developed in, and around, the extinct core of a shield volcano flanked by the Aranbanga Andesites to the west and silicified Curtis Island Metasediments to the east. The volcano's central core is an intensively fractured, collapse structure of dacite and dacite-rich volcaniclastics (Mine Sequence Volcanics) involving phases of tectonic reactivation, and intrusion of magmas through reactivated fractures that formed dacitic, rhyolitic and quartz-feldspar-biotite-porphyry (QFBP) dykes and sills. Trachyandesite and andesite dykes formed during the last phase of brittle fracturing.

The Atlas of Australian Soils (ASRIS, 2011) identifies two landscape units on the mine lease:

1) Steep hilly to mountainous country on metasediments (Tb88) on the west of the lease. Conversion of the Atlas of Australian Soils to the Australian Soil Classification identified the soil order of this landscape unit to be Tenosol; and
2) Low to moderately hilly lands on phyllites and schists (Tb103) on the east of the lease. Conversion of the Atlas of Australian Soils to the Australian Soil Classification identified the soil order of this landscape unit to be Sodosol. The Australian Soil Classification in the National Soil Grid (ASRIS, 2011) also recognized rudosol in this area, with occurrences of dermosol in areas that coincide with areas cleared for grazing.

The depth of the weathering profile is irregular. Isolated deep pockets of saprolite and oxidation transition zones provide groundwater storage on sloping land, which typically becomes depleted in the dry season.

There are three aquifers: soil and small pockets of alluvium in drainage lines (of limited extent and thickness), weathered rock (saprolite and oxidation transition zones) of varying thickness and subject to drainage on sloping land after rainfall events that recharge the aquifer, and the fractured rock aquifer. The weathered and fractured rock aquifers have structural features that potentially influence groundwater flow that include rock fabric (bedding planes and foliation), zones of argillization, dykes, faults and fracture planes. Groundwater compartments are identified in the weathered and fractured rock aquifer.

Hydrogeological properties were identified for soil and weathered-rock north of the TSF, in a known seepage pathway, and in fractured rock west of the TSF using a combination of field observations, hydrogeological modelling, and textbook values as follows:

1) Topsoil consists of permeable loamy sand / sandy loam, with K_{sat} of 0.9 – 2.7 m/d, bulk density of 1.4 – 1.6 g/cm^3 and porosity of about 0.4 (i.e. 40% pore space);
2) Subsoil consists of an illuvial clay / sandy clay horizon, with K_{sat} of about 0.01 m/d, bulk density of 1.4 – 1.5 g/cm^3 and porosity of 0.4 – 0.5;
3) Weathered rock developed from Curtis Island Metasediment, with K_{sat} value of 0.0537 m/d, bulk density of 2.6 – 2.7 g/cm^3 and a porosity of 0.04 – 0.07; and

4) Fractured rock, with a K_{sat} value of 0.00179 m/d, bulk density of 2.7 – 3 g/cm^3 and a porosity of 0.005.

The transmissivity (T) and permeability (κ) of aquifers were evaluated using hydraulic conductivity (slug) tests performed on groundwater bores. Results represent the combined weathered / fractured rock aquifer and range from impervious to semi-pervious rock (K_{sat} of 4.2E-3 to 5.5E-1 m/d, T of 1.2E-2 to 8.4E+0 m^2/d and κ of 6E-15 to 5E-13 m^2). The slug tests measure a thin skin of aquifer immediately surrounding the bore, and do not penetrate far into the aquifer where joints and fractures are contained by impermeable rock. Across larger volumes of rock, lower hydraulic conductivities, transmissivities and permeabilities are expected, and as such the slug tests provide conservative values for hydrogeological properties of the overall aquifer.

In addition to the bore-specific data summaries, the calibrated hydrogeological model provided a synthesis of the hydraulic conductivities and thicknesses of the various aquifers at the mine-lease scale. The hydrogeological characteristics of the aquifers were found to be consistent with semi-pervious soil and weathered rock, and semi-pervious to impervious fractured rock and basement rock.

Geological Barriers in the Mine Lease

Subsoil has a lower hydraulic conductivity than adjacent topsoil and weathered rock, which can impede recharge of the fractured rock aquifer. Faulting and fracturing in the fractured rock is complex and provide:

1) Flow barriers: Groundwater flow is obstructed by argillized gouge material, dykes, sills, faults. Along some faults there has been structural displacement of blocks with lower permeability than the surrounding wallrock. The block-faulted collapse structure of the volcano limits groundwater flow into the pit, because the pit walls align with faults;
2) Flow conduits: Groundwater flows through connected pores and planes of decollment in metasediments. Water also flows along the outside edges of thin crush zones of chloritized gouge material, which formed along the margins of dykes when minor tectonic reactivation reopened fault contacts. As such groundwater transmits adjacent to brittle faults and joints; and
3) Compartments: Groundwater obstructed from moving downward into the aquifer, or laterally across the aquifer, by flow barriers will be hosted interstitially in rock pores, intersecting open-fractures, along bedding planes and along joints. Where lateral flow of groundwater is restricted by flow barriers, evapotranspiration by deep rooted plants is potentially significant for dewatering groundwater during the dry season.

Ionic Composition of Groundwater and Mine Source Terms

Principal Components Analysis (ordination) and Cluster Analysis (classification) were used to evaluate variations in major ions (Na, SO_4, HCO_3), nitrogen compounds used in mining (NO_3, CN) and an element related to mineralization (As). These ions allowed native groundwater to be distinguished from mine source terms, and helped to identify where mine affected water had mixed with groundwater.

The principal components of the median groundwater and mine source term concentrations in groundwater bores and mine affected water were consistent with:

1) Solutes generated by weathering of feldspar and carbonate in the landscape, which explained 32.4% of the variation in solute chemistry;
2) Solutes generated from mining and processing of mineralised ore, which explained 27.7% of the variation in solute chemistry; and
3) Solutes generated from mineralised sources (i.e. not processed as tailings), which explained 19.4 % of the variation in solute chemistry.

The outcome of the ordination was well-structured data that explained 79.5% of ionic composition variations in the mine lease in response to weathering of the landscape and mineral deposits in the landscape, as well as seepage of water influenced by mining and processing of ore.

The classification identified five water quality groups as follows:

1) Group 1: Mine affected. Water influenced by tailings seepage;
2) Group 2: Mine affected, except for MRMB70. Water influenced by waste-rock seepage;
3) Group 3: Largely not mine affected, except for slight mine effects along Swindon Creek in MRMB41, MRMB43 and possibly also in MRMB55 and MRMB65. Water screens in basic, intermediate or felsic volcanic or plutonic rocks (some of which are hosted in Curtis Island Metasediment), which include some compliance monitoring bores located near the edge of the lease;
4) Group 4: Groundwater predominantly screening in Curtis Island Metasediment. There is a subgroup that is not mine affected (MRMB35, 67, 74, 75), a mine affected sub-group close to where the inferred West Dam Fault extends beneath the TSF (MRMB 09,10 and 69), and another mine affected sub-group north of the TSF (MRMB03, 04, 05, 06, 08, 21 and 39) and below the processing area (MRMB45); and
5) Group 5: Water screening predominantly in Curtis Island Metasediment, with some bores screening in or near intrusive rock. These bores are largely not mine affected, although mine effects have been noticed in a sub-group associated with South Dam and waste rock dams 1 and 2.

More detailed multivariate statistical interpretation of the ionic composition of groundwater and mine affected water are reported at the sub-catchment scale, which described changes in groundwater quality over time and identified the possibility of either groundwater mixing with mine seepage or alternative reasons for relatively high COPC concentrations in groundwater that might relate to soil and geology.

These multivariate statistical techniques were supported by univariate time-series charts of Electrical Conductivity, SO_4/Cl, NO_3_N and cyanide over time. Electrical conductivity represented total major ion concentrations (natural or mine related) in groundwater. SO_4/Cl was a lead indicator of mine influence adjusted for evaporative concentration, NO_3_N is an indicator of explosives residue in mined rock and CN indicated tailings seepage. A sub-catchment scale evaluation of groundwater quality is as follows:

1) Swindon Creek: Bores MRMB43 and MRMB44 show recent influence of mine seepage, while bores MRMB10, MRMB12, MRMB41 and MRMB42 show past influence of mine seepage that has stabilized. At this stage bore MRMB65 has ambiguous results that need to be evaluated further. Bore MRMB13 is not considered to be mine affected;
2) Unnamed creek between Swindon Creek and Rawdon Creek: Bores MRMB8 and MRMB9 are influenced by mine seepage. The declines in electrical conductivity and NO_3_N after 2005 coincide with seepage interception efforts, which indicate that some of the total salt contribution was removed by seepage interception, with some bypassing still occurring as evidenced by a steady increase of SO_4/Cl until 2010. In 2010 removal of clay from the borrow pit at the toe of the northern TSF batter wall coincided with downstream increases in SO_4/Cl and Total CN, when breakthrough of tailings seepage was observed to influence bores MRMB31 and MRMB30. There has been subsequent seepage mitigation involving the Toe Seepage Interception Drain and the Downstream Toe Interception Drain, which were respectively reconditioned and installed in 2017. At this stage it is too early to tell from monitoring data whether they are halting or reversing the breakthrough;

3) Rawdon Creek: A group of bores located on, or flanked by, a landscape spur between Rawdon Creek and Twelve Mile Creek are unaffected by mining (MRMB64, MRMB67, MRMB68 and MRMB74). The ionic composition in these bores can be explained by localized granite weathering, and downslope movement of salts. These bores appear to represent a distinct groundwater compartment.
    a) Along Rawdon Creek, bores MRMB1-7, MRMB21, MRMB23, MRMB29 and MRMB39 are influenced by mine seepage, particularly after 2012 when clay was removed from the borrow pit below the north wall of the TSF. Groundwater trends for SO_4/Cl and total cyanide also show the influence of improved waste rock management in 2005 and seepage mitigation strategies in 2013 that slowed, and in some bores reversed, seepage from the TSF;
4) Twelve Mile Creek: There is downslope movement of sulfate, nitrate and arsenic ions in groundwater towards Twelve Mile Creek under hypothetical scenarios:
    a) natural mobilisation of gypsum and nitrate in agricultural land sloping towards Twelve Mile Creek (no mine influence) is likely for MRMB28/78 some of the time, MRMB37, MRMB38, MRMB61 and MRMB62;
    b) increased mobilisation of ions present in soil, including from weathering of unmined mineral deposits, because of groundwater flow promoted by groundwater mounding below the NWRD. This secondary mining influence is considered plausible for MRPB1; and/or
    c) seepage of ions generated by weathering of waste rock in the NWRD as a direct mining influence is suggested for MRMB25, MRMB26 and MRMB27, and occasionally for MRMB28/78.

    Scenarios b or c are plausible for MRMB24, MRMB60 and MRMB63.
5) Southern drainage and Mingham Creek. Seepage of mine affected water has reported to bores MRMB69 and MRMB19 close to the tailings dam and/or waste rock in the southern drainage. In other bores along the southern drainage (MRMB17, MRMB50, MRMB70, MRMB71) hydrostatic displacement of the groundwater table by the combined effects of the TSF, South Dam, West Waste Rock Dump and West Dam may have mobilised ions naturally present in the aquifer. MRMB18 screens an aquifer in a sloping catchment subjected to seasonal recharge, which contained mine affected water during significant rainfall in January 2011, March 2012 and January 2013. There is no evidence for mining influence reporting to bores MRMB59, MRMB75, MRMB36, MRMB72 and MRMB35.
6) The aquifer screening bores MRMB46 and MRMB49 under the access road is mine affected, with seepage mitigation by Stans Well facilitating apparent stabilisation and reversal of the seepage trend in this area. The aquifer screening bores MRMB20, MRMB45 below the processing area shows seepage from the TSF or stormwater runoff from mined rock stockpiles/batter walls/road base, with apparent stabilisation and reversal of mine effects in groundwater reporting to MRMB45 after 2014

As such the groundwater chemistry was evaluated for possible influence by mining, which was shown to be possible for several groundwater bores. The possible groundwater mixing scenarios identified in the Stage 1 conceptual model (this report) will be tested in the Stage 2 geochemical modelling report.

Movement and Surface Expression of Groundwater Across the Mine Lease

The movement and surface expression of groundwater across the mine lease, as well as groundwater expression into drainage lines, was modelled using a steady state groundwater flow model (the United States Geological Survey groundwater model MODFLOW-SURFACT). Calibration against 31 water level targets was within the 10% scaled root mean square error limit. However, parts of the mine lease were excluded from the model because they were likely compartmentalised. These compartments included the landscape spur between Rawdon Creek and Twelve Mile Creek (bores MRMB64, MRMB67 and MRMB74), the lower portion of Twelve Mile Creek towards the impounded zone of the Perry River (MRMB38) and the headwaters of Twelve Mile Creek (bores MRMB61 and MRMB37).

The groundwater model showed that groundwater follows the topographic gradient and local drainages. Hyporheic transfer of groundwater follows drainage lines within 3 meters of the creek bed. Groundwater flows from the catchment headwaters west of the TSF, under the TSF, and towards the Perry River via Swindon Creek. The TSF and the NWRD have generated topographic highs, where groundwater mounding under these structures drive groundwater flow towards the Perry River via Rawdon Creek and via Twelve Mile Creek. In the Southern Corridor, groundwater flows westward into Mingham Creek, with the pit providing a localised sink for groundwater flow.

Conceptual Model

Conceptual hydrogeological models (Douglas and Cox 1994, Queensland Government 2003, KH Morgan and Associates 2007, Evolution, 2011) already developed for the landscape and the Mount Rawdon mine lease can be utilized with very little modification.

Dryland salinity is recognised in the Central Burnett. A conceptual model for solute generation from the weathering of granites in sloping terrain developed by Douglas and Cox (1994), identified that the chemistry and quality of groundwater represent the aquifer matrix through which water migrates as well as processes that contribute to soil salinity. The salinity hazard map for the Burnett Mary and Western Catchments of South East Queensland (Queensland Government, 2003) indicates a moderate to moderately high hazard of salt expression on the lower slopes of the mine lease. It indicates that sections of Twelve Mile Creek and Mingham Creek have salinity hazard in areas that coincide with soil that allows deep drainage, or areas where groundwater exfiltrates into Perry River. There is moderate salinity hazard on the lower slopes of Mingham Creek, Twelve Mile Creek and Rawdon Creek.

Water seeps observed downstream of the northern toe of the TSF wall are a continuation of the natural groundwater outflow resulting from rainfall recharge higher in the hillslope beyond the western cell of the TSF and outside the tailings perimeter (KH Morgan and Associates, 2007). Before mining groundwater movement had followed a subdued version of the topography (Evolution, 2011). After construction of the TSF and mining, the topography was altered, with the TSF becoming the highest head feature in the area leading to mounding underneath the TSF and groundwater flow in northern, eastern and southern directions. The pit became the lowest head feature in the area, and the fact that the pit remains relatively dry indicated the presence of flow barriers (faults) between the pit and the surrounding strata (including the TSF).

In 2019 these conceptual models remain valid, with the exceptions that the NWRD is now the highest topographic feature in the area, and additional seepage mitigation intercepts the flow of mine affected groundwater to downgradient receiving waters.

History of Water Management at Mount Rawdon Operations, including Events, Exceedances and Incidents

This report has tabled events, exceedances and incidents in the Mount Rawdon mine lease, which included:

1) overtopping events in 2003, 2010, 2012,2013, 2015 and 2017 to downstream receiving environments; and
2) increased tailings seepage after clay was removed in 2010 and 2012 from the borrow pit below the toe of the Northern Wall of the TSF.

Equigold and Evolution Mining responded to these events with a number of management actions, which included modified blasting procedures that lessen nitrogen residues in waste rock, better handling of waste and low grade ore, evaluation of the weathering characteristics of tailings and waste rock, and seepage interception downstream of the TSF and waste rock dumps.

1 Introduction

1.1 Purpose

Stage 1, Condition 2 of Environmental Evaluation STAT1264; EPML00712113 issued on 18th May 2018 requires Mount Rawdon Operations (MRO) to develop a conceptual model that identifies the dominant hydrogeological systems in the Mount Rawdon mine lease, by incorporating all available data from groundwater monitoring bores to determine:

- The characteristics of each hydrogeological feature of the hydrogeological systems to include soil and rock types, porosity, permeability, hydraulic conductivity, transmissivity, stratigraphy, and fault and fracture propensity;
- Any geological barriers that are overlying or underlying the hydrogeological features;
- The waters in the hydrogeological features, including their ionic compostions;
- The directions and flow rates of groundwater movement in the hydrogeological features;
- The interaction of groundwater in each hydrogeological feature with other underground hydrogeological features;
- The interaction of contaminated waters with waters in the hydrogeological systems, including a comparison of the ionic compositions of contaminated waters with native groundwater;
- The locations where water in the hydrogeological system(s) do, or may, express at the surface; and
- The spatial locations of environmental values in, or dependant on, the hydrogeological system(s): authorised release points, surface and groundwater monitoring points, locations of previous contamination events, and current/historical mining-related infrastructure/storage locations.

1.2 Available Data and Existing Studies

Groundwater monitoring in the Mount Rawdon Mine lease has been ongoing since 2001, from 9 compliance bores and 37 other bores, to report on the downslope movement of mine affected groundwater from the Tailings Storage Facility (TSF) and Waste Rock Dumps. Another 21 bores, now decommissioned, have been used for groundwater monitoring making a historical total of 67 groundwater bores that have represented groundwater trends in the mine lease. Results of groundwater monitoring have been reported annually. In addition there have been:

- Targeted groundwater investigations triggered by elevated electrical conductivities and high concentrations of cyanide, sulfate, nitrate, iron, manganese, arsenic, copper and zinc in groundwater bores downslope of the TSF and the Northern Waste Rock Dump (NWRD);
- Geophysical Surveys to identify seepage pathways below the northern and western flanks of the TSF;
- Geological reviews of non-mined anomalies in soil and rock samples that may explain some non-mine related exceedences of some trigger values for chalcophile metals (cadmium, lead, copper, zinc); and
- Relevant soil maps and National Heritage Trust State Investigation Projects that may explain some exceedences of electrical conductivity trigger values in granite terrain of the central Burnett region.

2 Methods

Metadata, reports and archives of MRO and National Heritage Trust reports were reviewed to develop the conceptual model as follows:

2.1 Literature Review

National Heritage Trust reports on landscape salinity, a known feature of the sloping granitic terrain in the central Burnett region of South East Queensland (Douglas and Cox, 1994, Queensland Government, 2003), were reviewed to understand landscape processes that are likely contributing to some high electrical conductivity and sulfate measurements observed on the mine lease. Soil maps (Qld Government) indicate that sodic soils may be present in the mine lease, which is consistent with the concept of salt generation in this landscape.

Reports identifying the nitrogen fixing properties of acacias help to explain high nitrate concentrations in groundwater in some parts of the mine lease (Brockwell *et al.,* 2005, Esslemont *et al.,* 2007).

In the mine lease geochemical exploration data involving soil assays and exploration bores were reviewed (Equigold, 2008; Evolution, 2018a; Evolution, 2019), to identify mineralisation in unmined parts of the lease that may explain exceedences of trigger values in some groundwater bores. Also in the mine lease, geochemical investigations involving isotopes have identified the age of groundwater near to and downslope of the TSF (Leaney, 2006), and the provenance of nitrate and sulfate in some groundwater bores (Northern Resources Consultants, 2015). Finally, annual groundwater reports provided useful records of groundwater condition throughout the life of the mine, and of mining-related incidents that resulted in exceedences of trigger values.

2.2 Characterising Aquifers in the Mine Lease

To elucidate the stratigraphy, fault and fracture propensity in the mine lease, soil maps and geological information were viewed spatially using 3D-GIS (Geology Leapfrog Viewer).

Three aquifers are recognised in the mine lease (Klohn Crippen Berger, 2010): soil and small pockets of alluvium in drainage lines (of limited extent and thickness), weathered rock (saprolite and oxidation transition zones) of varying thickness and subject to drainage on sloping land after rainfall events that recharge the aquifer, and the fractured rock aquifer. The thickness of the aquifer profiles were deduced from (a) records of the base of weathering, and base of chemical weathering, in logs of exploration bores and hydrogeological bores in the mine lease, and (b) geophysical (electrical resistivity imaging) profiles. Because groundwater bores screen in both the weathered rock aquifer and/or fractured rock aquifer, the groundwater bores represent variably weathered, fractured rock. In practical terms groundwater bores that screen 5 – 15m below the surface were grouped as regolith, and bores that screen 16 - 50m below the surface were grouped as fractured rock aquifer.

Primary minerals that potentially weather in contact with groundwater, and secondary minerals that they weather to, were identified from (a) waste rock and (b) country rock of the fractured rock aquifer (Ward, 2019). These minerals contribute solutes to groundwater, or remove solutes from groundwater, during groundwater flow through the aquifer.

To elucidate the hydraulic conductivies of the reglith and fractured rock aquifers, slug tests were performed on bores using the Hvorslev method. Some hydraulic conductivities measured by Northern Resources Consulting were also used. From these measurements, in combination with known aquifer thicknesses obtained from bore logs it was possible to elucidate the transmissivities of the aquifers. In combination with identification of dynamic viscosity and density parameters of brackish water in the expected temperature range (10 - 30°C) it was possible to identify the permeabilities of the aquifers.

To elucidate the hydraulic conductivity of the soil aquifer, field descriptions of the exposed soil profile north of the TSF were performed, and soil types were identified by hand texturing. Soil Water Characteristics software developed by the USDA Agricultural Research Service (Saxton & Rawls, 2006) was used to estimate the hydraulic conductivities, bulk densities and porosities of soil horizons down the soil profile from hand-textured samples.

2.3 Statistical Analysis of Groundwater Data

Geochemical source terms for (a) tailings, (b) mine waste-rock (used to build the TSF batter wall) and (c) non mine-affected groundwater, were established from historical records.

Time series graphs of COPC from the groundwater monitoring records at Mount Rawdon were plotted. The trends of electrical conductivity and sulfate/chloride concentration ratios were used as lead indicators of mine influence, with electrical conductivity representing the total amount of cations in groundwater and sulfate representing mine-influenced water resulting from dissolution of sulfides in tailings or waste rock, which has been normalised for evaporative effects that will be shown in section 4.1 to be a landscape process that concentrates dissolved ions in groundwater. A trend of total cyanide was used to represent the presence of tailings seepage in groundwater.

To understand patterns of variation in concentrations of Chemicals of Potential Concern (COPC) in groundwater, multivariate statistics (ordination and classification) were used to discriminate groundwater data from mine affected water, and identify mixing of these water types. Using this approach, hypotheses were set to address whether exceedences of trigger values were potentially associated with mine-related source terms, or with naturally varying environmental concentrations in groundwater from the mine lease.

2.4 Groundwater Modelling

Groundwater flow rates, and flow paths, accross the mine lease were elucidated using hydrogeological software developed by the USGS (MODFLOW-SURFACT). Northern Resource Consultants (2019) calibrated the hydrogeological model against 31 water level targets with a scaled root mean square error of 7.8%, indicating that the calibration was acceptable.

For Stage 2 of the Environmental Evaluation, which will be reported in May 2020, the groundwater chemistry of the aquifer will be elucidated by chemical speciation modelling using VISUAL MINTEQ verson 3.1 software developed by the USEPA (Gustafsson, 2018), informed by the solute chemistries measured in the groundwater used as model inputs. This will allow identification of weathering minerals that are stable in the aquifer.

Inverse modelling of groundwater plumes along flow paths for Stage 2 will use hydrogeochemical software developed by the USGS (NETPATH for Windows). Model inputs are (a) geochemical source terms for tailings or waste rock seepage (listed in sections 7.5.2 and 7.5.3), (b) groundwater concentrations reported in a sequence of bores along groundwater flow paths identified by Northern Resources Consultants (2019) and (c) weathering minerals identified from the aquifer characterisation. Model outputs that reconcile will be used as a starting point for more detailed solute transport modeling using USGS software (PHREEQC). These results will be reported seperately in the Stage 2 report.

3 Discussion

3.1 Hydrogeological Features of the Mount Rawdon Mine Lease

Mount Rawdon occurs on the Great Dividing Range, in a landscape of steep hills to mountains. The primary hydrogeological feature of the mine lease is a fractured rock aquifer developed in, and around, the extinct core of a shield volcano flanked by andesites to the west and silicified meta-sediments to the east. The central core of the volcano is an intensively fractured, collapse structure of dacite and dacite-rich volcaniclastics (the Mine Sequence Volcanics) formed during the late Triassic (235-215 Ma) involving phases of tectonic reactivation, intrusion of magmas through reactivated fractures that formed dacitic, rhyolitic and quartz-feldspar-biotite-porphyry (QFBP) dykes and sills. Trachyandesite and andesite dykes formed during the last phase of brittle fracturing.

3.1.1 Stratigraphy, Rock and Soil Types

The current geological map of the Mount Rawdon mine lease identifies four rock types:

1) The Mine Sequence Volcanics (described above), which is a complex of rhyodacitic, volcaniclastics and dacite rock units. This formed the original mountain, which has subsequently been mined and is now an open pit mine;
2) The Aranbanga Andesites, which contains andesic lavas, dacitic lavas and volcaniclastics. On the western flank of the TSF the volcaniclastics have been silicified;
3) The Curtis Island Metasediments that are silicified, which can feature relict bedding planes from the sedimentary rock fabric. These occur on the eastern part of the mining lease, and cover the largest area of the mining lease; and
4) Trachyte and granodiorite intrusives that penetrate the Curtis Island Metasediments.

The depth of the weathering profile is irregular as shown by Electrical Resistivity Imaging downslope of the northern and western walls of the TSF. Isolated deep pockets of saprolite and oxidation transition zones provide groundwater storage, which is subject to rainfall recharge where these zones occupy elevated sloping land. The stores typically become depleted in the dry season (Klohn Crippen Berger, 2010).

Faults manifest in the profile as zones of deep argillization adjacent to moderately weathered or fresh rock (Figure 1). These zones may or may not provide preferential flow paths for groundwater (refer section 3.1.3), noting that heavy clay in the West Dam Fault can provide a seal to groundwater flow and that groundwater compartments can be flanked by impermeable rock.

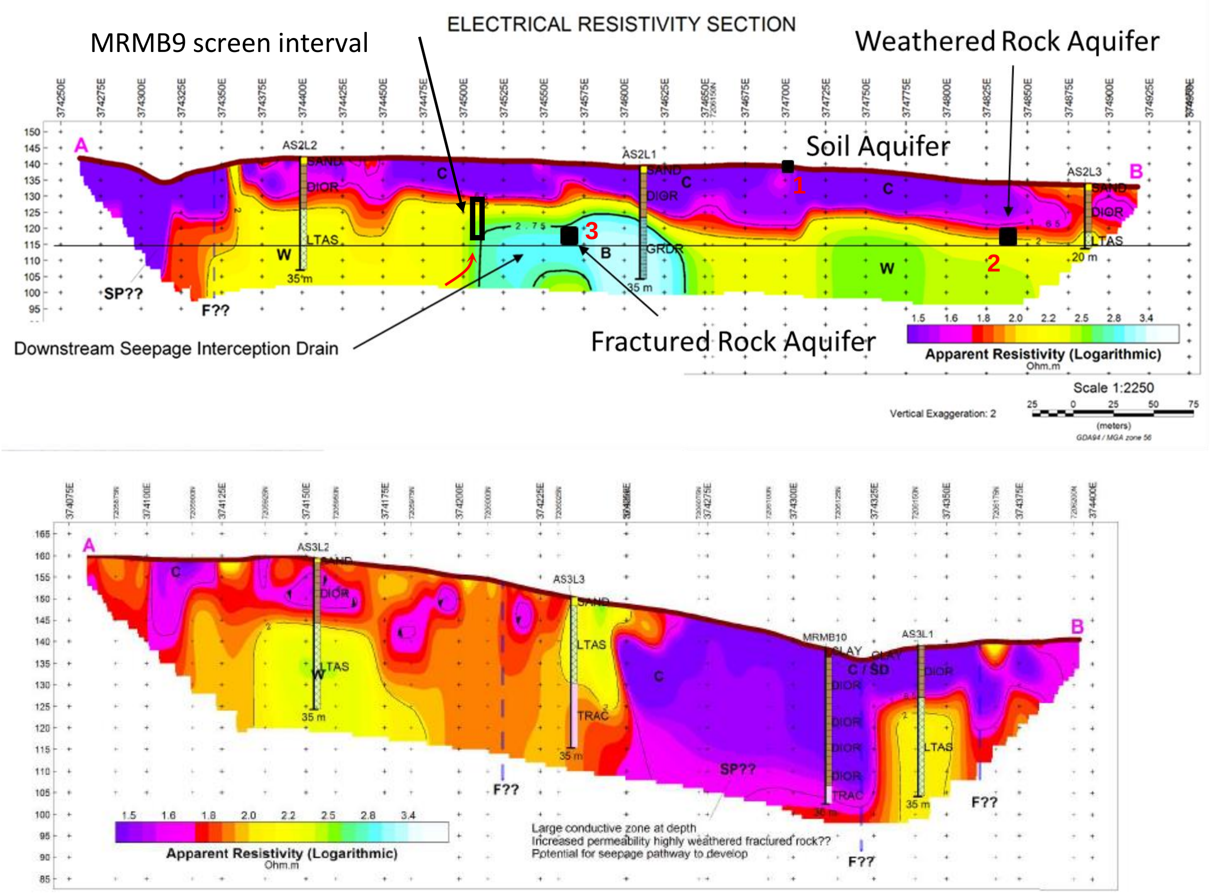

Figure 1: Geophysical profile along the northern embankment of the TSF[1]

The Atlas of Australian Soils (ASRIS, 2011) identifies two landscape units on the mine lease:

1) Steep hilly to mountainous country on metasediments (Tb88): chief soils are hard acidic yellow mottled soils (Dy3.41) with hard acidic red soils (Dr3.41) and (Dr2.41), all often stony. Associated are shallow loams (Um1.42) and (Um2.12) on the steeper slopes; (Dr2.21), (Dy2.21), and (Dy2.23) soils with smaller areas of (Uc1.21 and Uc1.23) on included granites; and (Uf6.41) and (Gn3.11) soils on included basic rocks. As mapped, small areas of units Tb90, Tb92, and Tb96 are included.

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[1] Electrical resistivity image (ERI) showing clay (navy blue zone marked C) and/or sand (navy blue zone marked SD), weathered rock (yellow and green zones marked W), basement rock (light blue zones marked B), fault inferred by ASST (F??) and seepage at depth inferred by ASST (SP??). Bore logs represent lithologies as sandstone, diorite, rhyodacite lapilli tuff (LTAS), trachyte and granodiorite. Symbols show the base of the Downstream Seepage Interception Drain at 115 m. AHD, as well as inferred upward displacement of groundwater into the screen interval of monitoring bore MRMB9, and the locations of photos for (1) the soil aquifer (refer Figures 3a & 3b), (2) weathered rock aquifer (refer Figure 3c) and (3) the fractured rock aquifer (refer Figure 3d).

Conversion of the Atlas of Australian Soils to the Australian Soil Classification identified the soil order of this landscape unit to be Tenosol (Ashton and McKenzie, 2011)

2) Low to moderately hilly lands on phyllites and schists (Tb103): a close pattern of hills with short to moderate slopes: chief soils are gravelly hard acidic yellow mottled soils (Dy3.41) and (Dy2.41) with shallow gravelly loamy soils (Um2.12) and (Um4.1) on crests and upper slopes. Associated are gravelly soils (Dr3.41). Minor soil occurrences include (Gn3.42).

   Conversion of the Atlas of Australian Soils to the Australian Soil Classification identified the soil order of this landscape unit to be Sodosol (Ashton and McKenzie, 2011).

The Australian Soil Classification in the National Soil Grid (ASRIS, 2011) identifies three soil orders on the mine lease as being predominantly rudosol developed over the Curtis Island Metasediments, with tenosol on the hills on the west of the lease and occurrences of dermosol in areas that coincide with areas cleared for grazing (Figure 2).

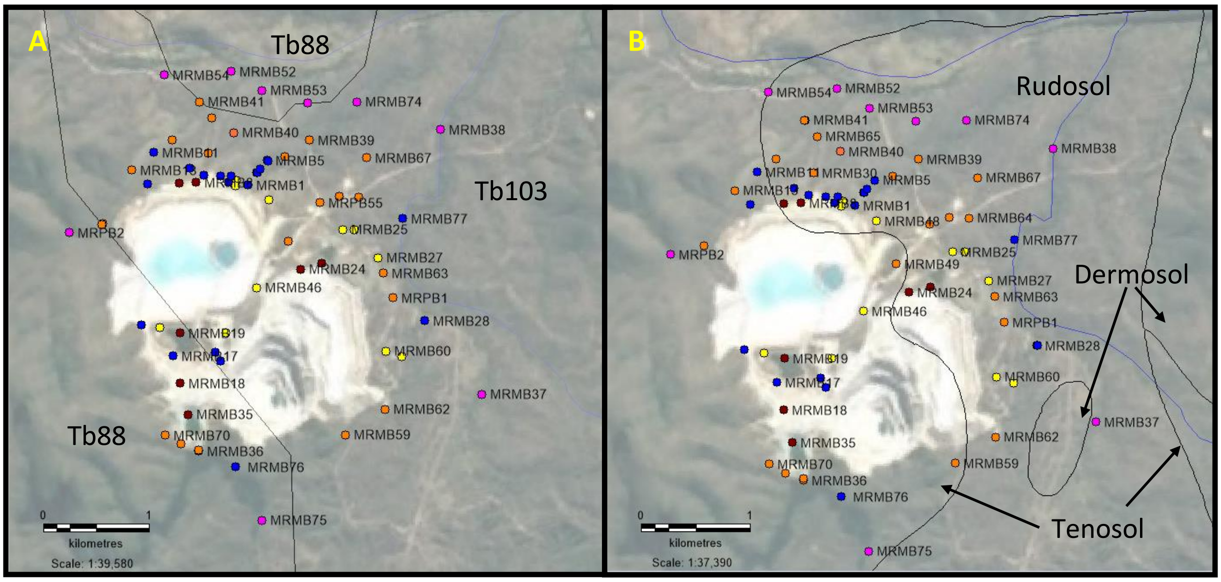

Figure 2: Soil maps[2]

The clay borrow pit north of the TSF shows the exposed stratigraphic profile of rudosol soil formed over Curtis Island Metasediments (Figure 3A and 3B), which is represented in the ERI profile and allows visualization of the stratigraphy represented by the geophysical image (Figure 1). Plate 3B shows the thin topsoil (A soil horizon) and eluviation zone (E soil horizon) over illuvial clay (B horizon soil), and plate 3A shows the saprolite zone (C horizon soil) deeper in the profile. This duplex soil has a shallow layer (220 – 430 mm) of permeable surface soil (A and E soil horizons) over less permeable clay (B soil horizon), below which saprolite (C soil horizon) features relict bedding planes in the parent rock that are potentially permeable to groundwater flow.

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[2] A) Landscape units of the Atlas of Australian Soils. B) Australian Soil Classification of the National Soil Grid (ASRIS, 2011)

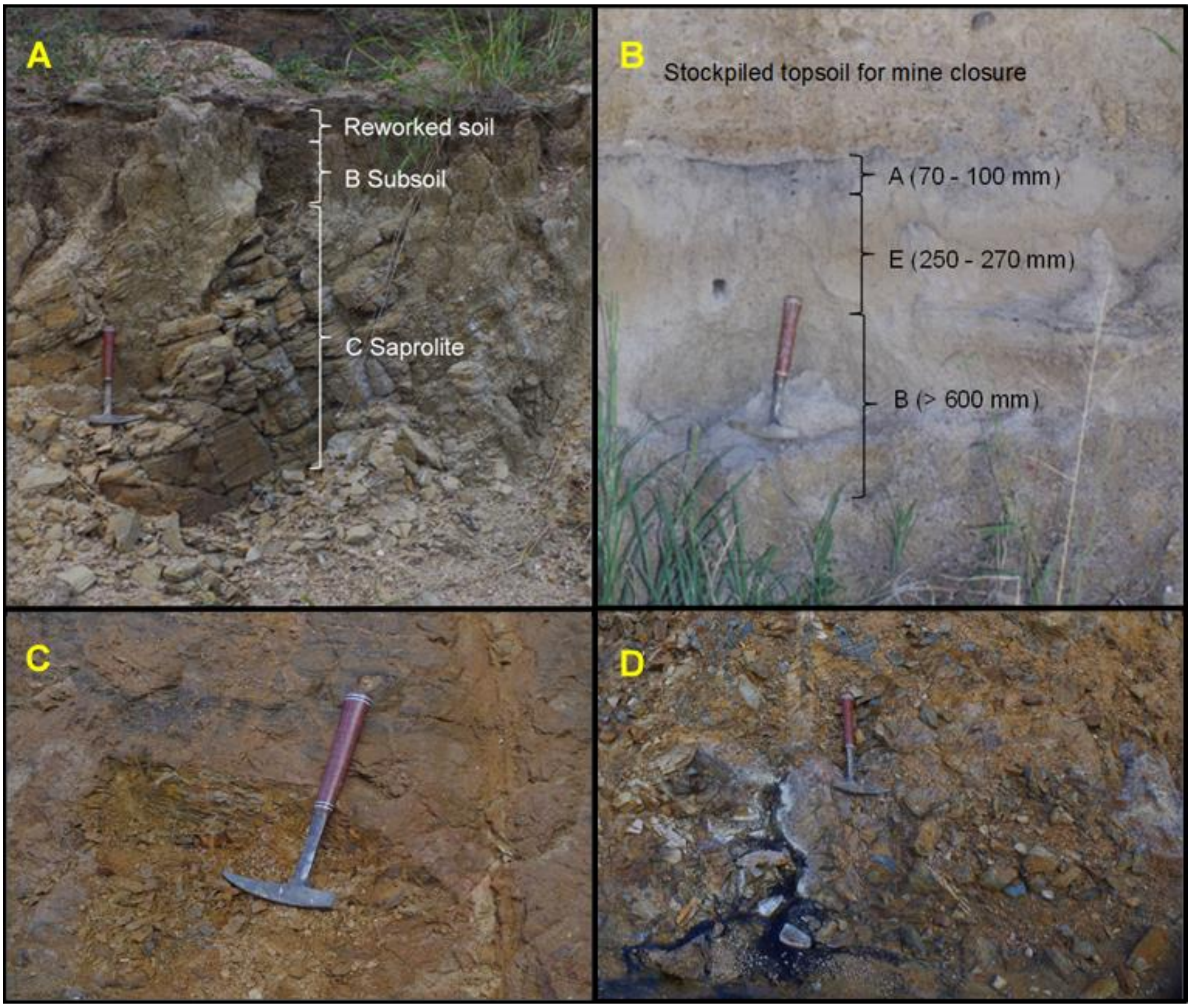

Figure 3: Profile of the Soil Aquifer, Weathered Rock Aquifer and Fractured Rock Aquifer [3]

Deeper in the weathered rock profile slow groundwater seepage through foliations of Curtis Island Metasediments, along flow paths partly compartmentalized by fracture planes and intrusive structures. Groundwater seeps into the Downstream Seepage Interception Drain (Figure 4).

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[3] Refer to ERI image (Figure 1) for location of photographic plates in the geological cross section, and Table 1 for hydrogeological properties of these aquifers. Plates A and B show the soil profile exposed in the clay borrow pit north of the TSF, where there is potential for water to flow through voids formed along planes of decollement along the bedding fabric of this rock (Plate A). These voids have possibly been enhanced by mechanical disturbance during excavation and occurred close to the contact between soil and weathered rock. Deeper in the weathered rock aquifer groundwater flow paths were along more compressed foliation planes in the rock fabric, marked by black manganese and black-brown iron secondary mineral precipitates along foliation planes (Plate C). The fractured-rock aquifer was transmitting groundwater through brittle-fractures (Plate D).

Figure 4: Weathered Rock Aquifer [4]

In summary the soil aquifer consists of a thin surface layer, formed over variably weathered, foliated metamorphic and volcanic rock. Structural features that potentially influence groundwater flow include rock fabric (bedding planes and foliations), zones of argillization, dykes, faults and fracture planes. Hydraulic properties of the soil aquifer, and the weathered rock/fractured rock aquifer, are discussed in section 3.1.2.

3.1.2 Hydrogeological Properties

Hydrogeological properties of the aquifers (hydraulic conductivity, bulk density, porosity) were evaluated using field observations of soil and weathered-rock north of the TSF, and in fractured rock west of the TSF. Figure 5 shows the location of the soil and rock samples, and where mine-affected groundwater has been observed in monitoring bores and surface seeps. Table 1 lists the aquifer properties of this soil and weathered rock profile.

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[4] Profile of the weathered rock aquifer in Curtis Island Metasediment, showing groundwater expressing into the Downstream Seepage Interception Drain. Groundwater is partly compartmentalized by fracture planes and intrusive structures. The MRMB33 standpipe is shown in the background.

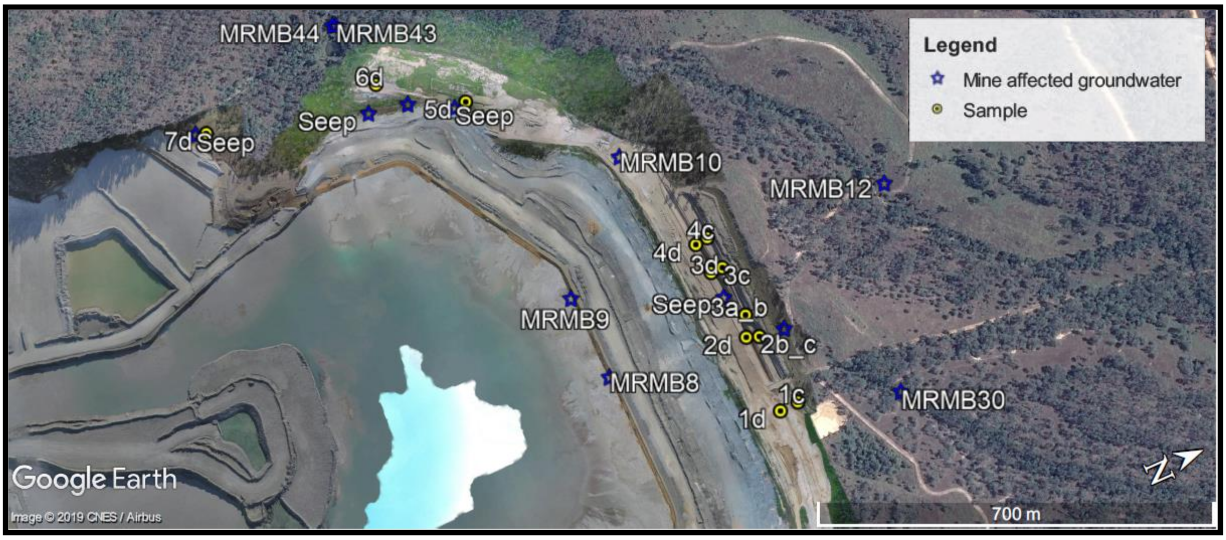

Figure 5: Locations of soil, weathered rock aquifer and fractured rock aquifer samples [5]

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[5] Refer Table 1

Sample Number [a]	Material [b]	Aquifer Minerals [c]	Comment	K_{sat} (m/d)	Bulk Density (g/cm^3)	Porosity
1c	Brown clay (50% clay, 40% sand).	Plagioclase, undetermined clay(s), possible chlorite & quartz.	Fault (argillised) adjacent to weathered granodiorite.	0.01[c]	1.38[c]	0.48[d]
1d	Brown saprolite.	Quartz, Albite, Orthoclase, possible Montmorillite.	Extension of the argillized feature into the Downstream Seepage Interception Drain, which is moist relative to the surrounding wallrock.	0.0537[e]	2.6-2.7[f]	0.04 - 0.07[f]
2b	Brown clay (30% clay, 50% sand).	Quartz, Albite, Kaolinite.	Mottled clay subsoil.	0.01[c]	1.38[c]	0.48[d]
2c	Brown to dark grey clay loam (34% clay, 33% sand).	Quartz, Albite, Biotite, Orthoclase.	Weathered slate.	0.052[c]	1.51[c]	0.43[d]
2d	Brown saprolite.	Quartz, Albite, Orthoclase, possible Kaolinite.	Weathered slate with secondary black/brown mineral precipitate along fracture and bed-plane surfaces.	0.0537[e]	2.6-2.7[f]	0.04 - 0.07[f]
3a	Dark brown, loamy sand (82% fine sand, 6% clay).	Quartz, Orthoclase.	A horizon of the original soil profile. Grey fine sand (charcoal present).	2.74[c]	1.43[c]	0.46[d]
3b	Brown loamy sand (80% fine sand, 10% clay).	Quartz, Orthoclase.	E horizon of the original soil profile. Fine sand. Gradual contact with B horizon subsoil.	1.97[c]	1.59[c]	0.4[d]
3b lower	Orange-brown sandy clay (52% fine sand, 42% clay).	Quartz, Orthoclase, Albite.	B horizon (>60 cm total horizon thickness). Heavy clay, featuring sub-rounded pebbles in increasing abundance down the profile.	0.016[c]	1.53[c]	0.42[d]
3c	Orange-grey saprolite.	Quartz, Albite, Orthoclase, possible Kaolinite.	Weathered granodiorite (argillized) adjacent to lithological contact.	0.0537[e]	2.6-2.7[f]	0.04 - 0.07[f]

3d	Grey fractured rock.	Quartz, Albite, Orthoclase.	Relatively fresh rock with alteration and chemical weathering associated with fracture surfaces. Some fracturing could be associated with dynamite blasting of this section of drain.	0.00179[e]	2.7 - 3[f]	0.005[f]
4b	Brown sandy loam (65% sand, 10% clay).	Quartz, Albite.	Loose, well sorted fine sand (E horizon soil).	0.897[c]	1.63[c]	0.38[d]
4c	Brown saprolite.	Quartz, Albite, Plagioclase, Orthoclase, possible Kaolinite.	Weathered slate, open folded, exfoliating. Zones of preferred weathering along brittle fractures (not shown in picture). Sampled in dry weathered rock below base of the soil profile.	0.0537[e]	2.6-2.7[f]	0.04 - 0.07[f]
4d	Brown saprolite.	Quartz, Albite, Orthoclase, possible Kaolinite.	Weathered slate.	0.0537[e]	2.6-2.7[f]	0.04 - 0.07[f]
5d	Weathered volcaniclastics.	Quartz, Albite, Plagioclase, Muscovite, possible Chlorite, possible Sericite.	Heavily weathered contact between volcaniclastic breccia and andesite.	0.00179[e]	2.7 - 3[f]	0.005[f]
6d	Red chert / grey andesite.	Quartz, Albite, Calcite, Orthoclase, Muscovite, possible Sericite.	Contact between weathered chert and fresh andesite, with chlorite gouge material along the contact. Secondary iron oxides on fracture surfaces above the contact.	0.00179[e]	2.7 - 3[f]	0.005[f]
7d	Grey aphanitic rock.	Quartz, Albite, Chlorite.	Fracture in fresh andesite (not weathered).	0.00179[e]	2.7 - 3[f]	0.005[f]

[a] Samples used to characterise the aquifer for geochemical modelling (Stage 2)

[b] Soil material estimated by hand texturing of soil or field observation of weathered rock

[c] Calculated from Soil Classification using *Soil Water Characteristics - Version 6.01.74* (Saxton & Rawls, 2006).

[d] Calculated from bulk density and particle density as follows: 1 - (Bulk Density)/(Particle Density)

[e] Model vertical hydraulic conductivity (Northern Resources Consultants, 2019)

[f] Textbook bulk density and porosity values for older and compacted shale (adopted to represent saprolite) and diorite (adopted to represent andesite dyke). Source: Hazelton and Murphy (2007).

Table 1: Saturated hydraulic conductivity, bulk-density and porosity estimates for aquifer materials

Topsoil consists of permeable loamy sand / sandy loam (A and E horizon soils represented by samples 3a, 3b and 4b), with K_{sat} of 0.9 – 2.7 m/d and porosity of about 0.4 (i.e. 40% pore space).

Subsoil consists of an illuvial clay / sandy clay horizon (B horizon soils represented by samples 2b and 3b lower), with K_{sat} of about 0.01 m/d and porosity of 0.4 – 0.5.

Weathered rock materials below the subsoil (samples 1c, 2c, 3c and 4c) were difficult to hand texture or were not suited to hand texturing. Instead the vertical hydraulic conductivity for weathered rock identified by the hydrogeological model (Northern Resources Consultants, 2019), and a textbook value for the porosity of older and compacted shale (Hazelton and Murphy, 2007), were used as indicative values. As such a K_{sat} value of 0.0537 m/d and a porosity of 0.04 – 0.07 were assumed for weathered rock developed from Curtis Island Metasediment.

Fractured rock, represented by samples 1d, 2d, 3d, 4d, 5d, 6d and 7d was represented by the vertical hydraulic conductivity value for fractured rock identified by the calibrated hydrogeological model (Northern Resource Consultants, 2019) and a textbook porosity value for diorite (the igneous intrusive equivalent of andesite). A K_{sat} value of 0.00179 m/d and a porosity of 0.005 were assumed.

The transmissivity and permeability of aquifers were evaluated using hydraulic conductivity (slug) tests performed on groundwater bores. The locations and standing water levels of these bores are appended (Table A1). Hydrogeological properties are also appended (Table A2) and summarized in Table 2 and Figure 6**.** Because both weathered rock and fractured rock typically screen in the same bore, results shown in Table 2 and Figure 6 represent the combined weathered / fractured rock aquifer and range from impervious to semi-pervious rock.

When viewing the hydrogeological data summary, there needs to be consideration of procedurally defined parameters. It was observed that field measurements of hydraulic conductivity obtained by slug tests were on average about 4x more conductive to groundwater flow than measurements obtained using pumping tests when the bore was purged of water and recharge was measured (Table 3). The reason for the discrepancy is that the slug test induces a small head change (about 60 cm) across a thin skin of aquifer immediately surrounding the bore, whereas the pumping test penetrates further into the aquifer where there is likely to be containment by impermeable rock. As such the slug test values reported in Table A1 and A2 are conservative values when representing the overall aquifer, in that there is a positive bias in favour of faster seepage of mine affected water into the landscape and hence there is more likelihood of overestimating rather than underestimating mine effects.

In addition to these bore-specific data summaries, the calibrated hydrogeological model provides a synthesis of the hydraulic conductivities and thicknesses of the various aquifers at the mine-lease scale. From these hydraulic conductivity and aquifer thickness values, it is possible to derive other hydrogeological properties (transmissivity and permeability) that are relevant at the mine-lease scale (Table 4).

In summary the hydrogeological characteristics of the aquifers were evaluated from field testing of groundwater bores as well as from groundwater modelling and were found to be consistent with semi-pervious soil and weathered rock, and semi-pervious to impervious fractured rock and basement rock.

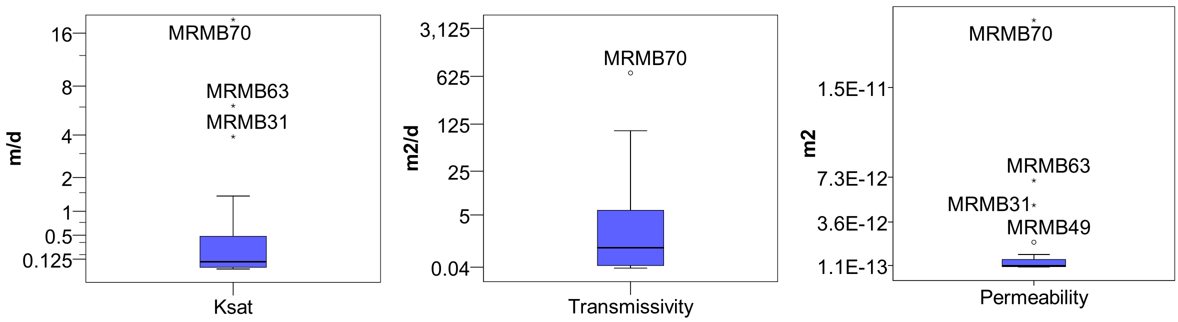

Figure 6: Boxplots of hydrogeological parameters[6]

Aquifer	K_{sat} (m/d)	T (m^2/d)		Permeability (m^2)		
			Category	10°C	20°C	30°C
			Good quality data			
20th percentile	4.2E-03	1.2E-02	Imperveous	6.E-15	5.E-15	4.E-15
50th percentile	8.4E-02	1.0E-01	Semi-perveous	1.E-13	9.E-13	7.E-14
80th percentile	5.5E-01	8.4E+00	Semi-perveous	8.E-13	6.E-13	5.E-13
			All bores			
20th percentile	6.6E-03	1.0E-01	Imperveous	1.E-14	8.E-15	6.E-15
50th percentile	8.9E-02	9.8E-01	Semi-perveous	1.E-13	9.E-14	7.E-14
80th percentile	6.0E-01	1.2E+01	Semi-perveous	9.E-13	7.E-13	6.E-13

Table 2: Summary hydraulic conductivity (K_{sat}), transmissivity (T) and permeability values across the anticipated temperature range for combined weathered / fractured rock aquifers[7]

Bore	K_{sat} (m/day)	
	Pumping Test	Slug Test
MRMB38	3.58E-02	2.10E-01
MRMB40	7.46E-03	1.60E-02
MRMB52	3.92E-02	2.30E-01
MRMB53	2.59E-01	9.80E-01

Table 3: Hydraulic conductivity values obtained by slug tests and pumping tests

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[6] Boxes represent 25th, 50th and 75th percentile values (i.e. 50% of data). Whiskers represent 1.5x of the height of the box, or the maximum or minimum value. Outliers (open circles) have values that do not fall in the whiskers, and extreme outliers (stars) have values more than 3x the height of the box.

[7] Good quality data involved well construction where (i) the entire screen was below the water table, (ii) adequate recovery (>50%) of the test slug volume, the addition or removal of the slug occurs instantaneously without inducing currents of water within the well casing. Table 2 lists a data summary representing percentiles developed using good quality data as well as using all data.

Hydrogeological model layer	Aquifer	Aquifer thickness (m)	K_{sat} (m/day)	T (m^2/day)	Permeability (m^2)			
					Category	10ºC	20ºC	30ºC
Soil/subsoil (high ranges)	Topsoil	0.5	Kx = 3.27E-02 Kz = 1.32E-02	1.6E-02	Semi-perveous	4.987E-14	3.879E-14	3.109E-14
	Subsoil clay and sand	4.5	As for topsoil As for topsoil	1.5E-01				
Soil/subsoil (valley)	Topsoil	0.5	Kx = 9.62E-01 Kz = 4.62E-02	4.8E-01		1.467E-12	1.141E-12	9.145E-13
	Subsoil clay and sand	4.5	As for topsoil As for topsoil	4.3E+00				
Alluvium	Alluvium	0.5?	Kx = 1.82 Kz = 1.22E-01	9.1E-01		2.775E-12	2.159E-12	1.730E-12
Weathered rock	Weathered rock	10	Kx = 1.21E-01 Kz = 5.37E-02	1.2E+00		1.845E-13	1.435E-13	1.150E-13
Fractured rock	Upper fractured rock	35	Kx = 1.79E-03 Kz = 1.79E-03	6.3E-02	Imperveous	2.730E-15	2.123E-15	1.702E-15
	Lower fractured rock	50	Kx = 1.79E-03 Kz = 1.79E-03	9.0E-02				
Basement	Non-fractured basement	250	Kx = 4.15E-03 Kz = 2.17E-03	1.0E+00		6.329E-15	4.923E-15	3.945E-15

Table 4: Hydraulic conductivity values assumed by the hydrogeological model

3.1.3 Fault and Fracture Propensity

Three regional fault orientations are influential at the mine lease scale:

1) North-South structures subparallel to the regional scale Mount Perry Fault, which reactivated early basement faults with major displacement. An important example is the West Dam Fault that contains moisture, but because it is filled with gouge material and secondary minerals water flow is impeded (Figure 7). This fault is inferred to pass directly below the TSF. In 2019 exploration drilling targeted the West Dam fault directly below the West Dam, where the fault crosscuts igneous rock (granite, granodiorite, dacite) and the weathering profile is negligible. The fault was found to be dry at depth. North of the TSF however, where the fault crosscuts metasediments, there has been block faulting of offshoot faults, and the weathering profile is deeper. It is possible that groundwater movement might be more dynamic in association with porous strata being juxtaposed with impermeable rock.

   In the hydrogeological model (Northern Resource Consultants, 2019) the West Dam fault was represented as a vertical structure assumed to be a semi-permeable flow barrier;

Figure 7: West Dam Fault (marked by red line) exposed in the Western Stormwater Drain[8]

2) East-North-East structures (Biggenden Set) contain water and are important for water transfer because adjacent rock types (e.g. granites and metasediments) with different permeabilities are juxtaposed, which directs groundwater flow along the strike of the fault. Important examples include:

   a) The contact between the Mine Sequence Volcanics and the Curtis Island Metasediments, between the TSF and the pit, is thought to be a fault barrier that prevents seepage of groundwater and tailings seepage into the pit. Instead groundwater flow is towards the East-North-East (refer to discussion in section 3.3.1.6 of statistical analysis of mine affected seepage mixing with native groundwater); and

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[8] The fault is filled with gouge material and secondary minerals. This photo taken during a rainfall event and shows surface water flowing down the flanks of the drain and ponding in the drain.

b) The Not-My-Fault fault is recognised in the pit, extends underneath the NWRD and connects with 12 Mile Creek via a gully where production bore MRPB1 is located. In the pit it is a dry fault, but immediately adjacent to Twelve Mile Creek where the production bore is located it is a highly permeable aquifer (Figure 8). Because there is no seepage into the pit via this fault, there is hydraulic disconnection between this aquifer and the pit along the fault alignment.

Figure 8: Aerial photo showing a gully entering Twelve Mile Creek [9]

3) Late brittle faults through which andesites intruded. They can influence groundwater flow in the manner that the Biggenden set does, where groundwater cannot flow through the andesite dyke but rather deflects along the strike of the andesite dykes. An example is the contact between chert and andesite in dewatering bore MRDB2, where the dewatering bore intercepts seepage from the TSF (Figure 9).

In addition to these fault orientations are localised sills, dykes and fractures that have been mapped in detail in the Mine Sequence Volcanics (along the pit walls). The mine appears to be within a volcanic collapse structure, where the pit walls are bounded by faults that seal and protect the pit from groundwater ingress and contribute to its “dry’’ condition.

As described earlier in section 3.1.1, the clay borrow pit and the Downstream Seepage Interception Drain along the northern wall of the TSF, provide excellent exposure of the soil and weathered rock profile. Late brittle faults (Figure 10A) in combination with the sedimentary fabric of the rock (Figure 10B), influence groundwater movement through this aquifer. Note that brittle faults transfer groundwater only if they are interconnected, and joints/faults may be water filled compartments that are not (or weakly) connected with other structures, or with the surface. In the mine lease there are isolated structures of fractured rock with low storage capacities, which recharge rapidly through rainfall and exhibit large

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[9] Features are the Northern Waste Rock Dump (NWRD), Waste Rock Dams 2 and 3 (WD2, WD3), Mount Rawdon Monitoring Bores, (MRMB27, MRMB60, MRMB63), Mount Rawdon Production Bore 1 (MRPB1) and a small farm dam above MRPB1. Brittle fractures that align with 12 Mile Creek, and with a gully associated with the Not-My-Fault fault that enters 12 Mile Creek, are shown as blue lines. The strike and dip (magnetic north) of these respective fracture planes are: 323.89 and 235.87.

water level declines due to evapotranspiration and downslope drainage (Klohn Crippen Berger, 2010).

Water conducting joints have been observed in otherwise impermeable rock. The north wall of the pit has well developed, widely spaced, 40° west dipping joints intersected by a similar set of steeply east dipping joints. These are open tension joints showing (downward) water flow into the open pit that respond rapidly to heavy rainfall events of a few days duration, which in the unmined state would have been contained by impermeable wall rock. In the unmined state, below the permanent groundwater table, joints were filled with a white pyrite-clay-calcite gel that becomes brown, desiccated and oxidised after mining.

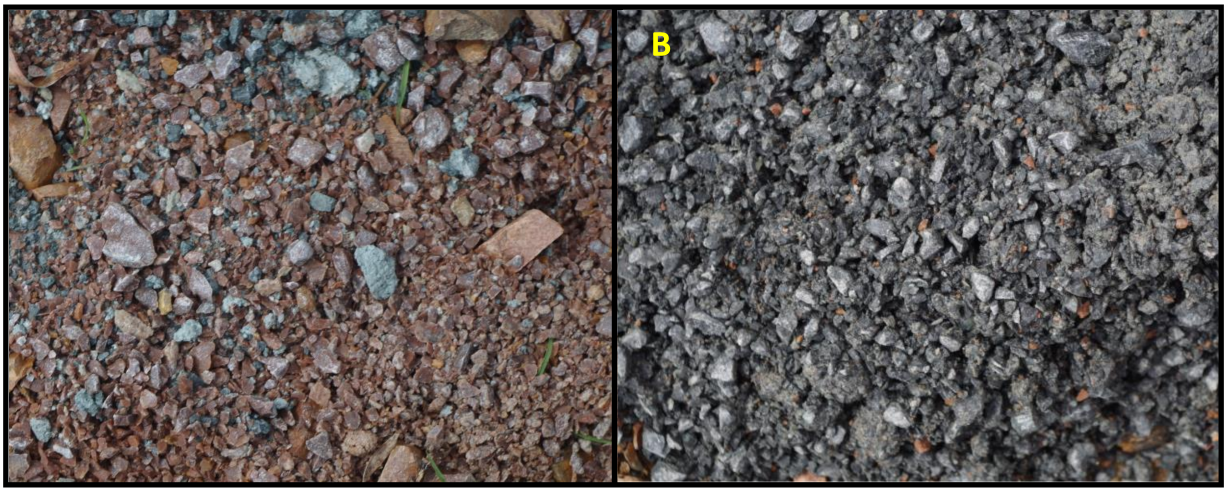

Figure 9: Drill chips from dewatering bore MRDB2[10]

In summary, faulting and fracturing in the mine lease is complex and provide:

1) Flow barriers: Groundwater flow is obstructed by argillized gouge material, dykes, sills and/or structural displacement of blocks with lower permeability than the surrounding wallrock. The block-faulted collapse structure of the volcano, where pit walls align with faults, limits groundwater flow into the pit;
2) Flow conduits: Groundwater transmits through brittle faults, joints, connected pores and planes of decollment in metasediments. Water flows through thin crush zones of chloritized gouge material that are permeable to groundwater flow, which formed on the margins of dykes where minor tectonic reactivation reopened fault contacts; and
3) Compartments: Groundwater obstructed from moving downward into the aquifer, or laterally across the aquifer, by flow barriers will be hosted interstitially in rock pores, intersecting open-fractures, along bedding planes and along joints that are perched above the flow barriers. Where lateral flow of groundwater is restricted by flow

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[10] Contact between red-orange chert country rock (A) and a black andesite (B) dyke at the 18-19 m depth interval, showing the thin contact between these lithologies as light-blue chloritized chips in (A). Slight reactivation of the fault appears to have generated gouge material at the margin of dyke that became chloritized. Above this contact was a perched aquifer, hosting about 2 meters of groundwater in the fractured chert that was flowing through the chloritized contact and parallel to the andesite dyke.

barriers, evapotranspiration by deep rooted plants is considered to be significant for dewatering groundwater during the dry season (Klohn Krippen Berger, 2010).

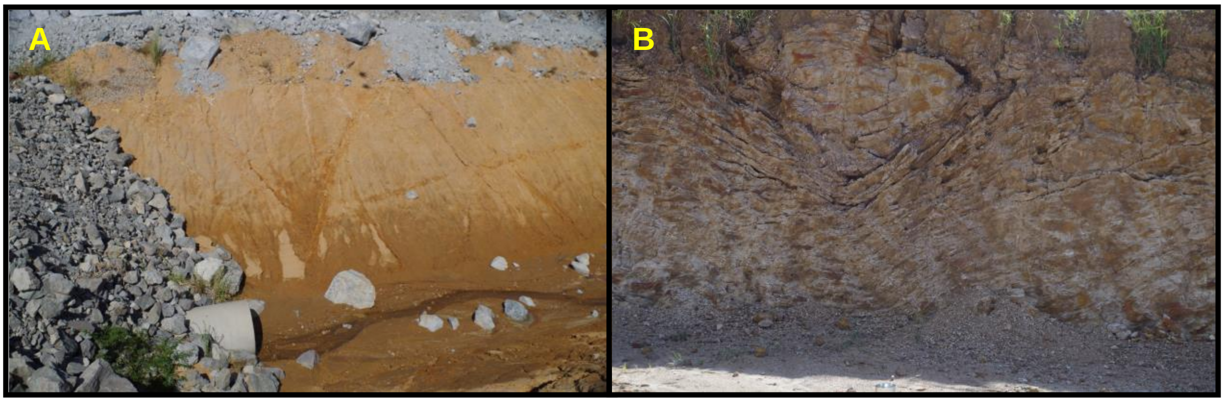

Figure 10: Structures that contribute to groundwater compartmentalisation[11]

3.2 Geological Barriers to Groundwater Flow

At the mine lease scale, the main geological barriers inferred to impede groundwater flow are the West Dam Fault south of the TSF, and faults around the walls of the pit (in particular between the TSF and the northern pit wall), as discussed in section 3.1.3. These geological barriers were initially represented in the hydrogeological model as impermeable vertical structures, but calibration of the model showed that that the structures were semi-permeable (Northern Resource Consultants, 2019).

Swindon Fault, a lineament that marks the contact between the Mine Sequence Volcanics and Curtis Island Metasediments, abuts the West Dam Fault south of the pit. The monitoring bore that intersects an offshoot of this fault (MRMB70) has high hydraulic conductivity, but adjacent bores have low hydraulic conductivities, indicated by field testing of hydraulic conductivity (MRMB71) or by very slow recharge rates that have been observed when purging the bores (MRMB36, MRMB72). From these observations it is inferred that MRMB70 intersects a groundwater compartment associated with a Swindon Fault structure bounded by impermeable strata.

Figure 11 shows the location of the West Dam Fault and the Swindon Fault.

Finer scale structures contribute more localised barriers to groundwater flow and to groundwater compartments. In the mine lease groundwater flows through a thin layer of topsoil and eluvial soil, and deeper in the profile groundwater flows along foliations in shallow bedrock as well as along interconnected joints and fractures. These finer scale structures are likely to locally influence recharge of the groundwater both vertically down the soil and weathered rock profile, and laterally through the sloping landscape towards

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[11] Exposure of weathered Curtis Island Metasediments in the Downstream Seepage Interception Drain (A) and clay borrow pit (B), along the northern wall of the TSF. Shown are a perched groundwater compartment bounded by a conjugate fault (A) and decollement of bedding planes associated with a fold hinge (B).

downstream receptors. These structures are important features of the conceptual groundwater model, and their influence on groundwater quality will be discussed further in section 4.1.

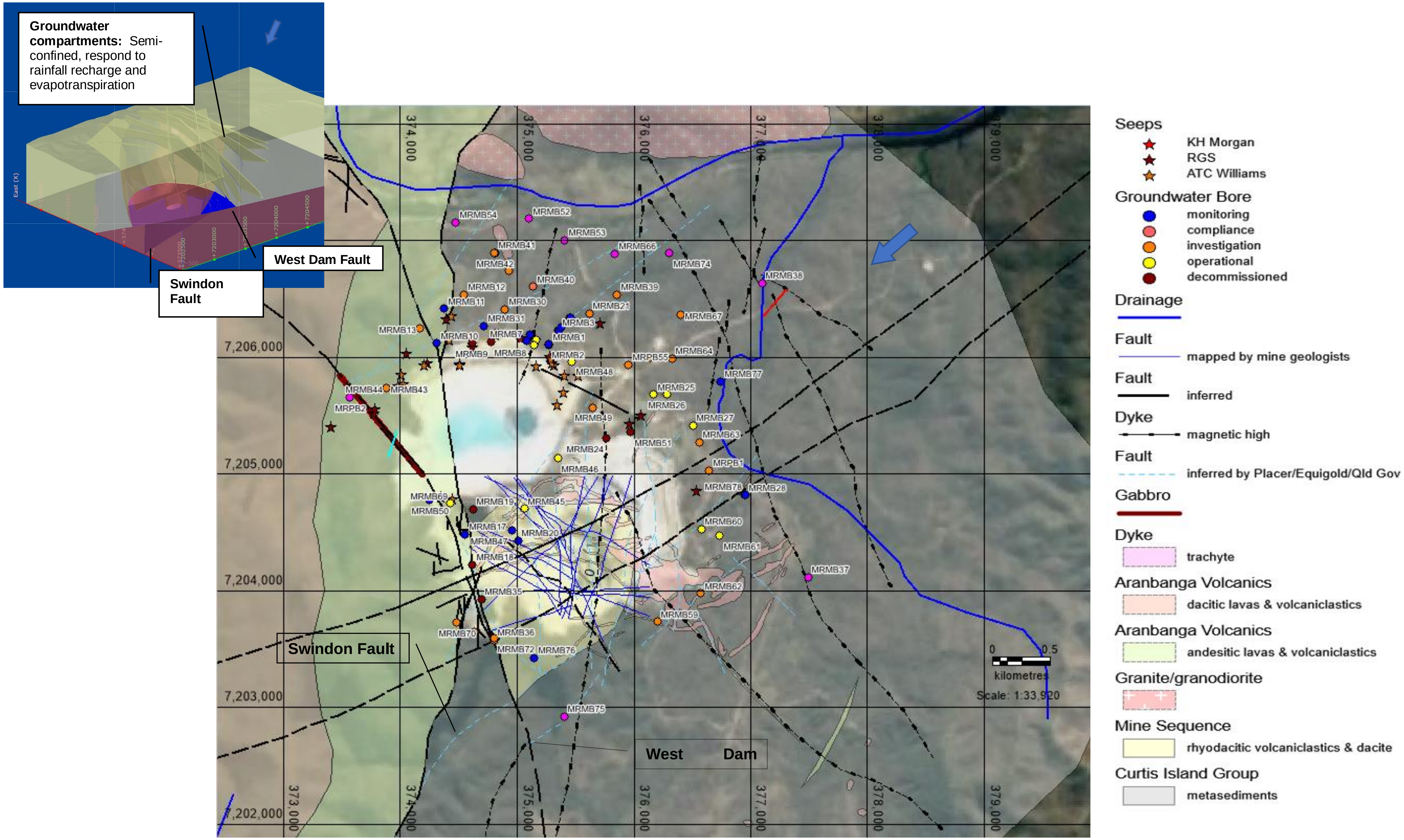

Figure 11: Sample location map showing groundwater monitoring bores in the context of lithology, and structures that contribute barriers to groundwater flow[12]

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[12] Plan view and an angled view from below ground level (insert) showing inferred fault structures that contribute to groundwater compartmentalization. The blue arrow references the below-ground direction of view of the insert.

The following geological features impede and/or direct groundwater flow among aquifer compartments:

1) Duplex soil. Around the TSF, former gullies filled with uncompacted soil that were likely backfilled when building the TSF have been shown to provide preferred flow paths. Figure 12 shows the influence of backfilled gullies and soil horizons on the lateral movement of groundwater through soil. Note that clay subsoil (B horizon soil) discussed in section 3.1.2 has a lower hydraulic conductivity than the adjacent topsoil and weathered rock, which can impede recharge of the fractured rock aquifer;
2) Faults. Clay formed along faults impede groundwater flow, forcing groundwater to move laterally along the fault planes (Figure 10A);
3) Sills and Dykes. Intrusive structures that align to some extent with the rock fabric (Figure 4) or associate with late-stage brittle faults that have been intruded by andesite to form dykes (Figure 9), contribute to partial compartmentalization in the weathered/fractured rock aquifer. Groundwater is forced to move laterally along these structures.

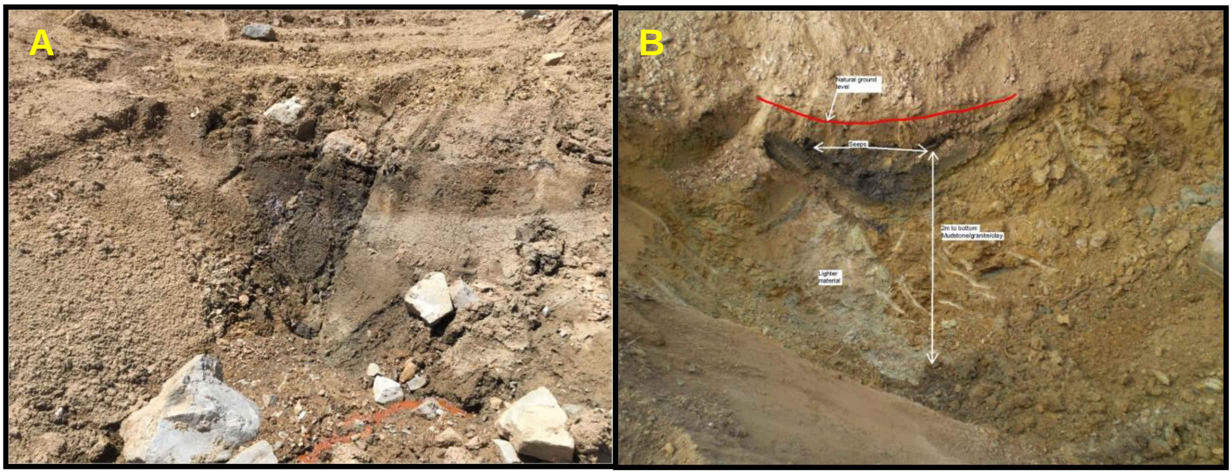

Figure 12: Groundwater seepage downgradient of MRMB10 [13]

3.3 The Ionic Composition of Groundwater and Mine-Related Source Terms

This section addresses provides the analytical basis of conceptual model development required by sections 1.1c and f of the environmental evaluation:

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[13] Plate A taken in 2018 shows seepage through a former gully backfilled with soil and boulders, marked by black coloured soil contrasting with lighter coloured soil. Clearly shown are seepage zones that correspond with the soil profile described in Figure 3B: moist topsoil A and E horizon soil (loam), a dry aquiclude that corresponds with B horizon soil (clay), below which is a moist C horizon soil (saprolite). As such the clay horizon provides a barrier to groundwater flow. Plate B, taken in 2008 prior to installing a clay cut-off wall that intercepted seepage pathways along two adjacent gullies, shows one of the seepage pathways where weathered rock was excavated below the base of the gully backfilled by black coloured soil.

1.1: Identify the dominant underground hydrogeological systems relevant to the premises incorporating all available data from groundwater monitoring bores, and determine:

> *c: the waters contained in the hydrogeological feature(s), including its ionic composition.*
>
> *f: the interaction of any contaminated waters, with the water in the hydrogeological system(s), including a comparison of the ionic compositions of the contaminated waters with the water in the hydrogeological system(s)*

Principal Components Analysis (ordination) and Cluster Analysis (classification) were used to evaluate the ionic compositions of groundwater and mine source terms, based on correlations among major ion and COPC concentrations in these water types. These statistical tools are efficient at identifying patterns of variation among environmental datasets subject to interacting landscape processes, and for this reason are used for hypothesis setting to explain the structure of data variation. In this report these techniques were used to support the conceptual model.

Major ions are commonly used for groundwater characterization. Because major ions such as Na, Cl, Mg, Ca, K and to a lesser extent SO_4 and HCO_3 are conservative, so their relative concentrations can be used as high-fidelity indicators of groundwater types. For example, groundwaters enriched in magnesium, calcium and bicarbonate can be defined and distinguished from other groundwater types enriched in sodium and chloride, or enriched in potassium and sulfide, based on the various correlations in element chemistry.

Mount Rawdon Operation mines and processes sulfide ores using cyanide leaching, and mine affected groundwater also contains high concentrations of certain major elements (described below), nitrate (from explosives), cyanide (from process water stored in the tailings dam) and chalcophile (sulfur loving) metals such as arsenic (As), cadmium (Cd), copper (Cu) and zinc (Zn). These non-conservative elements are biochemically and/or chemically reactive, therefore in some circumstances are less reliable indicators of mine sources than the conservative major ions listed above. Cyanide (CN) breaks down biochemically to ammonia and carbonate. Nitrate breaks down to nitrogen or can be generated in the landscape from non-mining sources (e.g. nitrogen fixing plants such as acacia, decaying plant matter in boggy ground, or ash residues after hot bushfires). Chalcophile metals can form sulfide minerals that precipitate or dissolve in response to the presence of dissolved oxygen in a fluctuating groundwater table. The metal ions also adsorb to the surfaces of clays and iron oxides. However, under circumstances when the chemical kinetics of cyanide and nitrogen and chalcophile metal conversion are inhibited (e.g. by lack of availability of dissolved organic carbon or other electron donors in groundwater) and where adsorption sites on clay and fracture mineral surfaces are saturated, these COPC's behave conservatively in the mining landscape. These COPC's are potential environmental hazards, and their presence in water bodies on the Mount Rawdon lease needs to be evaluated.

The water chemistry data collected at Mt Rawdon was used to indicate the source terms of (i) Process Water associated with the TSF, (ii) Pit Sump water (used as a surrogate for Waste Rock Dump seepage while a database is being developed from field measurements) and (iii) native groundwater sources on the Mount Rawdon Mine Lease. Because of the large amount of data, it was useful to (i) initially aggregate data as median data per bore to develop a site-scale conceptual model, and then (ii) partition data into smaller landscape units (individual drainage lines) to develop sub-catchment scale conceptual models. Partitioning data this way highlighted mine-lease scale variations in COPC and major ion chemistry among mine affected water and native groundwater, and at the sub-catchment scale showed the influences of soil/geology, seasonality, and progressive mine seepage acting on the ionic chemistry of groundwater over time.

The multivariate statistical techniques described above were supported by univariate time-series charts of Electrical Conductivity, SO_4/Cl, NO_3_N and Cyanide over time. Electrical conductivity represented the presence of total major ions (natural and mine related) in groundwater, SO_4/Cl was a lead indicator of mine influence adjusted for evaporative concentration, NO_3_N is an indicator of explosives residue present in mined rock and CN indicated tailings seepage.

3.3.1 Mine-Lease Scale Comparison of the ionic compositions of groundwater and mine-influenced water

The ordination performed was Principal Components Analysis (PCA) using a correlation cross-products matrix (PCORD Software, McCune and Mefford, 2018).

Results are shown graphically in Figure 13, and figures 44 – 49 in Appendix 7.3. The principal components of variations in major ions (Na, SO_4, HCO_3), nitrogen compounds used in mining (NO_3, CN) and an element related to mineralization (As), were consistent with:

1) Solutes generated by weathering of feldspar and carbonate in the landscape represented by positive correlations with HCO_3 and Na, and negative correlations with NO_3, on component 1 (axis 1) of the distance-based biplot (Figure 13, and figures 44 – 45 in Appendix 7.3). This component explained 32.4% of the variation in solute chemistry;
2) Solutes generated from mining and processing of mineralised ore represented by positive correlations with SO_4, NO_3, CN and As on Component 2 (Axis 2) of Figure 13 and figures 44 - 46, which explained 27.7% of the variation in solute chemistry; and
3) Solutes generated from mineralised sources (i.e. not processed as tailings) represented by positive correlation with As, and negative correlation with CN, on Component 3 (Axis 3) of Figure 13 and figure 49 in Appendix 7.3. This component explained 19.4 % of the variation in solute chemistry.

The outcome of the ordination was well-structured data that explained 79.5% of water chemistry variation in the mine lease in response to inferred weathering of the landscape and of mineral deposits, as well as seepage of water influenced by mining and processing of ore. The biplots showed that the mining and ore-processing source terms (i.e. the ionic composition of water in tailings and the containment dams) plotted at the edge of the data distribution (figures 13 and figures 44 – 46 in Appendix 7.3). At this scale of analysis there were no distinctive water chemistry groups based on geology, soil or landscape position.

Water chemistry data were then classified using polythetic hierarchical agglomerative cluster analysis involving Euclidean distance, with flexible beta group linkage to limit the low amount of chaining evident in the classification (<2%). With $\beta = 0.55$ chaining was 0.88%.

Five water quality groups were identified with an objective function of 21.935 (out of a total of 57), which represents groups with greater than 62% similarity. Results are shown in figures 14 – 15, and are described as follows:

Group 1. Predominantly tailings seepage affected water: tailings discharge, South Dam, Sediment Dam 1 and Sediment Dam 3, MRMB1, MRMB2, MRMB7, MRMB23, MRMB29, MRMB30, MRMB31, MRMB46 and MRMB49;

Group 2. Predominantly waste-rock seepage affected water (except for MRMB70 for reasons discussed in section 3.3.1.3) as follows: the Pit Sump, West Dam, Sediment Dam 2,WD1, WD2, WD3, WD4, MRMB20, MRMB12, MRMB32, MRMB34, MRMB42, MRMB48, MRMB70;

Group 3. Groundwater that screens in or adjacent to andesite/dacite, rhyodacite, granite/rhyolite, granodiorite, gneiss (MRPB1, MRMB11, MRMB17, MRMB43, MRMB50, MRMB53, MRMB55, MRMB65, MRMB71) and/or close to the edge of the lease (MRPB2, MRMB38, MRMB52, MRMB54, MRMB66). MRPB2, MRMB38 screen in tuff and metasediment respectively, MRMB52, MRMB53 and MRMB54 screen in basalt/gabbro, and MRMB66 screens in granodiorite. Some of the intrusive rocks listed above are hosted in Curtis Island Metasediments at depth; which include some compliance monitoring bores located near the edge of the lease;

Group 4. Water screening in:

a) Curtis Island Metasediment (MRMB63), granites that had intruded Curtis Island Metasediment at depth (MRMB67, MRMB74, MRMB75) or dacite (MRMB35);

b) Curtis Island Metasediment along Rawdon Creek northwest of the TSF (MRMB3, MRMB4, MRMB5, MRMB6, MRMB8, MRMB21, MRMB39, MRMB21) or south east of the TSF (MRMB45); and

c) Curtis Island Metasediment (MRMB9, MRMB10) or dacite (MRMB69) immediately south and north of the TSF, and close to the inferred West Dam Fault.

Group 5. Water screening in Curtis Island Metasediment in:

a) the south-east of the lease (MRMB37, MRMB59, MRMB60, MRMB61, MRMB62) and under a landscape spur on the north-east of the lease (MRMB64, MRMB68). Three bores screening in Aranbanga Andesite / tuff in the west of the lease (MRMB18, MRMB13, MRMB44) are members of this group; and

b) metasediment (MRMB19, MRMB24) or granite/rhyolite (MRMB25, MRMB26, MRMB27). Two adjacent bores screen in granite (MRMB72) or dacite (MRMB36) near the faulted contact between the Mine Sequence Volcanics and Curtis Island Metasediments.

More detailed interpretations of the ionic composition of groundwater and mine affected water are reported at the sub-catchment scale in the following sections. They describe changes in ground water quality over time and the possibility that either groundwater has mixed with mine seepage or provide alternative reasons for relatively high COPC concentrations observed in groundwater such as associations with soil and geology.

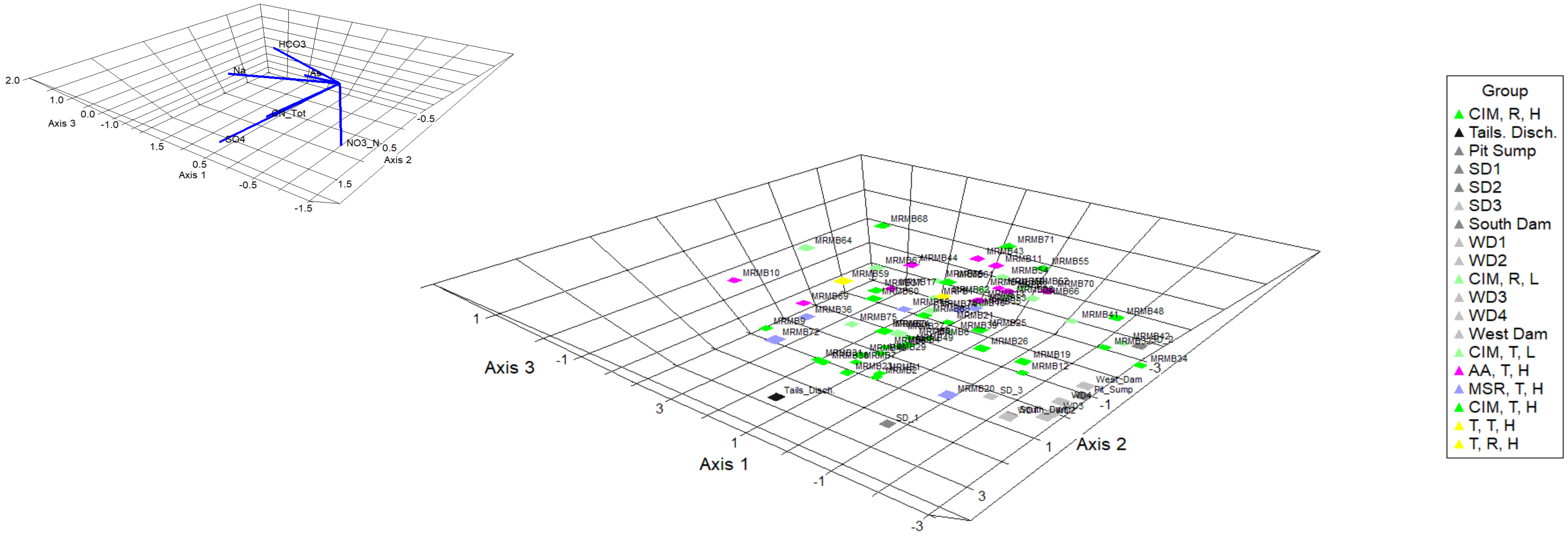

Figure 13: Principal Components Analysis of major ions and COPC concentrations in groundwater tailings, sediment dams and waste rock dams [14]

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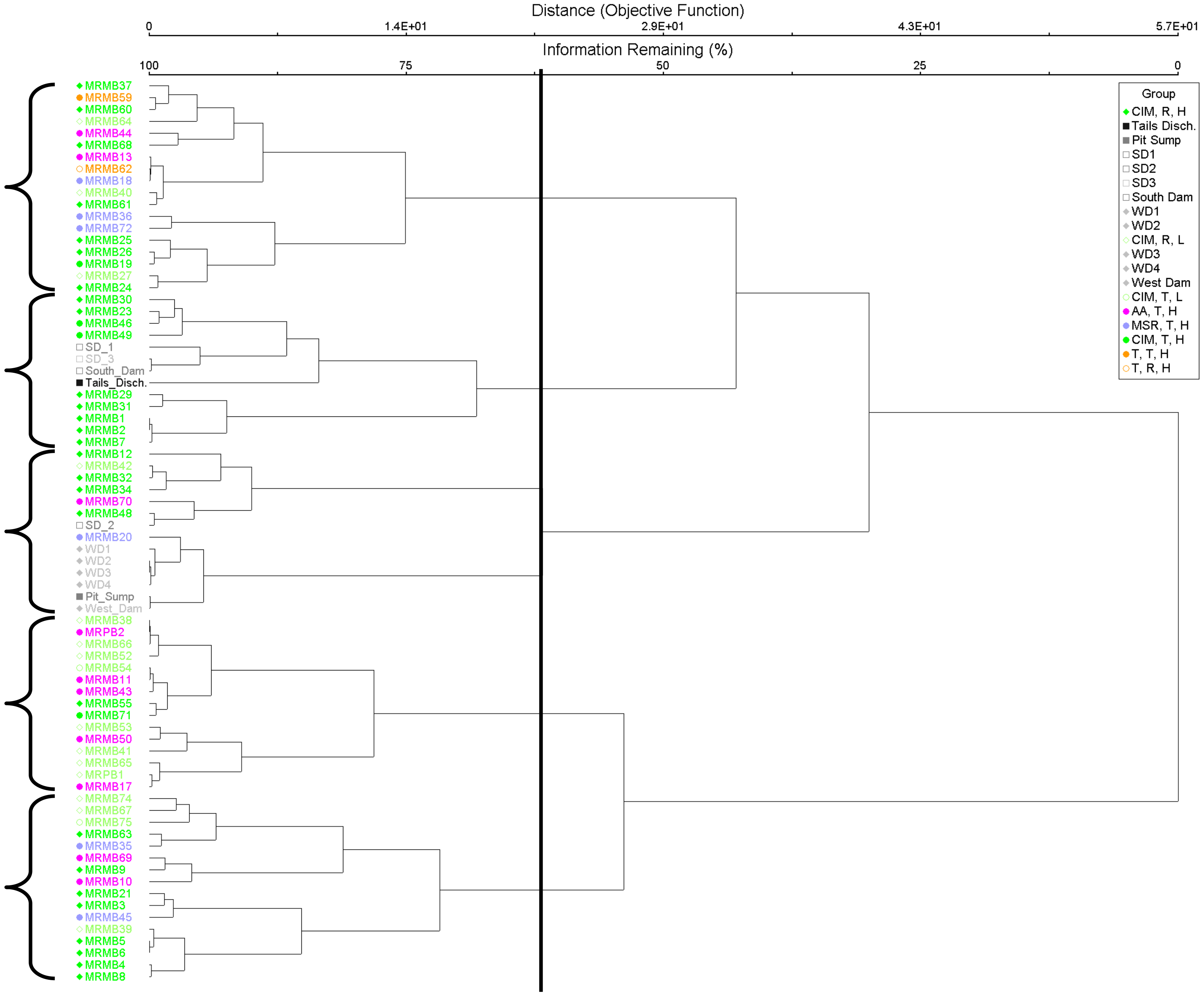
[14] Colour code for groups of water types are mine related source terms:

(1) Tailings discharge in black, (2) South Dam, Pit sump (surrogate for Waste Rock seepage), Sediment Dam 1 (SD1) and Sediment Dam 2 (SD2) in dark grey; (3) Sediment Dam 3 (SD3), Waste Rock Dam 1 (WD1), Waste Rock Dam 2 (WD2), Waste Rock Dam 3 (WD3), Waste Rock Dam 4 (WD4) and West Dam in light grey;

Colour code for groundwater indicating the geology, soil and landscape position of the aquifer:

(4) Curtis Island Metasediments (CIM), Rudosol (R) or Tenosol (T), high landscape position (H) in dark green; (5) Curtis Island Metasediment, Rudosol or Tenosol, Low landscape position in light green; (6) Aranbanga Andesite (AA), Tenosol, High landscape position in pink; (7) Mine Sequence Rhyolite (MSR), Tenosol, High landscape position in purple; (8) Trachyte, Tenosol, High landscape position in yellow; (9) Trachyte, Rudosol, High landscape position in yellow.



Group 5: Screening predominantly in Curtis Island Metasediment, with some bores screening in or near intrusive rock.

Group 1: Influenced by tailings-seepage

Group 2: Influenced by waste-rock seepage

Group 3: Screening in volcanic or plutonic rocks (some of which are hosted in Curtis Island Metasediment), with some monitoring bores located near the edge of the lease

Group 4: Screening predominantly in Curtis Island Metasediment with one subgroup located in the Rawdon Creek Sub-catchment, and another subgroup close the TSF and the inferred West Dam Fault

Figure 14: Classification of major ions and COPC concentrations in groundwater tailings, sediment dams and waste rock dams[15]

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[15] Vertical line indicates the level of grouping with 62% similarity

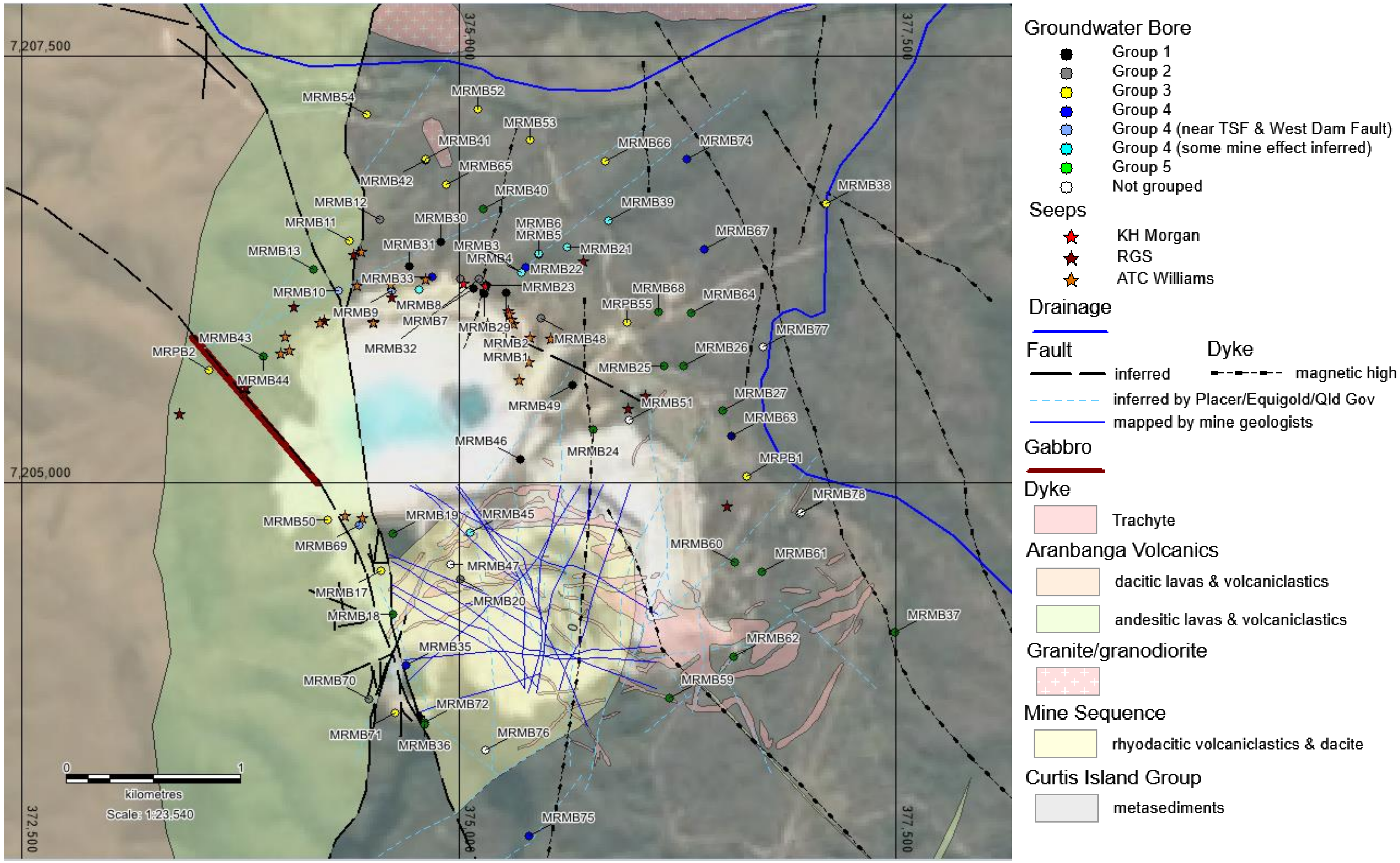

Figure 15: Spatial locations of groundwater classification groups in the Mount Rawdon Mine Lease[16]

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[16] Groundwater in Group 1 has been influenced by tailings seepage, in Group 2 by waste rock seepage (except for MRMB70 for reasons discussed in section 3.3.1.5), and in Groups 3, 4 & 5 predominantly by geology and landscape. Mine influenced groundwater has affected Group 4 groundwater near the intersection of the TSF & West Dam fault, and along Rawdon Creek.

3.3.1.1 Sub-catchment Scale comparison of the ionic compositions of Swindon Creek water with mine affected water

Principal Components Analyses (PCA) explained 93% of the variation in groundwater chemistry on 3 axes (with an eigenvalue < 1) using ions associated with:

1) Mining and processing of sulfide ore.
    a) Component 1 (axis 1) explained 45.6% of the variation in groundwater chemistry, by As, SO_4 and Tot. CN that negatively correlated with this axis; and
    b) Component 3 (axis 3) explained 15.7% of variance by NO_3_N and SO_4 that positively correlated with axis 3, and Total CN that negatively correlated with axis 3.
2) Geology (Na, HCO_3) and explosive residues associated with mined rock (NO_3_N). Component 2 (Axis 2) explained 31.6% of variance, was structured by Na, HCO_3 (negative correlated with axis 2) and NO_3_N (positively correlated with axis 2), noting that bicarbonate and nitrate can also be produced by organic matter decay in wet environments.

Results are shown graphically in Figure 16 and in Appendix 7.3 (figures 51 – 55). From this data structure it was inferred that the ionic composition of groundwater in Swindon Creek were structured by:

- Geology and soil attributes that influenced Na and HCO_3 concentrations along this gradient (refer inserted graph in Figure 16). MRMB10 is enriched in Na and HCO_3 relative to MRMB41, MRMB42 and MRMB12, which are downslope bores closer to the Perry River;
- NO_3_N possibly from blast residues in waste rock used on the outer batter wall of the TSF and/or from biogeochemical processes associated with the landscape and wetland soil. Groundwater data in bores MRMB12, MRMB13, MRMB10 and MRMB44 featured data alignment with the NO_3_N vector; and
- Non-mine affected (background) bores that plotted near the origin (zero).

The lack of data distributing along the CN vector indicates that tailings seepage might not be the predominant mine signature, whereas alignment of data along the NO_3_N vector indicates that either NAF waste rock seepage (blast residues marked by NO_3_N) and/or landscape and wetland processes (nitrification) are influential in Swindon Creek.

As such the hypothesis set by the PCA analysis was that NAF waste rock seepage reporting to downgradient receptors and/or buildup of nitrate in the landscape and wetland soils associated with soil processes such as the decay of organic matter and nitrogen fixation may have influenced the data distributions for MRMB12, MRMB13, MRMB44 and MRMB10 along the NO_3_N vector.

The next step in the multivariate analysis was to classify data. Five groups are shown in Figure 17. The classification supported the PCA interpretation except for MRMB13, which grouped with groundwater from reference sites known not to be mine affected (this is discussed further below).

The final step in data interpretation was univariate interpretations of time-series trends of electrical conductivity and concentrations of potentially mine related elements (SO_4/Cl, NO_3_N and Tot. CN) in groundwater. Time-series graphs in Appendix 7.4.1 show:

- increasing trends for SO_4/Cl and Tot. CN in MRMB43 and MRMB44, suggesting breakthrough of mine affected seepage that is mixing with native groundwater. This trend is being addressed by improved seepage management;

- increased trends in the past for SO_4/Cl in MRMB10, MRMB12, MRMB41 and MRMB42 that have ceased to be monitored and/or are presently monitored where trends have stabilized indicating that mitigation of mine seepage had some success;
- an increased trend in the past for Tot. CN in MRMB12, where trends have stabilized indicating some success with mitigating mine seepage;
- increasing trends for Tot. CN concentrations in MRMB65, which are not supported by trends for EC and SO_4/Cl which are stable. This will be investigated using solute transport modelling during the Stage 2 investigation;
- Peak concentrations of NO_3_N in first flush events in MRMB12 (on 16/01/10, 15/01/12, 15/04/14 and 24/03/17) and in MRMB13 (on 16/01/10 and 15/04/14).

In summary bores MRMB43 and MRMB44[17] show recent influence of mine seepage, while bores MRMB10, MRMB12, MRMB41 and MRMB42[18] show past influence of mine seepage that has stabilized. At this stage bore MRMB65 has ambiguous results that need to be evaluated further. In bore MRMB13 the lack of appearance of other mine related elements (SO_4/Cl, Tot. CN) accompanying spikes in NO_3_N concentrations, together with MRMB13 grouping with non-mine affected bores in the classification analysis, indicates that nitrogen biogeochemistry and wet season flushing of soils in the upper part of Swindon Creek is the likely reason for occasionally high concentrations of NO_3_N observed in this bore. Bore MRMB13 is not considered to be mine affected.

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[17] In Figure 15 MRMB43 and MRMB44 are nested bores (Figure 15 only shows MRMB43). MRMB43 is deep (37 m.) and intersects the main aquifer at 3 – 10 m. and 14 – 31 m., while MRMB44 is shallow (13 m.) and intersects the main aquifer at 3 – 13 m. (N.B. gravel screens extend below the bentonite seals for the lengths of each bore). In terms of water quality associations (Figure 14) MRMB43 associates with group 3 and MRMB44 with group 5. Figures 44, 45, 47 and 48 show that MRMB44 is slightly more concentrated in SO_4 and NO_3 than MRMB43, which could respectively include contributions from weathering of sulfides and from explosive residues or wetland function.

[18] In Figure 15 MRMB41 and MRMB42 are nested bores (Figure 15 only shows MRMB 41). MRMB41 is deep (40.2 m.) and intersects the main aquifer at 11 – 13 m. and 28 – 35 m., while MRMB42 is shallow (16 m.) and intersects the main aquifer at 12 – 14 m.. Bore construction is as above. In terms of water quality associations (Figure 14) MRMB41 associates with group 3 and MRMB42 with group 2. Figures 44 and 45 show that MRMB41 is slightly more concentrated in Na and HCO_3 than MRMB42. MRMB42 is slightly more concentrated in NO_3 than MRMB41. Respectively these groundwater quality features can result from weathering of igneous rocks and from explosive residues or wetland function.

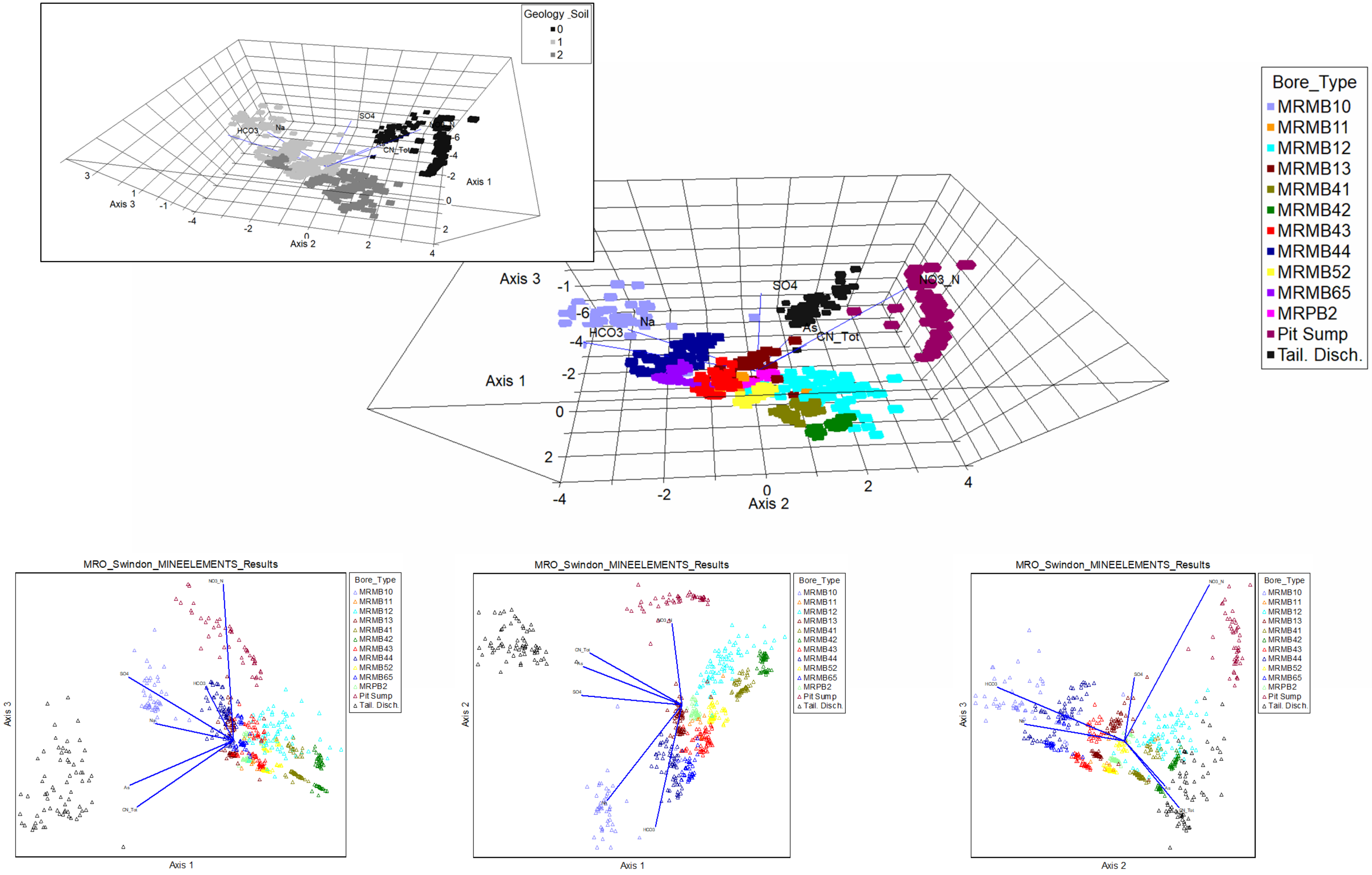

Figure 16: Principal Components Analysis of ions in groundwater and mine affected water from Swindon Creek [19]

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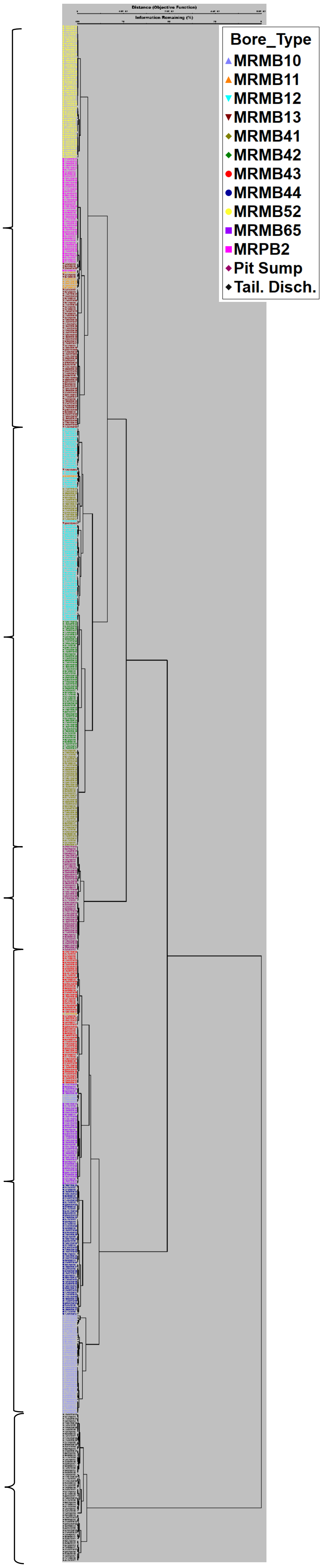
[19] The inserted graph (top left) shows the effect of soil / geology loading on the Na and HCO_3 vectors. **Geology and Soil Code:** 0 = mined rock, 1 = Tenosol over Aranbanga Andesite, 2 = Rudosol over Curtis Island Metasediment



"Group 1" containing reference bores MRMB52 and MRPB2. MRMB13 and MRMB11 group closely with MRPB2 (97.3% information remaining), which represents a group of bores in the upper part of Swindon Creek (above the hinge-line of the catchment), and group slightly less closely with MRMB52 (93.7% information remaining), which is the bore at the toe of the Swindon Creek sub-catchment. These bores are not mine affected.

"Group 2" represents groundwater in the lower part of the Swindon Creek sub-catchment, below the hinge-line of the catchment. This group contains MRMB42, MRMB12 and MRMB41, which have had apparent mine influence. MRMB11 and MRMB13 occasionally have groundwater in this group.

"Group 3" representing groundwater sourced from weathering of mined rock (pit sump style water was used as the source term for mined rock on the outer batter of the TSF wall). This group associated with groups 1 and 2 with 71.5% of information remaining.

"Group 4" representing MRMB10, MRMB44, MRMB65 and MRMB43. These rocks predominantly screen in Aranbanga Andesite above the hinge line, except for MRMB65 that screens in fresh granite. MRMB43, MRMB44 and MRMB10 screen in variably weathered tuff/volcaniclastics, and the sodium and bicarbonate characteristics of the groundwater could relate to geology and soil. MRMB10 had, and MRMB43 and MRMB44 have apparent mine influence.

"Group 5" represents Tailings discharge. It is different from the other groups.

Figure 17: Classification of ions in groundwater and mine affected water from Swindon Creek

3.3.1.2 Sub-catchment Scale comparison of the ionic compositions in water of an unnamed creek (between Swindon Creek and Rawdon Creek) with mine affected water

Bores in an unnamed creek between Swindon Creek and Rawdon Creek monitors a flow-path from the TSF. Bore MRMB9 was positioned in a gully to intercept seepage from the TSF. MRMB31 was positioned in the gully downstream of MRMB9 to check on underflow from MRMB9. MRMB30 was positioned in the same gully downstream of MRMB31.

Principal Components Analyses (PCA) explained 90.4% of the variation in groundwater quality data on 3 axes (with an eigenvalue < 1) using ions associated with:

1) Mining and processing of sulfide ore. Component 1 (Axis 1) explained 43.1% of variance by As, SO_4, Tot. CN, which negatively correlated with axis 1;
2) Geology, soil and possible mining attributes. Component 2 (Axis 2) explained 29.8% of variance by Na, HCO_3 (positive correlation with axis 2) and NO_3_N (negative correlation with axis 2). Nitrate and carbonate could have biogeochemical associations unrelated to mining as explained in the previous section, but bicarbonate may also be associated with carbonate (in tailings and/or weathered rock) and nitrate associated with mined rock (explosive residue); and
3) Possible mining attributes. Component 3 (Axis 3) explained 17.5% of variance by NO_3_N and SO_4 (negative correlation with axis 3).

Results of the PCA are shown graphically in Figure 18, and in figures 56 – 61 in Appendix 7.3. From this data structure it was inferred that the ionic composition of groundwater in the unnamed creek is structured by:

- Relatively high concentrations of Na and HCO_3 down the gully hosting bores MRMB9, MRMB31 and MRMB30, which are ordered by distance from the TSF;
- MRMB8 is not in the same gully alignment as the above bores. Its groundwater geochemistry is intermediate between the above three bores and bores further downgradient (refer below dot point); and
- Bores MRMB53 and MRMB40 downgradient along the creek, and some distance from the mine).

The hypothesis set by the PCA analysis is that groundwater chemistry is structured by concentrations of HCO_3 and Na. Mine influence upon groundwater chemistry can be discerned by concentrations of SO_4, Total CN and NO_3, with consideration of other possible sources of nitrate enrichment in groundwater unrelated to mining (as discussed for Swindon Creek).

The next step in the multivariate analysis was to classify data. Five groups are shown in Figure 19. The classification identified:

- group 1 that contained bores MRMB8 between 2002 and 2006, MRMB30 during 2007, MRMB40 and MRMB53,
- groups 2 and 3 that have been affected by mining. Group 2 contained MRMB9 during 2004 - 2010, MRMB31 and MRMB30. Group 3 contained MRMB8 and MRMB9 during 2011 and 2014;
- groups 4 and 5 that represent mining related source terms. Group 4 represents mined rock used to construct the outer batter wall of the TSF. Group 5 represents the tailings source term.

The final step in data interpretation was univariate interpretations of groundwater for trends of electrical conductivity and concentrations of potentially mine related elements (SO_4/Cl,

NO_3_N and Tot. CN). Refer to Appendix 7.4.2 for time series graphs, which show trends for groundwater listed above:

- Group 1 (MRMB40, MRMB53, MRMB8 in 2002 – 2006, MRMB30 in 2007): Steady or increasing SO_4/Cl concentration ratios and electrical conductivity readings, with occasional peaks in NO_3_N and total CN concentrations;
- Group 2: (MRMB9 during 2004 – 2010, MRMB30 after 2007, MRMB31): Slight but steady declines in electrical conductivity readings after 2010. Gradual increase in SO_4/Cl between 2006 and 2018. Increases in total CN concentrations and NO_3_N concentrations after 2010. NO_3_N shows peaks in concentration in 2014 and 2017 and troughs in concentration in 2016 and 2018; and
- Group 3 (MRMB8, MRMB9 during 2011 and 2014)): Steady decline in electrical conductivity readings after 2005. Gradual increase in SO_4/Cl between 2002 and 2010 associated with moderate concentrations of NO_3_N. After 2010 there was a marked increase in SO_4/Cl concentration ratios and total CN concentrations accompanied by lower NO_3_N concentrations.

In summary bores MRMB8 and MRMB9 are interpreted as being influenced by mine seepage. The decline in electrical conductivity and NO_3_N after 2005 may coincide with early seepage interception efforts, which indicate that some of the total salt contribution was removed by seepage interception, with some bypassing still occurring as evidenced by a steady increase of SO_4/Cl until 2010. In 2010 removal of clay from the borrow pit at the toe of the northern TSF batter wall coincided with increases in SO_4/Cl and Total CN, when breakthrough of tailings seepage was observed. Bores MRMB31 and MRMB30 further downstream also show these water quality trends for electrical conductivity, SO_4/Cl, Tot. CN and NO_3_N. This will be discussed further in section 5.

As such there is evidence that seepage mitigation efforts have captured some of the total salt load (shown by declining EC), and that some seepage from the outer batter wall and from within the TSF containment has bypassed seepage interception (shown by SO_4/Cl, NO_3_N and Total_CN trends). At this stage it is too early to tell from monitoring data whether the Toe Seepage Interception Drain and the Downstream Toe Interception Drain, which were respectively reconditioned and installed in 2017 (and collectively recover 598 m^3/day of seepage) are halting or reversing the breakthrough. Early signs are that NO_3_N concentrations are starting to reverse, and total cyanide concentrations are starting to stabilize.

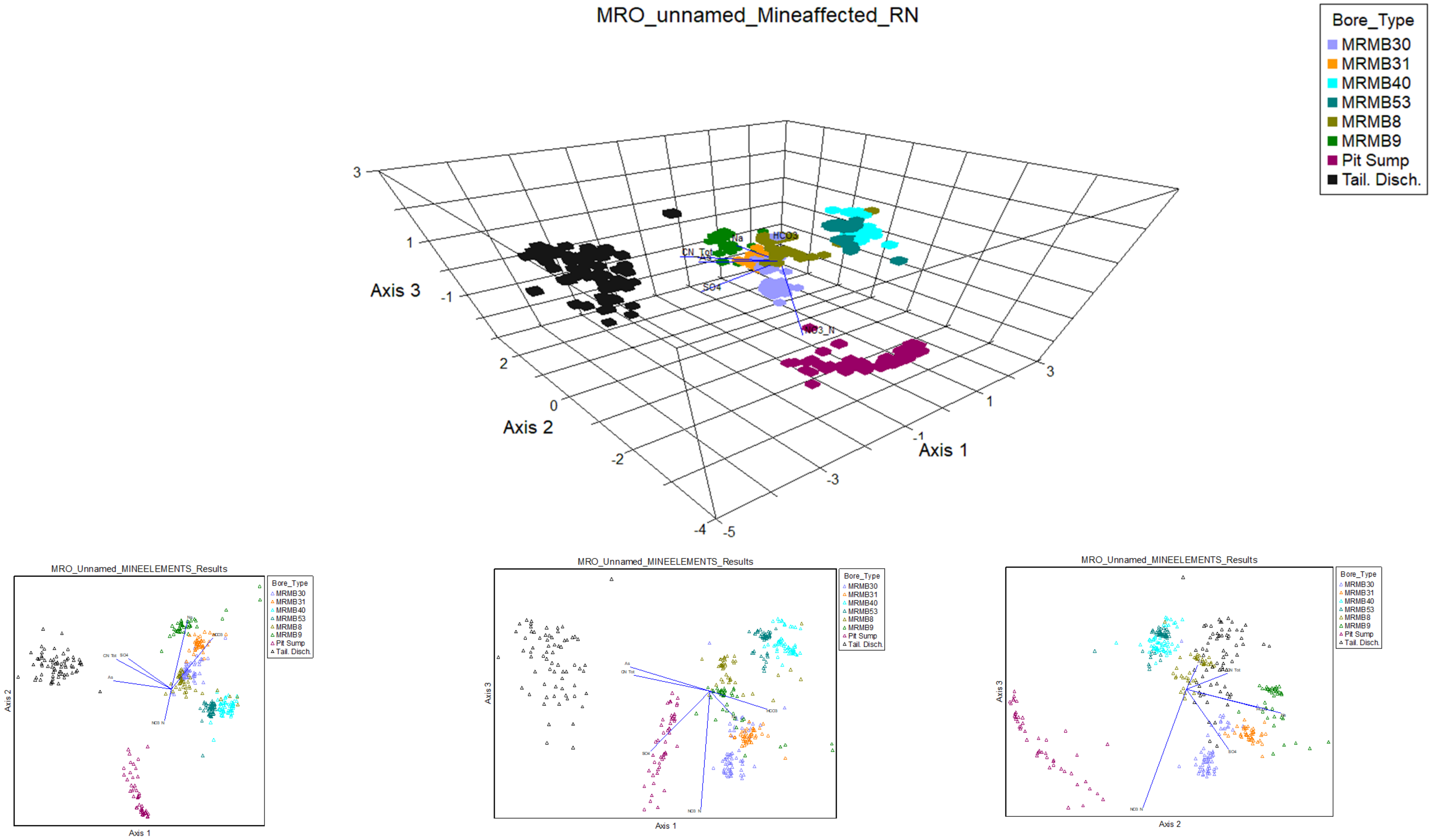
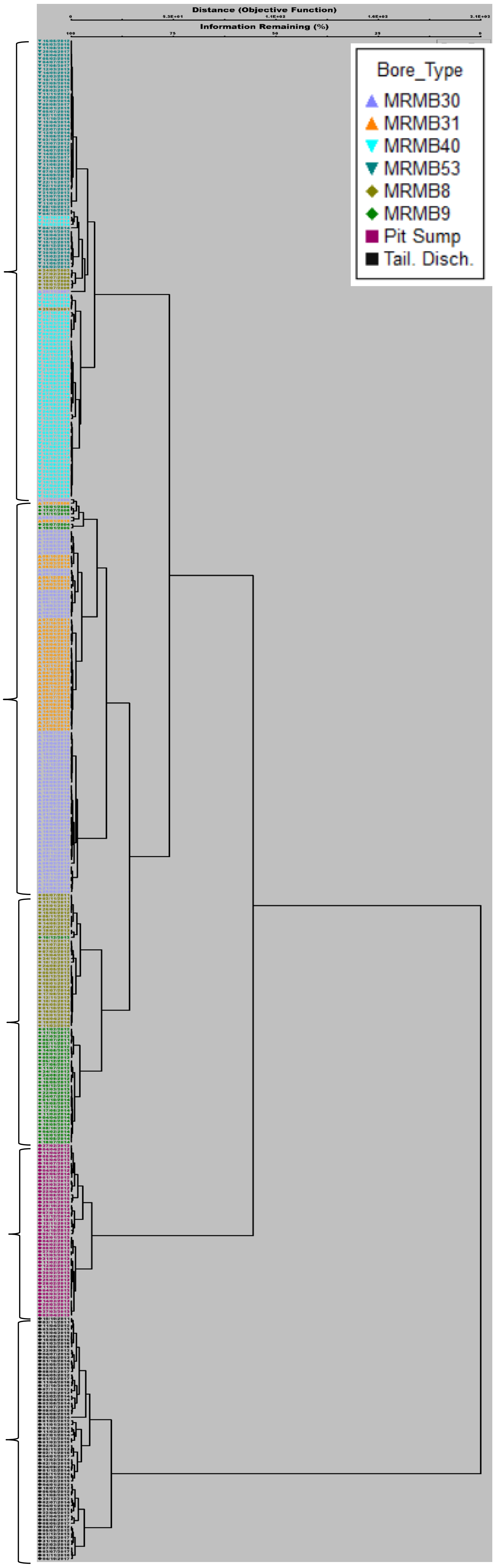


Figure 18: Principal Components Analysis of ions in groundwater and mine affected water in the unnamed creek between Swindon Creek and Rawdon Creek.



"Group 1" containing the downstream compliance bore MRMB53 and another downstream bore MRMB40. MRMB53 and MRMB40 grouped with MRMB8 during 2002-06 and with MRMB30 in 2007, before the latter two bores were affected by mine seepage (marked by SO_4 and Tot. CN trends) This group represents bores not affected by mine seepage.

"Group 2" contains mine affected investigation bores in MRMB31, MRMB30 and during 2004-2010 in MRMB9. These bores occur in a gully line leading into the unnamed gully from the TSF northern wall.

"Group 3" contains investigation bores MRMB09 and MRMB08 sampled that were mine affected between 2011-2014.

"Group 4" representing groundwater sourced from weathering of mined rock used for the outer batter of the TSF wall.

"Group 5" represents TSF water.

Figure 19: Classification of ions in groundwater and mine affected water in the unnamed creek between Swindon Creek and Rawdon Creek.

3.3.1.3 Sub-catchment Scale comparison of the ionic compositions of Rawdon Creek water with mine affected water

Principal Components Analyses (PCA) explained 86% of the variation in groundwater chemistry by three components (with an eigenvalue < 1), using ions associated with:

1) Mining and/or processing of sulfide ore.
    a. Component 1 explained 38% of variance by strong positive correlations ($r \geq 0.69$) of Na, As, SO_4 and Tot. CN with Axis 1; and
    b. Component 3 explained 18% of variance by strong positive correlation ($r \geq 0.45$) of NO_3_N and SO_4, and moderate negative correlation ($r = 0.35$) of total CN and As, with axis 3.
2) Geology, soil and possible mining influences. As with Swindon Creek and the Unnamed Creek, sodium and bicarbonate can be associated with bores that screen in igneous rock, and nitrate can be associated with mined rock (explosive residue). Alternatively nitrate and bicarbonate can be associated with biogeochemical processes. Component 2 explained 30% of variance by Na and HCO_3 being negatively correlated with axis 2, and NO_3_N being positively correlated with axis 2.

From this analysis the principal components of groundwater quality in Rawdon Creek (Figure 20, figures 62 – 67 in Appendix 7.3) were interpreted to be:

- Captured stormwater and seepage water in SD2/SD3 and SD1, which graded between the ionic compositions of waste rock runoff and groundwater. There is influence of tailings seepage in SD1 water;
- Relatively high concentrations of Na and HCO_3 at one end of an environmental gradient involving bores MRMB68, MRMB67 and MRMB64, which screen below a landscape spur located north east of the TSF; and
- Gradation between mine affected water (SD2/SD3), bores close to the TSF and the sediment dams (MRMB32, MRMB5, MRMB6 and others), and bores further away from the TSF and sediment dams (MRMB21, MRMB39).

The hypothesis set by the PCA analysis was that groundwater chemistry varies with proximity to sediment dams that intercept tailings seepage and waste rock runoff. Bores near the sediment dams (MRMB1-6, MRMB23 and MRMB29) have a water chemistry that grades with sediment dam water, indicating that seepage from the sediment dam has mixed with groundwater. Bores further from the sediment dams', MRMB21 and MRMB39, had less mixing with sediment dam water. Bores unaffected by mining occur on a landscape spur some distance from the sediment dams (MRMB64, MRMB67, MRMB68), and have a groundwater chemistry enriched in Na and HCO_3. Of possible relevance is possible association of bores MRMB64, MRMB67, MRMB68 and MRMB74 within a groundwater compartment identified by the groundwater flow model (Northern Resource Consultants, 2019), which will be discussed further in section 3.4.

The next step of classifying data identified five groups shown in Figure 21, as follows:

- Group 1 unaffected by mining that contained bores MRMB64, MRMB67, MRMB68 and MRMB74. The first three of these bores are located on a landscape spur between Rawdon Creek and Twelve Mile Creek, and screen in granites below the Curtis Island Metasediment. Enrichment of sodium ions in these bores can be explained by localized granite weathering. MRMB74 is a member of this group, and its low position in a valley means that solutes generated by weathering of granite further upslope have potentially been transferred down the flank of the landscape spur as discussed in the conceptual model (section 4.1);

- Group 2 are mine affected bores (MRMB1-7, MRMB23, MRMB29) close to a known seepage path from the TSF into Rawdon Creek, along which mine affected water has mixed with groundwater;
- Group 3 are downstream of, or more distant from, the TSF than group 2. Group 3 bores are MRMB21, MRMB39 and MRMB55. Bore MRMB32, also in this group, is close to the TSF. SD2 and SD3 type water has mixed with groundwater in bores MRMB21 and MRMB39. MRMB32 may have had slight occasional exposure to mining affected water, evidenced by pulses of SO_4/Cl, NO_3_N and total cyanide shown by the univariate statistics discussed below;
- Group 4 contains waste-rock type stormwater (represented by pit sump water) that is predominantly SD1 type water, with some SD2 type water; and
- Group 5 represents the tailings source term.

Univariate statistics show trends of COPC over time, and the influence of seepage mitigation strategies between 2005-08 and in 2013 that slowed, and in some bores reversed, seepage trends (Appendix 7.4.3). Trends are interpreted as follows:

- Group 2 bores MRMB1, MRMB2, MRMB3 and MRMB4 displayed increasing electrical conductivity until 2010, after which electrical conductivity decreased. Bores MRMB5 showed a peak in electrical conductivity in 2013, after which the trend stabilized and started to reverse. Bores MRMB23 and MRMB29 displayed slightly increasing electrical conductivity until 2014, after which the trends stabilized and in MRMB29 started to reverse. The reversals of electrical conductivity indicate the capture of solutes in SD1, SD2 and SD3 which were returned to the TSF and removed by enhanced evaporation.

  However, group 2 bores have been subject to TSF seepage that increased after removal of clay from the borrow pit that commenced in 2010, and most dramatically manifested in 2012 when egress of total cyanide reported to groundwater bores MRMB1-7, MRMB23 and MRMB29.

  Increased seepage of SO_4/Cl from the NAF batter wall and/or tailings seepage reported in bores MRMB1 and MRMB2 after 2001, which stabilized and reversed between 2002 and 2006 (coinciding with improved classification and handling of the NAF waste rock used to construct the TSF outer batter wall), then increased between 2009 and 2013 (coinciding with the removal of clay from the borrow pit) after which trends stabilized and reversed again. Further downslope in Rawdon Creek in bores MRMB3 and MRMB4 the stabilization and reversal of SO_4/Cl occurred after 2010, whereas in MRMB5 the SO_4/Cl concentration ratio has been relatively stable, apart from a brief spike in 2006.

- Group 3 includes bores MRMB21, MRMB39 and MRMB55.

  MRMB21 has reported slight oscillations in electrical conductivity records over time, while MRMB39 reports slowly declining electrical conductivity since 2014. In terms of SO_4/Cl concentration ratios MRMB21 reports a slight decrease after 2016, while after late 2017 MRMB39 shows stabilization of an increasing trend. Bores MRMB21 and MRMB39 have shown stabilization of an increasing Total CN trend. As such bores MRMB21 and MRMB39 have been less influenced by mining activity than group 2 bores, with mine influence stabilizing or diminishing over time.

  Bore MRMB55 has shown stable electrical conductivity recordings over time, and a slight increase in the SO_4/Cl concentration ratio, interpreted to be either early lead indication of mine seepage or alternatively localized oxidation of sulfides in the aquifer. Total CN has always been below detection in MRMB55.

In summary there are a group of bores unaffected by mining (MRMB64, MRMB67, MRMB68 and MRMB74), located on or flanked by a landscape spur between Rawdon Creek and Twelve Mile Creek. Enrichment of sodium ions in these bores can be explained by localized granite weathering, and downslope movement of salts, which will be discussed further in sections 3.4 and 4.

Along the Rawdon Creek drainage line, bores MRMB1-7, MRMB23, MRMB29, MRMB21 and MRMB39 are interpreted as being influenced by mine seepage (refer groups 1 and 4 in figures 14 and 15), particularly after 2012 when clay was removed from the borrow pit below the north wall of the TSF. Mine seepage is shown by time-series graphs of SO_4/Cl concentration ratios and of total cyanide concentrations (Section 7.4.3), which show that mine influence is still present in groundwater downstream of the SD3 impoundment. These trends also show the influence of improved waste rock management in 2005 and seepage mitigation strategies in 2013 that slowed, and in some bores reversed, seepage from the TSF.

Bore MRMB55 has time series trends interpreted to be either early lead indication of mine seepage or alternatively localized oxidation of sulfides in the aquifer.

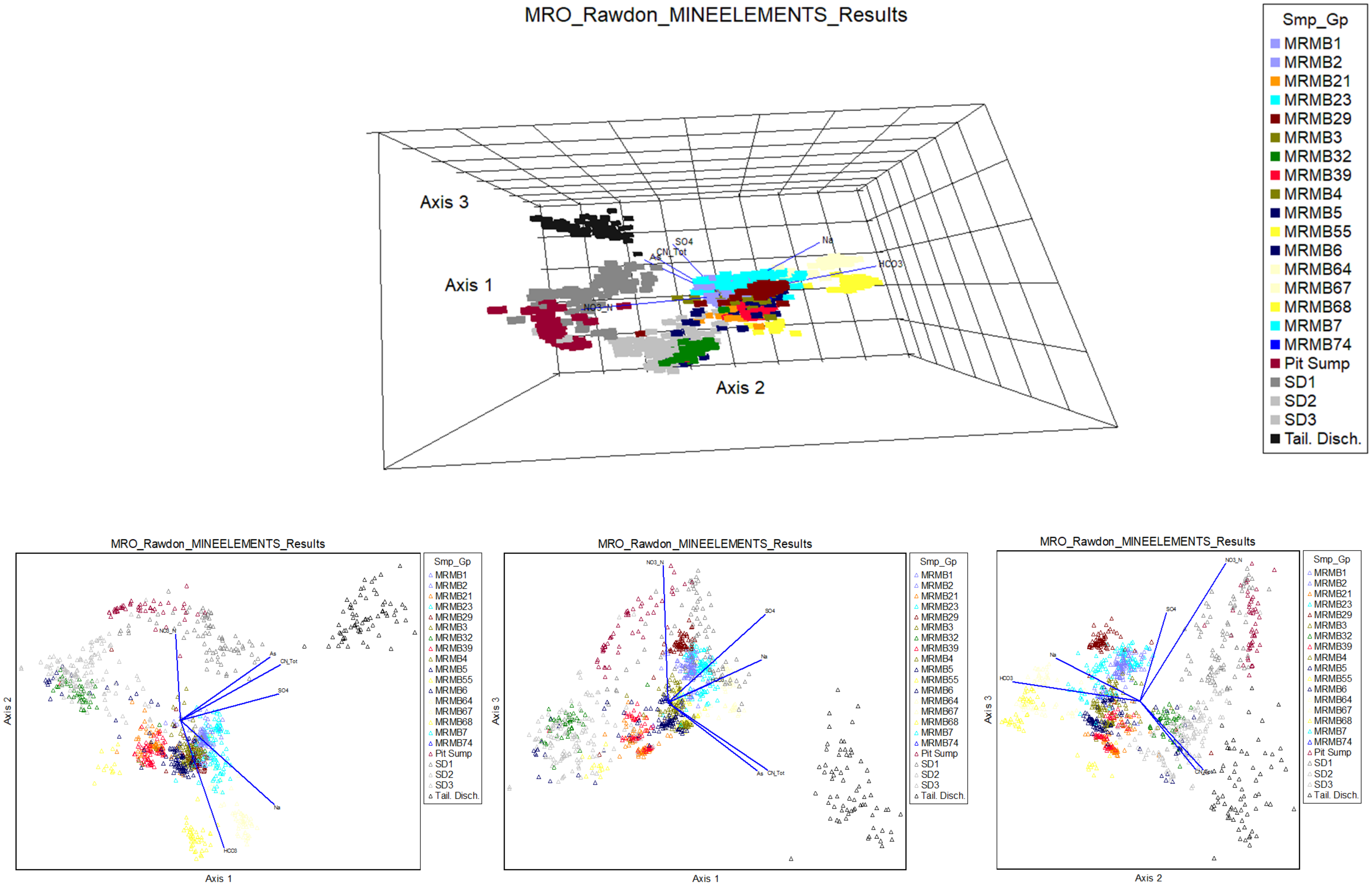
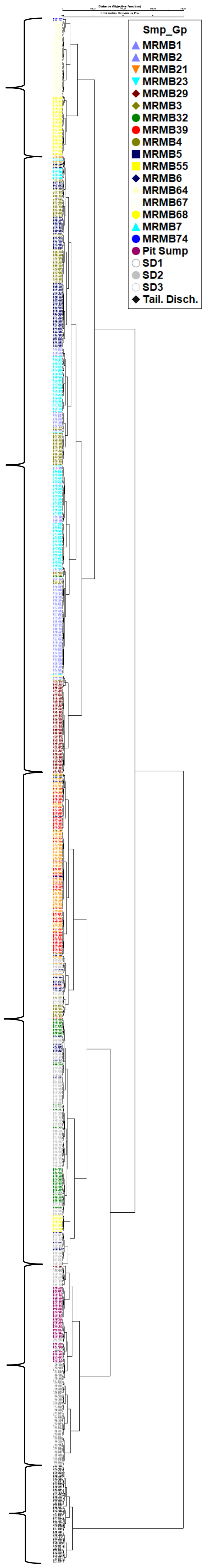


Figure 20: Principal Components Analysis of ions in groundwater and mine affected water from Rawdon Creek.



"Group 1" containing the downstream compliance bore MRMB74 and three bores located on a landscape spur (MRMB64, MRMB67 and MRMB68). These bores are not mine affected and screen in relatively fresh granites below Curtis Island Metasediment. Enrichment in sodium is explained by granite weathering.

"Group 2" are mine affected bores close to the known seepage path from the TSF into Rawdon Creek. Seepage has mixed with groundwater. These bores are MRMB1-7, MRMB23 and MRMB29.

"Group 3" are MRMB21, MRMB39, MRMB32 and MRMB55. MRMB21 and MRMB39 include seepage from SD2 and SD3 that mixed with groundwater downstream of group 2 and the TSF. MRMB32, also in this group, is close to the TSF but apparently not in the seepage path associated with group 2. MRMB55 might not be mine affected.

"Group 4" containing waste-rock type stormwater (represented by pit sump type water) and predominantly SD1 type water (with some SD2 type water).

"Group 5" containing Tailings type water. Group 5 is distinguished from the other groups.

Figure 21: Classification of ions in groundwater and mine affected water from Rawdon Creek.

3.3.1.4 Sub-catchment Scale Comparison of the ionic compositions of Twelve Mile Creek water with mine affected water

Principal Components Analyses (PCA) explained 84% of the variation in groundwater quality data on 3 axes (with an eigenvalue <1), with the following principal components as shown in Figure 22 and figures 68 – 73 in Appendix 7.3:

1) Seepage from waste rock stockpiled in the NWRD. Component 1 (Axis 1) explained 50% of variance in data, using ions associated with rock weathering (HCO_3, Na) that positively correlated with axis 1 ($r \geq 0.48$) and ions associated with mining of sulfide ore using explosives (SO_4, NO_3) that negatively correlated with axis 1 ($r \geq -0.40$). Water types rank along component 1 in the following order: (a) stormwater from mined rock (pit sump type water and waste rock dam water), (b) mine-affected groundwater in the footprints of WD1 and WD2 (MRMB24, MRMB25, MRMB26, MRMB27 and MRMB63), (c) groundwater in the vicinity of WD3 and the aquifer that supplied the former homestead (MRMB60, MRMB61, MRPB1) and (d) the upstream control site (MRMB37). Component 1 describes a gradient from the waste rock affected source term to native groundwater.
2) Component 2 explained 18.5% of variance in data structure by As and Tot. CN (positively correlated with axis 2). Total CN is potentially sourced from wash-down water from South Dam that is routinely used as dust suppressant on haul roads. Arsenic is present both in seepage water from mined rock, and in non-mined groundwater associated with MRMB60, MRMB61 and MRMB62. A non-economic gold anomaly near MRMB60 (mineralisation) potentially explains the presence of As in this area.
3) Component 3 explained 14.9% of variance in data structured by Tot. CN (negatively correlated with axis 3) and As (positively correlated with axis 3). This axis may assist with discriminating between mined rock (that contains cyanide from recycled wash down water) and non-mined mineralisation that contains As but not cyanide.

As such the principal components of groundwater in Twelve Mile Creek are:

- Mined rock characterised by NO_3 and SO_4, with inclusion of Tot. CN potentially included in dust suppression water sourced from South Dam;
- Native groundwater characterised by high concentrations of Na and HCO_3 in groundwater screened in weathered rock; and
- Mineralisation influencing high concentrations of As in both native groundwater (near MRMB60, MRMB61, MRMB28 and MRMB37) and in mined rock stockpiled in the NWRD.

The hypothesis set by the PCA analysis (refer Figure 22, figures 68 – 73) was that seepage water from the NWRD contains blast residues (NO_3_N) and sulfur (SO_4). These ions were relatively concentrated in stormwater and seepage water collected in the Waste Rock Dams. Native groundwater can be distinguished by the relatively high concentrations of Na and HCO_3 in the weathered regolith. There is evidence of non-mined mineralization near MRMB60, MRMB61, MRMB28 and MRMB37, which potentially explains the presence of chalcophile elements (e.g. As) in groundwater from this part of the Twelve Mile Creek catchment.

The next step of classifying data identified five groups shown in Figure 23, as follows:

- Group 1 that includes the upstream reference bore MRMB37, and bores in the upslope section of Twelve Mile Creek (MRMB24, MRMB60 and MRPB1). MRMB62 briefly associated with this group during July, November and December 2015. Of interest unmined mineralization of sulfide is reported near bores MRMB24 (Equigold, 2008), MRMB60 and MRMB37 (Evolution, 2009), so there is the potential influence of unmined mineral deposits with some of the characteristics of NWRD seepage;
- Group 2, also in the upstream part of Twelve Mile Creek, includes MRMB61, MRMB62 with some association with MRPB1;
- Group 3 includes MRMB38 (the downstream compliance bore) and MRMB63. There may be occasional inclusion of MRMB26 groundwater (June 2012, December 2012, May 2017) and waste rock dam type seepage water with this group;
- Group 4 includes MRMB25 and MRMB26 downstream of Waste Rock Dam 1, and MRMB27 downstream of Waste Rock Dam 2; and
- Group 5 is Pit Sump and Waste Rock Dam type water.

Univariate statistics (Appendix 7.4.5) show temporal trends of COPC as follows:

- Group 1 features sulfate, nitrate and arsenic ions mobilised in groundwater under scenarios that may or may not involve mine influence, as discussed below;
- Group 2 showed no evidence of mine influence in MRMB61 or MRMB62 based on electrical conductivity and SO_4/Cl trends. There is long-term variation in NO_3_N concentrations in MRMB61, but no trend indicative of breakthrough of nitrate residues from the NWRD;
- Group 3 showed no evidence of mine influence in MRMB38, based on the electrical conductivity, SO_4/Cl and NO_3_N trends, but there is mine influence in samples representing the waste rock dams and MRMB26. MRMB63 showed an increasing SO_4/Cl trend that stabilised and reversed after 2014, but no commensurate change in EC and NO_3_N despite the SO_4/Cl trend. It is unclear whether or not MRMB63 is mine affected, as other landscape processes are active (discussed below).
- Group 4 showed breakthrough of mine influenced seepage water, based on electrical conductivity, SO_4/Cl concentration ratios and NO_3_N concentrations;
- Group 5 is mine affected water.

Groups 1, 2 and 3 water types show downslope movement of sulfate, nitrate and arsenic ions mobilised in groundwater towards Twelve Mile Creek under hypothetical scenarios:

a. natural mobilisation of gypsum and nitrate in agricultural land sloping towards Twelve Mile Creek (no mine influence);

b. mobilisation of ions naturally present in soil (from weathering of unmined mineral deposits) by increased groundwater flow driven by groundwater mounding below the NWRD (secondary mining influence); and/or

c. seepage of ions generated by weathering of waste rock in the NWRD (direct mining influence).

Scenario a is likely for MRMB37, MRMB61 and MRMB62, based on consistent SO_4/Cl concentration ratios over time, and variable (not increasing) NO_3_N concentrations in groundwater over time.

Scenario a is likely for MRMB38. While the ratio of sulfates to chloride in this bore is high, the SO_4/Cl ratio has remained relatively constant over time. This result is consistent with hyporheic movement of salts coupled with evaporative/ evapotranspirative concentration processes described by the conceptual model for dryland salinity in granitic terrain of Douglas and Cox (1994). This process is discussed in section 4.

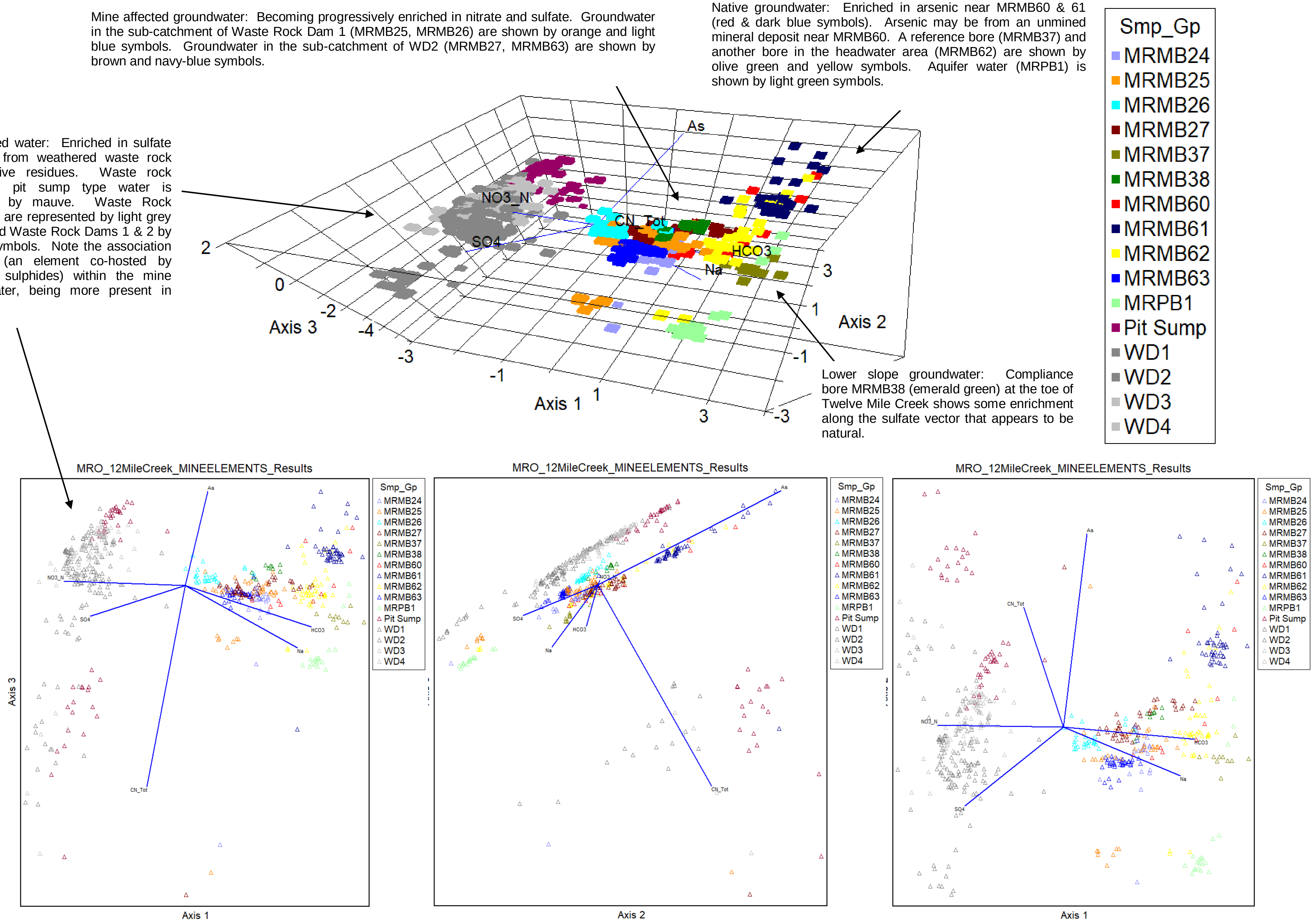
Scenarios a and c are likely for MRMB28/78, based on electrical conductivity readings and SO_4/Cl concentration ratios over time. In these adjacent bores, electrical conductivity readings increased between 2005 and 2008, and between 2017 and 2019, when evapo-transpiration during failed wet seasons caused salts to concentrate in the aquifer. During these dry periods SO_4/Cl concentration ratios did not increase, indicating that additions of sulfate from seepage of mine affected water did not report to the aquifer. However wet season overtopping events on 15/12/2010 and 11/01/2013 resulted in SO_4/Cl concentration ratios peaking in the aquifer shortly after these incidents, then disappearing as the temporary mining influence was flushed out of the aquifer. While NO_3_N did not report during the 2010 peak (tree roots were observed in the bore, so plant uptake of nitrate might have occurred), NO_3_N reported to MRMB28 and peaked shortly after the 2013 event. As such the overtopping events reported to groundwater as transient events.

Scenarios b or c are plausible for MRMB60 and MRMB24, which report progressive increases in the SO_4/Cl concentration ratio, and in MRMB63 that reported an increase in the SO_4/Cl concentration ratio that stabilised and reversed after 2014. In MRMB60, NO_3_N concentrations also increased over time, but in MRMB24 and MRMB63 NO_3_N concentrations did not increase over time.

Isotopic analyses performed by Northern Resources Consultants (2015) show that the sulfate in MRMB24 and MRMNB63 is either mine derived or associated with sulfide mineralization upgradient of MRMB24 (Equigold, 2008) and MRMB63 (Evolution, 2009), and that denitrification processes may have removed nitrate from groundwater in MRMB63. The Northern Resources Consultants (2015) analysis of dissolved nitrate and sulfate observed a strong isotopic shift in $\delta^{15}N_{Nitrate}$ of 71.9 $^{o}/_{oo}$ and in $\delta^{18}O_{Nitrate}$ of 36.8 $^{o}/_{oo}$ in MRMB63 that conformed with an expected trendline for denitrification, and an isotopic shift in $\delta^{15}N_{Nitrate}$ of 17.1 $^{o}/_{oo}$ and in $\delta^{18}O_{Nitrate}$ of 17.5 $^{o}/_{oo}$ in NWRD seepage near MRMB24 that was close to the expected isotopic signature for nitrate in explosives (and similar to the isotopic signatures observed in WRD1-4).

Based on the stable isotope investigation (Northern Resources Consultants, 2015), scenario b likely for MRPB1.

Scenario c is suggested for MRMB25, MRMB26 and MRMB27, with groundwater being sucked through the aquifer and returned to WD1 by the pumpback bores installed in MRMB26 and MRMB27.



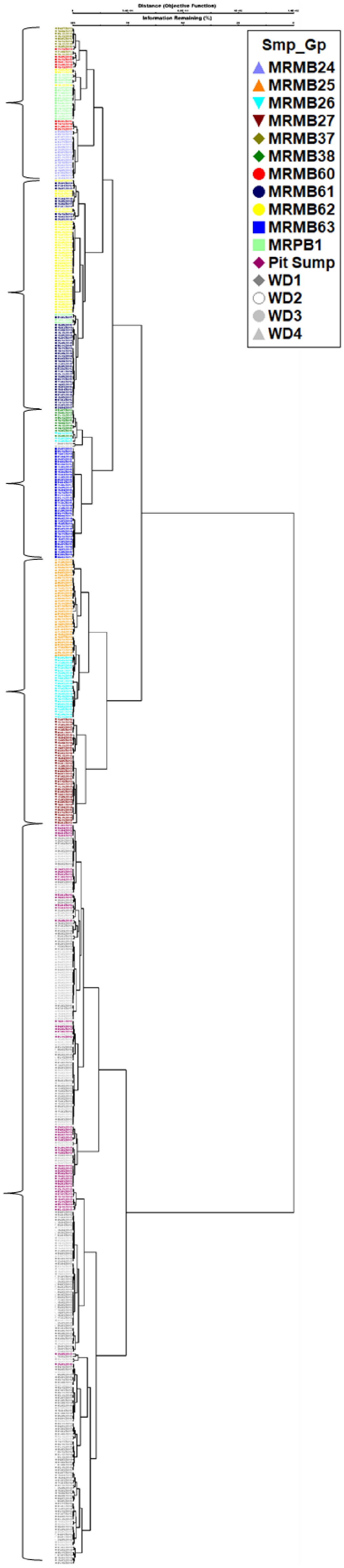
Mine affected groundwater: Becoming progressively enriched in nitrate and sulfate. Groundwater in the sub-catchment of Waste Rock Dam 1 (MRMB25, MRMB26) are shown by orange and light blue symbols. Groundwater in the sub-catchment of WD2 (MRMB27, MRMB63) are shown by brown and navy-blue symbols.

Native groundwater: Enriched in arsenic near MRMB60 & 61 (red & dark blue symbols). Arsenic may be from an unmined mineral deposit near MRMB60. A reference bore (MRMB37) and another bore in the headwater area (MRMB62) are shown by olive green and yellow symbols. Aquifer water (MRPB1) is shown by light green symbols.

Mine affected water: Enriched in sulfate and nitrate from weathered waste rock and explosive residues. Waste rock leachate in pit sump type water is represented by mauve. Waste Rock Dams 3 & 4 are represented by light grey symbols, and Waste Rock Dams 1 & 2 by dark grey symbols. Note the association of arsenic (an element co-hosted by mineralised sulphides) within the mine affected water, being more present in WRD3 & 4.

Lower slope groundwater: Compliance bore MRMB38 (emerald green) at the toe of Twelve Mile Creek shows some enrichment along the sulfate vector that appears to be natural.

Figure 22: Principal Components Analysis of ions in groundwater and mine affected water from Twelve Mile Creek.



"Group 1" containing the upstream compliance bore MRMB37 and groundwater bores MRMB24, MRMB60 and MRPB1. There is association of MRPB1 and MRMB62 with this group and with group 2. There may be As associated with an unmined mineral deposit near groundwater bore MRMB60.

"Group 2" are MRMB61 and MRMB62, with some association of MRPB1. There may be As associated with an unmined mineral deposit near MRMB61

"Group 3" is native groundwater MRMB38 and MRMB63. There may be some inclusion of seepage water (i.e. Waste Rock Dam and MRMB26 type water) with this group. MRMB38, the downstream reference site some distance away has some coincidental landscape control unrelated to mining, which influenced this association (e.g. higher HCO_3, SO_4 and Na concentrations associated with lower landscape position).

"Group 4" is native groundwater (MRMB25, MRMB26 and MRMB27) that contains seepage water from WRD1 and WRD2

"Group 5" containing Pit Sump and Waste Rock Dam type water. This water contains seepage and stormwater runoff from the Northern Waste Rock Dump.

Figure 23: Classification of ions in groundwater and mine affected water from Twelve Mile Creek.

3.3.1.5 Sub-catchment Scale Comparison of the ionic compositions of Mingham Creek water with mine affected water

Principal Components Analyses (PCA) explained 92% of the variation in groundwater quality data on 3 axes (with an eigenvalue < 1), as shown in Figure 24 and figures 74 – 79 (Appendix 7.3) and described below:

1) Component 1 (axis 1), which explained 38% of the data variation, described ions associated with mining and processing of sulfide ore (As, SO_4, Tot. CN) that negatively correlated with axis 1. Total CN and As report to bores MRMN69 and MRMB19, which are close to the southern margin of the TSF. Arsenic reports to several bores in the southern drainage (MRMB17, MRMB35, MRMB70, MRMB71), which can be explained by known mineralisation in unmined rock (Evolution, 2009);
2) Component 2 (axis 2), which explained 33% of the data variation, described ions associated with weathering of volcanic rock (Na and HCO_3 positively correlate with Component 2) and hot bushfires or explosive residues (NO_3_N negatively correlated with Component 2); and
3) Component 3 (axis 3) explained 15% of the data variation. It was structured by Na and SO_4 (negative correlation of $r \geq 0.45$ with axis 3) as well as As (positive correlation of $r = 0.43$ with axis 3).

As such the principal components of groundwater in the southern drainage were:

- Tailings seepage structured by inclusion of total cyanide, with influences of As and SO_4;
- Solutes generated from mined rock structured by the inclusion of NO_3_N[20], and SO_4 from weathering of pyrite; and
- Native groundwater structured by relatively high concentrations of Na and HCO_3, and influences of As and SO_4 from sulfide minerals.

The hypothesis set by the PCA analysis was that water sourced from NAF waste rock can be traced by blast residues (marked by NO_3_N) and sulfur (marked by SO_4). Fires in the catchment above the Western Stormwater Diversion Drain were known to occur in 2014, 2017 and 2018 are another possible source of NO_3_N in ash residues reporting to groundwater. Because the southern drainage hosts sulfide mineralization in some faults (e.g. Swindon Fault) that has been proven by exploration but has not been mined, the enhanced hydraulic head caused by groundwater mounding below the South Dam, West Waste Rock Dump and West Waste Rock Dam, might locally mobilize SO_4 and As ions reporting to some monitoring bores (refer Figure 24 and figures 74 – 79 in Appendix 7.3).

The next step was to classify data into groundwater groups (Figure 25), as described below:

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[20] The presence of NO_3_N in MRMB70 (with notable absence of other indicators of mined rock such as SO_4/Cl) indicate possible association with residues from a hot bushfire in 2014 that entered the Western Stormwater Diversion Drain. This drain hosts surface expression of an offshoot of the Swindon Fault that at depth is screened by MRMB70, so it is possible that this Swindon Fault groundwater compartment recharged from the surface during the wet season following this bushfire.

Group 1 is groundwater from MRMB17, MRMB18, MRMB36, MRMB69, MRMB72 and the compliance bore MRMB75. This group is relatively enriched in Na and HCO_3 with some bores reporting high concentrations of SO_4 and/or As. These bores are not considered to be mine affected, except for MRMB69 for reasons discussed below;

Group 2 is groundwater from MRMB17 and MRMB18, which is enriched in Na and HCO_3 relative to other groundwater bores on the mine lease, with SO_4 also being present. Total CN concentrations are low, though NO_3_N and As are present;

Group 3 is groundwater from MRMB50, MRMB70 and MRMB71 which feature Na, abundant HCO_3, low to moderate SO_4 concentrations, and low to high As concentrations;

Group 4 is groundwater in bores MRMB19, MRMB18 and MRMB35, which screen along the southern drainage line and away from the TSF. MRMB19 screens mine affected groundwater;

Group 5 is mine affected water (Pit Sump water, South Dam, West Dam and some MRMB19 samples); and

Group 6, distinct from the other groundwater types, is Tailings Discharge.

Further evaluation of univariate trends of COPC concentrations over time (Appendix 7.4.6) indicated:

Group 1. MRMB69 has shown progressive increases in SO_4/Cl and Tot. CN since 2014, which indicates increasing ingress of mine influenced water into this bore. Two bores downslope of the West Dam, MRMB72 and MRMB36, show stable SO_4/Cl concentration ratios and increasing electrical conductivity values (mainly between 2012 and 2014), which indicate that the sulfate trend observed since 2012 (Appendix 7.4.6) is being normalized by evaporation and/or evapotranspiration (effects of evaporation/evapotranspiration are discussed in section 4).

MRMB75 screens water adjacent to Mingham Creek, in the wet base of a forested valley that would receive water and solutes from higher in the landscape (discussed further in section 4). Based on SO_4/Cl concentration ratios and NO_3_N concentrations there is no evidence for mine effects in MRMB75. MRMB59, a “dry” bore that screens groundwater further upslope in this valley, also shows no evidence of mine effects based on these parameters. However low-trace concentrations of cyanide have occasionally reported to MRMB75 and MRMB59. The reason for cyanide traces being present is unclear based on hydrogeological considerations (discussed in section 3.4), because the pit forms a localized groundwater sink between the TSF and bores MRMB59 and MRMB75 and there are no direct groundwater flow paths between the TSF and these receptors. It is possible that naturally occurring cyanide in eucalyptus reports to groundwater (occasional trace concentrations of cyanide have been reported elsewhere in the mining lease), or alternatively it is possible that there has been cross contamination involving sampling equipment. These possibilities are being further investigated during Stage 2 of the Environmental Evaluation.

Group 2. MRMB17 and MRMB18 featured stable or slightly increasing SO_4/Cl ratios between 2001 and 2012. After 2012 the SO_4/Cl concentration ratio declined in MRMB18, which coincided with significant rainfall events and West Dam construction. In MRMB18 there were also sudden decreases in electrical conductivity values, and SO_4 concentrations, which may be explained by rainfall ingress entering the aquifer.

Group 3. MRMB50, MRMB70 and MRMB71 are groundwater bores on sloping ground that screen in dacite or granodiorite rocks of the Aranbanga Andesite. These bores screen native groundwater, with low but slowly increasing SO_4/Cl concentration ratios. There is known mineralization associated with faults in this area, which may explain the presence of As in MRMB70 and MRMB71. NO_3_N reported to MRMB70 between April 2014 and May 2016, which coincided with a hot fire in the catchment upslope of the Western Stormwater Diversion Drain during 2014 (the possibility of recharge of MRMB70 from this drain is discussed in footnote 17);

Group 4. MRMB19 shows ingress of SO_4, an increasing trend for electrical conductivity between 2001 and 2010 and some high values of NO_3_N. The SO_4/Cl concentration ratios have varied very substantially over time, indicating ingress of mine-affected seepage water. This bore is in the middle of South Dam, and impounded water flowed into the bore from the dam. MRMB18 located further downslope featured a slow, progressive increase in the SO_4/Cl concentration ratio, which declined after the West Dam was built.

Group 5 and Group 6 are mine affected water.

In summary there is no evidence for mining influence reporting to bores MRMB59, MRMB75, MRMB36, MRMB72 and MRMB35.

There is evidence of ingress of seepage from the tailings dam and/or from waste rock seepage in bores MRMB69 and MRMB19, as shown by SO_4/Cl concentration ratios and increasing trend/spike occurrences of total cyanide reporting to groundwater over time.

There is evidence of stable or slowly increasing SO_4/Cl concentration ratios in MRMB17, MRMB50, MRMB70, MRMB71. Arsenic reports to MRMB70 and MRMB71, and a pulse of NO_3_N reported to MRMB70 in recharge water following a hot bushfire event. It is possible that hydrostatic displacement of the groundwater table by the combined effects of the TSF, South Dam and West Dam has mobilised sulfur and arsenic associated with known mineralisation along the margins of faults in the southern drainage.

MRMB18 featured a change in electrical conductivity values and SO_4/Cl concentration between 2012 and 2014, which coincides with rainfall events and the construction of West Dam. This aquifer is in a sloping catchment and subject to recharge and dewatering in response to rainfall and evaporation/evapotranspiration. The significant rainfall events of January 2011, March 2012 and January 2013 have recharged the aquifer screened by MRMB18, which reported as pulses of low electrical conductivity that coincided with spikes of NO_3_N and SO_4/Cl. The presence of NO_3_N and SO_4/Cl suggest that recharge included mine-affected water

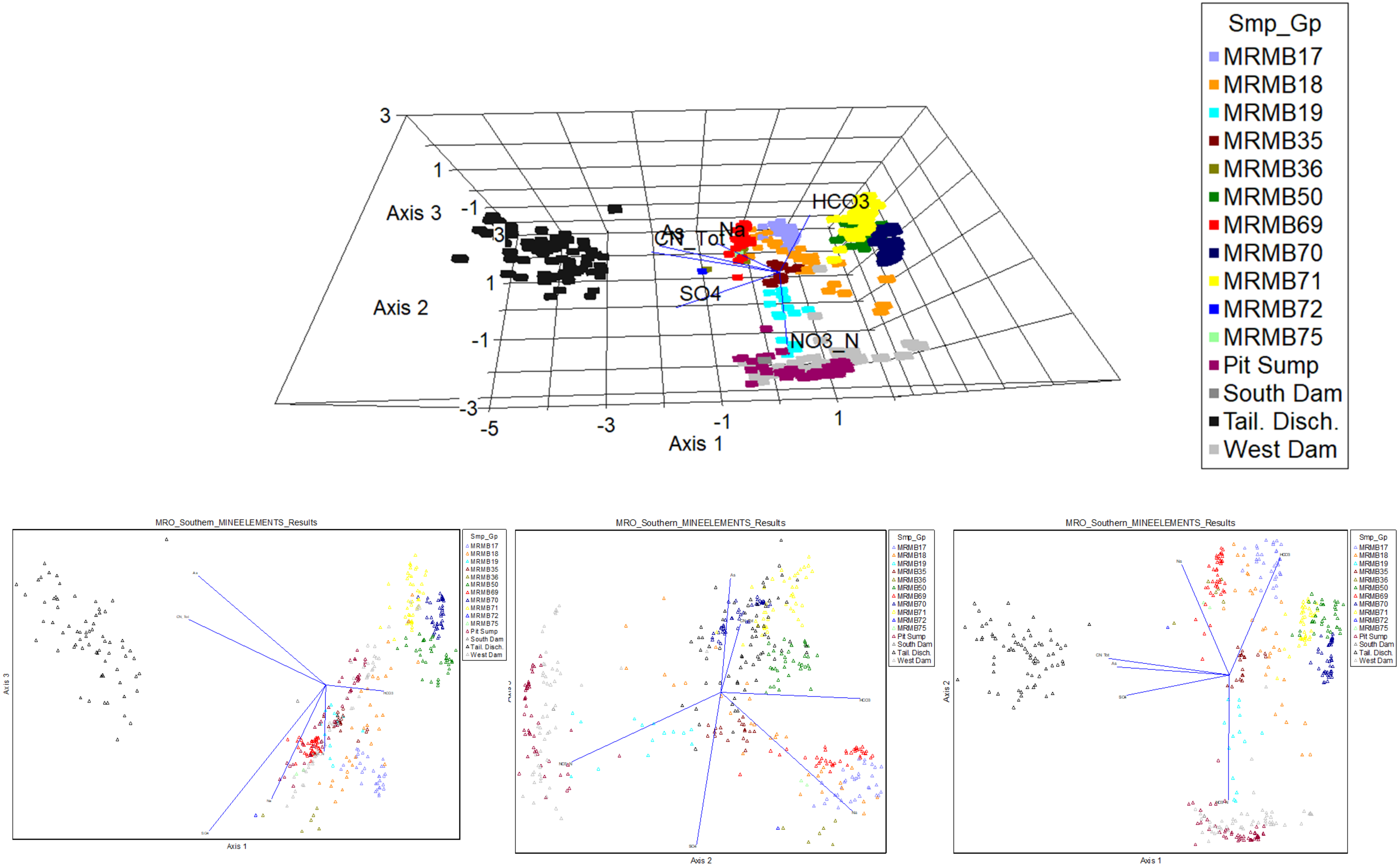
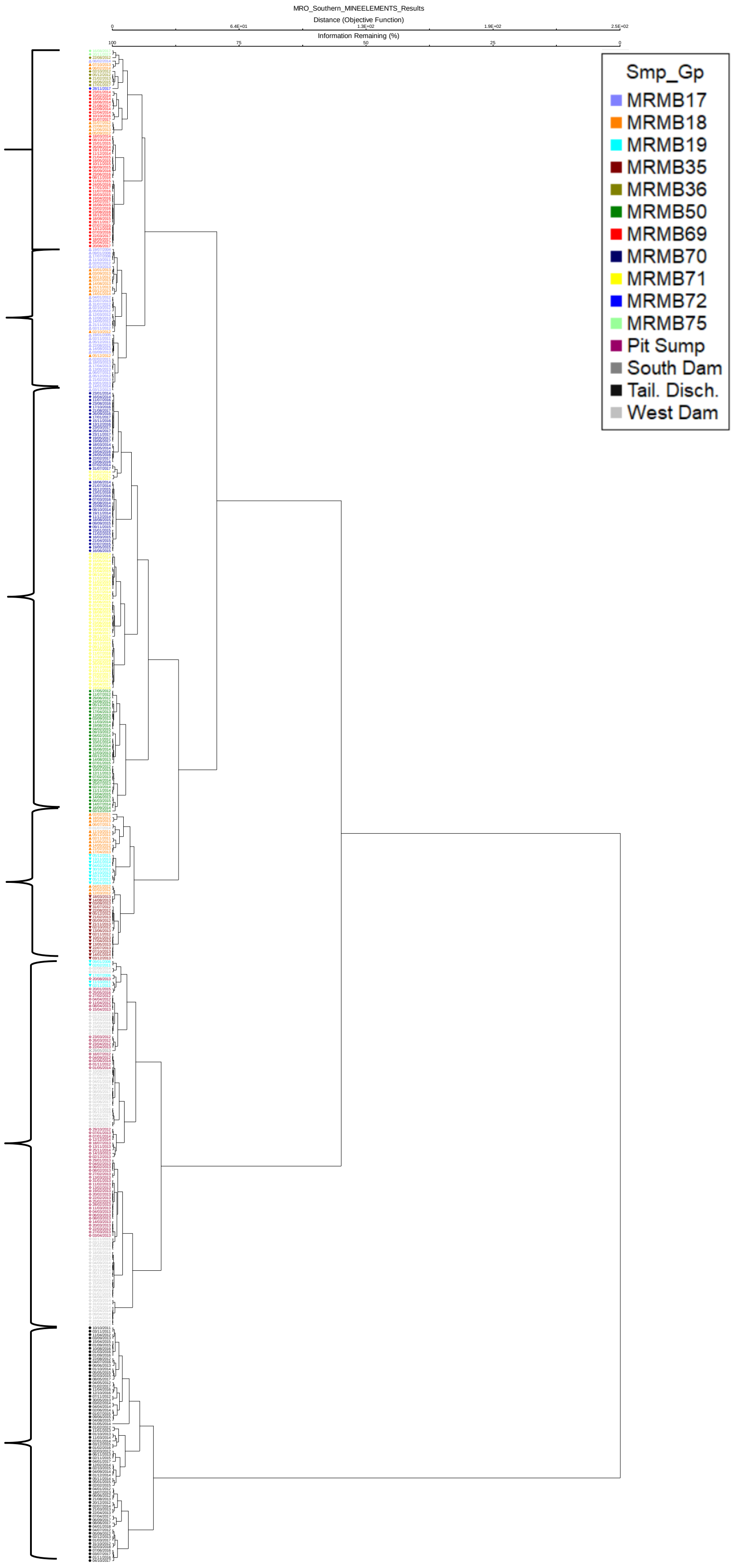


Figure 24: Principal Components Analysis of ions in groundwater and mine affected water from the southern drainage including Mingham Creek.



"Group 1" is groundwater in the downstream compliance bore MRMB75 and in bores MRMB36, MRMB18, MRMB17, MRMB69 and MRMB72. MRMB36 screens in dacite with minor carbonate, MRMB69 in dacite and MRMB72 in fresh granite. MRMB69 has received seepage from the TSF (evidenced by Tot. CN concentrations), and the other bores do not appear to be affected by mining.

"Group 2" is groundwater in MRMB17 and MRMB18. MRMB17 screens in rhyolite, and MRMB18 in silicified, brecciated andesite

"Group 3" is groundwater in MRMB50, MRMN70 and MRMB71. MRMB50 and MRMB70 screen in dacite and MRMB71 in granodiorite.

"Group 4" includes MRMB18, MRMB19 and MRMB35, which screen below the southern drainage line and along the inferred West Dam Fault.

"Group 5" includes waste rock affected water (Pit Sump water, South Dam, West Dam), as well as some MRMB19 samples.

"Group 6" containing Tailings Discharge. This group is distinct from the other groups.

Figure 25: Classification of ions in groundwater and mine affected water from the southern drainage including Mingham Creek.

3.3.1.6 Sub-catchment Scale comparison of the ionic compositions of bores along the access road/processing area with mine affected water

Bores MRMB20, MRMB45, MRMB46 and MRMB49 screen the aquifer between the TSF, the landscape spur east of the TSF and the open pit. Groundwater flow to the south (into the pit or down the southern drainage) is limited by a fault barrier. This area is affected by seepage that egresses south east from the TSF, which is managed by an interception trench and well (Stans Well) that transfers collected seepage to the process water dam for reuse.

Bores MRMB55, MRMB64, MRMB67 and MRMB68 have already been reviewed in the context of the Rawdon Creek sub-catchment (section 3.3.1.3), with MRMB64, MRMB67 and MRMB68 being shown to be a distinct subgroup of groundwater. To evaluate the possibility of seepage from the south east of the TSF mixing with native groundwater below this landscape spur, these groundwater bores are reviewed again here in the context of this possible groundwater flowpath.

Principal Components Analyses (PCA) explained 93% of the variation in groundwater quality data on 3 axes (with an eigenvalue < 1). Results shown in Figure 26, and in figures 80 – 85 (Appendix 7.3) identify:

1) Component 1 (41% of variance explained) structured by Na, HCO_3, Tot. CN and As that negatively correlate with axis 1. NO_3_N positively correlates with Axis 1;
2) Component 2 (32% of variance explained) structured by HCO_3 (positive correlation with axis 2) and Tot. CN, SO_4, NO_3_N (negative correlation with axis 2); and
3) Component 3 (20% of variance explained) structured by Na, SO_4, HCO_3 and NO_3_N (positive correlation with axis 3) as well as Tot. CN (negative correlation of 0.43).

The principal components of variation in the ionic composition of groundwater along the access road of the mine lease are hard to group as discrete water types, except for tailings type water and the groundwater type under the landscape spur (MRMB64, MRMB67 and MRMB68). The aquifer under the access road/processing area is interpreted as being a mixing zone where source terms from tailings and waste rock have blended with native groundwater. Figure 26 and figures 80 – 85 (appendix 7.3) show:

- Water contained by sediment dams 2 and 3, the Pit Sump, South Dam and West Dam structured by relatively high to moderate NO_3_N and SO_4 concentrations;
- Tailings affected water structured by relatively high As, Tot. CN and SO_4 concentrations; and
- Native groundwater structured by relatively high Na, HCO_3 concentrations, and relatively moderate SO_4, As, and NO_3 concentrations.

The hypothesis set by the PCA analysis was that water sourced from waste rock can be traced by blast residues (marked by NO_3_N) and SO_4. Water sourced from tailings seepage can be traced by total cyanide and arsenic. Native groundwater on the landscape spur features relatively high concentrations of sodium and bicarbonate, and relatively moderate concentrations arsenic, sulfur and nitrate.

The next step was to classify data into groundwater groups (Figure 27) as follows:

Group 1. MRMB46, MRMB49, and some MRMB20 groundwater samples contain a combination of SO_4, NO_3_N and Tot. CN concentrations that indicate mine affected groundwater. This groundwater groups predominantly with SD1/South Dam type water, and to a lesser extent with pit sump and SD3 type water;

Group 2. MRMB20 groundwater samples contain a combination of NO_3 and SO_4 concentrations that indicate mine affected groundwater, which grouped predominantly with seepage from waste rock (i.e. pit sump type water). Some SD3 and SD1 type waters, known to contain tailings seepage as well, are represented in this group;

Group 3. MRMB55 and MRMB45 groundwater grouped with SD2 type water, and to a lesser extent with SD1 type water. In the classification performed for Rawdon Creek, the association of MRMB55 groundwater and SD2 type water was also evident;

Group 4. Groundwater under the landscape spur (MRMB64, MRMB67 and MRMB68) formed a distinctive group, which was observed also in the classification performed for Rawdon Creek; and

Group 5. Tailings discharge, which formed a water type distinguishable from other water types in the Mount Rawdon Lease.

Further evaluation of univariate trends of COPC concentrations over time (appendices 7.6, 7.7 and 7.8) indicated:

Group 1. MRMB46 and MRMB49 showed breakthrough of tailings seepage into the aquifer, reporting as increasing concentrations of total cyanide over time in these bores. Because trends have reversed in MRMB46 since 2013, seepage management in the vicinity of Stans Well appears successful. The trend reversal shows removal of total salts (measured by electrical conductivity), NO_3_N and Tot. CN from the aquifer, and an increasing presence of SO_4/Cl in the aquifer represents the increasing proportion of seepage water that is being drawn through Stans Well (which is near MBRM46). Further downgradient along the access road in MRMB49 stabilisation has not yet occurred for total cyanide or for total salts (electrical conductivity), but there is evidence for stabilisation of SO_4/Cl (lead indication that less seepage water is moving downgradient from Stans Well and MRMB46);

Group 2. MRMB20 showed a rising trend in total salts (electrical conductivity) and SO_4 until 2012, after which there were additional mining effects in groundwater (traced by NO_3_N and Tot. CN in groundwater). Because the SO_4/Cl concentration ratio remained stable until this time, the increasing electrical conductivity and sulfate concentrations were interpreted to be a result of evaporative concentration resulting from the aquifer draining to the pit. After 2012 the increased presence of SO_4/Cl, NO_3_N and occasional spikes of total cyanide indicate that the aquifer has subsequently been mine affected;

Group 3. MRMB45, also in the processing area, has shown a declining SO_4/Cl concentration ratio after 2014, as well as stabilisation and reversal of total salts (electrical conductivity) and total cyanide concentrations since 2017. There have been occasional spikes of NO_3_N throughout this period. MRMB55, located along the access road and on the edge of the landscape spur has shown a steady increase in SO_4/Cl concentration ratio, but concentrations of solutes in this bore are relatively low for the mine lease;

Group 4. MRMB64, MRMB67 and MRMB68, located on the landscape spur, formed a distinctive group that show no trends that indicate mine influence. Concentration ratios of SO_4/Cl were flat or declining, NO_3_N concentrations were relatively flat (there were occasional spikes) and total cyanide concentrations were typically below detection; and

Group 5 was tailings discharge type water.

From the above interpretations, the following conclusions were drawn to support the conceptual model:

1. There are mine effects in the aquifer under the access road, because bores MRMB46 and MRMB49 contained cyanide (associated with seepage from the TSF), and the classification grouped groundwater from these bores with mine affected water known to contain tailings seepage (SD1/SD3/South Dam). Time series

interpretation showed that seepage mitigation by Stans Well (near MRMB46) has stabilised and reversed seepage trends in this area after 2013;

2. There are also mine effects below the processing area, affecting groundwater screened by MRMB20 (monitored between 2001 and 2015) and MRMB45 (monitored between 2014 and 2019). Groundwater in MRMB20 associated with Pit Sump and SD3 type waters, and groundwater in MRMB45 associated with SD2 type water (a mine influenced source term with lower solute concentrations than SD3 and the Pit Sump). These water types indicate seepage from the TSF or stormwater runoff from mined rock stockpiles/batter walls/road base. After 2014 there appears to be stabilisation and reversal of mine effects in groundwater reporting to MRMB45;

3. A groundwater bore at the edge of the landscape spur adjacent to the access road (MRMB55) may or may not be mine affected (refer discussion in section 3.3.1.3). There is clear association with SD2 type water in multivariate classifications involving this bore performed both here and for Rawdon Creek (discussed in section 3.3.1.3). Furthermore, between 2012 and 2019, SO_4/Cl concentration ratios have steadily increased in MRMB55. However, despite these associations with mine affected water cyanide has never reported to MRMB55 and the electrical conductivity readings and salt concentrations (Na, Cl) in MRMB55 groundwater have consistently been low relative to other bores on this landscape spur (MRMB64, MRMB67, MRMB68); and

4. Groundwater associated with MRMB64, MRMB67 and MRMB68 under the landscape spur are distinguished by moderate to high concentrations of HCO_3 and Na, and moderate concentrations of NO_3_N. There are also heavy metals (As, Cd, Cu, Pb, Fe, Zn) reporting in these three bores (Appendix 7.4.4). Of note these bores appear to represent a distinct groundwater compartment (Northern Resources Consultants, 2019).

   The location and construction of these bores are of interest, because they are on top of a landscape spur. Bores MRMB64 and MRMB67 are “dry” in the sense that the standing water level is below, and near the base of, the screen (there is no sump in these bores to collect water). These bores screen in granite or dacite, and it is conceivable that groundwater in these bores represents recharge that has flowed vertically through soil and weathered rock into the landscape spur, redissolving and releasing salts from the host aquifer during transit. The abundance of acacias on the landscape spur, noticeably near MRMB64 and MRMB67, might contribute NO_3_N as vadose water that is vertically leached through soil and fractured rock. Acacias are nitrogen fixing plants that incorporate nitrogen from the atmosphere (Brockwell *et al.,* 2005, Esslemont *et al.,* 2007). Heavy metals that report in these three bores, could be from sulfide minerals that have oxidised as a result of air (oxygen) entering the aquifer when the water table becomes lower during the dry season, or even air entering the aquifer through the open screen of the groundwater bore.

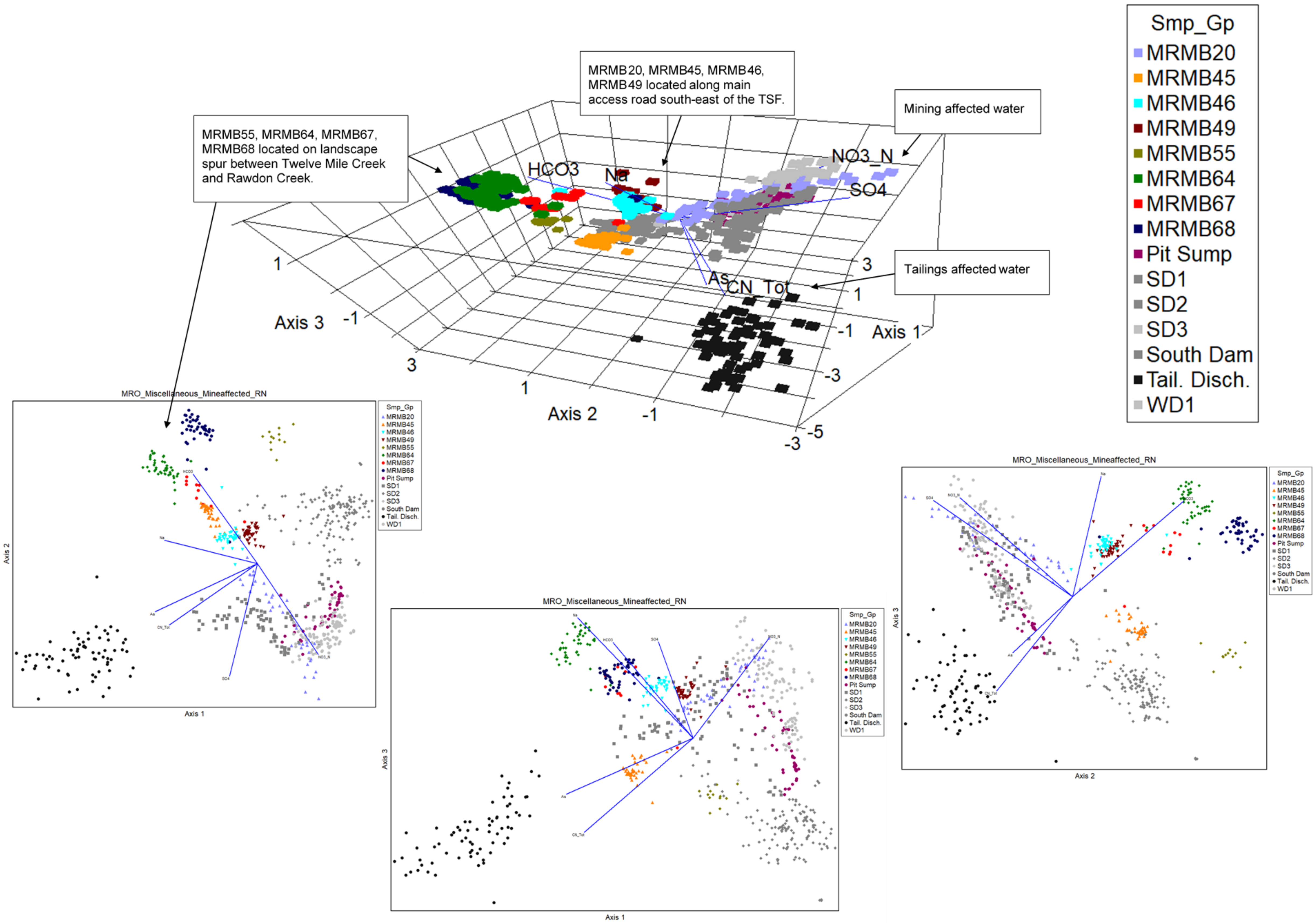
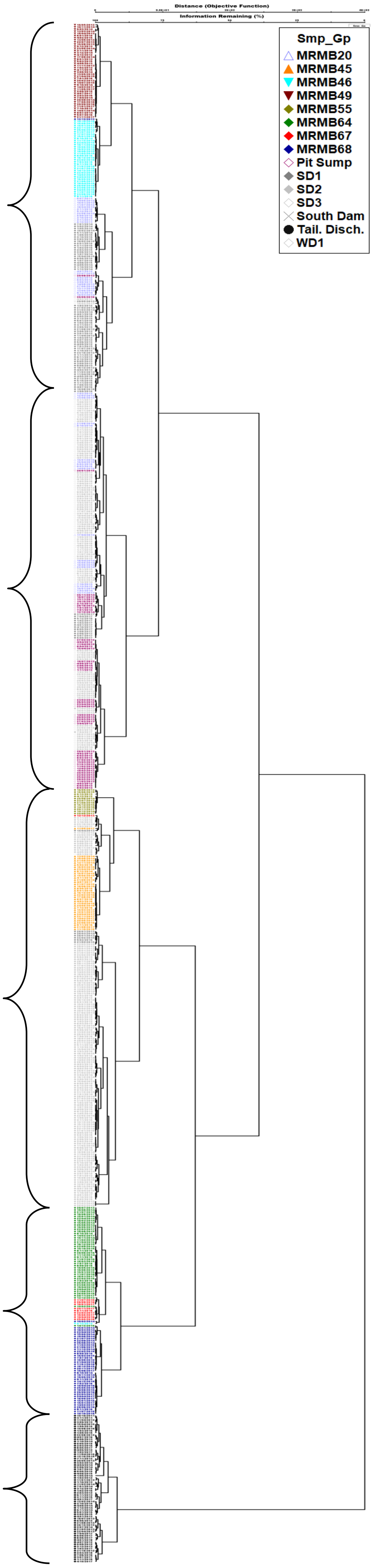


Figure 26: Principal Components Analysis of ions in mine affected water and groundwater below the access road/processing area of the Mt Rawdon mine lease.



"Group 1" is mine-affected groundwater below the access road near MRMB49 and MRMB46, with some representation of MRMB20 water. These groundwaters grouped predominantly with SD1/South Dam type water.

"Group 2" is mine-affected groundwater below the processing area near MRMB20, which grouped predominantly with seepage from waste rock (i.e. pit sump, SD3). Some SD1 type water, known to contain tailings seepage as well, is represented in this group.

"Group 3" is groundwater below the processing area near MRMB45 (mine affected) and below the landscape spur near MRMB55 (possibly not mine affected), which groups predominantly with SD2 type water. Some SD1 type water is represented in this group.

"Group 4" is native groundwater below the landscape spur near MRMB64, MRMB67 and MRMB68 (not mine affected).

"Group 5" is tailings discharge

Figure 27: Classification of ions in mine affected water and groundwater below the access road/processing area of the Mt Rawdon mine lease.

3.4 Movement and Surface Expression of Groundwater across the Mine Lease and its Surface Expression into Drainage Lines

This section addresses objectives 1.1 d and g of the Environmental Evaluation.

1.1: Identify the dominant underground hydrogeological systems relevant to the premises incorporating all available data from groundwater monitoring bores, and determine:

> *d. the movement of groundwater in the hydrogeological feature(s)(direction and flow rate, at a minimum).*
>
> *g. the locations where water contained within the hydrogeological system(s) does or may potentially express at the surface*

The movement and surface expression of groundwater across the mine lease, as well as groundwater expression into drainage lines, was modelled using a steady state groundwater flow model (Northern Resource Consultants, 2019). The United States Geological Survey groundwater model MODFLOW-SURFACT was developed for the Mount Rawdon Mine Lease using best available data, and was calibrated against 31 water level targets to simulate groundwater levels and fluxes across the mine lease. Calibration was within the 10% scaled root mean square error limit recommended by the Australian Groundwater Modelling Guideline (Barnett *et al.,* 2012). However parts of the mine lease were excluded from the model because they were likely compartmentalised and difficult to model without better resolution of underlying strata. These likely compartments were in the eastern part of the mine lease, and included the landscape spur between Rawdon Creek and Twelve Mile Creek (bores MRMB64, MRMB67 and MRMB74) discussed in sections 3.3.1.3 and 3.3.1.6, the lower portion of Twelve Mile Creek towards the impounded zone of the Perry River (MRMB38) and the headwaters of Twelve Mile Creek (bores MRMB61 and MRMB37). There will be further discussion of these groundwater compartments in section 4, which addresses the conceptual model.

The groundwater model showed that groundwater follows the topographic gradient and local drainages (Figure 28). Groundwater flows from the catchment headwaters west of the TSF, under the TSF, and towards the Perry River via Swindon Creek. The TSF and the NWRD have generated topographic highs, where groundwater mounding under these structures drive groundwater flow towards the Perry River via Rawdon Creek and via Twelve Mile Creek. In the Southern Corridor, groundwater flows westward into Mingham Creek, with the pit providing a localised sink for groundwater flow.

Surface expressions of groundwater into creek lines were identified in the upper catchment of Swindon Creek, and in the headwaters of Mingham Creek, most of which occurs upstream of mining activity (Figure 29).

The groundwater model identified rates of groundwater exfiltration into drainages for nine water budget zones (Figure 30). The most significant groundwater input is to zone 5 in the middle of Twelve Mile Creek, downslope of the NWRD. There is potential for hyporheic groundwater flow below drainage lines, including in areas downstream of mining influence in Swindon Creek, Rawdon Creek, Twelve Mile Creek, and in the southern drainage line leading into Mingham Creek (Figure 31).

In summary the post mining topography of the mine lease has generated groundwater mounding below the TSF and NWRD, which has enhanced groundwater expression into Twelve Mile Creek. The greatest potential for surface expression of groundwater is to zone 5 of Twelve Mile Creek, which discharges 10 m^3/day under steady state groundwater flow conditions. Hyporheic transfer of groundwater follows drainage lines within 3 meters of the creek bed.

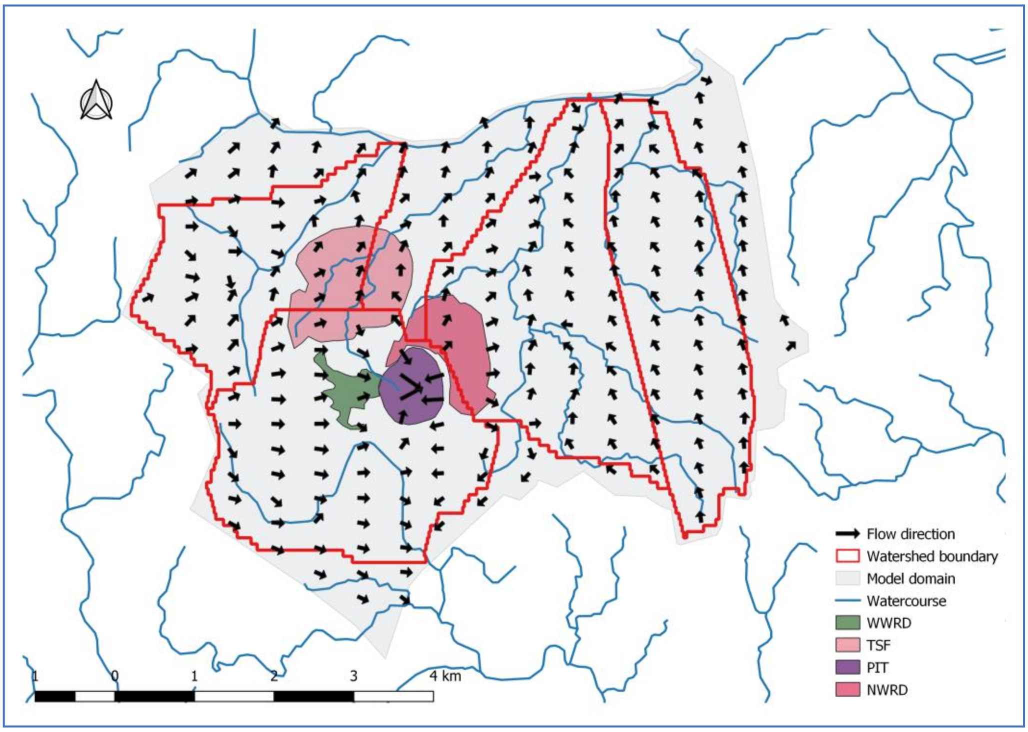


Figure 28: Groundwater movement in the Mount Rawdon Mine Lease (Source: Northern Resources Consultants, 2019)

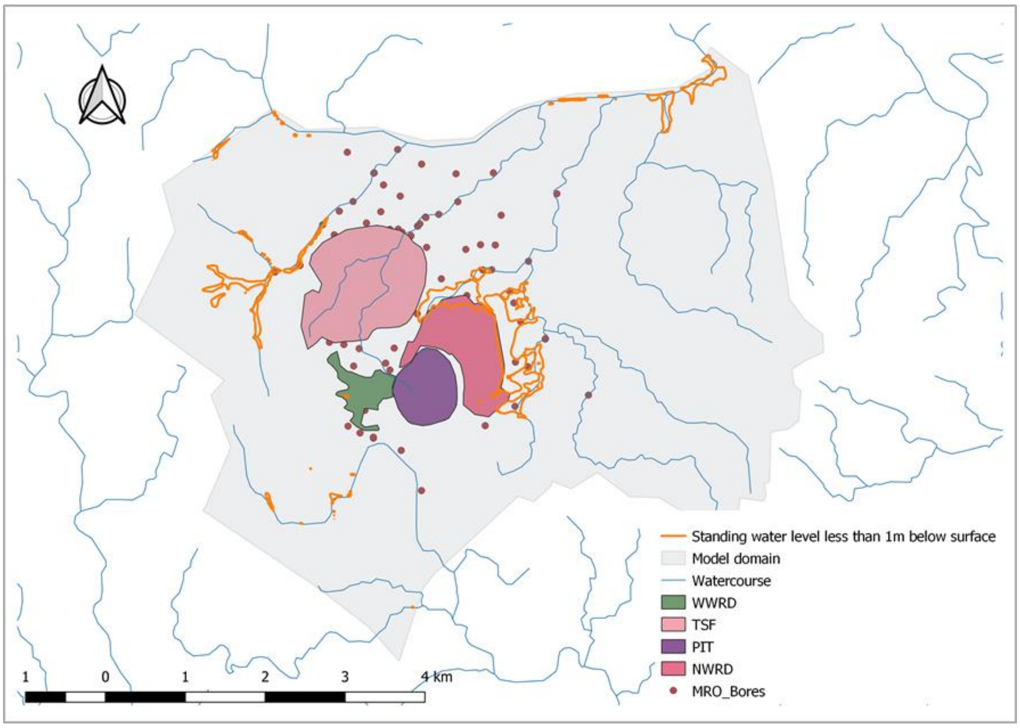


Figure 29: Groundwater egress into surface water drainages (Source: Northern Resources Consultants, 2019) [21]

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[21] The groundwater model generally overestimated the groundwater level in fractured rock aquifer by about 1 meter. Therefore, model prediction within 1 meter of the landscape surface, as shown in Figure 29, is representative of the surface expression of groundwater.

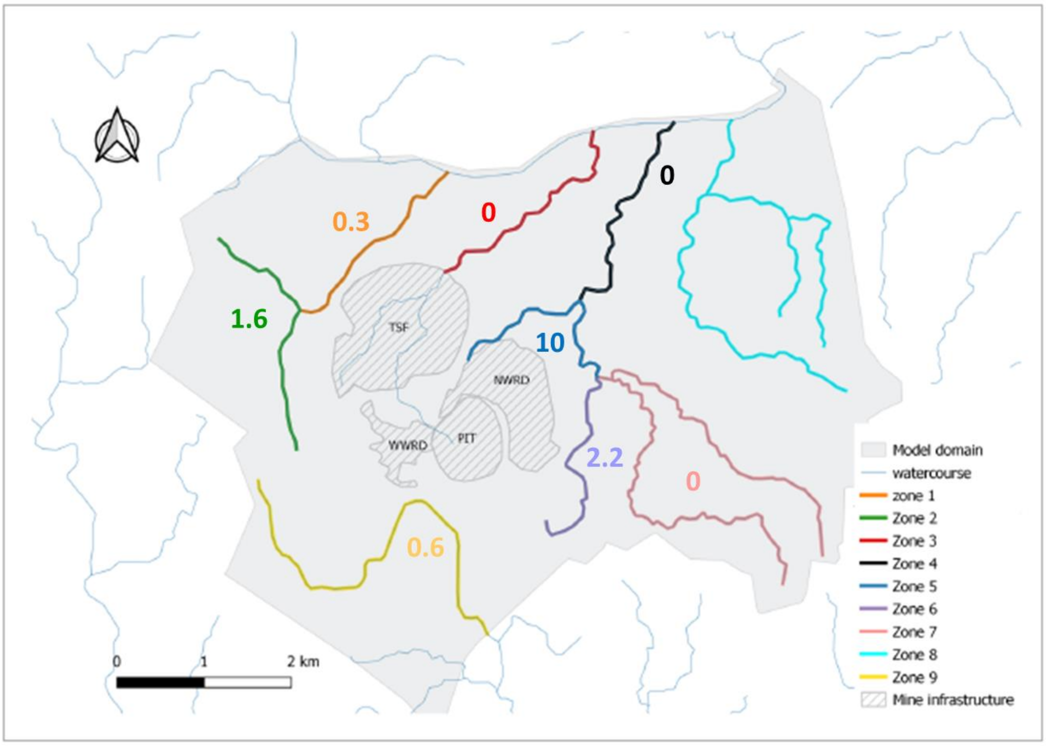

Figure 30: Groundwater exfiltration (m^3/day) into water budget zones (Source: Northern Resources Consultants, 2019)

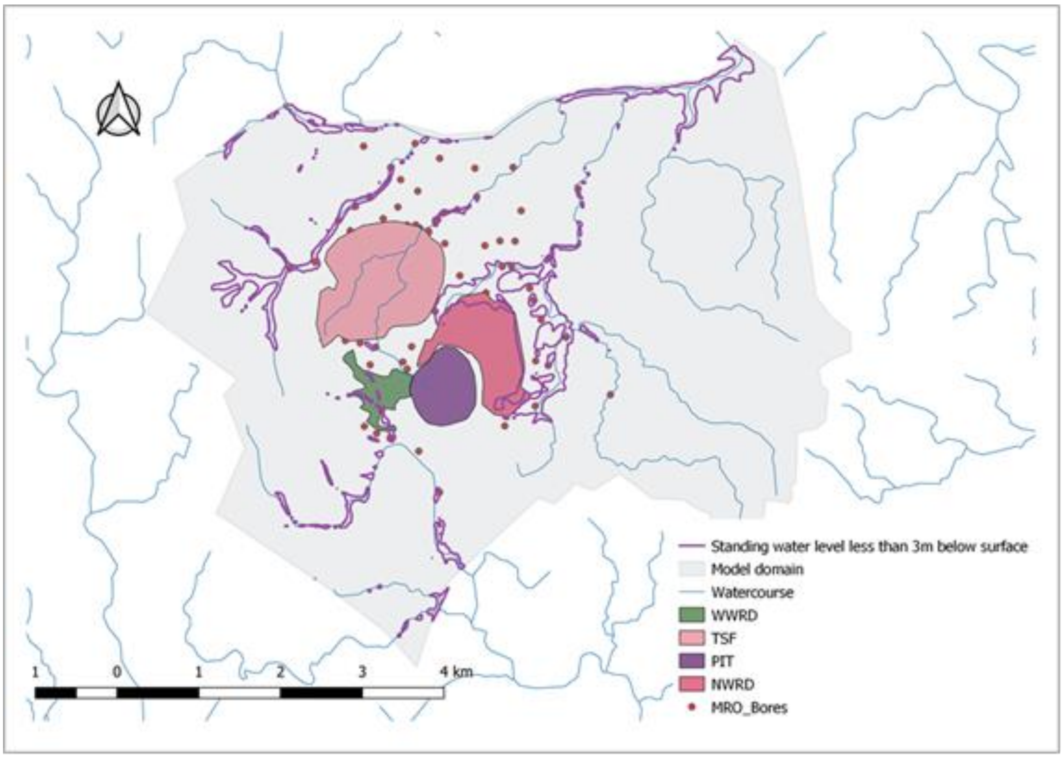

Figure 31: Hyporheic groundwater movement in the Mount Rawdon Mine Lease (Source: Northern Resources Consultants, 2019)

3.5 Interactions of Groundwater among Hydrogeological Features

This section addresses objectives 1.1 e of the Environmental Evaluation.

1.1: Identify the dominant underground hydrogeological systems relevant to the premises incorporating all available data from groundwater monitoring bores, and determine:

> *e. The interaction of groundwater contained in each hydrogeological feature with any other underground hydrogeological feature*

Section 3.1 of this report identified the dominant hydrogeological systems relevent to the mine lease, which in the hydrogeological model is assumed to be subsoil clay and sand, and the weathered rock aquifer. Table 4 shows that these are the most transmissive groundwater compartments in the mine lease, with relatively high hydraulic conductivities that potentially facilitate lateral groundwater transfer across the landscape (refer K_z values in Table 4). Table 4 showed that alluvium along the creek lines also has high hydraulic conductivity, but its shallow profile limits the tranmissivity of this aquifer. The groundwater model also identified groundwater compartments in the mine lease, notably in the landscape spur between Rawdon Creek and Twelve Mile Creek, as well as in the lower section of Twelve Mile Creek near the impounded zone, and in the headwaters of Twelve Mile Creek. For understanding steady stage groundwater flow across the mine lease, these assumptions are reasonable as demonstrated by the strength of calibration of the hydrogeological model.

Geophysical transects and field observations of the profile of the seepage zone along the northern wall of the TSF provide more detail, and allow interpretation of potential groundwater interactions between the soil, weathered rock and fractured rock aquifers (refer sections 3.1.1 and 3.1.2). The observed soil profile here is thinner than assumed by the groundwater model, and its clay subsoil potentially limits vertical transfer of rainfall recharge into the aquifer (refer K_{sat} values in Table 1). Also observed were preferred groundwater flow paths in soil and shallow weathered rock, through gullies with loose backfill (Figure 12) and along planes of decollment in bedded metasediment (Figures 3A and 10B). There are also barriers to groundwater seepage caused by faults, dykes and sills (Figures 4, 9 and 10A), which realign groundwater flow and contributes to groundwater compartmentalization (Figure 11). Figure 1 shows the location of a bore screen (MRMB9) in weathered rock adjacent to fresh rock (pictured in Figures 3C and 3D respectively), which has received seepage from the TSF. Historical observations of seepage at this location indicate that laterally moving groundwater below the TSF is forced to the surface because the imperveous fresh rock is less transmissive than the semi pervious, foliated and weathered rock that the bore screens in. Similar influences on groundwater movement might also be occurring near MRMB10 (also shown in Figure 1).

In fresh rock, below the soil and weathered zone, groundwater flows along the edges of reworked faults enclosed by otherwise impermeable rock, as shown in Figures 3d and 9.

In summary groundwater flows through subsoil (clay and sand), and weathered rock, with groundwater being compartmentalised by the juxtaposition of deeply weathered and fresh rock, faults, dykes and sills that contain and redirect groundwater flow.

3.6 The Interaction of Mine Affected Waters with Groundwater

This section addresses objective 1.1f of the environmental evaluation:

1.1: Identify the dominant underground hydrogeological systems relevant to the premises incorporating all available data from groundwater monitoring bores, and determine:

> *f: the interaction of any contaminated waters, with the water in the hydrogeological system(s), including a comparison of the ionic compositions of the contaminated waters with the water in the hydrogeological system(s)*

Section 3.3 of this report identified that the principal components of the median ionic compositions of water in the mine lease were consistent with (1) weathering of feldspar and carbonate in the natural landscape (represented by high concentrations of Na and HCO_3 ions, and low concentrations of NO_3 ions), (2) solutes generated from mining and processing of mineralised ore (represented by high concentrations of SO_4, NO_3, Tot. CN, and As ions) and (3) solutes generated from unmined mineralised sources (represented by high concentrations of As and low concentrations of Tot. CN ions). Furthermore it was possible to group these water types on the basis of predominantly tailings affected water, predominantly waste rock seepage affected water, water screening in aquifers containing igneous rocks that might release sodium and bicarbonate during weathering, and intermediate groups that coincided with locations where mixing of mine affected water and groundwater has been recognised (refer sections 3.3.1 and Figure 15).

More detailed interpretations at the sub-catchment scale were made with individual data, which allowed identification of influences on the ionic composition of groundwater caused by soil and geology variations in the landscape, as well as periods when groundwater was not mine affected before breakthrough of mine related seepage occurred. This interpretation also identified the ambiguity of some tracers of mine influence, where landscape processes that influence the concentration of NO_3 in groundwater (nitrogen fixing plants, nitrification in organic rich soil), as well as As and SO_4 in groundwater (unmined sulfide in a mineralized area), were recognised as potential confounds to interpretations of mining influence. Interactions between mining affected water and groundwater were identified as follows:

- Swindon Creek is experiencing active seepage of mine affected water into groundwater its headwater area (reporting to bores MRMB43 and MRMB44), which was reported to DES in November 2018 and March 2019. This seepage is currently being addressed by the installation of pumpback bores in addition to extension of the Downstream Toe Interception Drain. There has also been historical reporting of mine affected water to MRMB10, MRMB12 (cyanide affected) with mine influence possibly extending as far as MRMB41 and MRMB42 (sulfate lead indication only). Long term trends show stabilisation and reversing of mine effects as a result of upslope seepage mitigation, and these trends continue to be monitored. MRMB65 has reported ambiguous results that are being investigated further;
- The unnamed creek between Swindon Creek and Rawdon Creek has experienced seepage of mine affected water that has reported to bores MRMB8, MRMB9, MRMB31 and MRMB30, which manifested when clay adjacent to the toe of the TSF northern wall was removed in 2010. Long term trends suggest that seepage mitigation efforts such as reconditioning the Seepage Interception Drain and installing the Downstream Toe Interception Drain are starting to have an effect, but it is too early to tell from monitoring data whether these recovery efforts are halting and reversing the breakthrough;
- Rawdon Creek has historically experienced seepage of mine affected water that has reported to bores MRMB1-7, MRMB23, MRMB29, MRMB21 and MRMB 39 (cyanide affected), which manifested after 2010 and became particularly severe in 2012 after clay was removed from the toe of the TSF northern wall. Long term trends show the

influence of seepage mitigation strategies in 2005 and 2013 that slowed the reporting of mine affected water to downgradient bores;

- The landscape spur between Rawdon Creek and Twelve Mile Creek hosts a group of bores within a groundwater compartment, which are unaffected by mining (MRMB64, MRMB67, MRMB68 and MRMB74) although they report relatively high electrical conductivities and concentrations of sodium, bicarbonate and heavy metals possibly associated with pyrite oxidation. These high concentrations might result from localised weathering processes on this landscape spur, and are being investigated further in stage 2 of this report;
- Twelve Mile Creek, which has been shown to contain groundwater compartments and unmined mineral deposits, hosts bores subjected to either direct or indirect mine influences that transfer solutes towards Twelve Mile Creek. This process of solute transfer is natural for this part of this landscape, as will be explained further in section 4. Enhanced mobilisation of pre-existing salts in the sloping landscape, by the increased hydraulic head induced by groundwater mounding below the NWRD, is an indirect mine influence. Direct mine influence (seepage of mine affected water from the NWRD) reports below Waste Rock Dams 1 and 2, and is intercepted and returned to the dams by pumpback bores before entering Twelve Mile Creek;
- The southern drainage towards Mingham Creek has historically reported mine influence (seepage of cyanide) in bores MRMB69 and MRMB19. There are other influences in this drainage line that are not seepage related, such as a pulse of nitrate associated with a hot bushfire, high concentrations of As associated with unmined sulfide mineralisation, and slowly increasing sulfide concentrations in some bores in possible response to hydrostatic displacement of the groundwater table by nearby water impoundments; and
- There is mine influenced groundwater (seepage of cyanide) under the access road. The aquifer below the processing area also appears to have received seepage from the TSF and/or mined rock. Groundwater monitoring records show that seepage interception (likely pumping from Stans Well) has stabilised and begun to reverse the seepage trend in this area.

In summary there is current and historical evidence that parts of the aquifer in the Mount Rawdon mine lease have received mine affected water, as well as demonstration that seepage mitigation efforts have had some success in stabilising and reversing seepage trends. Figure 32 summarises the location of seep exfiltration and groundwater monitoring bores in the mine lease, in the context of the potentiometric surface in meters above sea level, and inferred fault structures that might provide barriers to groundwater flow. This figure clearly shows the influence of groundwater mounding below the NWRD on groundwater flow towards Twelve Mile Creek, as well as the influence of the pit as a groundwater sink on groundwater flow towards Mingham Creek. Figure 33 is a variation of the same figure, with colour inversion to represent the depth of groundwater below the landscape surface. Hence while groundwater level contours represent the same potentiometric surface above sea level shown in Figure 32, red signifies that the soil and weathered rock aquifer are dry while blue signifies relatively wet soil and weathered rock conditions.

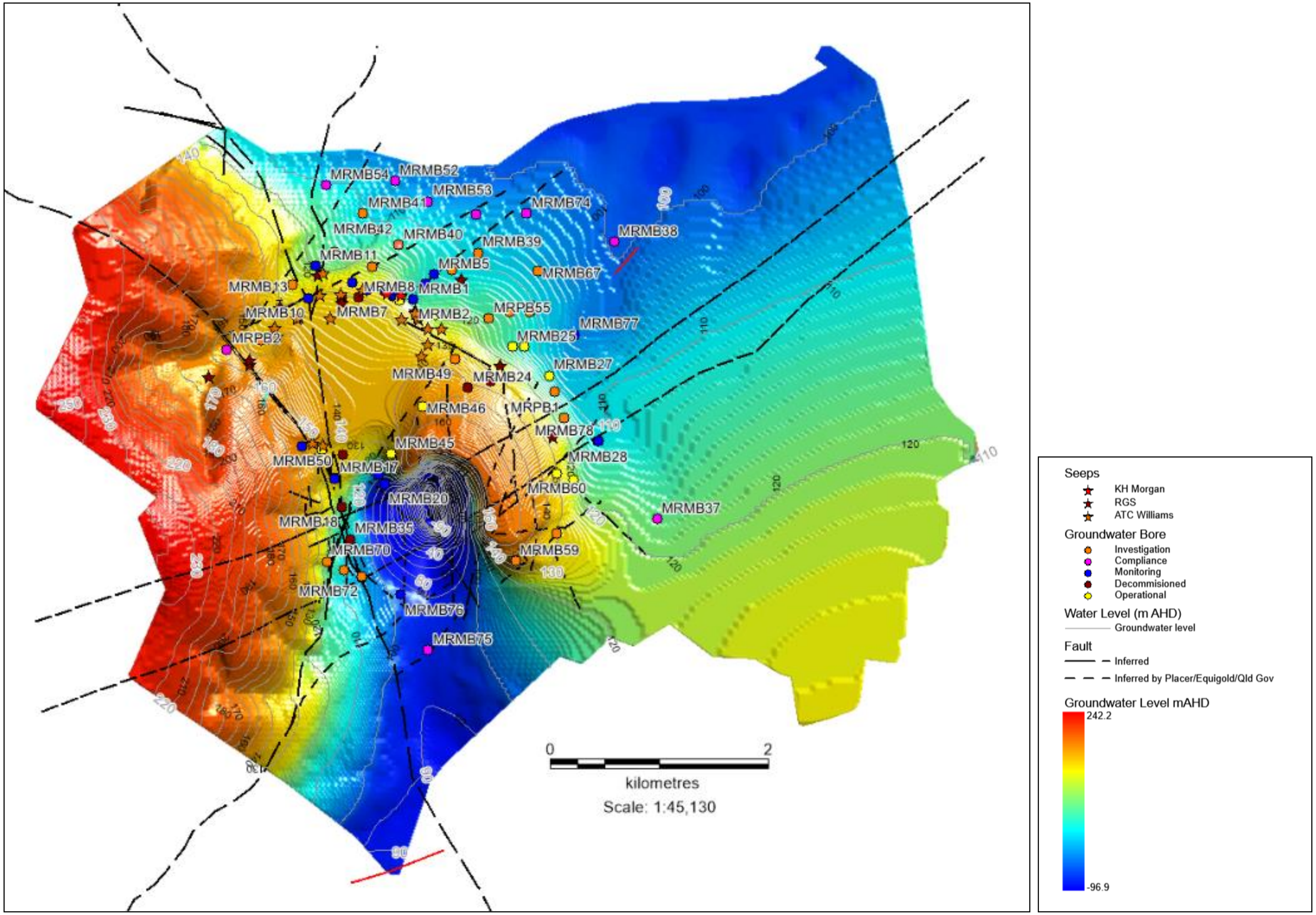

Figure 32: Groundwater model of the potentiometric surface across the Mount Rawdon mine lease (Source: Northern Resources Consultants, 2019)

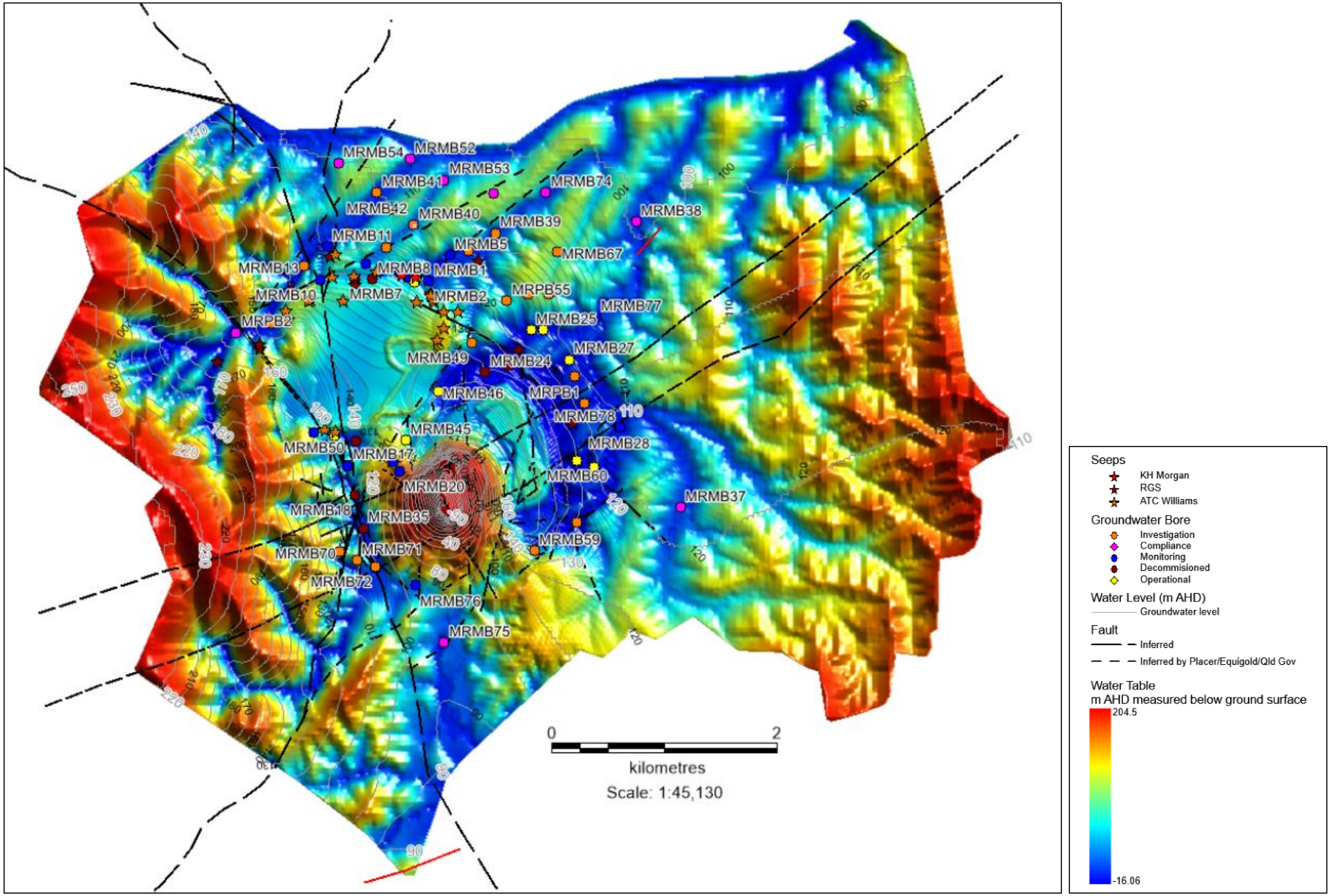

Figure 33: Groundwater model of the depth to water across the Mount Rawdon mine lease (Source: Northern Resources Consultants, 2019)

3.7 The Spatial Locations of Environmental Values within or dependant on the Hydrogeological System

Environmental values were developed for the Burnett-Baffle Water Quality Improvement Plan (BMRG, 2010). The environmental values identified by the Water Quality Improvement Plan that are applicable to the Mount Rawdon Operations mine lease are:

1. Aquatic Ecosystems. The protection/enhancement of aquatic ecosystem values, habitat and wildlife are relevant to local watercourses that provide a water source and are of environmental value to native flora and fauna. The applicable guidelines were the current EA requirements, Burnett-Baffle WQIP and ANZECC (2000) guidelines for a 95% level of protection;
2. Stock Watering. Suitability of water supply for production of healthy livestock. Pastoral land is predominant around MRO, and cattle drink from watercourses. The applicable guidelines were the Burnett-Baffle WQIP and ANZECC (2000) guidelines – Livestock drinking water for all surface waters;
3. Aquaculture, human consumption of aquatic foods. Recreational fishing could be an environmental value at Perry River Dam, although currently this is not the case. There is no evidence of industrial aquaculture around MRO. The applicable guidelines were the Burnett-Baffle WQIP and ANZECC (2000) guidelines. Although the applicability of this environmental value at MRO is not evident, it will be protected with aquatic ecosystem protection.
4. Visual Appreciation. The amenity of waterways for recreation that does not involve any contact with water is an environmental value. The mine lease is not open to the public so creeks on the mine lease are not accessed for their aesthetics. The applicable guidelines were the Burnett-Baffle WQIP and ANZECC (2000) recreational guidelines – Visual use no contact;
5. Industrial Use. The suitability of water supply for industrial use is relevant, and while the water is suitable for industrial use there is no significant industry present within 10 km of Mount Rawdon Operations.

The spatial locations of environmental values within or dependant on the hydrogeological system include the Perry River Dam, and creeks that are recharged by groundwater (Figure 29, Figure 31) where there is surface water in Swindon Creek, Twelve Mile Creek, Rawdon Creek and Mingham Creek that cattle can drink form.

There are authorised release points from the spillways of Waste Rock Dam 1, Waste Rock Dam 2, Waste Rock Dam 3, Waste Rock Dam 4, Sediment Dam 3 and West Dam if release water quality criteria are demonstrably met by surface water quality monitoring, as stated in Environmental Authority EPML00712113. Together with the TSF, processing area, South Dam, West Waste Rock Dump and Northern Waste Rock Dump (from which stormwater runoff reports to the waste rock dams and sediment dams), these impoundments are the main current and historical mining infrastructure/storage locations that potentially release mine affected water to downstream receptors.

The location of groundwater monitoring bores are shown in Figure 15, and also in Figure 32 (in relation to groundwater flow direction across the mine lease) and Figure 33 (in relation to the proximity of groundwater to the landscape surface). Groundwater is closer to the landscape surface below catchment hinge lines, in river valleys and in the agricultural landscape of Twelve Mile Creek. There are surface water monitoring locations at upstream points in Swindon Creek (near MRPB2), Twelve Mile Creek (between MRMB78 and MRMB37), Mingham Creek (near MRMB72) and Perry River (upstream of the impoundment). Downstream surface water monitoring is located below the Perry River Dam, and below mining activity in Swindon Creek (near MRMB52), Rawdon Creek (near MRMB39), Twelve Mile Creek (near MRMB38) and Mingham Creek (near MRMB75).

Several uncontrolled releases of mining affected water into Rawdon Creek and Twelve Mile Creek have occurred from overtopping of the sediment dams and waste rock dams. Seepage of mine affected water into groundwater has also been recognised through shallow fractured rock both north-west, north and south of the TSF, which has entered Swindon Creek, Rawdon Creek, as well as through soil below waste rock dams 1 and 2. To date REMP investigations have not identified adverse environmental effects to in-stream aquatic ecosystems in response to environmental insults such as overtopping events, groundwater mixing or other mining activity, despite exceedances of trigger values relevant to ambient surface water conditions (ANZECC, 2000). On this basis these releases are not contamination.

However, there have been contamination events involving birds, marsupials and mammals entering the TSF, which have died in response to exposure to cyanide (discussed in section 5.1).

4 Conceptual Hydrogeological Model

This section addresses objective 2 of the environmental evaluation:

Develop a conceptual hydrogeological flow model integrating items (a)-(h) from requirement 1. The conceptual hydrogeological flow model must be diagrammatically presented and define:

the assumptions relied upon; and

the uncertainties and exclusions.

Conceptual hydrogeological models already developed for the landscape and the Mount Rawdon mine lease can be utilized with very little modification. These models are described below in sections 4.1 and 4.2.

4.1 Landscape Processes in the Mount Rawdon Mine Lease

Dryland salinity is recognised in the Central Burnett (Douglas and Cox, 1994; Queensland Government, 2003). A conceptual model for solute generation from the weathering of granites in sloping terrain was developed by Douglas and Cox (1994), which identified that the chemistry and quality of groundwater represent the aquifer matrix through which water migrates as well as processes that contribute to soil salinity. Two types of aquifers were identified:

1) Crystalline rock aquifers connected by faults and fractures, and
2) The overlying unconsolidated sedimentary aquifers.

Variations in groundwater flow hydraulics within each aquifer depends on influencing geological features. Within fractured granite, groundwater movement is controlled and limited by the extent and distribution of fracture zones and rises to the near surface where dykes or impermeable faults create barriers. Lower permeability metamorphic rock produces a rise in groundwater due to lateral restrictions on deeper granitic aquifers. Anisotropic groundwater movement due to faults and dykes increases groundwater discharge into overlying alluvial aquifers in valleys lower in the landscape. In unconsolidated aquifers, there is relatively free movement of groundwater influenced by localised variations in permeability.

Within the larger tributaries' groundwater seepage occurs along an interface zone between clay alluvium within the channel and coarser hill-slope colluvium along the banks. At these sites there are semi-confining aquifer conditions due to clay-rich alluvium laid over a sandy clay aquifer, which causes the groundwater potentiometric surface to rise above the land surface at the interface zone. The result is prolonged periods of groundwater seepage over 6 to 9 months of the year. Movement of water by capillary action also transports ions from the shallow, confined water table to the soil surface where concentration occurs by evaporation. Surface seepage can also produce localised ponding in the lower catchment. These processes are shown schematically in Figure 34.

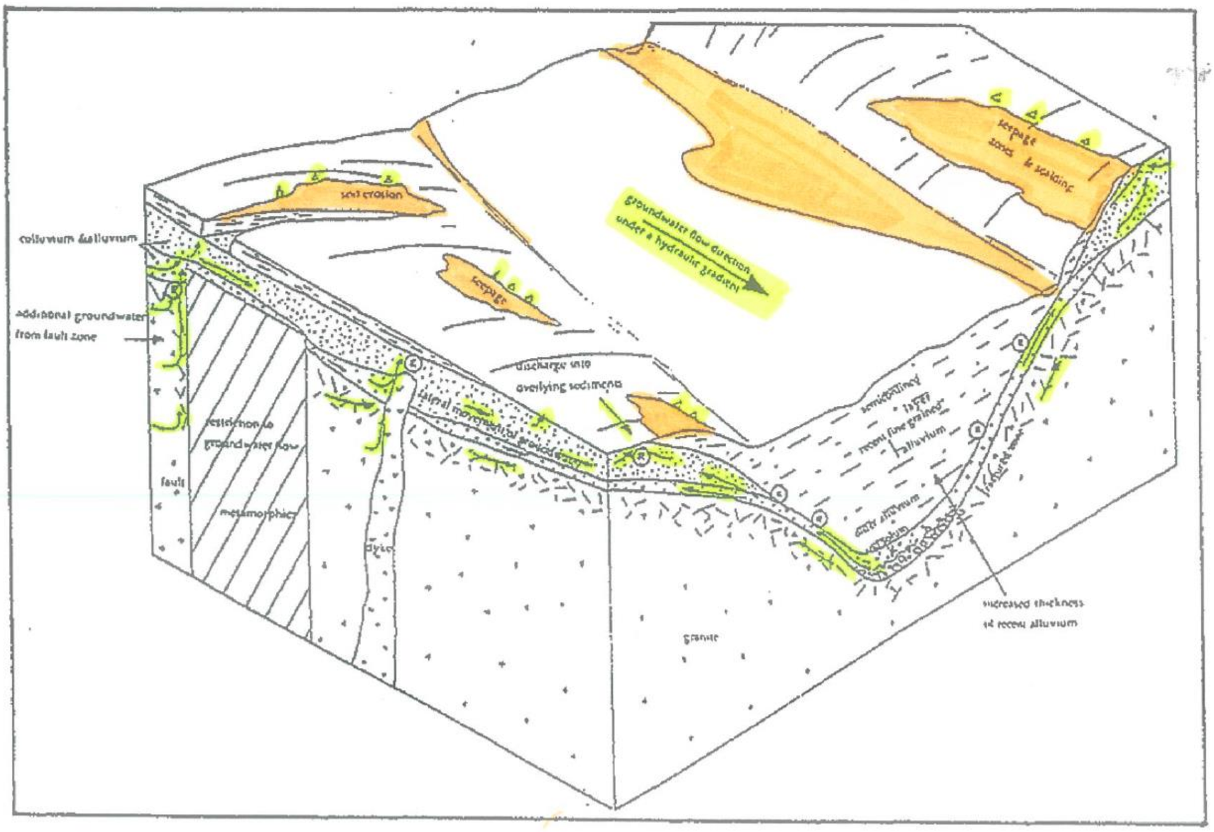

Figure 34: Conceptual Hydrogeological Model of solute generation and movement in groundwater in sloping terrain of the Central Burnett (Source: Douglas & Cox, 1994)

Schematic graphs showing the evolution of ions in the landscape is shown in Figure 35. Initially rainfall recharges the aquifer with a total dissolved ionic composition (TDI) of 15 mg/L (23 µS/cm), which infiltrates soil of the recharge zone (stage 1). After infiltration, the groundwater TDI increases due to dissolution of soluble salts in the soil (stage 2a), which continues to increase during transit through fractured granite when partially weathered granite adds a small amount of salt to the groundwater TDI (stage 2b), and then a larger increase in TDI as seepage exfiltrates through overlying surficial alluvium on lower slopes when ions are released from clays (stage 2c). At this stage the TDI concentration is about 500 mg/L (750 µS/cm). Stage 3 in the conceptual model involves cation exchange during soil breakdown and subsequent evaporation, which is accentuated by seasonal variations in groundwater levels that can continually remobilise ions back into solution. At the end of the process, the TDI concentration is about 3000 mg/L (4,500 µS/cm). This scematic indicates that there is a 200x increase in TDI concentration from recharge to lower slope discharge.

In summary these concepts can be assumed to occur in the Mount Rawdon mine lease, to describe groundwater flow in gullies that connect with the Perry River and Mingham Creek. The presence of faults filled with impermeable gouge material, dykes and block-faulted granite and metamorphic rock are known in the mine lease (refer section 3 of this report). The main limitation with applying this conceptual model is the unknown effect of the Mount Perry Weir, because impounded surface water also reports to groundwater, and in this context it is noted that the compliance bores closest to the Mt Perry Weir (MRMB74 and MRMB38) were excluded from the calibration of the steady state hydrogeological model (refer section 3.4) because of poor fit (i.e. steady state groundwater flow cannot be assumed for these bores). As such assumed backflow of groundwater through river gravel as shown in Figure 34, would manifest as wet ground on the fringes of the impoundment as a permanent rather than seasonal feature. It is uncertain how groundwater seepage mixes with groundwater below the impoundment (if at all) before it expresses at the surface.

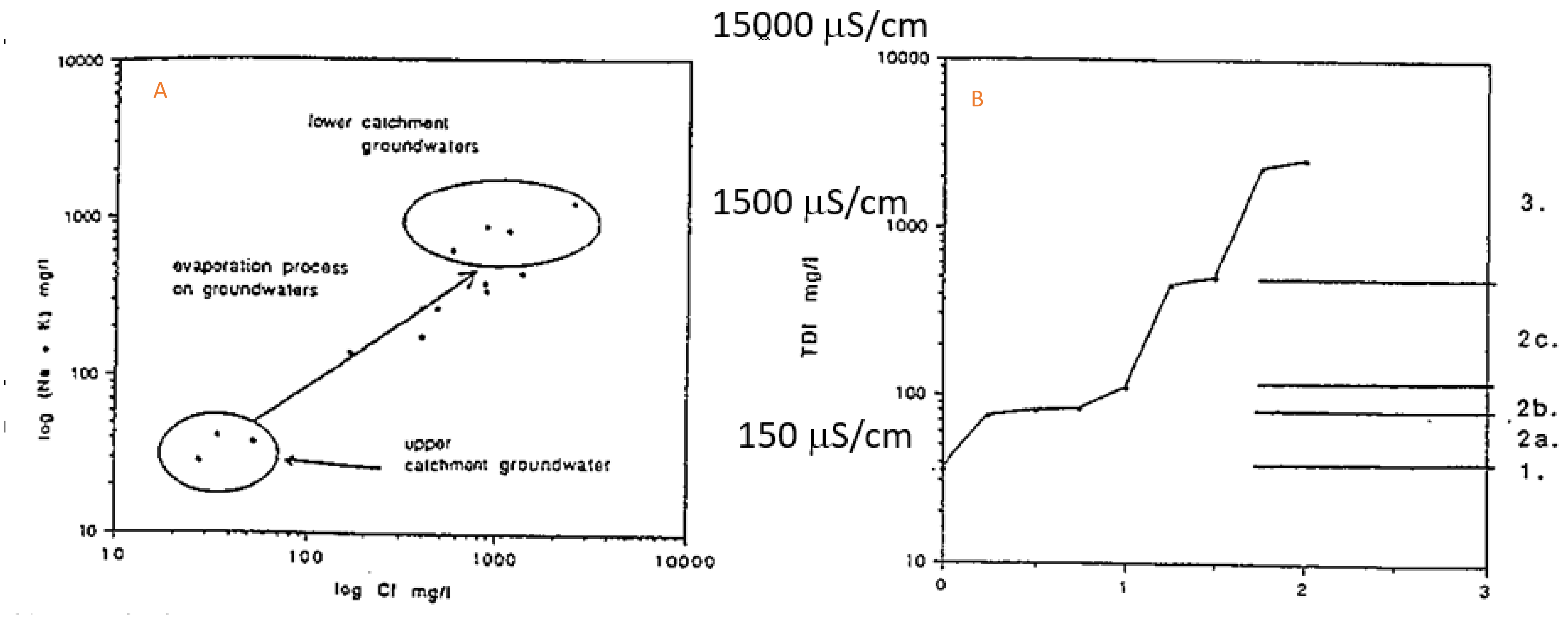

Figure 35: Schematic concentration of increases in (a) Cl/(Na+K) along the groundwater migration path and (b) the evolution of ions through the hydrogeological system (Source: Douglas & Cox, 1994)

It is noted also that groundwater screening below the landscape spur between Rawdon Creek and Twelve Mile Creek (MRMB64, MRMB67 and MRMB74), and in the headwaters of Twelve Mile Creek (MRMB61 and MRMB37) were excluded from the steady state hydrogeological model, indicating that the steady state assumption does not apply well in other parts of the Twelve Mile Creek drainage line. Other possibilities such as seasonal recharge of groundwater compartments by rainfall might be more applicable to these sections of Twelve Mile Creek.

The salinity hazard map for the Burnett Mary and Western Catchments of South East Queensland (Queensland Government, 2003) was developed using landscape information about rainfall patterns and soil properties that consider the quantity of salt in the landscape, the recharge potential of water moving into groundwater, and the discharge sensitivity of the landscape most sensitive to change in the water balance (Figure 36). The salinity hazard map indicates potential for salt expression in the landscape from landscape properties, rather than the actual salt expression that depends more on the way land is managed. It is possible to have low salt expression on well managed land with high salinity hazard, or alternatively high salt expression in poorly managed land with low salinity hazard.

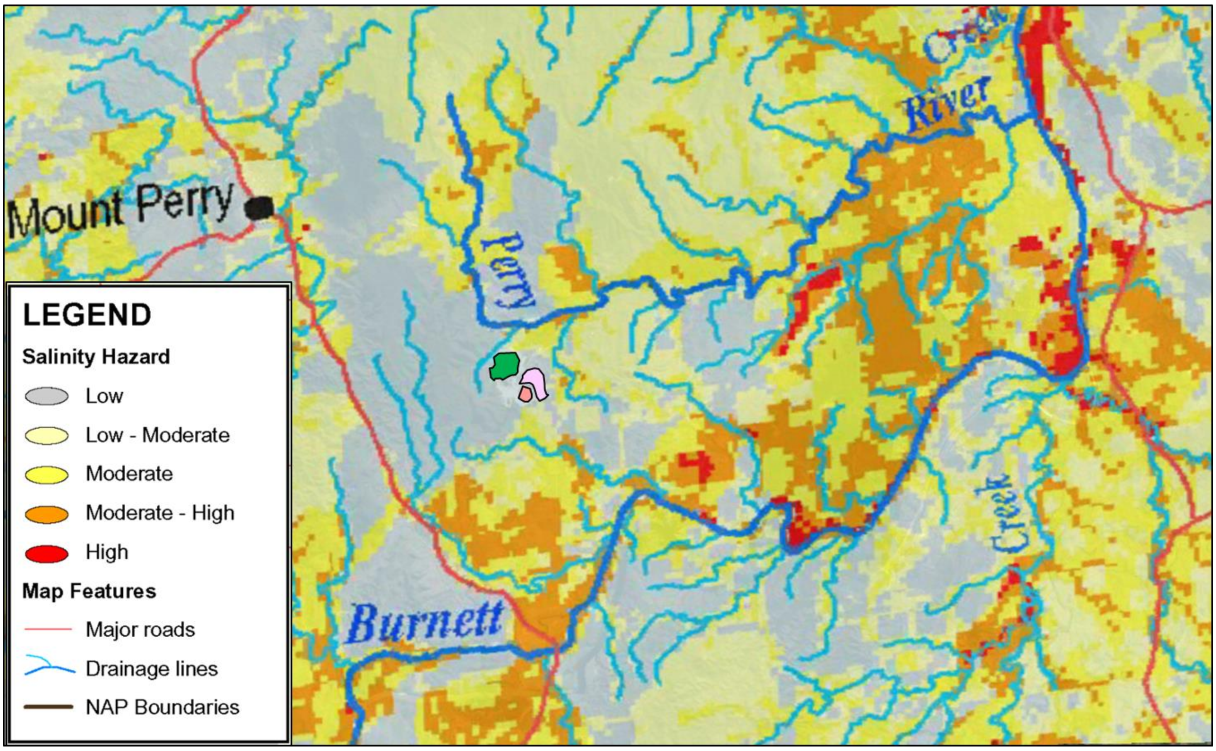

Figure 36: Salinity Hazard (Source: Queensland Government, 2003) [22]

The salinity hazard map indicates that sections of Twelve Mile Creek and Mingham Creek have salinity hazard in areas that coincide with soil that allows deep drainage (refer Figure 2B) or areas where groundwater exfiltrates into Perry River (Figure 29). There is moderate salinity hazard on the lower slopes of Mingham Creek, Twelve Mile Creek and Rawdon

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[22] The TSF (green), Northern Waste Rock Dump (pink) and the pit (orange) shown in the context of salinity hazard.

Creek. As such the salinity hazard map indicates a moderate to moderately high hazard of salt expression on the lower slopes of the mine lease.

4.2 Post-Mining Hydrogeological Processes

A conceptual model for tailings hydrogeology was developed by KH Morgan and Associates (2007) to address water seeps observed from the downstream toe of the northern TSF wall and from the run of mine pad at the Mount Rawdon gold mine. The seeps were described as a continuation of the natural groundwater outflow resulting from rainfall recharge higher in the hillslope beyond the western cell of the TSF and outside the tailings perimeter.

Maintenance of these flows in the dry season are assisted by recharge from tailings into fractures and rock fissures between the tailings pile close to the dam wall, and by continued recharge from the hill flanking the western cell of the TSF. A pressure balance interchange is likely to occur between wet and dry seasons as a result of changing water head in the hill. The observed seeps resulted from groundwater flowing beneath the depth of the cut-off key trench below the clay core of the dam wall (Figure 37). The report recommended installing a 2m deep interception trench backfilled with conductive rock debris (the Toe Seepage Interception Drain) approximately 20 meters out from the wall toe. This drain has remained operational and in 2017 was reconditioned before being overlaid by outer batter wall of the TSF stage 5 lift, and supported by a deeper open drain outside the stage 5 wall toe (the Downstream Toe Interception Drain).

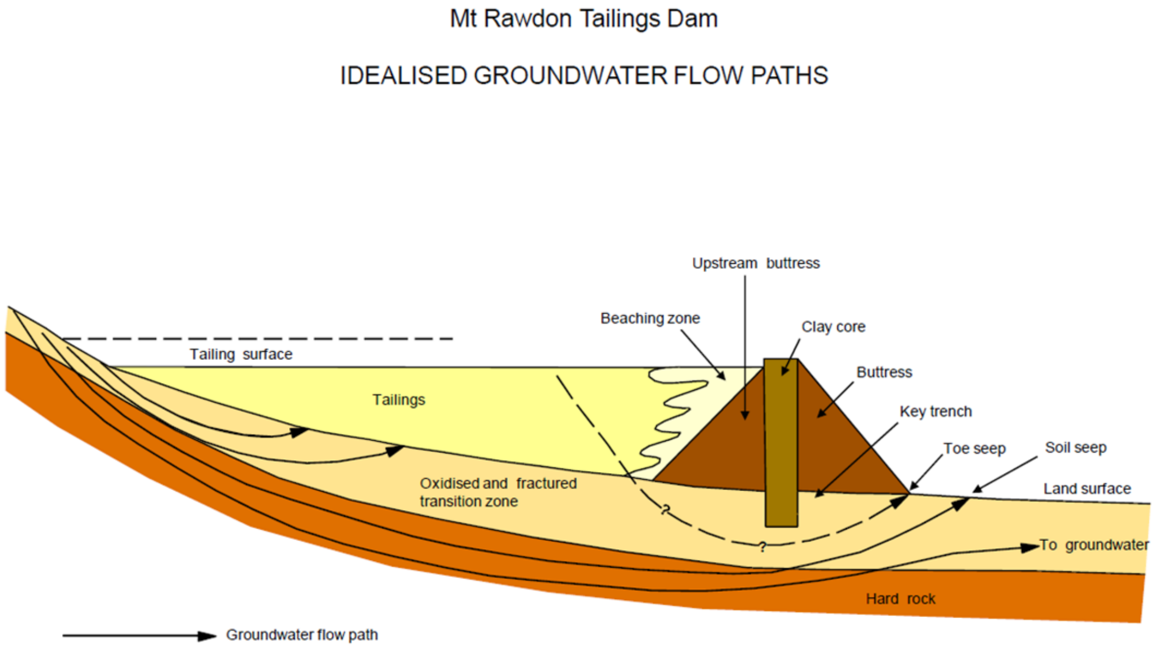

Figure 37: Idealised groundwater flow below the northern TSF wall (Source: Morgan, 2007)

In 2011 the conceptual flow model for the Mount Rawdon mine lease was developed further and compared the pre-mining and post-mining groundwater flow regimes (Evolution, 2011). Before mining groundwater followed a subdued version of the topography. After construction of the TSF and mining, the topography was altered by morphology and elevation, with the TSF becoming the highest head feature in the area leading to mounding underneath the TSF and groundwater flow in northern, eastern and southern directions via faults and fractures. The pit became the lowest head feature in the area, and the fact that the pit remains relatively dry indicated the presence of flow barriers (faults) between the pit and the surrounding strata (including the TSF).

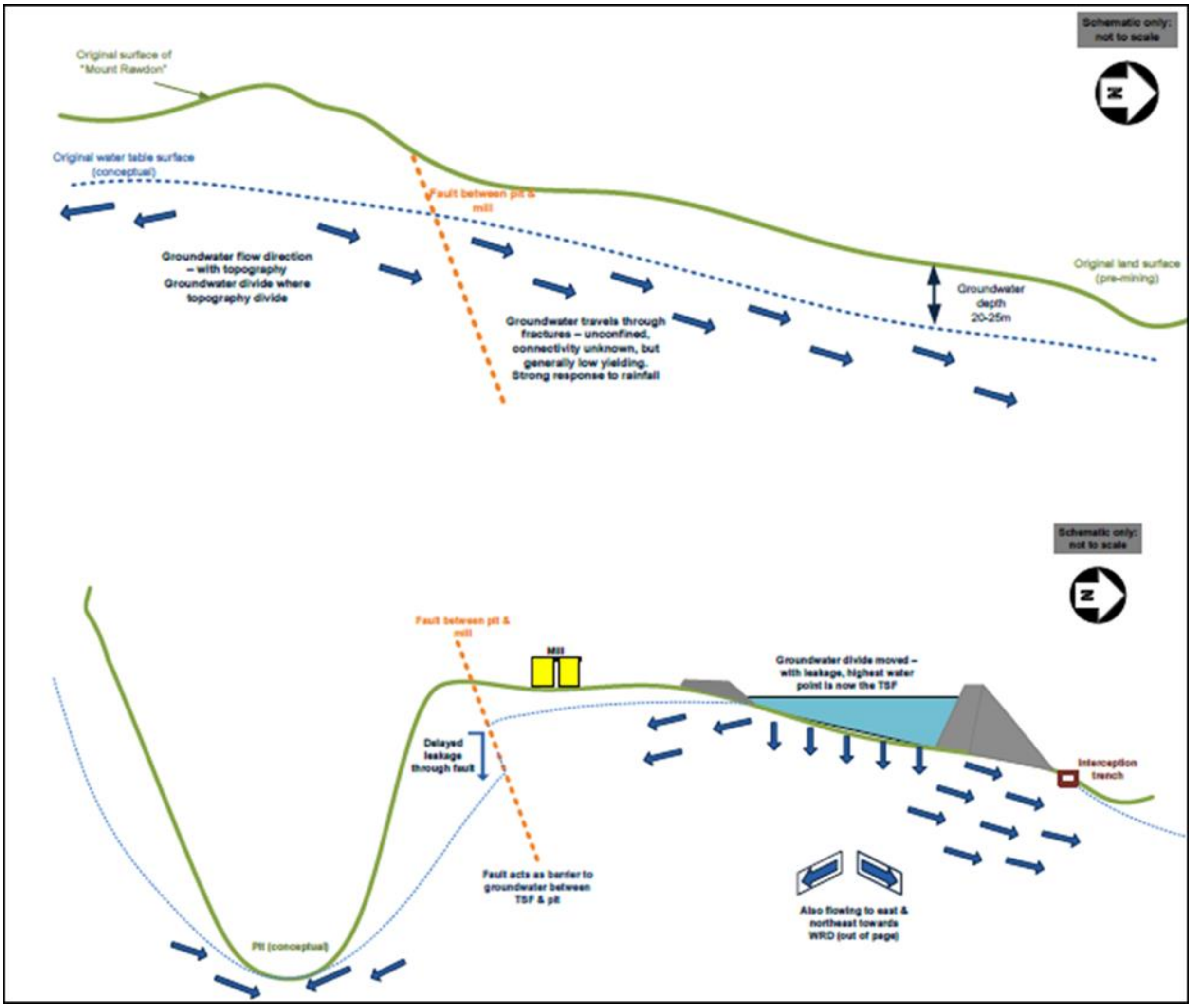

Figure 38: Idealised groundwater flow across the mine, operational area and TSF (Source: Evolution, 2011)

In 2019 these conceptual models remain valid, with the exceptions that the NWRD is now the highest topographic feature in the area, and additional seepage mitigation intercepts the flow of mine affected groundwater to downgradient receiving waters (Evolution, 2019). The hydrogeological model (Northern Resources Consultants, 2019) shows modelled groundwater flow paths and seepage from mining infrastructure in the Mount Rawdon mine lease (Figures 39, 40 and 41).

Figure 39 shows the layout of cross section profiles across the mine lease, between the mining infrastructure and drainage lines. Figure 40 shows cross sections between the TSF and Swindon Creek, and indicates the potentiometric surface associated with steady state groundwater flow from the hill behind the western cell of the TSF (not shown, but to the left of the cross section in Figure 40,), below the TSF and towards Swindon Creek. Figure 40 also shows tailings fluid recharging the groundwater table below the TSF.

Figure 41 shows the cross sections between the TSF and Rawdon Creek, between the NWRD and Twelve Mile Creek, and between the TSF and Mingham Creek. In Twelve Mile Creek the potentiometric surface is above the pre-mining elevation, and seepage from the NWRD is captured by waste rock dams as surface flow. The dams are installed in natural drainage lines.

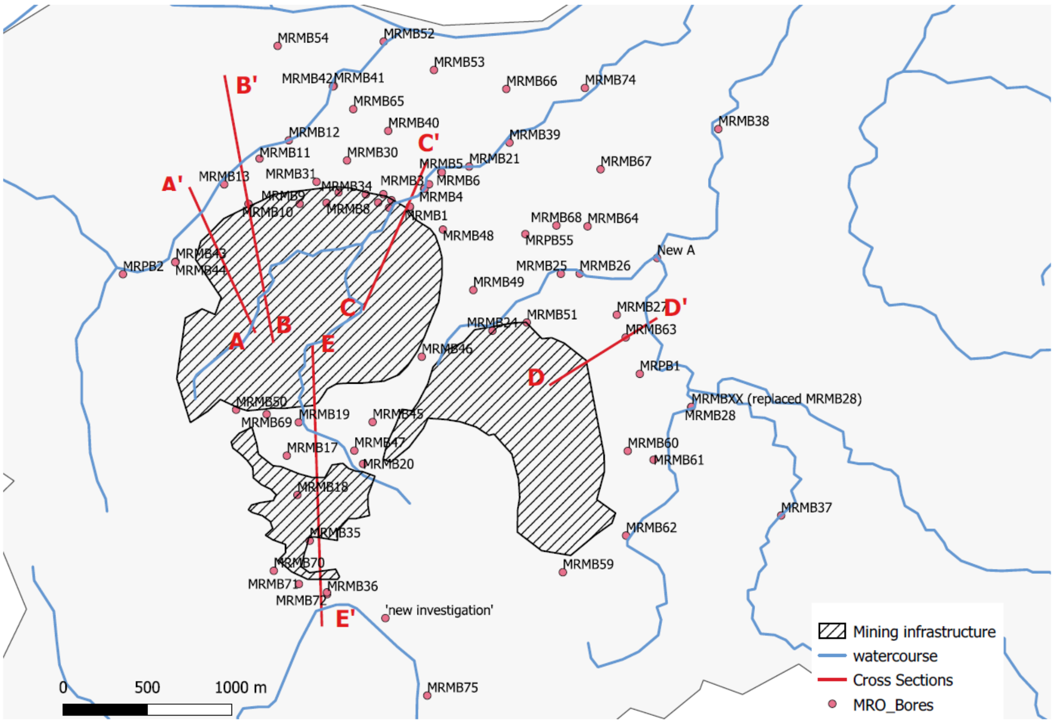

Figure 39: Reference map of groundwater profile sections in the Mount Rawdon mine lease (Source: Northern Resources Consultants, 2019)

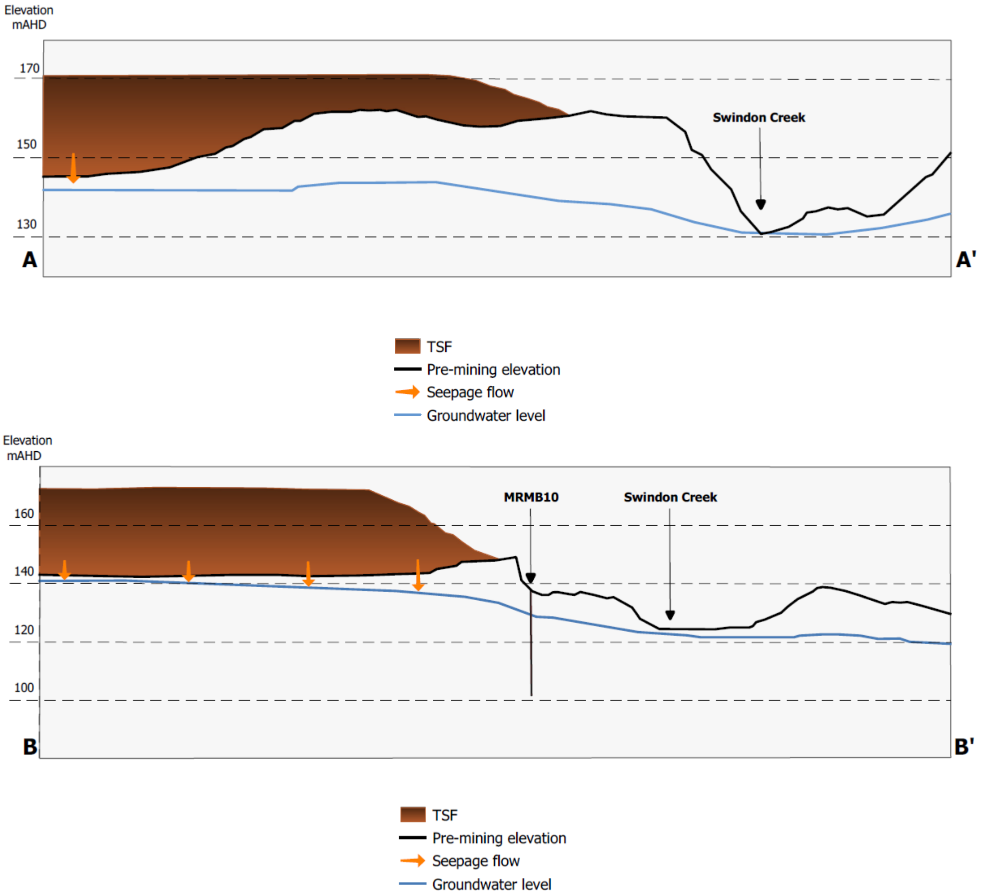

Figure 40: Groundwater profiles entering Swindon Creek (Source: Northern Resources Consultants, 2019)

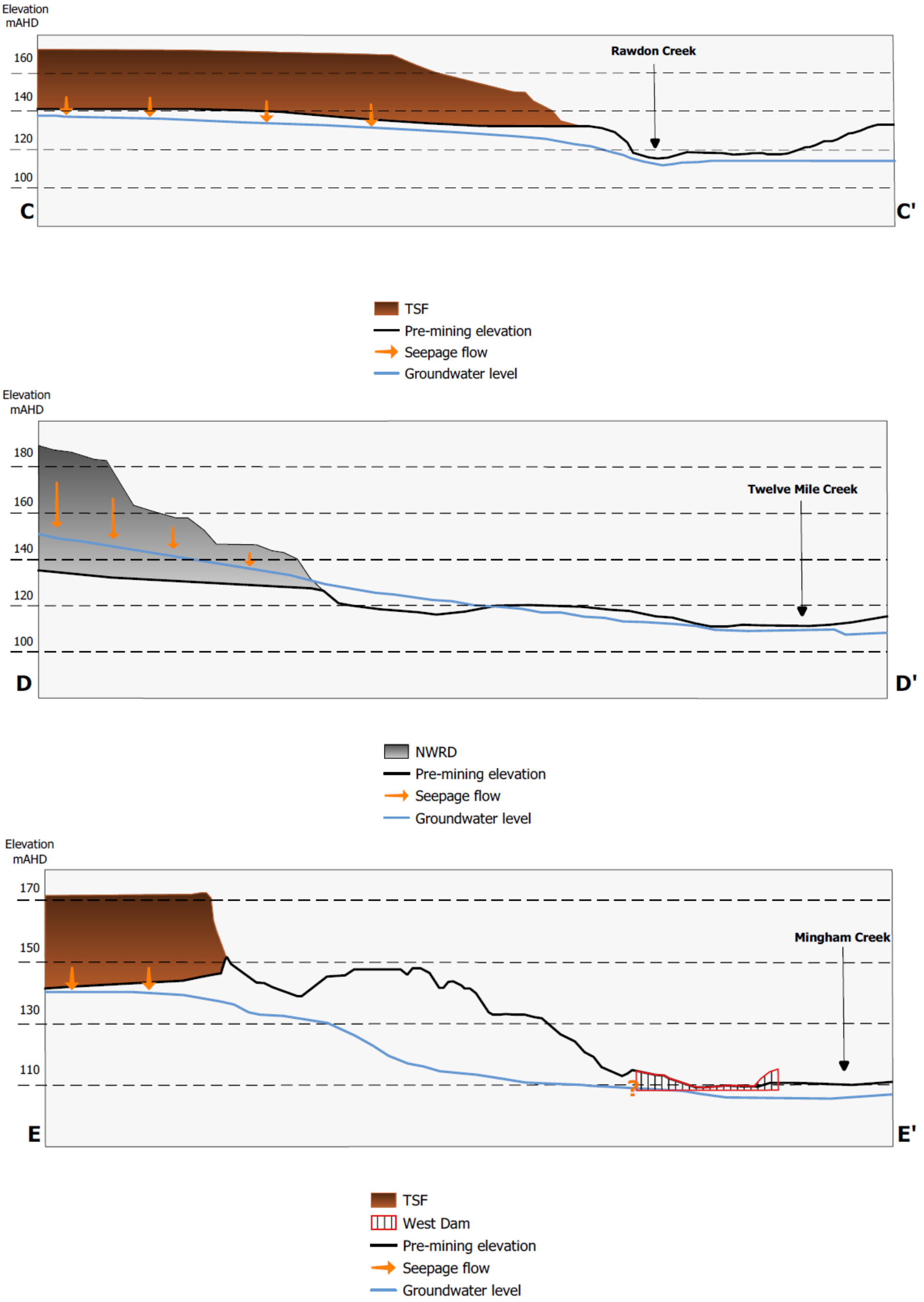

Figure 41: Groundwater profiles entering Rawdon Creek, Twelve Mile Creek and Mingham Creek (Source: Northern Resources Consultants, 2019)

5 Solute Release from Mount Rawdon Operations

This section addresses objective 3 of the environmental evaluation:

3) *Identify the sources of all contaminants that are being, or have been, released from the premises, which are likely to have impacted, or are currently impacting, on receiving waters. Sources of contamination to be considered should include as a minimum:*

   a) current and historical knowledge including events, exceedances and incidents such as releases;

   b) on-site water management infrastructures (including dams, storages and ponds), and/or diffuse mine-related sources; and

   c) any possible mine-related source of contamination to groundwater which is relevant to this investigation.

In this report events are periods when rainfall events and stormwater flows (Figure 42) increased the potential for off-site mobilization of COPC. Wet season rainfall occurs between November and April each year. Events also refer to mining activities that potentially increased the environmental risk of off-site mobilization of COPC and environmental harm. Appendix 8.0 (Table A3) provides a list of events that show the timing of mining activities and mitigation efforts on groundwater quality trends.

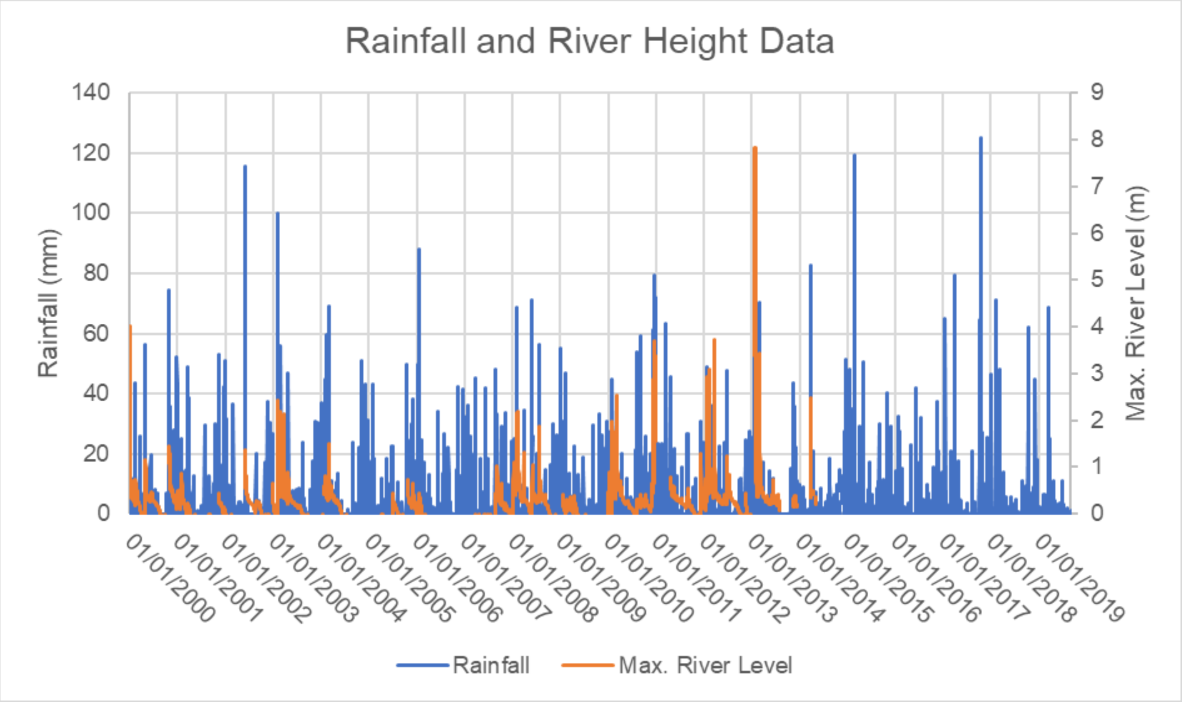

Figure 42: Rainfall (station 39070) and river height data (station 136019A)

On-site impoundments mitigate the risk of off-site mobilization of COPC, by capturing and containing stormwater from the waste rock dumps and TSF outer batter wall. The source terms of COPC contained in these impoundments are discussed in section 5.2 below.

5.1 Historical Records of Events, Exceedances and Incidents

Tailings discharge into the TSF commenced in January 2001, and cyanide began reporting to groundwater bores downstream of the TSF northern wall three months later. Equigold responded promptly to these exceedances by implementing seepage management, as discussed in section 5.2.

The first off-site release of mine affected water occurred during a rainfall event on the 3rd February 2003, involving 227 mm in the first week of February and 336.75mm for the whole of February, which resulted in leaching of the NWRD and overtopping of the interception dam into 12 Mile Creek. In addition, low pH water sample reported to Rawdon Creek. After this event there was a prolonged drought and failed wet seasons over the next five years until January 2008. Overtopping did not occur again until 15th December 2010.

In response to the 2003 overtopping event, Equigold employed engineering consultants to investigate better ways to manage acid mine drainage potential and impound stormwater from the minesite. Equigold also implemented a strategy that limited cyanide exposure in the TSF to avian fauna.

In 2007 exceedances in groundwater, and in seepage water contained in impoundment dams, reported to MRMB20, Sediment Dam 1 and South Dam. In 2008 animal deaths were reported in the TSF, and there were more exceedances south of the TSF (in MRMB19, MRMB20 and South Dam), north of the TSF (in MRMB10) and downgradient of the NWRD (in MRMB24). Equigold made substantial efforts that year to understand and address these exceedances, by:

(i) initiating a soil investigation into heavy metals in vicinity of WD1 (e.g. to identify the provenance of cadmium reporting to MRMB24);

(ii) developing a Stormwater Management Plan; and

(iii) installing engineering works to intercept seepage through the northern seepage zone, and the southern drainage (discussed further in section 5.2.2).

During 2009 and 2010 there were several incidents in the processing area involving tailings spills, raw water spills and minor oil spills.

On the 15th December 2010, there was uncontrolled release of water from WD1, WD2, WD3, WD4 and SD2 that did not comply with the licence condition.

In July 2011 groundwater monitoring of seepage reporting to MRMB10 was recommended. Electrical conductivity in MRMB10 declined until 27/6/2012, then continued to decline at a slower rate until 2015, which signified that the total salt load reporting to this bore was diminishing, possibly because the Toe Interception Seepage Drain had been installed. After August 2013, following additional improvement to the pump-out/seepage recovery capacity from the upper western abutment, the SO_4/Cl ratio reporting to MRMB10 started to decrease. This signified that capture of seepage from this flow path had been improved by the added pump-out seepage recovery.

Despite the improvement observed in MRMB10 in 2011 and 2013, there was increased breakthrough of tailings seepage elsewhere along the northern seepage zone in 2010 and 2012 manifesting as cyanide reporting to MRMB8, MRMB9, MRMB31 and MRMB30. In 2012 there were exceedances of trigger values for cyanide reporting to MRMB8 and MRMB09. These increases and exceedances were attributed to removal of clay from the borrow pit below the toe of the TSF northern wall, which allowed groundwater flowing below the TSF to report to the surface and to downgradient receptors (refer figure 1). In addition, desludging of SD1 in October 2011 damaged the clay bund in SD1, which contributed to cyanide reporting further downgradient along Rawdon Creek. In December 2011, SD2 water became more like SD1 water as a result of the increased transmission of seepage water. SD2 overtopped on the 12th – 13th December 2011, and again in February 2012.

In 2012 there were exceedances of SO_4 and NO_3 reporting to MRMB25 and MRMB27 in Twelve Mile Creek (investigated by Northern Resources Consultants). On the 11th January

2013 there was a regionally significant stormwater event that resulted in overtopping of the Waste Rock Dams into Twelve Mile Creek. In 2014, remedial works were performed on Waste Rock Dams 1 and 2, as discussed in section 5.2.2.

In 2016 Evolution notified DERM of intent to improve water management practices in the borrow pit below the toe of the TSF northern wall, and in mid-2017 construction of the Downstream Seepage Interception Drain commenced.

Between March and April 2017, SD1 and SD2 overflowed into Rawdon Creek.

In November 2017 Evolution informed DES that it did not meet the Design Storage Allowance due to heavy rainfall and stormwater flows earlier that year. However, by November 2018 successful dewatering and lack of substantive rain meant that the required freeboard in the interception dams had been restored by November 2018.

In February 2018 seepage was observed in a gully near Bore 10. ATC Williams provided a response on how to contain seepage water, which has been actioned.

Between March 2018 and May 2019 there have been seepages reporting from the north-western flank of the TSF. Seep 21 expressed downstream of the Western Saddle Embankment near the former Clean Water Diversion Drain (CWDD) outlet, and seep 26 expressing near Well 1, identified using geophysical imagery to be flowing through shallow basement sequences. Evolution Mining are installing 3 pump-back bores to capture these seeps, and will extend the Downstream Toe Interception Drain to capture potential seepage/stormwater bypassing Well 1.

In late 2019 there are multiple groundwater nonconformances that are being investigated by this Environmental Evaluation. These include A-limit non-compliances in MRPB1 (EC,SO_4), MRPB2 (Fe), MRMB21 (EC), MRMB41 (Fe), MRMB42 (EC), MRMB43 (EC, SO_4), MRMB44 (Cu, EC, SO_4), MRMB49 (EC), MRMB54 (Fe), MRMB67 (Zn), MRMB71 (SO_4), MRMB74 (EC, SO_4), MRMB75 (EC, SO_4, Fe). B limit non-compliances report in MRPB1 (EC, SO_4), MRMB42 (SO_4), MRMB43 (EC, SO_4), MRMB44 (EC, SO_4), MRMB49 (EC), MRMB63 (EC), MRMB67 (Zn), MRMB68 (EC), MRMB71 (SO_4), MRMB74 (EC, SO_4), MRMB75 (EC, SO_4, Fe), MRMB77 (EC, SO_4, Cu, As V), MRMB78 (EC, SO_4, Zn).

5.2 On-Site Water Management Infrastructures and Diffuse Mine-Related Sources

On-site Water Management Infrastructures involve:

i) Containing tailings within the TSF, as well as intercepting and returning seepage from the TSF;

ii) intercepting seepage from the NWRD and the WWRD, and returning the seepage to the process water circuit.

5.2.1 Management of Tailings Seepage

The Stage 1 TSF was originally designed as a valley type storage, formed by the primary embankment at the downstream (northern) end of the site, an upstream embankment (southern end) and saddleback embankment (western end). The Starter Embankment Crest was formed using rock fill (run-of-mine waste rock) with a clay fill core and associated filter zone within the upstream embankment face. Over time, the TSF has grown into a turkeys nest structure in a series of successive builds.

Seepage infrastructure was installed in the northern seepage zone seven months after tailings discharge commenced in January 2001. Permanent flow pumps with meters installed were commissioned, and warning signs of cyanide risk erected.

In 2008 Equigold made substantial efforts to understand and address exceedances in groundwater reporting through the northern seepage zone and the southern drainage, by:

(i) installing the Southern Embankment seepage collection system, which is a seepage collection trench with subsurface drainage pipe that extends approximately 550m beneath the Southern Embankment along the eastern perimeter and drains to a sump (Stan's Well) located adjacent to the site office. Seepage water collected within the sump is recovered and transferred to the Process Water Dam in the plant site; and

(ii) installing the Toe Seepage Interception Drain below the Northern Embankment toe, which extends the length of the embankment. This drain discharges into TSF Sed Dam 1.

Before 2008 pumpback bores had already been established in the Rawdon Creek drainage in MRMB1, MRMB22 and MRMB23.

Over time it became evident that the Toe Seepage Interception Drain had limited flow capacity due to inadequate gradient, therefore the system was upgraded in 2013 to include a further three sumps (TSF Well 2, TSF Well 3, TSF Well 4) on the western part of this drain, which provided additional pump-out/seepage recovery capacity from the upper western abutment that reported to MRMB10. After August 2013, the SO_4/Cl ratio reporting to MRMB10 started to decrease, which signified that seepage capture from this flow path had been improved by the additional pump-out seepage recovery.

Between 2010 and 2012, substantial removal of clay from the borrow pit below the toe of the TSF northern wall allowed groundwater flowing below the TSF to report to the surface and to downgradient receptors (MRMB8, MRMB31 and MRMB30). In addition desludging of SD1 in 2012 had damaged the clay bund lining this dam, which allowed transmission of tailings affected water downstream along the Rawdon Creek drainage line. Evolution Mining initiated a corrective action to restore the damaged clay bund in SD1 after the wet season had finished. Other corrective actions implemented in late 2012 included installing a temporary dewatering trench ("Marty's Trench") downgradient of MRMB8 and changing dewatering practices to avoid overloading the drains. In 2013 a dewatering bore was installed and equipped on the Stage 2C (RL 150.0m) crest of the Northern Embankment to transfer water to TSF Sed Dam1. This bore extends some 7m into the upstream rock fill shell of the Stage 1/Stage 2 (starter embankment), and is intended to:

i) Remove excess water in the rock fill of the Starter Embankment, which is likely to be applying head to the Northern Embankment core and cut-off key;

ii) Allow greater dewatering of the tailings beach adjacent to the Northern Embankment, thereby enhancing tailings consolidation and associated beach strength, and reducing the liquefaction potential subject to an extreme seismic event; and

iii) Assess the further potential to install additional bores along the Northern Embankment to further enhance the seepage recovery.

Siphoning was halted in late 2016, to allow revaluation of the system in light of the alternate seepage and embankment stabilisation measures.

In late 2015, an action plan was developed to address non-compliance of MRMB31 during October 2015, which had been foreshadowed by groundwater trends observed since clay removal from the borrow pit 2010 and 2012. In January 2016, a clay seepage cutoff wall (140m x up to 6m deep) was installed either side of TSF Well 3 (the efficacy of this cutoff wall was questioned because abundant seepage water made it difficult to compact the clay). At the same time leaks in TSF Well 3 were repaired. In April 2016, a battery was installed to provide back-up power for the solar pump installed at TSF Well 3, which allowed 24hr/day pumping. In December 2016 a pumpback bore between Marty's trench and MRMB30 was installed. In 2016 stormwater reporting to Rawdon Creek was better managed with the TSF Sediment Dam 3 development.

In mid-2017 construction of the Downstream Seepage Interception Drain commenced as part of the TSF Sed Dam 3 development. This drain borders the downstream toe of the

TSF Northern Embankment and penetrates weathered rock by up to 4m (to 115m AHD) to enhance the overall seepage recovery. Seepage entering the trench reports to TSF Sed Dam 1.

5.2.2 Intercepting Seepage from Waste Rock Dams

At the beginning of February 2003, leachate from the stockpile had been observed. As a result of heavy rainfall on already wet soil, the sediment dams that collect water from the north tailings dam wall and the newly constructed waste rock dump drain overflowed. Water samples showed that the overtopping contained metal concentrations well in excess of the EA. The management response to recover this water after receiving the lab tests was immediate.

In response Equigold commissioned Allan Watson and Associates to design four interception dams. Two dams, designed to capture a 1:20 year rainfall event, were completed by 15th October 2003 to intercept and transfer all flows from the then current waste dump for use in the process water circuit. As an added precaution to raise water pH and immobilise metal ions to sedimented substrates, calcium hydroxide solutions were added to the catch drains at the toe of the waste rock dump and some 100 tonnes of Aglime was added adjacent to the toe of the waste rock dump, with higher applications targeting the flow paths to the interception dams. The two remaining interception dams, WD3 and WD4, were constructed to fulfil the same purpose. These control measures were inspected by EPA officials on 11 December 2003.

Equigold also commissioned geochemical consultants to revise and improve the waste rock classification and handling procedures, which was actioned in 2005 (discussed further in section 5.3.2).

In 2014 the WD1 crest and spillway was raised by 1 meter to increase its storage capacity and the clay core and cut-off key was reconstructed. WD2 remedial works also involved raising the crest and spillway to increase total storage capacity. Seepage works were installed at the downstream toes of WD1 and WD2, to intercept and pump-back groundwater seepage through an alluvial layer and fractured rock. Successful interception of mine affected seepage from WD2 is indicated by the trend of SO_4/Cl in MRMB63 which stabilised and declined in late 2014. In addition, the MRO Mining Department adjusted the use of explosives in a way that lessened NO_3_N residues in waste rock.

5.3 Potential Mine-Related Sources of Contamination to Groundwater

Potential mine related sources of contamination to groundwater include seepage from tailings into groundwater flowing under the TSF, and seepage from waste rock dumps into groundwater as shown in figures 40 and 41.

5.3.1 Potential Mine-Related Sources of Contamination from Tailings

In section 3.3.1 of this report, leaching from tailings was shown to report cyanide, sulfur and metals (e.g. arsenic) concentrations at higher than usual concentrations for native groundwater (refer to discussion in section 3.3.1 of the group 1 type water identified using multivariate statistics). Appendix 7.5 (Table A4) shows the ionic composition of tailings fluid pressed from fresh tailings slurry, which can be compared with the ionic compositions of the decant water (sampled from the surface of the decant), the laboratory-based column tests set up by RGS sampled over one or two years of artificial leaching under controlled laboratory conditions (discussed further below), and seepage water collected by the sediment dams in Rawdon Creek, South Dam, Stan's Well that intercept tailings seepage.

In 2009 MRO identified the need for additional geochemical and mineralogical studies to understand the nature of, and risks from, tailing materials stored at the Mount Rawdon Mine.

RGS (2009) performed a Stage 1 geochemical assessment that identified a low risk of acid generation from tailings materials at MRO, but there was uncertainty with classifying the materials. They identified the major non-sulfide mineral phases to be quartz, muscovite, chlorite (chlinochlore) and albite, with the latter two minerals offering acid buffering potential. Sulfides are pyrite, with minor sphalerite, and traces of galena, pyrrhotite and arsenopyrite. Carbonates are calcite, with minor manganoan calcite (~5%). NAG tests suggested that acid-forming potential was dependent on grainsize (i.e. samples pulverised to a very fine sand texture were non-acid forming). Pulverising increased both ANC and acidity generated by all samples during NAG tests, but the ANC increase was greater than the acidity generation. As such pulverised (fine sand textured) tailings is protected from acid mine drainage and generates a more alkaline leachate despite the greater potential for sulfide weathering.

RGS (2009) also identified considerations with respect to leachate generated by 'fine' and 'coarse' textured material, where coarse tailings contain a greater proportion of sulfides and lower ANC capacity than fine tailings. The potentially acid forming (PAF) nature of coarse tailings has implications for tailings management if there is significant segregation of coarse and fine tailing materials (e.g. if the coarse tailings fraction settles on the beach areas whereas the fines flow to the centre of the TSF).

The high variability of the ore feed is reflected by the variable nature of tailings material reporting to the TSF. The kinetic tests showed that surface runoff and seepage from tailings will remain slightly alkaline to pH neutral, with low concentrations of salts and trace metals, for significant time (> 20 years). The rate of sulfide oxidation is currently low and unlikely to generate acid leachate for this period. RGS considered that the final cover over tailings could consist of low risk waste rock, which has CEC and ESP results that indicate it will allow revegetation as part of rehabilitation activities while also allowing armouring against excessive erosion.

RGS (2017a) performed further kinetic and mineralogical investigations for the Stage 2 report to eliminate the uncertainty in classification, clarify the ongoing geochemical nature of these materials and investigate the long-term risk posed by seepage from storage areas to the quality of surface runoff. They assessed the long-term characteristics of aged tailings materials stored in the TSF. Near-surface tailings were collected from the isolated south-west cell of the TSF, some parts of which had been exposed to oxidising conditions for up to 5 years. The tailings were characterised by static geochemical tests and then subjected to kinetic leach column tests under saturated (anoxic) and unsaturated (oxic) conditions for 2 years. The anoxic conditions are thought to represent a cover placed over the tailings, and the anoxic conditions represent no cover system. The geochemical characteristics of tailings material, and risks associated with long term seepage of the material, were reported and recommendations made.

The four tailings samples had similar geochemical characteristics (by contrast with the earlier RGS 2009 results that had indicated variability associated with the high variability of the ore feed). The leach tests operated under a bi-monthly watering and leach cycle for the first year (5 leach events), then under a six-monthly watering and leach cycle for the second year (2 leach events). Each 1.6 kg sample was subject to leaching under a constant 10cm head of deionised water (saturated) or under diurnally activated heat lamps and freely draining (unsaturated). Leachates were tested for EC, pH, alkalinity, dissolved metals, dissolved major elements.

The aged tailings are enriched with As, Cd, Cu and Zn, as would be expected with pyrite mineralised gold ore. The tailings materials were alkaline (pH 8.2-8.6) and slightly brackish (759 - 3,330 mS/cm). There is just over 1% total sulphur, of which about 70% is pyrite (potentially acid generating) and 30% is sulfate, galena or sphalerite (not acid generating). The Maximum Potential Acidity (MPA) of tailings is 24.3 - 25.7 kg H_2SO_4/t and the Acid Neutralising Capacity (ANC) 27.5 - 47.5 kg H_2SO_4/t, and previous studies have shown that at least half of the ANC is immediately available to buffer any acid generation with the remainder being slower to react and only available at lower pH values. As such the Net

Acid Producing Potential (NAPP) is -1.8 to -23.2 kg H_2SO_4/t, averaging -10.9 kg H_2SO_4/t, and the ANC:MPA ratio ranges from 1.07 to 1.95 (less than 2) that indicate the tailings material is marginally classified as Non-Acid Forming (NAF).

Leachate from the tailing's column test yielded circumneutral pH (6.0 - 7.8), with the water saturated leachate being slightly more acidic than the water unsaturated leachate, and the trend for both conditions being towards higher pH over the leaching period. The net alkalinity value was positive over time but decreased over the two years indicating that carbonate alkalinity was interacting as a pH buffer against acid generation. The EC concentrations were initially high (6.7 - 8.2 mS/cm) but decreased to 1.6 mS/cm or less. The dominant major ions were Ca and SO_4, with lesser contributions of K, Mg, Na and Cl. After 2 years of leaching, nearly 85% of sulfur remained in the tailings (measured by subtracting the SO_4 that had leached out of the sample), and at least 89% of the ANC remained (ANC includes chlorite, albite and carbonates). The rate of sulfate generation was 45 - 53 mg/kg/week, which is a low to moderate sulfide oxidation rate for mine materials (mine materials with this oxidation rate and moderate ANC capacity are likely to generate neutral rather than acidic mine drainage). Therefore, the kinetic test supported the NAF classification of the static test. Trace metals concentrations were low and predominantly below detection, except for Mn and Cd in the water saturated column, and the Mo concentration in the water unsaturated column, which were high compared with livestock drinking water guideline values. RGS considered that the risk of release of significantly elevated concentrations of dissolved metal/metalloids was low and manageable. WAD cyanide values were below detection.

Kinetic testing of aged tailings resembled results of the tests done on fresh tailings (RGS, 2009), in that the tailings are slow to react and a long (>20 year) time is expected before the ANC could become exhausted. Since sulfide depletion parallels ANC depletion, it is not expected that lower pH conditions will eventually occur when the ANC is exhausted.

Recommended management measures were to continue to monitor pH, EC, acidity, alkalinity, major ions, dissolved metals in TSF decant water as well as in groundwater seeps downstream of the TSF.

5.3.2 Potential Mine-Related Sources of Contamination from Waste Rock

In section 3.3.1 of this report, waste rock seepage was shown to contain a combination of nitrate and sulfur reporting at higher concentrations than usual for native groundwater (refer to the group 2 water type identified using multivariate statistics in section 3.3.1). Appendix 7.5 (Table A5) shows the ionic composition of seepage from freshly blasted rock reporting to the pit sump[23], compared with the ionic compositions of laboratory-based column tests representing NAF, Medium PAF and High PAF sampled over one year of artificial leaching under controlled laboratory conditions (discussed below), and seepage water collected by the waste rock dams.

In 2003 Equigold commissioned Dobos and Associates, a specialist company, to investigate the AMD problem and associated risks relating to the waste rock dump and waste rock classification in response to overtopping that had occurred that year. The original (EGI96) method of selectively handling waste rock was reviewed and was shown to have flaws

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[23] A waste rock source term being measured at 4 seepage locations over 2 years between 2018 and 2020. In the meantime, the Pit Sump water type is used as a surrogate for waste rock seepage water (i.e. for the Environmental Evaluation Stage 1 report). Because some ore is represented in Pit Sump water, this is a conservative assumption consistent with the precautionary principle of environmental protection.

(Equigold, 2004, Equigold, 2005), which will be discussed below. EGI96 had proposed a waste rock assessment based on NAG (Net Acid Generation) and ABA (Acid Base Accounting) on the total S and total C of 99 ore and waste samples. EGI96 classified rocks as type 1 (net acid neutralising), type 2 (nominally producing no acid) ... type 5 (relatively high acid producing to be handled separately). The EGI96 report formed the basis of the waste rock handling procedure (EMOS99), which was implemented from the inception of mining in mid-January 2001. Materials placed during early waste rock dump and tailings dam construction followed precisely the EMOS99 protocol. The design intent of the waste rock dump was to create an inner core of net acid producing rocks (types 3 and 4) and an outer rim of rocks with neutralising capacity (types 1 and 2). The strategy behind this design was that acid leachates generated in the inner core will become neutralised by passage through the encapsulating layer. Similarly, the design intent of the TSF was to construct an inner batter of types 1 - 4 waste rock on the upstream side of the clay barrier inside the TSF, and an outer batter of type 1 - 2 on the exterior (outer) batter of the TSF. This strategy failed because the original waste rock classification of EGI96 underestimated the risk of acid generation.

Problems with the EGI96 classification included:

(i) The availability of late-stage sulfide minerals to oxygenated groundwater was under-represented by powdered bulk rock samples from percussion drilling, where properly spilt and subsampled rock yielded true total C and S analysis but not the exposed sulfide mineral surfaces. Blasted rock preferentially fractures along curvilinear shears, faults, joints and earlier veins, within which (late stage) pyrite has mineralised. These sulfide minerals are exposed on the surfaces of blasted waste rock. However, carbonate minerals are more evenly distributed within the rock, shielded from oxygen containing groundwater that contacts sulfides on exposed fracture surfaces, and these carbonates are not immediately available to neutralise acidified groundwater. A reverse bias was recommended to accommodate for certain percentages of sulfide minerals being exposed to groundwater and carbonates being shielded from groundwater. Note that this weathering process applies only to late stage pyrite mineralisation, and not to the earlier pyrite mineralisation in the volcaniclastics (RGS, 2009 identified that early stage pyrites are shielded from groundwater solution by silicate minerals, as was previously discussed in section 5.3.1).

(ii) The EGI96 classification scheme raised several questions including:

   a. improper original interpretation of the 'acid neutral line' graph of C and S concentrations in rock, which caused acid producing rock to be incorrectly classified as being zero acid producing rock; and

   b. analytical precision associated with the C analyses.

   The revised analytical classification scheme addressed these conflicts by using classifications parallel to the 'acid neutral line' in the graph of C and S concentrations in mined rock and allowed conservatism with regards to analytical precision when the %C was recognised to be low. It was identified that early in the mining operation some rocks had been mis-classified as being non-acid forming, and had as a result been incorrectly placed in the outer rim of the waste rock dump and the outer shell of the TSF, which has left a legacy issue that needs to be factored into both the mine operational plan and the mine closure plan.

Dobos and Associates proposed a new classification (renamed Type A, B, C, D and E to avoid confusion with the earlier numerical notation associated with the EGI96 report), which accommodates for the heterogenous mineralogy of waste rock and is also conservatively biased towards the precautionary principle. In 2005 the original (EGI96) method of selectively handling waste rock was replaced by the updated waste rock classification and handling scheme, which has worked more effectively since then. Waste Rock Dams 3 and

4 drain a part of the NWRD built entirely using the updated waste rock classification scheme and have reported better water quality than the part of the NWRD partly built using the original waste rock classification that drains into Waste Rock Dams 1 and 2. These improved results demonstrate successful implementation of waste rock handling procedures at avoiding acid mine drainage and consequently minimising solute generation from weathering of waste rock. Dobos and Associates also recommended a research program to fully understand the AMD risks associated with rock weathering.

RGS (2009) performed a Stage 1 geochemical assessment that reviewed existing work and performed new static tests. The outcomes were to assist MRO to optimise the waste rock, low-grade ore and tailing management strategy, to identify potential for acid and metalliferous drainage (AMD) from the waste rock dumps and TSF (into which high PAF waste rock is placed) and minimise the risk of significant environmental harm to the immediate and downstream environment.

Existing work indicated that:

(i) most waste rock (about 70%) and ore (about 80%) will be NAF;

(ii) the fresh tuff ore type is expected to be NAF whereas the dacite and breccia ore types are expected to be PAF; and

(iii) sulfides in the PAF ore and waste rock materials are expected to react slowly with a lag of at least 10-20 years before acid conditions could occur. In the low risk acid categories, carbonates formed rims around pyrite grains, whereas in the high acid risk category spalerite formed in contact with pyrite while carbonates were irregularly distributed. High risk acid samples were more concentrated in the zone of chloritic alteration than in the sericitic zone of alteration. There is an existing block model that codes the acid forming potential for the waste rock material.

The Stage 1 investigation predicted:

(i) Initial surface runoff / leachate from waste rock and low-grade ore materials was expected to be alkaline and non-saline;

(ii) most waste rock and low-grade ore materials will be non-acid forming (NAF), Uncertain (NAF) or Acid Consuming (AC);

(iii) Some uncertainty was associated with the geochemical classification of most (>50%) of the waste rock and low-grade ore samples tested, being caused by a low ANC/MPA ratio (<2). This result suggested a lower factor of safety;

(iv) the total carbon value of the waste rock and low-grade ore samples strongly correlates with the experimentally derived acid neutralising capacity (ANC), suggesting that most of the carbon in the samples is reactive carbonate. However, acid buffering characteristic curve (ABCC) test results suggest that only a portion of this ANC is readily available to buffer any acidity generated through sulfide oxidation;

(v) available ANC is relatively high in low risk waste rock samples (67-80%) and moderate in low-grade ore samples (40-50%). However, it is relatively low in medium risk and high-risk waste rock samples (25-30% and 24-37%, respectively);

(vi) Kinetic NAG results indicate that inherent sulfides in waste rock and low-grade ore are less reactive under strongly oxidising conditions than expected, because they are shielded from oxidation by crystalline silicates that are relatively stable in an oxidising environment (Figure 43). Further geochemical and mineralogical tests on representative samples of waste rock and low-grade ore materials were required from the stage 2 tests (reported in RGS 2017b).

RGS (2009) stated that total metal concentrations in waste rock and low-grade ore materials were unlikely to present concerns related to mine operation and final rehabilitation. The low risk waste rock materials are amenable for use as the final surface and batters of the WRD, and as part of a final cover system over tailings at the TSF. Cation exchange capacity (CEC) and exchangeable sodium percentage (ESP) results for waste rock and low-grade ore indicate that low risk waste rock materials should be amenable to revegetation as part of rehabilitation activities. The selective handling and encapsulation control strategies employed by MRO for the management of waste rock and low-grade ore materials currently appear to be reasonably successful.

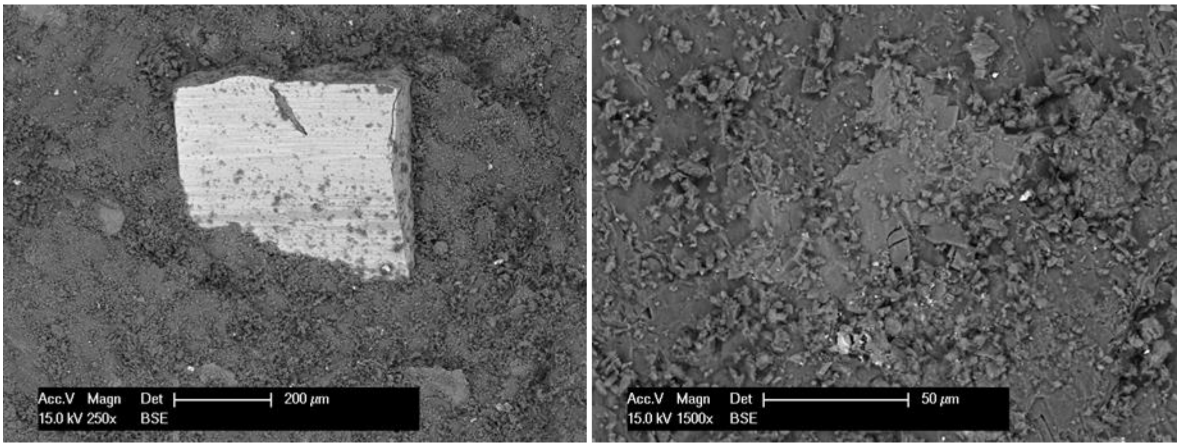

Figure 43: Pyrite (left) and manganoan calcite (right) encapsulated in composite rock from the high risk waste rock sample (Source: University of South Australia, cited in RGS 2009)

For waste rock and low-grade ore materials, RGS (2009) recommended that MRO maintains the current conservative selective handling and encapsulation control strategy for managing waste rock and low-grade ore materials at the WRD for the time being as a result of the uncertainty associated with the geochemical nature and classification of some materials.

For the Stage 2 investigation RGS (2017b) assessed the long-term characteristics of waste rock types, as well as tailings/waste rock mixtures that represent potential long-term storage situations for TSF materials. They performed geochemical assessments (static and 12-month kinetic leaching) on field-aged Non-Acid Forming (NAF), Medium Potentially Acid Forming (PAF), High PAF, and NAF/uncertain tailings rock types (refer results in Appendix 7.5, Table A5). The methodology was consistent with other geochemical tests that RGS have done on waste rock and tailings.

Findings were that some samples (e.g. PAF waste rock) were geochemically more benign than initially thought after the static geochemical results performed for stage 1. That is they weather slowly, despite sometimes having elevated sulfur content (1.5 - 4.3% of which 1.3 - 3.6% is potentially acid generating), moderate ANC and a reduced factor of safety with respect to AMD potential if exposed to long term oxidative weathering (ANC:MPA ratio of 1.6 to 0.3). NAF waste rock has negligible sulfur content (0.5% of which 0.4% is potentially acid generating), elevated ANC (ANC:MPA ratio of 8.3) and a high factor of safety with respect to Acid Mine Drainage (AMD), Neutral Mine Drainage (NMD) or Saline Drainage (SD).

Initial discharges from NAF and PAF waste rocks are expected to be pH neutral to slightly alkaline with low salinity. Ongoing discharges from the NAF materials are likely to contain excess alkalinity (thereby retaining low AMD risk). PAF waste rock material are expected to have a lag of > 6-12 months preceding acid generation. The waste rock is enriched in Cd in some PAF waste rock, as expected in association with a pyrite hosted gold mine. Most metals are sparingly soluble at the predicted pH of the discharges, but Al, Fe and Cu may become solubilised and mobilised from PAF waste rock if exposed to oxidative weathering and acidic pH conditions are allowed. As such encapsulation of high PAF waste rock within NAF in the TSF as well as in the WRD (as currently practiced by MRO) is likely to reduce the risk of AMD, and maintain or improve the quality of surface runoff and seepage.

RGS (2017b) recommended that crushed limestone should be added if PAF is left uncovered for more than 1 year, and in any case prior to placing the cover system in the draft conceptual closure plan.

6 Conclusion and Recommendations

Mount Rawdon Operations (MRO) have developed a conceptual model for the dominant hydrogeological systems of the mine lease, and sources of COPC that have been released from the TSF, waste rock dumps and processing area.

Hydrogeological Features of the Mine Lease

MRO is a fractured rock aquifer associated with the extinct core of a shield volcano, with the Aranbanga Andesite to the west and silicified Curtis Island Metasediment to the east. There are two landscape units:

1) Steep hilly to mountainous country on metasediments on the west of the lease. The soil order of this landscape unit is tenosol; and
2) Low to moderately hilly lands on phyllites and schists on the east of the lease. The soil orders of this landscape unit are sodosol, rudosol and dermosol.

An irregular weathering profile features isolated deep pockets of saprolite and oxidation transition zones on sloping land, which are subject to drainage after rainfall events and become depleted in the dry season. There are three aquifers:

1) soil and alluvium (limited in extent and thickness);
2) weathered rock; and
3) fractured rock.

There are groundwater compartments in the weathered and fractured rock aquifers, which have structural features that influence groundwater flow: bedding planes and foliation, zones of argillization, dykes, faults and fracture planes. Hydrogeological properties in soil and rock are:

1) Topsoil. K_{sat} 0.9 – 2.7 m/d, bulk density 1.4 – 1.6 g/cm^3, porosity 0.4;
2) Subsoil. K_{sat} about 0.01 m/d, bulk density 1.4 – 1.5 g/cm^3, porosity 0.4 – 0.5;
3) Weathered rock. K_{sat} 0.0537 m/d, bulk density 2.6 – 2.7 g/cm^3, porosity of 0.04 – 0.07; and
4) Fractured rock. K_{sat} 0.00179 m/d, bulk density 2.7 – 3 g/cm^3, porosity 0.005.

The hydraulic conductivity (K_{sat}), transmissivity (T) and permeability (κ) of the combined weathered / fractured rock aquifer range from impervious to semi-pervious (K_{sat} of 4.2E-3 to 5.5E-1 m/d, T of 1.2E-2 to 8.4E+0 m^2/d and κ of 6E-15 to 5E-13 m^2).

In addition to the above, the calibrated hydrogeological model provided a mine-lease scale synthesis of the hydraulic conductivities and thicknesses of the aquifers. They were consistent with semi-pervious soil / weathered rock, and semi-pervious to impervious fractured rock / basement.

Geological Barriers in the Mine Lease

The low hydraulic-conductivity subsoil potentially impedes recharge of the fractured rock aquifer. Structural controls and the fabric of the fractured rock aquifer provide:

1) Flow barriers where argillized gouge material, dykes, sills, faults obstruct groundwater flow. Associated with block faulting are lithologies with lower

permeability than the surrounding wallrock. The block-faulted collapse structure of the volcano limits groundwater flow into the open pit;

2) Flow conduits along thin crush zones formed along the margins of dykes, brittle faults and joints; Groundwater also flows through planes of decollment and connected pores in metasediments; and
3) Compartments that host groundwater interstitially in pores and foliations, as well as in intersecting open-fractures and joints. Evapotranspiration by deep rooted plants is potentially significant for dewatering the compartments during the dry season.

Ionic Composition of Groundwater and Mine Source Terms

Principal Components Analysis (ordination) and Cluster Analysis (classification) allowed native groundwater to be distinguished from mine source terms, and helped identify mine affected groundwater.

At the mine lease scale, the principal components of groundwater and mine source term chemistries were consistent with:

1) Solutes generated by weathering of feldspar and carbonate in the landscape;
2) Solutes generated from mining and processing of mineralised ore; and
3) Solutes generated from mineralised sources.

79.5% of ionic composition variations in the mine lease was explained as a response to weathering of the landscape and of mineral deposits in the landscape, as well as seepage of water influenced by mining and processing of ore.

The classification identified the following five water quality groups:

Group 1: Water influenced by tailings seepage;

Group 2: Water largely influenced by waste-rock seepage;

Group 3: Largely not mine affected, except for slight mine effects along Swindon Creek and possibly at another location in the mine lease. This group includes some compliance monitoring bores located near the edge of the lease;

Group 4: Groundwater predominantly screening in Curtis Island Metasediment. A subgroup is not mine affected, though there are two mine affected sub-groups. One mine affected sub-group is close to where the inferred West Dam Fault extends beneath the TSF. The other is north of the TSF (mostly along Rawdon Creek) and below the processing area; and

Group 5: Groundwater screening predominantly in Curtis Island Metasediment, with some bores screening in or near intrusive rock. This group is not mine affected, except for a sub-group associated with South Dam and waste rock dams 1 and 2.

Sub-catchment scale interpretation of the ionic composition of groundwater and mine affected water using multivariate analysis, supported by univariate time-series charts of Electrical Conductivity, SO_4/Cl, NO_3_N and cyanide over time, indicated the following:

1) Swindon sub-catchment: Bores down gradient of the TSF western cell, in the upper section of Swindon Creek, show recent influence of mine seepage (which is being addressed in FY20). Bores in the central section of Swindon Creek, downgradient of the TSF northern seepage zone, show past influence of mine seepage that has stabilized;
2) Unnamed sub-catchment between Swindon Creek and Rawdon Creek: Mine affected water has reported to the TSF northern seepage zone in the headwater of this creek. Seepage interception resulted in declining electrical conductivity and NO_3_N concentrations in mine affected groundwater after 2005, although the SO_4/Cl ratio in groundwater shows some bypassing of the interception continued until 2010. In 2010 removal of clay from the borrow pit at the toe of the northern TSF batter wall

coincided with breakthrough of mine affected water into groundwater in the upper section of the unnamed creek (manifested as SO_4/Cl ratios and total cyanide in groundwater). Upgraded seepage mitigation occurred in 2017 (the Toe Seepage Interception Drain was reconditioned, and the Downstream Toe Interception Drain was commissioned), but it is it is too early to tell from monitoring data whether the upgrade has halted or reversed the breakthrough;

3) Rawdon Creek: Bores located on, or flanked by, a landscape spur between Rawdon Creek and Twelve Mile Creek are unaffected by mining. The ionic composition of groundwater in these bores can be explained by localized granite weathering and downslope movement of salts. These bores represent a distinct groundwater compartment.

   Along Rawdon Creek several groundwater bores are mine affected, particularly after 2012 when clay was removed from the borrow pit below the north wall of the TSF. Groundwater trends for SO_4/Cl and total cyanide follow improved waste rock management in 2005, and seepage mitigation strategies in 2013, which slowed (and in some locations reversed) the mine effect on groundwater;

7) Twelve Mile Creek: Downslope movement of sulfate, nitrate and arsenic ions in groundwater towards Twelve Mile Creek is potentially caused by:
   a) Naturally occurring gypsum and nitrate in agricultural land in the headwater and upper section of Twelve Mile Creek. This groundwater is not mine affected, and in part associates with a distinct groundwater compartment;
   b) Groundwater mounding below the NWRD increasing the hydraulic head of groundwater potential to Twelve Mile Creek, thereby increasing the mobilization of ions released from soil and weathered rock (including from weathering of unmined mineral deposits) by groundwater. Though not seepage of mine affected water, this could be a secondary mining influence affecting the concentrations of COPC in groundwater; and/or
   c) Weathering of waste rock in the NWRD generating ions that enter groundwater seeping along drainage lines and being captured by the waste rock dams as well as by interception wells and groundwater bores downslope of the waste rock dams. This could be a direct mining influence on the concentrations of COPC in groundwater.

8) Southern drainage and Mingham Creek: Mine effects have been reported in groundwater close to the tailings dam and waste rock in the southern drainage. Further downslope along the southern drainage, it is inferred that groundwater mounding by the combined effects of the TSF, South Dam, West Waste Rock Dump and West Dam may have mobilised ions naturally present in the aquifer. There was evidence of seasonal recharge of an aquifer in a sloping catchment, which contained mine affected water, during significant rainfall events in January 2011, March 2012 and January 2013. There is no evidence for mining influence reporting to groundwater in Mingham Creek.

9) Groundwater under the access road is mine affected, with seepage mitigation by Stans Well facilitating apparent stabilisation and reversal of the seepage trend in this area. Groundwater below the processing area is affected by mining, with apparent stabilisation and reversal of the mine effect after 2014

As such the ionic composition of groundwater in the lease area was evaluated for influence by mining, which was shown to be possible close to the TSF and NWRD.

Movement and Surface Expression of Groundwater Across the Mine Lease

The movement of groundwater across the mine lease, as well as into drainage lines, was modelled using a steady state groundwater flow model. The model identified that parts of the mine lease are likely compartmentalised. These compartments include the landscape spur between Rawdon Creek and Twelve Mile Creek, the lower portion of Twelve Mile Creek towards the impounded zone of the Perry River, and the headwaters of Twelve Mile Creek.

Groundwater flow follows the topographic gradient and flows below drainage lines within 3 meters of creek beds. Groundwater flows below the TSF towards the Perry River. The TSF and the NWRD have generated topographic highs, where groundwater mounding under these structures drive groundwater flow towards the Perry River via Rawdon Creek and via Twelve Mile Creek. In the Southern Corridor, groundwater flows westward into Mingham Creek, with the pit providing a localised sink for groundwater flow.

Conceptual Model

Existing conceptual hydrogeological models developed for the landscape and the Mount Rawdon mine lease remain valid, and can be utilized with little modification.

Dryland salinity is recognised in the Central Burnett. Solutes are generated from the weathering of granites in sloping terrain, with the chemistry of groundwater representing both the soil and rock matrix through which water flows as well as landscape processes that contribute to soil salinity. The salinity hazard map for the Burnett Mary and Western Catchments of South East Queensland indicates a moderate to moderately high hazard of salt expression on the lower slopes of the mine lease.

Seeps downslope of the northern toe of the TSF wall are an expression of natural groundwater outflow resulting from rainfall recharge higher in the hillslope beyond the western cell of the TSF. Before mining groundwater followed a subdued version of the topography. After construction of the TSF and mining, the TSF became the highest head feature in the area leading to mounding below the TSF promoting groundwater flow in multiple directions. The pit became the lowest head feature in the area, and remains relatively dry because of flow barriers between the pit and the surrounding strata.

In 2019 these conceptual models remain valid, with the exceptions that the NWRD is now the highest topographic feature, and seepage mitigation intercepts mine affected groundwater flowing to downgradient receiving waters.

History of Water Management at Mount Rawdon Operations, including Events, Exceedances and Incidents

This report has tabled events, exceedances and incidents in the Mount Rawdon mine lease, which included overtopping events in 2003, 2010, 2012 and 2013 that affected downstream receiving environments, and tailings seepage that increased in 2010 and 2012 after clay was removed from the borrow pit below the toe of the Northern Wall.

Equigold and Evolution Mining responded to these events with management actions that included modified blasting procedures, better handling of waste and low-grade ore, evaluation of the weathering characteristics of tailings and waste rock, and seepage interception downstream of the TSF and waste rock dumps.

Recommendations for Stage 2 of the Environmental Evaluation

Stage 1 of the Environmental Evaluation has identified landscape processes (weathering of granites, soil properties) that increase electrical conductivity at the base of slopes, and provide reasons for COPC concentrations in groundwater of the mine lease that exceed the current Environmental Authority limits for reasons other than mining. Stage 1 has also collated data suitable for developing appropriate groundwater limits, which is a required deliverable of Stage 2 of the Environmental Evaluation.

Stage 2 will use appropriate statistics (spatial trends, temporal trends) to demonstrate the possibility of mine influence in groundwater, and background groundwater data will be used to develop local guidelines. Data will be reviewed in terms of soil, geology and landscape position using box plots, piper plots and Fisherian statistics, and tests will be performed to validate the assumptions required of a representative sample set for guideline setting (spatial and temporal independence, homogeneity of variance, normality, number of samples). Refer to the *Groundwater Management and Monitoring Plan* (section 6.1 and Figure 14 in Evolution Mining 2018b) for more detail on the statistical method. These local guidelines will be used to verify the extent of COPC release to groundwater caused by mining activity.

Possible mixing of mine affected water with groundwater scenarios identified in the Stage 1 conceptual model (this report) will be tested in the Stage 2 geochemical modelling report.

A solute transport model is under development, which will utilize parameters listed below to model the transport of COPC along the groundwater flow pathways described in Figure 39, and understand groundwater interaction with aquifer matrices along these pathways. The solute transport model will be calibrated with respect to records of measured groundwater quality, and sensitivity tests will test the influence of parameters such as pH, Oxidation Reduction Potential (ORP), flow rate, Cation Exchange Capacity (CEC) and Specific Surface Area of adsorbent minerals (SSA) on the interaction of dissolved COPC in groundwater with fracture minerals in the aquifer. In conjunction with groundwater flow rates predicted by the hydrogeological model, the solute transport model will predict the extent of COPC transfer along groundwater flow paths towards surface water receiving environments.

Weathering pathways of tailings and mined waste rock assumed by the model will refer to monitoring data (source terms listed in Table A4 in Appendix 8.5.2 and Table A5 in Appendix 8.5.3 of this report), as well as technical and research reports relevant to Mount Rawdon that include column tests performed under laboratory conditions, and leaching trials of waste rock pads under field conditions. The Environmental Evaluation has already completed work that provides a basis for identifying and describing the pathways and mechanisms for the potential release of mining related contaminants into groundwater at Mount Rawdon, which includes:

1) Laboratory tests (x-ray techniques) of primary and secondary minerals generated in the waste rock pads;
2) Laboratory tests of salt expressions (x-ray techniques and 1:5 soil:water extracts with testing for EC, pH, exchangeable ions and an ICP-MS scan);
3) Laboratory tests of the matrices of soil, weathered rock and fractured rock aquifers in terms of:
   a) cation exchange capacity (CEC);
   b) specific surface area (SSA);
   c) representative surface areas of hydroferrous oxide and goethite (SSA_{HFO}, $SSA_{GOETHITE}$);
   d) exchangeable ions released into a solution equivalent to rainwater; and
   e) exchangeable ions released into a solution equivalent to wetland conditions rich in putrescible organic matter.

In addition the Environmental Evaluation is measuring the ionic composition and physico-chemical properties of groundwater plumes leached from the NWRD.

Potential options of preventing further releases into receiving environments may involve the use of geophysics (electrical resistivity imaging) to guide the positioning of solar powered dewatering bores in Swindon Creek, the unnamed creek and Rawdon Creek. Longer term remediation may involve bioreactors or constructed wetlands, which are currently being trialled in conjunction with CSIRO and Australian Wetlands Consulting. Prefeasibility trials have involved:

- static testing of sulfate reduction, nitrate reduction and cyanide decomposition in mine affected water, utilising soil and plant materials that are locally available in waste rock dams; and

- Immobilisation of heavy metals and phosphorus using *Virtual Curtain* technology, which involves developing a synthetic clay in mine affected water that settles out to form a geochemical screen at the base of the dam. *Virtual Curtain* has longer term ANC than hydrated lime.

The prefeasibility trials were successfully completed, and in FY20 are progressing to feasibility trials that will involve a field trial of *Virtual Curtain* application in Waste Rock Dam 2, a laboratory scale column test of denitrification, sulfate reduction and immobilisation, and heavy metal immobilisation, and a field trial of three wetland options that can be utilised at Mount Rawdon.

The final report (stage 3 of the Environmental Evaluation) will utilise outputs of the hydrogeological model developed during stage 1 (discussed in section 3.4 of this report), and the solute transport model being developed during stage 2 (discussed above), to describe the exfiltration of COPC from groundwater into surface water in the mine lease. A United States Environmental Protection Agency surface water model (PC SWMM) will quantify the dilution of exfiltrated COPC in response to stormwater events and riverine processes, to help assess the potential impacts to surface water environments. This model has the capacity to incorporate treatment units, such as dewatering bores, bioreactors and constructed wetlands, and is a suitable platform for demonstrating proof of concept of water management in the Mount Rawdon mining lease.

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8 Appendix

8.1 Glossary

Abbreviation	Meaning
ABCC	Acid Buffering Characteristic Curve of the rock or tailings sample being tested for AMD potential, which is developed by slow titration of the sample while measuring pH to show the portion of the ANC that is immediately available for neutralising.
AMD	Acid Mine Drainage.
ANC	Acid Neutralising Capacity of the rock or tailings sample being tested for AMD potential. An acid (HCl) that will not react with pyrite is reacted with the sample, which consumes some of the HCl in proportion to the neutralising capacity of the sample. The solution is back titrated with NaOH to determine the amount of unreacted HCl. As such the acid consumed by reaction with the rock is calculated, and expressed in terms of kg H_2SO_4/t.
Andesite	Volcanic rock with fine hornblende and plagioclase crystals, which gives the rock a dark green to black colour. At Mount Rawdon andesite was associated with late stage brittle fracturing, where they formed narrow dykes common throughout the deposit area.
Argillization	Weathering of primary minerals in a rock to clay (e.g. feldspar to kaolinite).
Arsenopyrite	FeAsS. An arsenic mineral common in metallic sulfide ores. At Mount Rawdon it is an occasional trace accessory to pyrite.
ASST	**Applied Scientific Services and Technology:** Geophysical consultants (www.asstgroup.com) based in Perth, W.A..
Carbonate	Common minerals that contain carbonate at the Mount Rawdon Mine are calcite ($CaCO_3$) and minor manganoan calcite ($CaMn[CO_3]_2$), which are minerals that occur in both unweathered and metamorphic rock fabrics, and possibly also in weathered rock and soil. They are important for the capacity of waste rock and soil on the lease to neutralise potential acid mine drainage and immobilise some constituents of potential concern by controlling groundwater pH. In circum neutral groundwater dissolved carbonate predominantly occurs as bicarbonate ion (HCO_3^-) but when groundwater is near to or above 8.2 pH the bicarbonate ion (CO_3^{2-}) occurs as well. In these situations in the mine lease, total alkalinity represents the sum of bicarbonate and carbonate ions.
Chalcopyrite	$CuFeS_2$. A copper mineral present in metallic sulfide ores. In the Mount Rawdon deposit, it occurs in narrow (< 5 mm wide) discontinuous veinlets as a trace accessory to pyrite.
CEC	Cation-exchange capacity (CEC) is a measure of how many cations can be retained on soil particle surfaces. Negative charges on the surfaces of soil particles bind positively-charged atoms or molecules, but allow these to exchange with other positively charged particles in the surrounding soil water. This is one of the ways that solid materials in soil alter the chemistry of the soil. CEC affects many aspects of soil chemistry, and is used as a measure of the capacity to retain pollutant cations (e.g. Pb^{2+}).
Chlorite	$[Mg,Fe]_3[Si,Al]_4O_{10}[OH]_2$. A green mineral associated with early metamorphic alteration at Mount Rawdon, which replaced iron-rich (mafic) minerals in the primary rock. Chloritisation pre-dated and was partly overprinted by later sericite alteration. In the context of moderating possible acid mine drainage potential, chlorite contributes to the neutralising capacity of the parent rock and forms part of the crystalline rock fabric that shields disseminated pyrite from oxidation.
COPC	Chemical of Potential Concern are chemicals that have been shown through analysis to be those that are likely to be causing risk to the plants and animals at a site.
Dacite	A silica oversaturated lava intermediate between andesite and rhyolite. It is pale

	cream to dark green in colour, contains crystals of plagioclase, amphibole, biotite, Fe-Ti oxide and disseminated pyrite in a fine grained siliceous groundmass, and occurs as both lavas and welded volcanic tuff formed by explosive reaction (pyroclastics).
Dermosol	Soil that lacks strong texture contrast and has a well-structured B2 horizon with low levels of free iron. It is a high agricultural potential soil with good structure, moderate to high chemical fertility and water holding capacity
Epidote	$Ca_2[Al,Fe]Al_2[SiO_4[[SiO_7][O,OH]_2$. An apple green, calcium aluminosilicate mineral.
Galena	PbS. A lead mineral common in metallic sulfide ores. In the Mount Rawdon Mine it is an occasional trace accessory to pyrite.
Gangue	The commercially valueless material in which ore is found.
Gouge Material	When the two sides of a fault move along each other, the grinding and milling results in loosely fragmented material. First a fault breccia will form, but if grinding continues the rock becomes fault gouge.
Illite	$K_{1.5}Al_2[Al_{1.5}Si_{2.5}O_{10}][OH]_2$. A common potassium clay formed by weathering of feldspar and other aluminosilicate minerals.
Kaolinite	$Al_2[Si_2O_5][OH]_4$. A common clay formed by weathering or hydrothermal alteration of feldspar and other aluminosilicate minerals.
MODFLOW - SURFACT	MODFLOW-SURFACT Flow and Transport groundwater simulation software describes complex saturated/unsaturated subsurface flow and transport processes. It is based on the USGS modular groundwater flow model, MODFLOW.
MPA	The Maximum Potential Acidity determined from the %S in a rock or tailings sample being tested for AMD. MPA (kg H_2SO_4/t) = (Total %S)*30.6, assumed as pyrite.
Muscovite	$KAl_2[AlSi_3O_{10}][F,OH]_2$. A common mineral in metamorphic and igneous rocks.
NAG	The Net Acid Generating potential of a rock or tailings sample being tested for AMD. The result is expressed in kg H_2SO_4/t units.
NAF	Non acid forming rock or tailings sample being tested for AMD.
NETPATH for Windows	NETPATH is an interactive computer program used to interpret net geochemical mass-balance reactions between an initial and final water along a groundwater flow path. NETPATH computes the mixing proportions of two to five initial waters and net geochemical reactions that can account for the observed composition of a final water. The calculations are useful for interpreting geochemical reactions, mixing proportions, evaporation and (or) dilution of waters, and mineral mass transfer in the chemical evolution of natural and environmental waters.
PAF	Potentially acid forming rock or tailings sample being tested for AMD.
PC SWMM	A version of the industry standard USEPA Storm Water Management Model, which has enhanced GIS capability that has been developed by Computational Hydraulics International.
PHREEQC	PHREEQC is a computer program designed to perform a wide variety of hydrogeochemical calculations. It performs chemical speciation and inverse modelling calculations, with enhanced capacity to customize the C++ programming language to specific groundwater situations.
Phyllite	Low grade, fine-grained metamorphic rock with grained chlorite, quartz, and sericite.
Plagioclase	A series of feldspars ranging from albite ($NaAlSi_3O_8$) to anorthite ($CaAl_2Si_2O_8$). At Mount Rawdon, albite contributes to the neutralising capacity of the parent rock and to the crystalline rock fabric that shields disseminated pyrite from oxidation.
Porphyry	Quartz-feldspar-biotite porphyry is a rock-type at Mount Rawdon characterised by large crystals of quartz (3-5%), plagioclase (5-10%) & biotite (3-5%) in a fine-grained rock matrix of mainly k-feldspar with plagioclase (30-35%).
Propylitic alteration	Hydrothermal alteration of a volcanic rock, caused by iron and magnesium bearing fluids that alter biotite or amphibole in the rock groundmass to epidote, chlorite and albite.

Pyrite	FeS_2. A common iron sulfide mineral that contributes to the acid mine drainage potential associated with weathering in the presence of water and oxygen. At Mount Rawdon it occurs as a minor mineral (1-2% by volume of rock) associated with the ore, either within the crystalline matrix of the rock where it is shielded from weathering, or as a late mineral formed along curvilinear shears, faults, joints and veins that are potentially exposed to weathering.
Quartz	SiO_2. The most common silica mineral.
Rudosol	Poorly developed young soil, shallow and stony with a B2 horizon (>15% clay), potentially low fertility and low water holding capacity. Minimal development of an A1 horizon and presence of weathered rock or <10% clay/iron oxide precipitate in fissures of the parent rock
Saprolite	Chemically weathered rock that occurs at the base of the soil profile and represents deep weathering of the bedrock surface.
Schist	Intermediate grade, coarse-grained, metamorphic rock with foliated layers of dark and light coloured minerals such as quartz, feldspar, biotite.
Sericitic alteration	Wall-rock alteration with products that are predominantly fine-grained muscovite (sericite) and quartz. At Mount Rawdon the main dacite is pervasively sericite altered, with sericite being accompanied by lesser amounts of illite-smectite, kaolinite, quartz and pyrite alteration products.
Smectite	The bentonite group of swelling clays that include montmorillonite $[Al,Mg]_8[Si_4O_{10}]_3[OH]_{10}. 12[H_2O]$.
Sphalerite	A zinc mineral common in metallic sulfide ores. In the Mount Rawdon Mine it is a minor accessory to pyrite.
SSA	Specific surface area (SSA) is a property of solids defined as the total surface area of a material per unit of mass (with units of m^2/kg or m^2/g). The value can be used to represent the type and properties of an aquifer material (e.g. hydroferrous oxide) that has particular importance for adsorption and reactions on surfaces
Tenosol	As for Rudosol with more developed A1 horizon or less developed B horizon
Trachyandesite	A volcanic rock with lower $Na_2O + K_2O$ content than trachyte and no large crystals (phenocrysts) of plagioclase feldspar.
Tremolite	$Ca_2Mg_5Si_8O_{22}[OH]_2$. An amphibole mineral associating with actinolite. It forms part of the Mount Rawdon hydrothermal alteration assemblage.
TSF	**Tailings Storage Facility:** The Mount Rawdon TSF commenced in 2001 as a valley type storage, formed by a primary embankment (Northern Embankment), an embankment on the southern end that extends around the eastern perimeter (Southern Embankment) and a saddle embankment to the west (Western Saddle Embankment). The TSF has subsequently been built in 3-meter lifts to form a turkeys-nest style containment, and maintain freeboard requirements where on the 1st November of each year it can capture a 1:200 AEP 4 month wet season plus process inputs for the 4 month wet season as required by the Environmental Authority.
Virtual Curtain	VCL has worked with CSIRO to provide long term solutions for the remediation and neutralisation of geochemically complex wastewaters to a quality suitable for reuse or for discharge into the natural environment. The licenced product, *Virtual Curtain*, involves the synthesis and application of hydrotalcite (a magnesium clay).
VISUAL MINTEQ	Visual MINTEQ is a chemical equilibrium model for the calculation of metal speciation, solubility equilibria, sorption and other processes for natural waters.

8.2 Groundwater Bore Properties

Bore	Coordinates			Height of casing above ground (mm)	Depth of screen (m .bgl)	Historic SWL (m)			
	Easting	Northing	m (ahd)			Max. (.bgl)	Min. (.bgl)	Max. (.ahd)	Min. (.ahd)
MRPB2	373568	7205655	149.92	294	36-49	-8.31	-4.87	141	145
MRMB11	374267	7206233	123.969		18-30			124	124
MRMB12	374545	7206538	119.03	252	5-27	-7.76	-1.67	111	117
MRMB13	374164	7206247	125.11	449	18-30	-5.30	-0.72	119	124
MRMB30	374892	7206410	127.89	572	22-40	-7.26	-3.00	120	124
MRMB31	*374605*	*7206078*	*NA*	*425*	16-28	-7.26			
MRMB36	374800	7203578	108.73		36-49	-24.24	-13.87	84	95
MRMB38	377096	7206635	104.2	180	13-40	-11.80	-3.70	92	100
MRMB39	375856	7206535	112.42		23-41	-7.60	-2.10	105	110
MRMB40	375135	7206605	121.72		25-43	-16.10	-13.58	106	108
MRMB41	*374809*	*7206896*	*113.04*	*365*	22-40	-5.79	-2.72	107	110
MRMB42	*374804*	*7206892*	*113.06*	*375*	7-16	-5.94	-2.78	107	110
MRMB43	373880	7205740	137.7	330	24-37.5	-2.73	0.00	135	137
MRMB44	373878	7205736	138	157	10-13	-3.42	0.00	134	138
MRMB46	375348	7205133	151.34	728	26-35	-4.41	-2.12	146	148
MRMB52	375103	7207188	112.51	530	17.1-29.5	-9.46	-7.90	103	104
MRMB53	375403	7207005	111.88	546	17.7-23.9	-7.10	-6.60	104	105
MRMB55	375956	7205939	127.6	648	25-31	-13.89	-11.07	113	116
MRMB60	376577	7204529	131	340	27-35	-5.84	-4.42	125	126
MRMB61	376731	7204473	128	377	25-31	-28.90	-14.99	99	113
MRMB62	376572	7203977	148	284	26-35	-12.67	-1.17	135	147
MRMB63	376558	7205270	128	383	19-22.5	-9.53	-6.50	118	121
MRMB64	376325	7205993	125	578	35-41	-37.70	-21.70	87	103
MRMB65	374926	7206745	122.7	228	27-30	-12.90	-12.20	110	110
MRMB66	375834	7206885	127.34	550	27-30	-22.30	-22.00	104	105
MRMB68	376140	7205997	134.9	396	27-30	-22.65	-21.86	112	113
MRMB70	374482	7203728	147.5	397	32.5-42	-28.20	-20.90	119	126
MRMB71	374632	7203643	133.5		32.5-39	-28.10	-16.60	105	117
MRMB74	376301	7206896	108.6	343	36-42	-10.00	-9.50	98	99
MRMB75	375401	7202922	98.7	313	24-30	-16.48	-16.28	82	82
MRMB78				353	17 - 29	N.A.	N.A.		
MRDB1	373970	7205451	165.959	565	6.0 - 42.0	N.A.	N.A.		
MRDB3	374105	7205907	159.537	576	6.0 - 42.0	N.A.	N.A.		
MRDB2	374008	7205768	154.4	564	6 - 41.5	N.A.	N.A.		
MRMB25	376169	7205682	115.82	428	depth. 34m	-4.54	-0.07	111	115
MRMB49	375650	7205571	145.36	612	17-30	-18.80	-14.00	126	131
MRMB54	374473	7207154	125.12	511	17.1-29.5	-18.80	-17.50	106	107

Table A1: Groundwater bores used for slug testing

Bore	Aquifer	Ksat (m/day)	T (m^2/day)	Permeability (m^2)			
				Category	10°C	20°C	30°C
MRPB2	Weathered rock*	1.00E+00	3.E+01	Semi-perveous	2.E-12	1.E-12	1.E-12
MRMB11	Weathered rock*	3.90E-02	6.E-01	Semi-perveous	6.E-14	5.E-14	4.E-14
MRMB12	Fractured rock*	4.30E-01	9.E-01	Semi-perveous	7.E-13	5.E-13	4.E-13
MRMB13	Weathered rock*	4.50E-01	1.E-01	Semi-perveous	1.E-13	8.E-14	6.E-14
MRMB30	Weathered/Fractured rock*	6.10E-02	5.E-01	Semi-perveous	9.E-14	7.E-14	6.E-14
MRMB31	Weathered/Fractured rock*	3.90E+00	4.E+00	Semi-perveous	6.E-12	5.E-12	4.E-12
MRMB36	Weathered rock*	9.70E-02	1.E-01	Semi-perveous	1.E-13	1.E-13	9.E-14
MRMB38	Fractured rock	2.10E-01	4.E+00	Semi-perveous	3.E-13	3.E-13	2.E-13
MRMB39	Weathered/Fractured rock*	8.90E-02	1.E+00	Semi-perveous	1.E-13	1.E-13	8.E-14
MRMB40	Fractured rock*	1.60E-02	3.E-01	Semi-perveous	2.E-14	2.E-14	2.E-14
MRMB41	Weathered rock*	2.90E-01	3.E+00	Semi-perveous	4.E-13	3.E-13	3.E-13
MRMB42	Fractured rock*	5.30E-01	1.E+00	Semi-perveous	8.E-13	6.E-13	5.E-13
MRMB43	Weathered rock*	2.60E-04	6.E-03	Impervious	4.E-16	3.E-16	3.E-16
MRMB44	Weathered rock	7.90E-02	8.E-01	Semi-perveous	1.E-13	9.E-14	7.E-14
MRMB46	Colluvium/Fractured rock*	4.30E-03	1.E-01	Impervious	6.E-15	5.E-15	4.E-15
MRMB52	Fractured rock	2.30E-01	6.E+00	Semi-perveous	3.E-13	3.E-13	2.E-13
MRMB53	Fractured rock	9.80E-01	2.E+01	Semi-perveous	1.E-12	1.E-12	9.E-13
MRMB55	Fractured rock	2.00E-02	6.E-01	Semi-perveous	3.E-14	2.E-14	2.E-14
MRMB60	Fractured rock	7.10E-02	2.E+00	Semi-perveous	1.E-13	8.E-14	7.E-14
MRMB61	Fractured rock	4.30E-04	1.E-02	Impervious	7.E-16	5.E-16	4.E-16
MRMB62	Fractured rock	2.00E-03	6.E-02	Impervious	3.E-15	2.E-15	2.E-15
MRMB63	Fractured rock	6.10E+00	1.E+02	Semi-perveous	9.E-12	7.E-12	6.E-12
MRMB64	Fractured rock*	2.10E-03	7.E-02	Impervious	3.E-15	3.E-15	2.E-15
MRMB65	Fractured rock	4.50E-01	1.E+01	Semi-perveous	7.E-13	5.E-13	4.E-13
MRMB66	Fractured rock	4.80E-01	7.E+00	Semi-perveous	7.E-13	6.E-13	5.E-13
MRMB68	Fractured rock	3.50E-02	1.E+00	Semi-perveous	5.E-14	4.E-14	3.E-14
MRMB70	Weathered rock*	1.90E+01	7.E+02	Semi-perveous	3.E-11	2.E-11	2.E-11
MRMB71	Fractured rock	2.10E-04	8.E-03	Impervious	3.E-16	3.E-16	2.E-16
MRMB74	Fractured rock	4.70E-02	2.E+00	Semi-perveous	7.E-14	6.E-14	5.E-14
MRMB75	Weathered rock*	6.20E-01	1.E+01	Semi-perveous	9.E-13	7.E-13	6.E-13
MRMB78	Fractured rock	7.70E-04	2.E-02	Impervious	1.E-15	9.E-16	7.E-16
MRDB1	Fractured rock*	3.91E-03	7.E-02	Impervious	6.E-15	5.E-15	4.E-15
MRDB3	Weathered rock*	3.E-02	6.E-01	Semi-perveous	5.E-14	4.E-14	3.E-14
MRDB2	Weathered rock*	7.E-02	7.E-01	Semi-perveous	1.E-13	8.E-14	6.E-14
MRMB25	Fractured rock*	4.00E-01	2.E+00	Semi-perveous	6.E-13	5.E-13	4.E-13
MRMB49	Fractured rock*	1.40E+00	2.E+01	Semi-perveous	2.E-12	2.E-12	1.E-12
MRMB54	Fractured rock	1.00E+00	2.E+01	Semi-perveous	2.E-12	1.E-12	1.E-12

** Weathered rock: Gravel pack extends through weathered rock and fractured rock. The main aquifer is weathered rock.*

** Weathered/Fractured rock: Gravel pack extends the length of the bore through weathered and fractured rock.*

** Fractured rock: Gravel pack extends through weathered rock and fractured rock. The main aquifer is fractured rock.*

Table A2: Hydrogeological properties developed from slug tests

8.3 Principal Components of the Ionic Composition of Groundwater

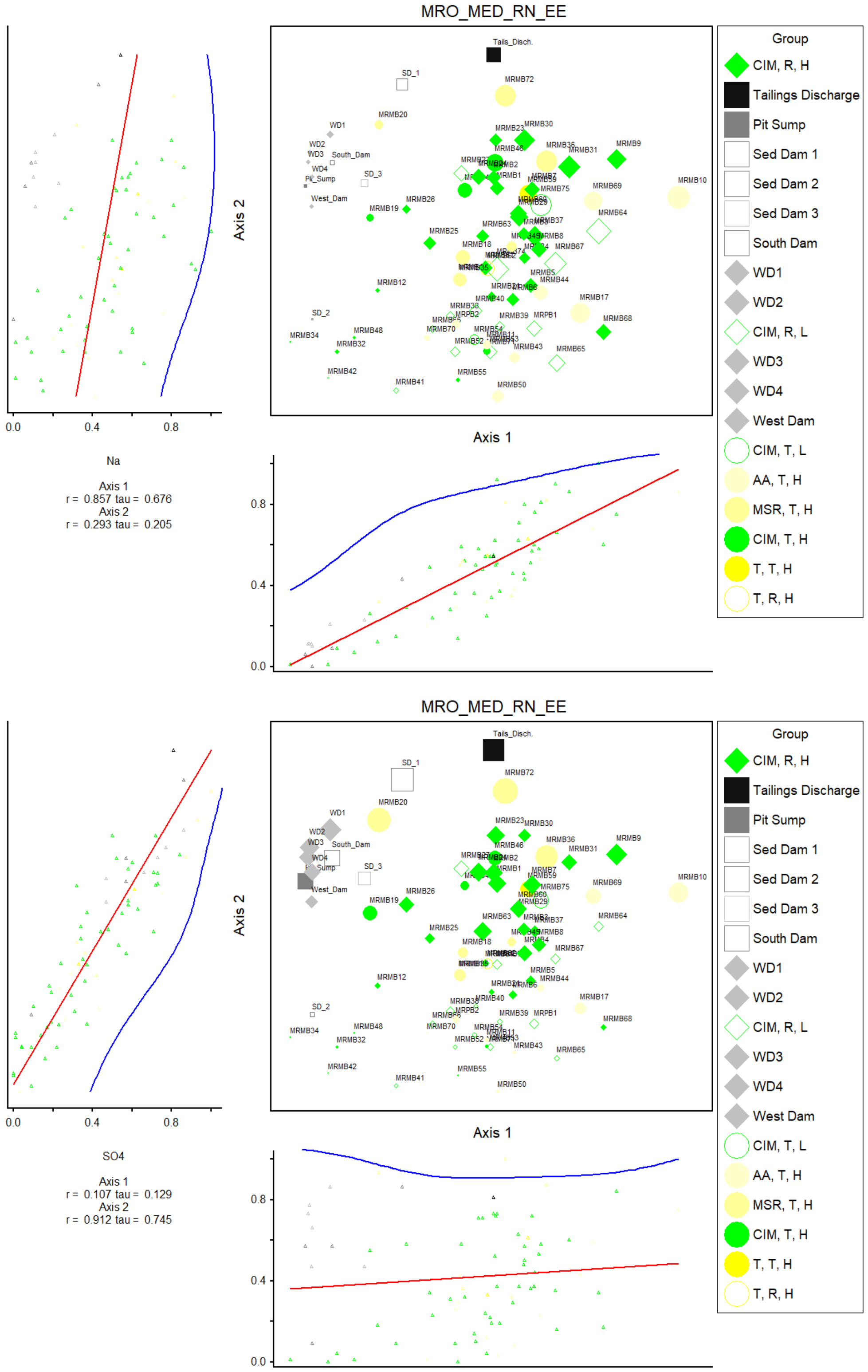


Figure 44: Principal Components 1 and 2 at the mine lease scale, highlighting the variation of sodium and sulfate in water

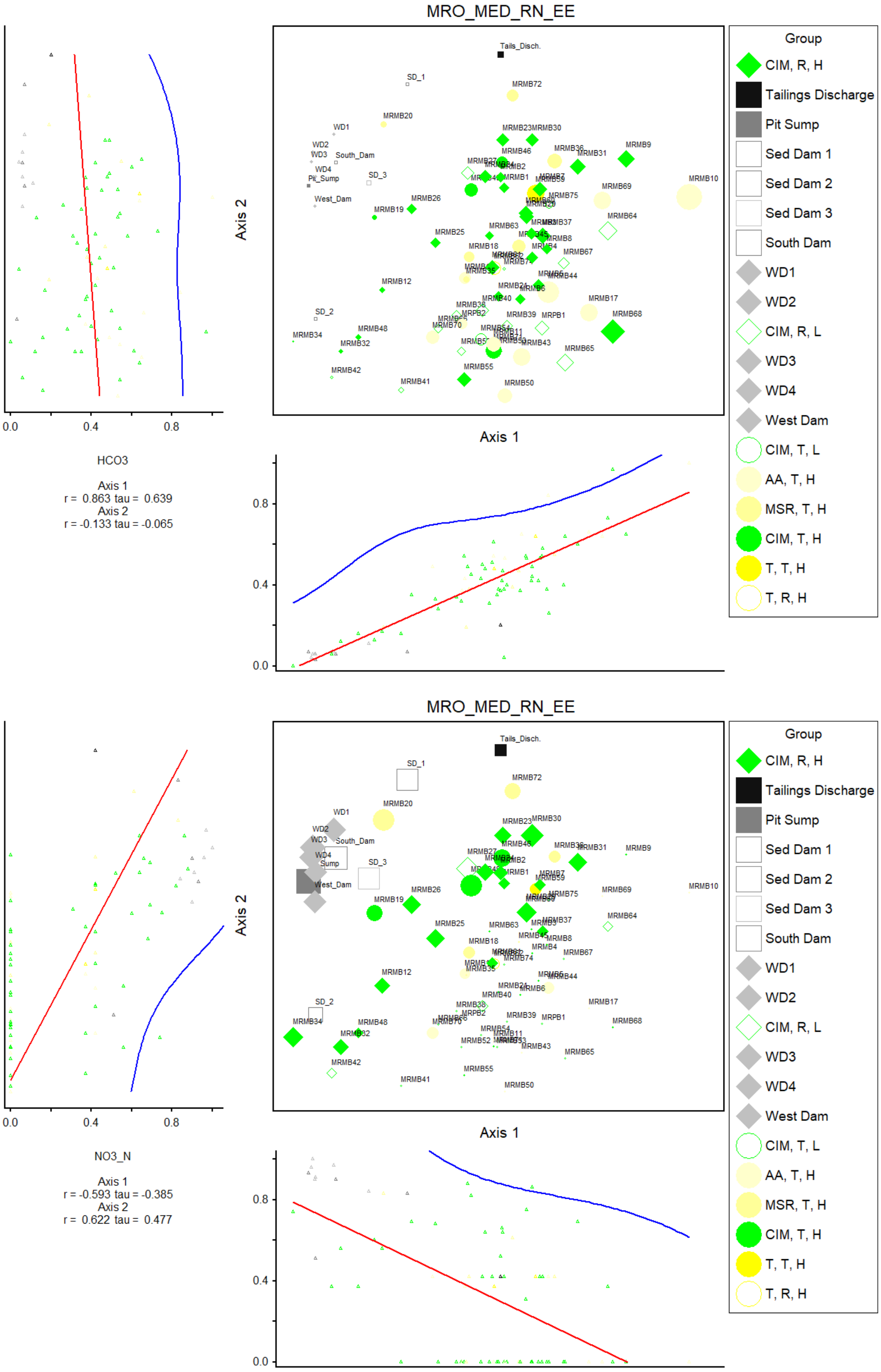


Figure 45: Principal Components 1 and 2 at the mine lease scale, highlighting the variation of bicarbonate and nitrate-N in water

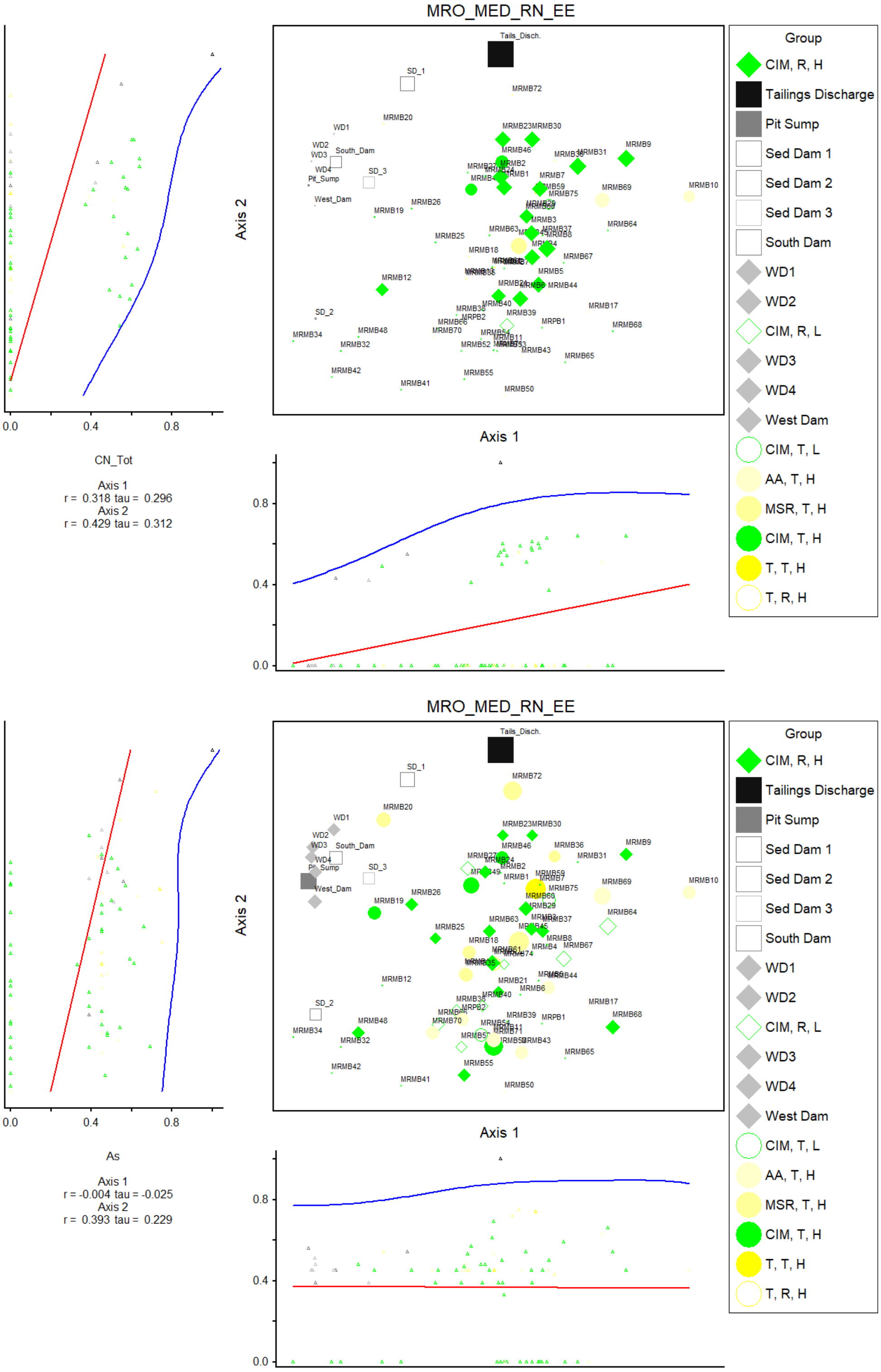


Figure 46: Principal Components 1 and 2 at the mine-lease scale, highlighting the variation of total cyanide and arsenic in water

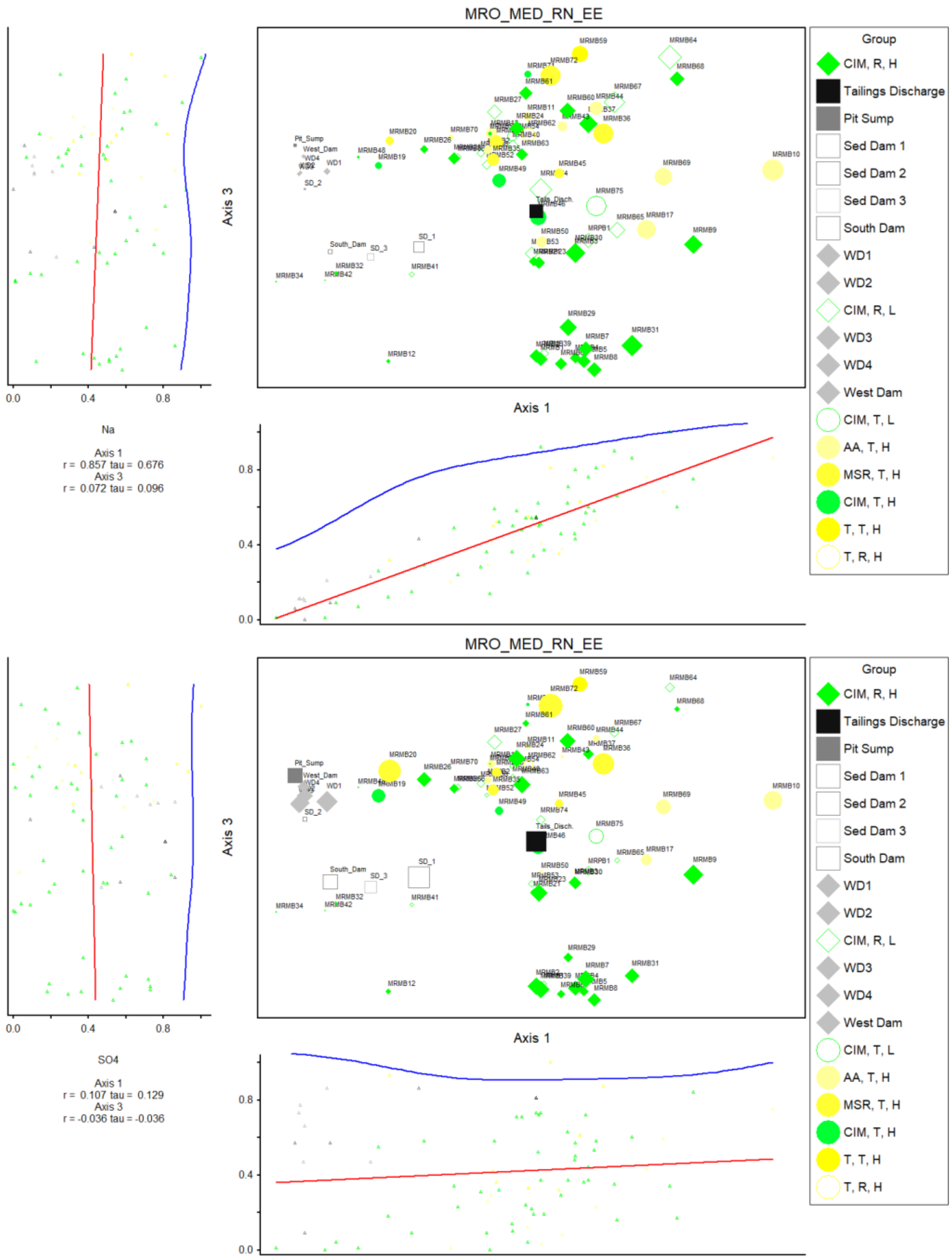


Figure 47: Principal Components 1 and 3 at the mine lease scale, highlighting the variation of sodium and sulfate in water

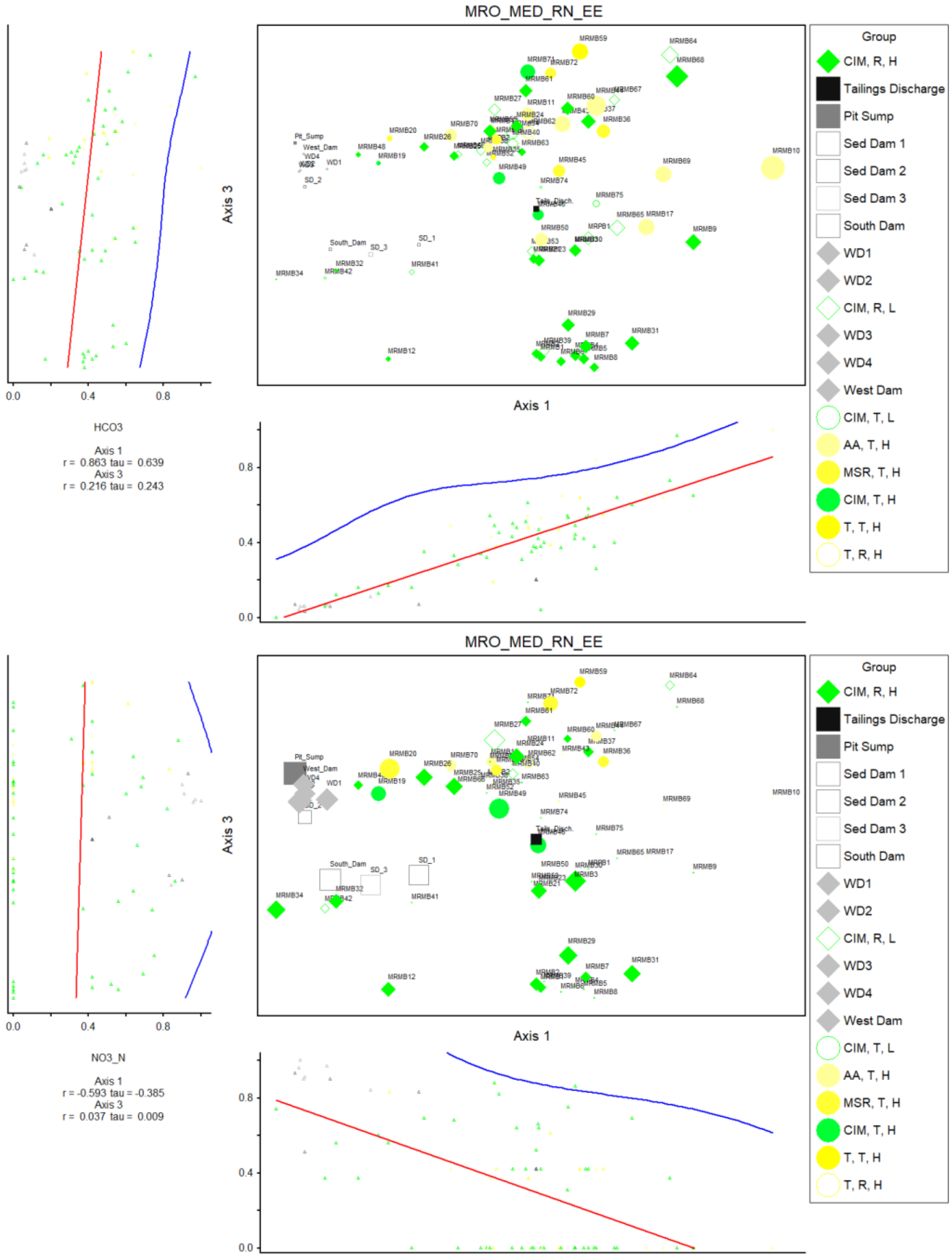


Figure 48: Principal Components 1 and 3 at the mine lease scale, highlighting the variation of bicarbonate and nitrate-N in water

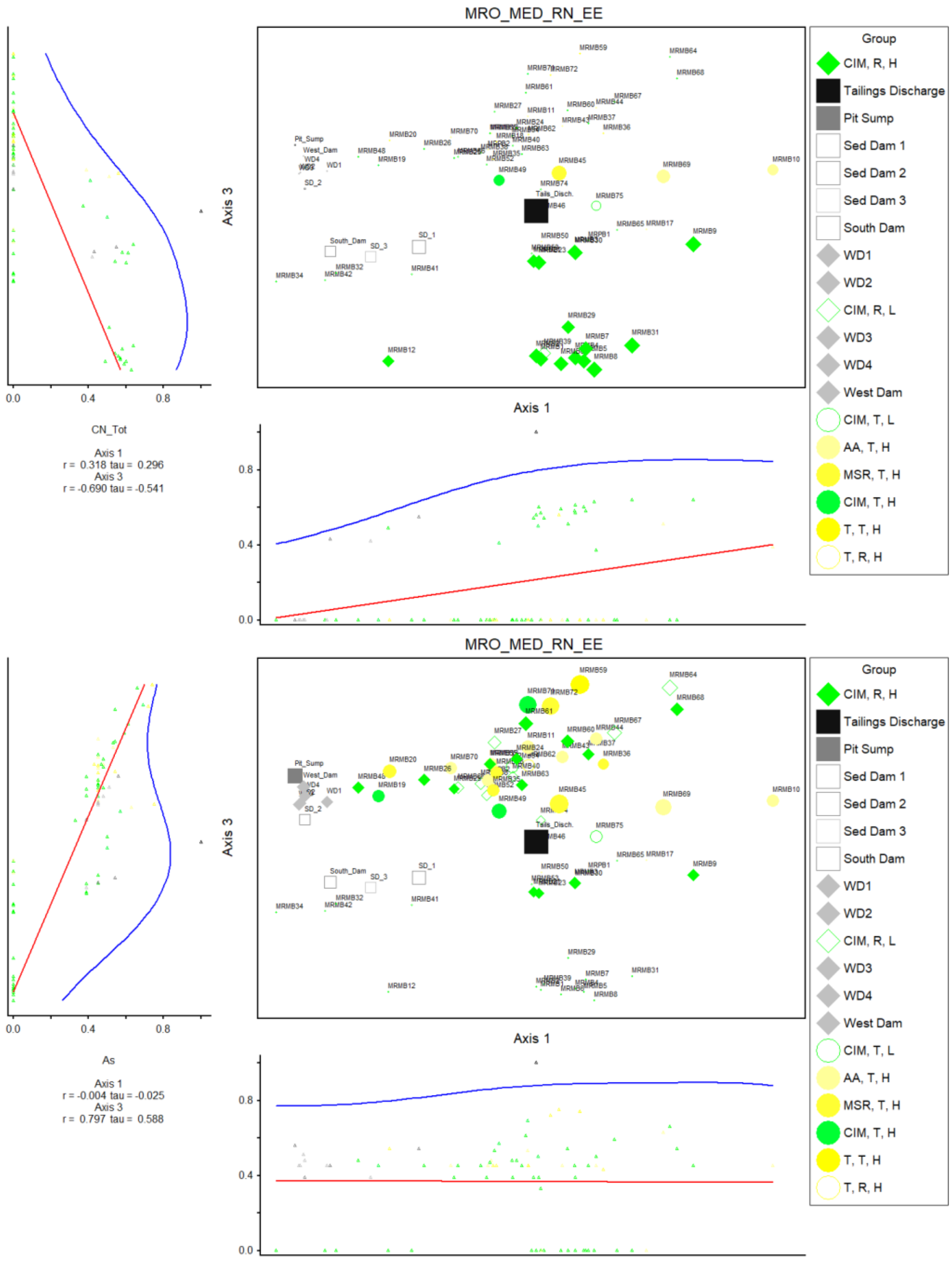


Figure 49: Principal Components 1 and 3 at the mine-lease scale, highlighting the variation of total cyanide and arsenic in water

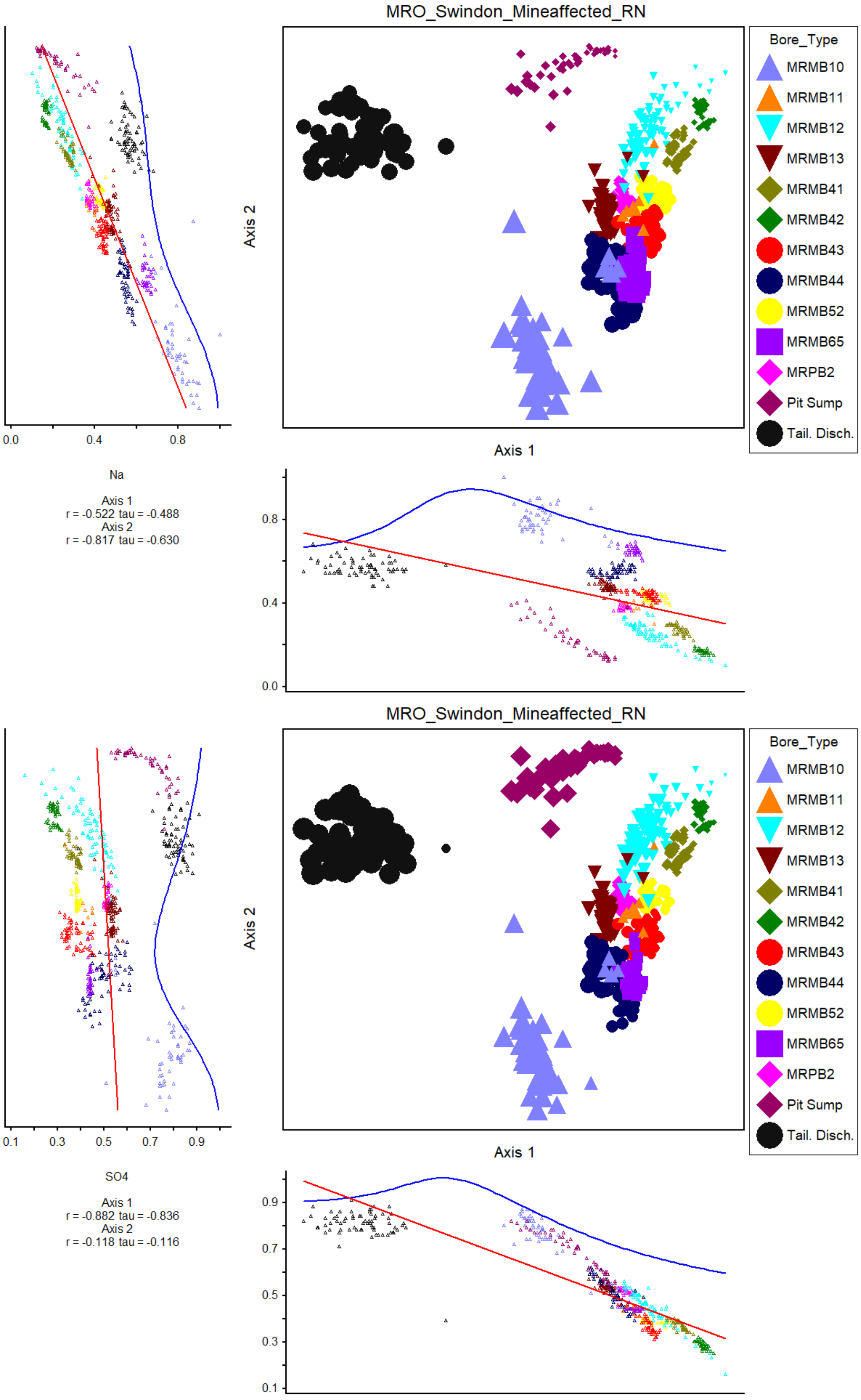


Figure 50: Principal Components 1 and 2 in Swindon Creek, highlighting the variation of sodium and sulfate in water

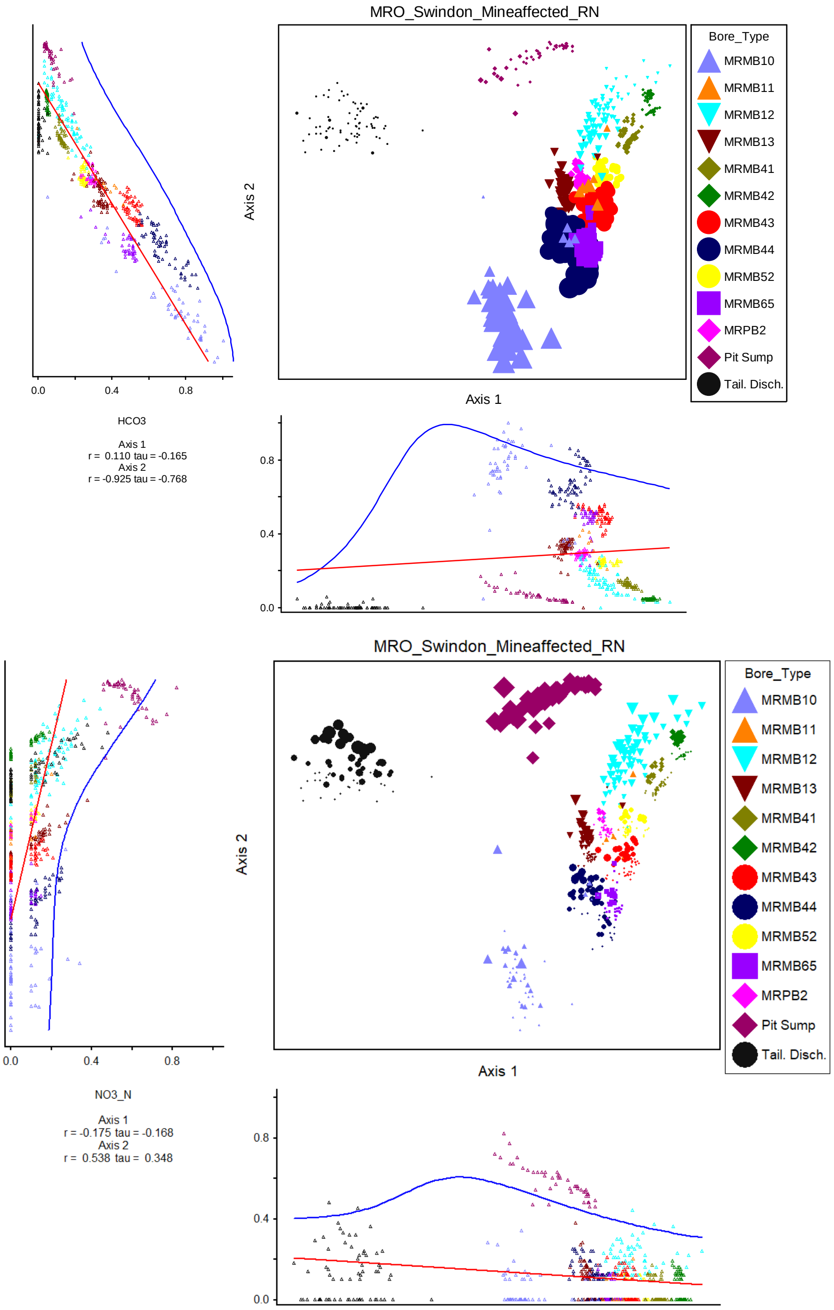


Figure 51: Principal Components 1 and 2 in Swindon Creek, highlighting the variation of bicarbonate and nitrate-N in water

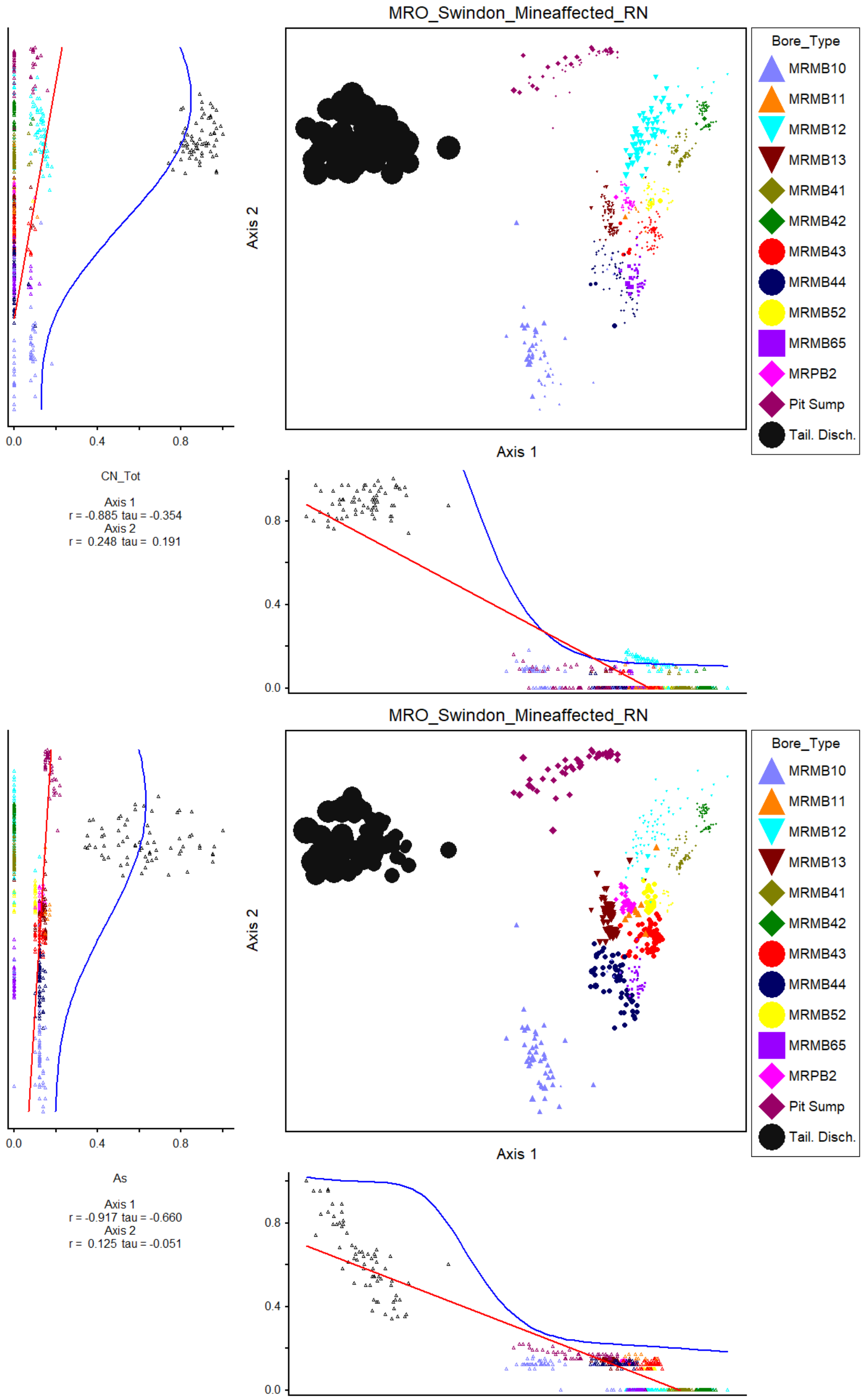


Figure 52: Principal Components 1 and 2 in Swindon Creek, highlighting the variation of total cyanide and arsenic in water

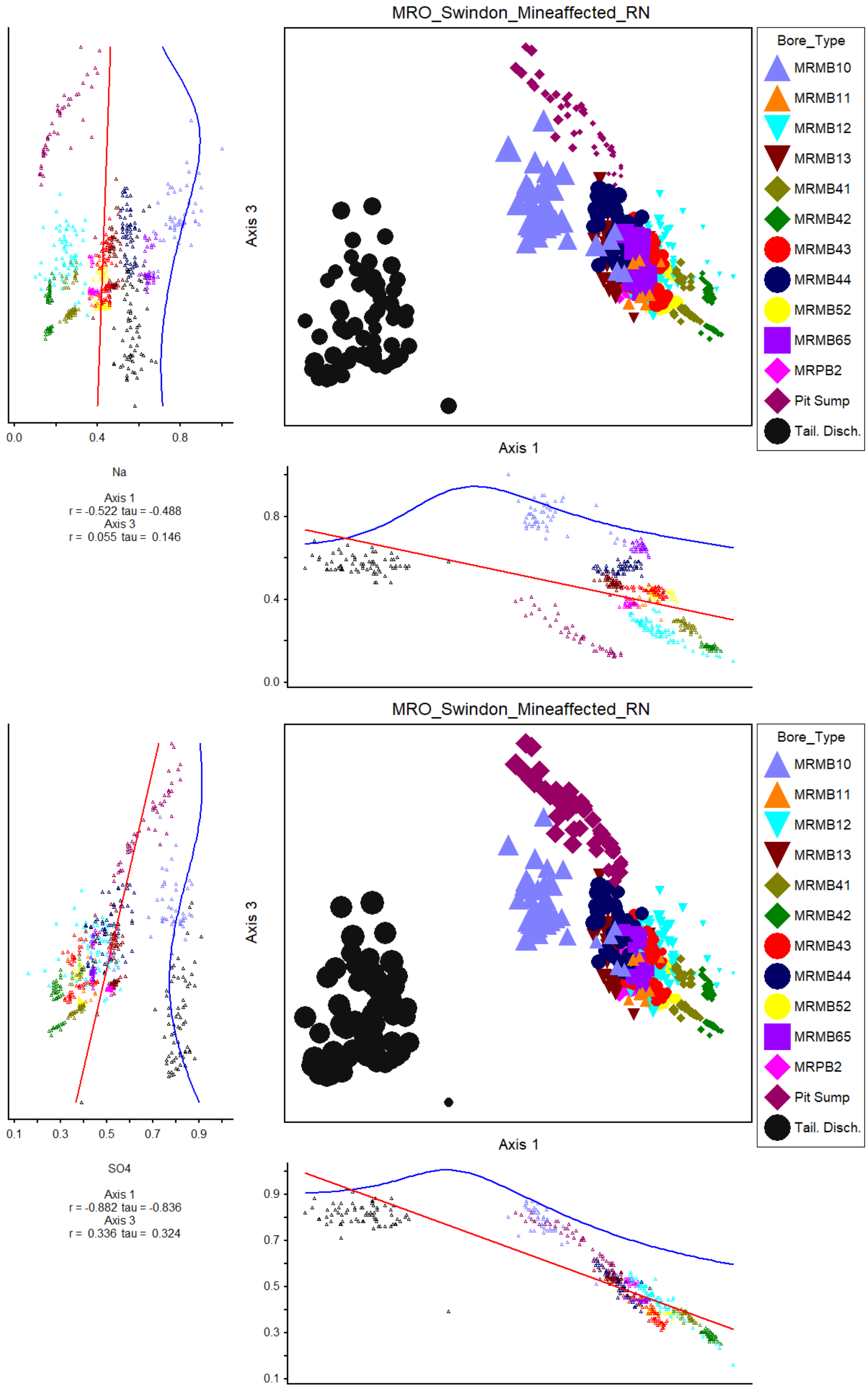


Figure 53: Principal Components 1 and 3 in Swindon Creek, highlighting the variation of sodium and sulfate in water

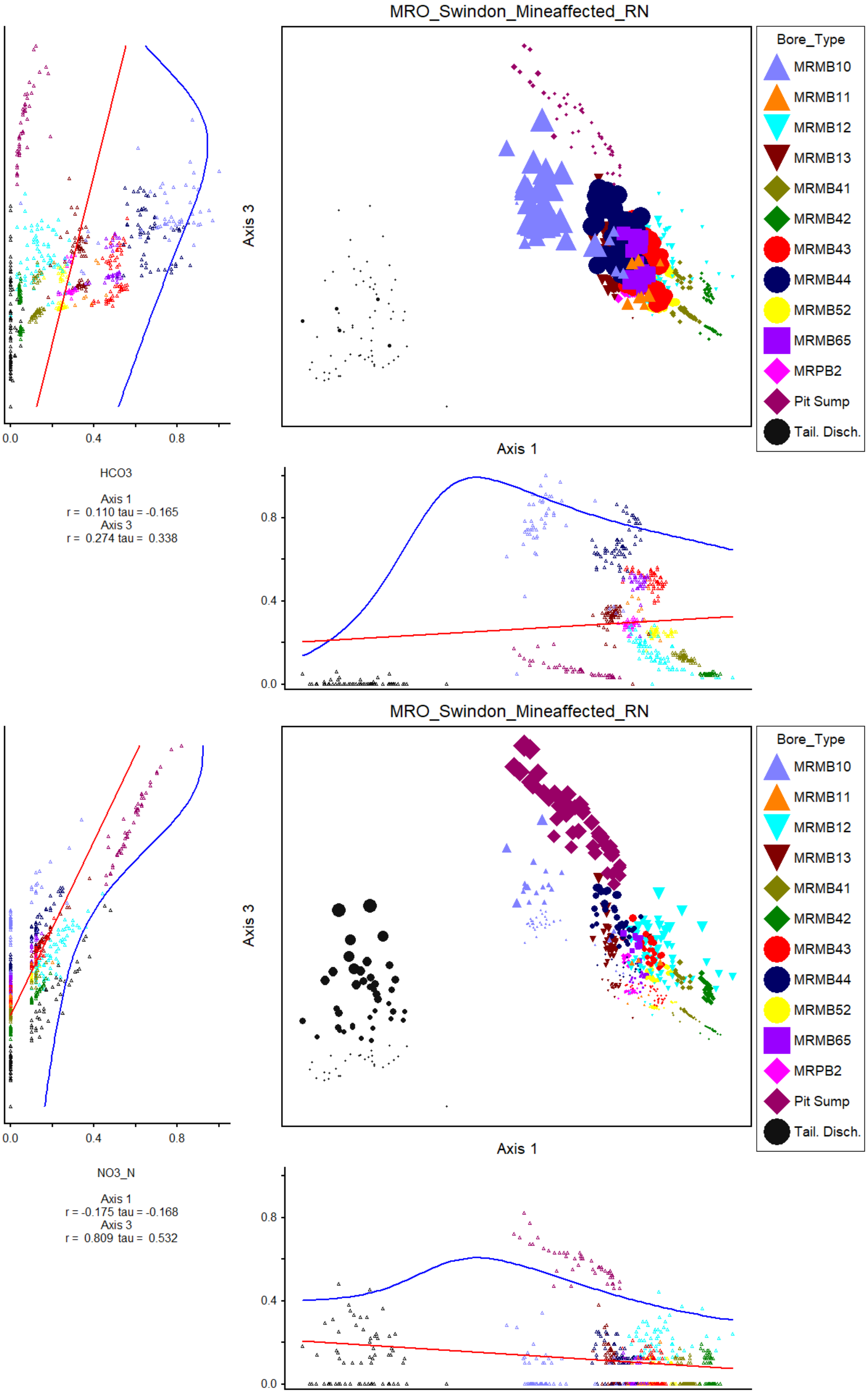


Figure 54: Principal Components 1 and 3 in Swindon Creek, highlighting the variation of bicarbonate and nitrate-N in water

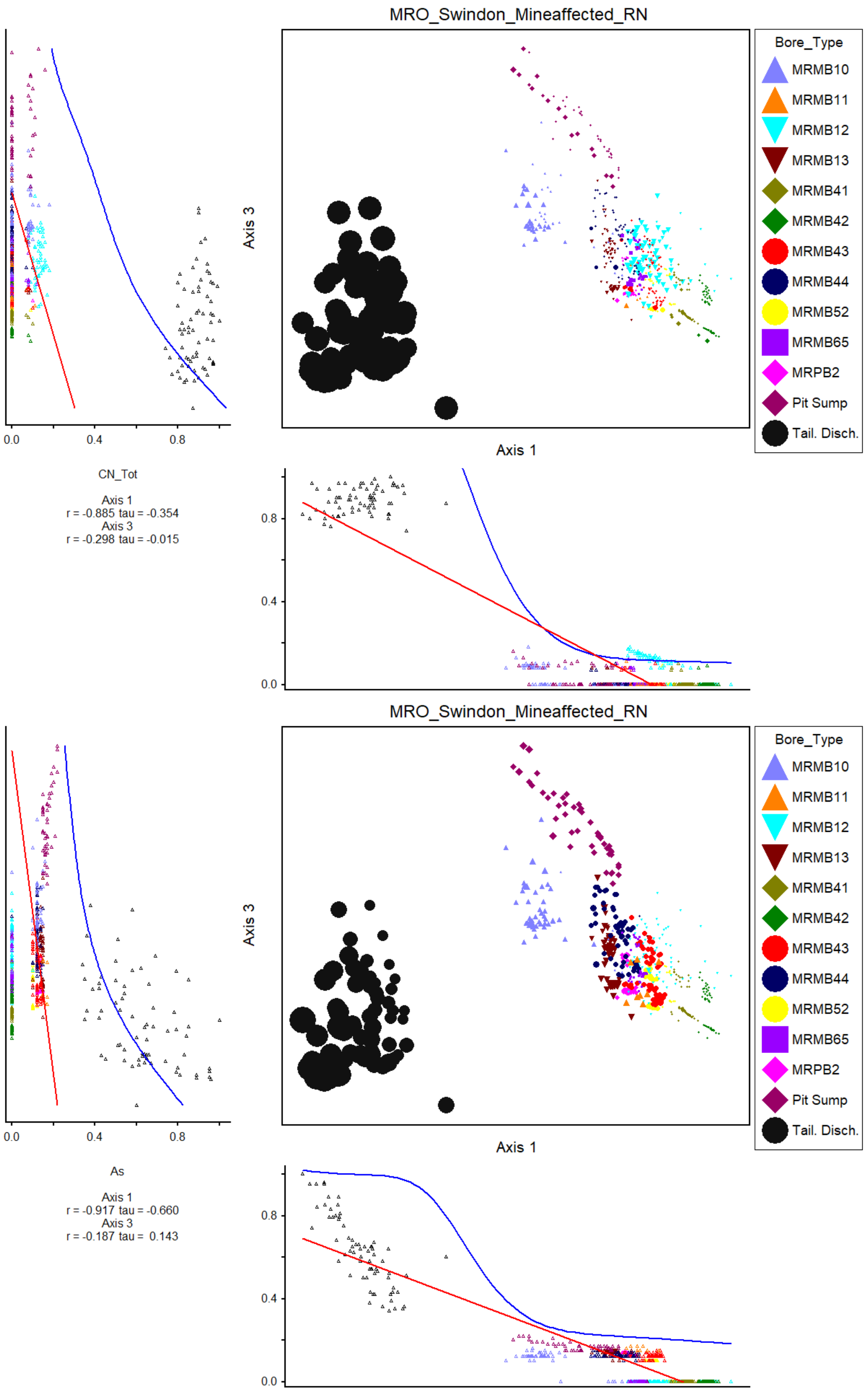


Figure 55: Principal Components 1 and 3 in Swindon Creek, highlighting the variation of total cyanide and arsenic in water

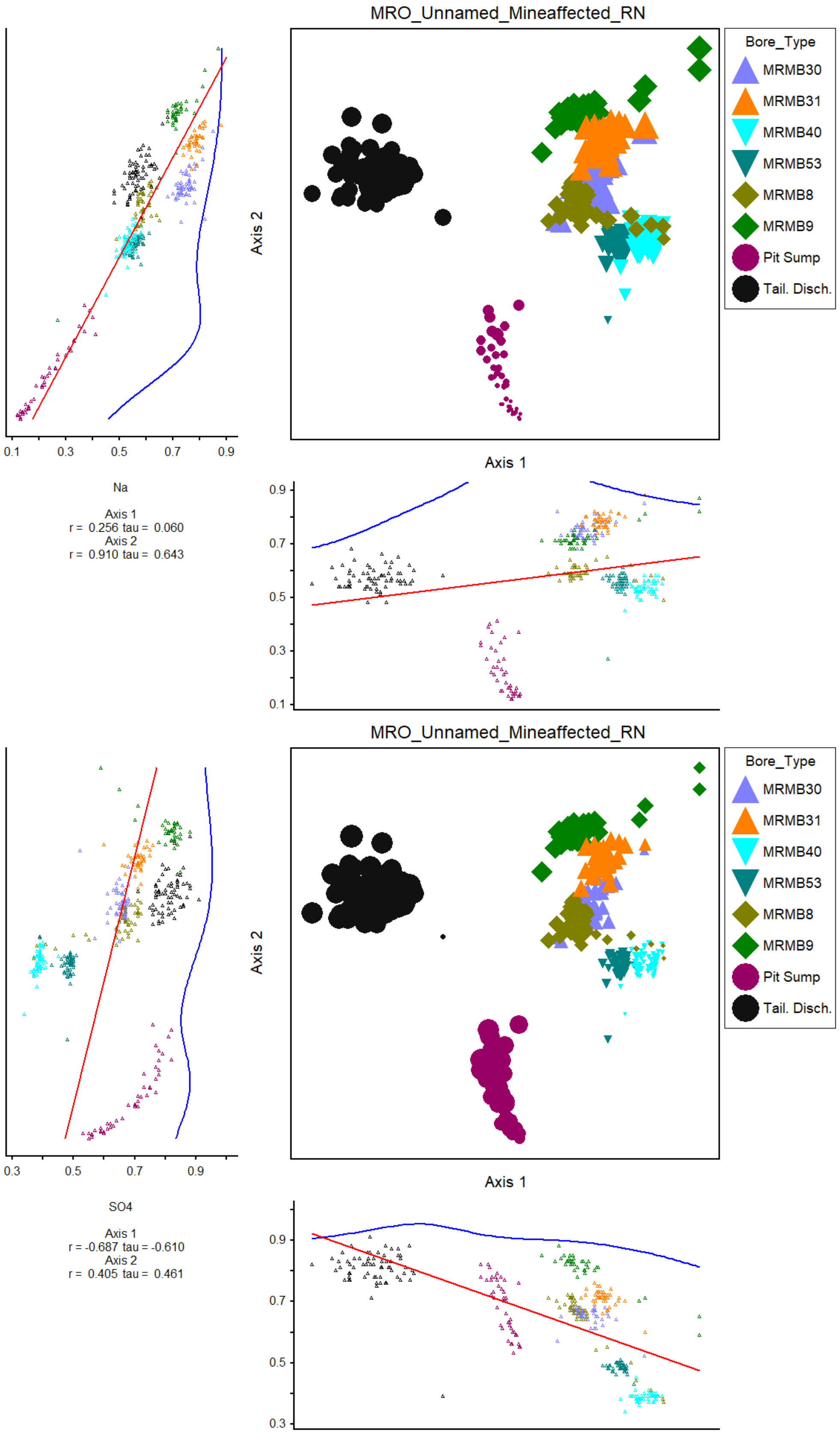


Figure 56: Principal Components 1 and 2 in unnamed creek, highlighting the variation of sodium and sulfate in water

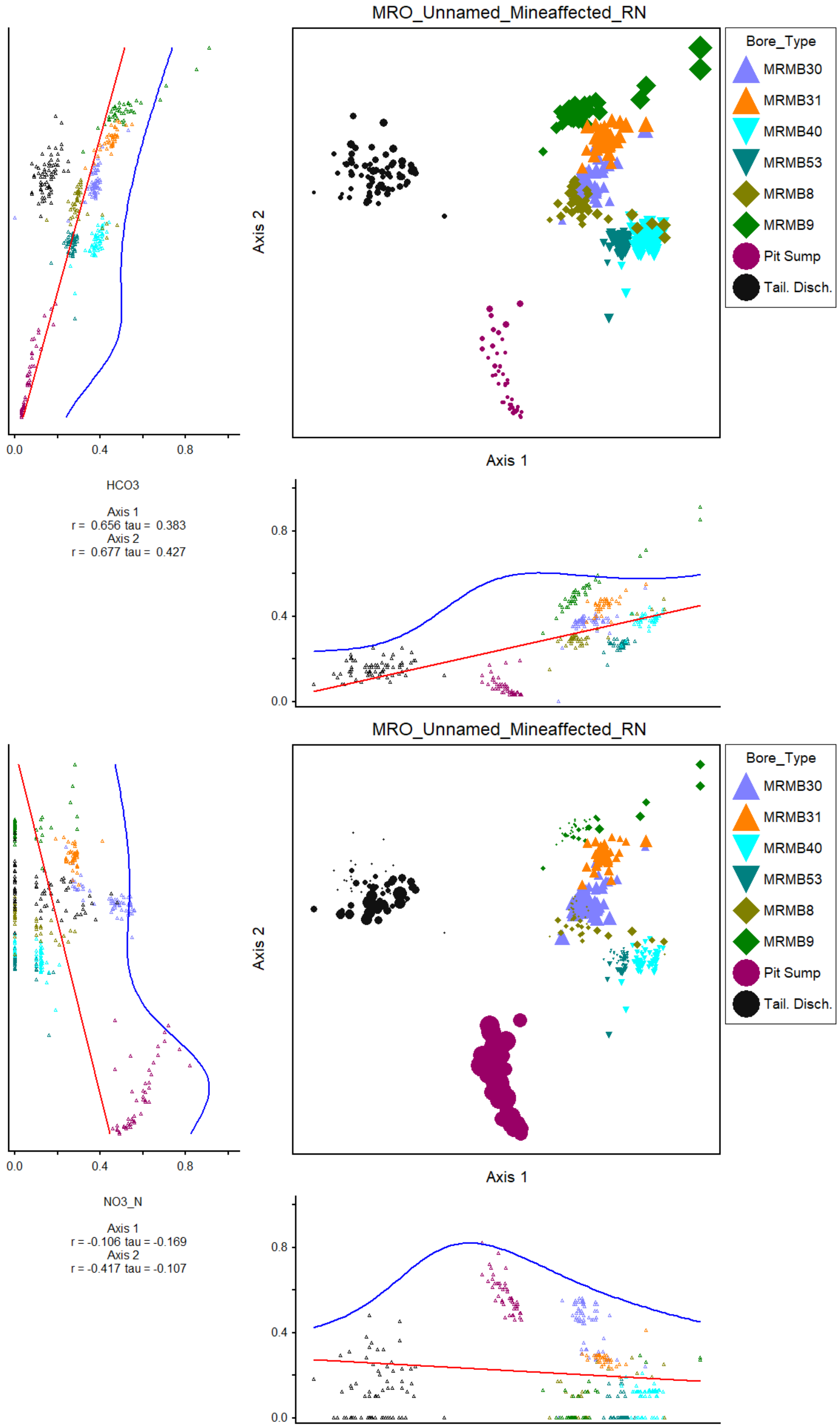


Figure 57: Principal Components 1 and 2 in unnamed creek, highlighting the variation of bicarbonate and nitrate-N in water

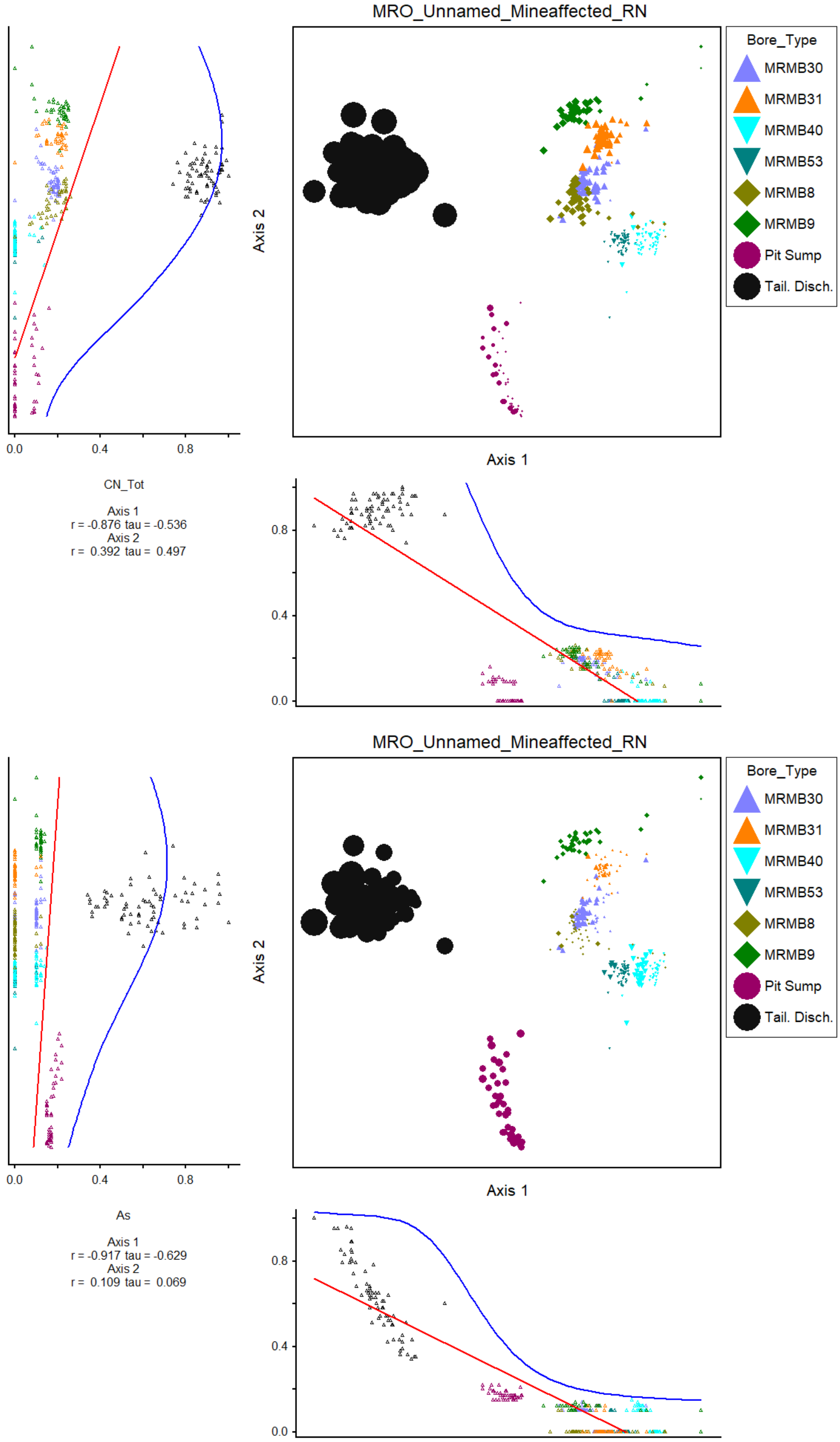


Figure 58: Principal Components 1 and 2 in unnamed creek, highlighting the variation of total cyanide and arsenic in water

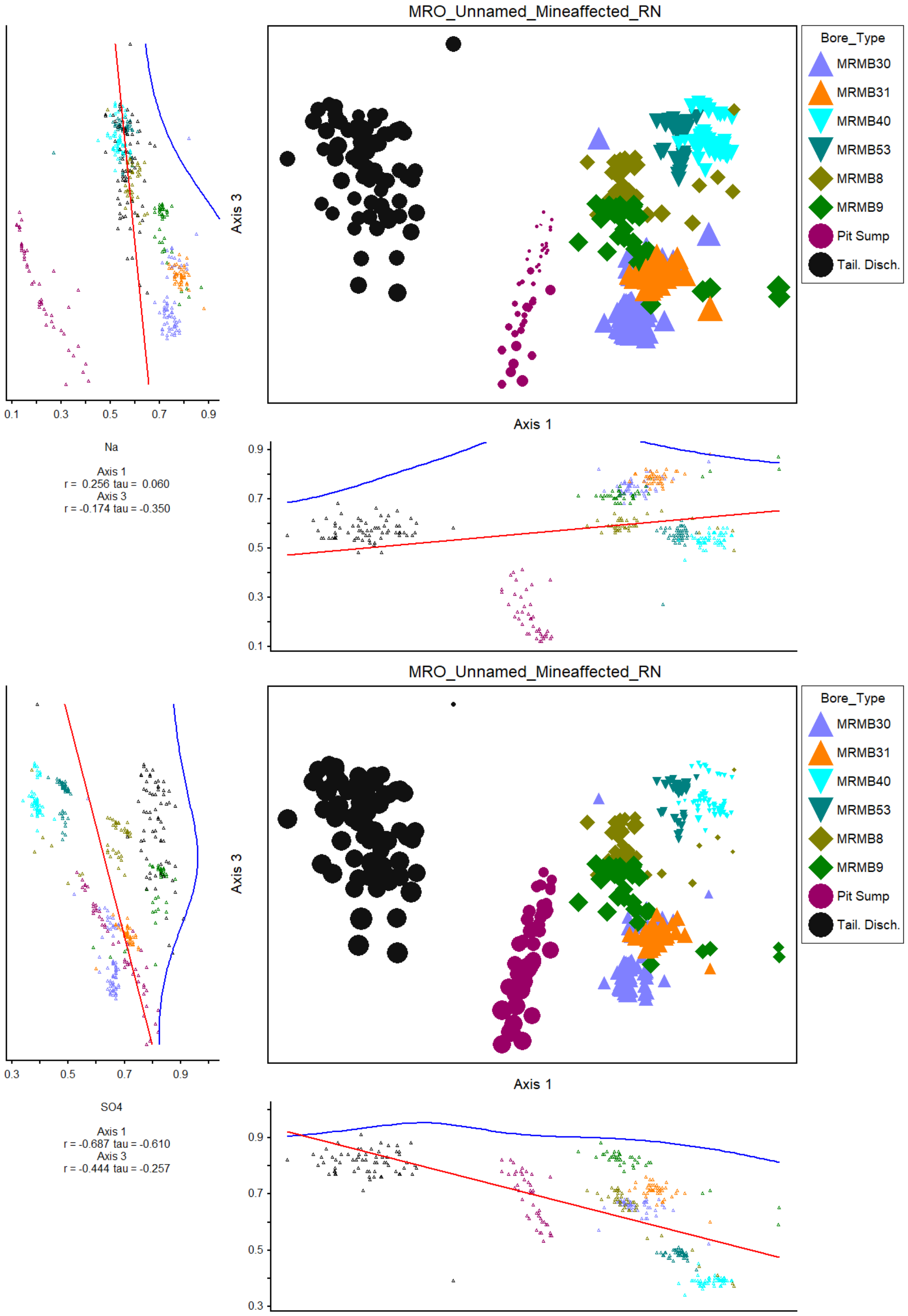


Figure 59: Principal Components 1 and 3 in unnamed creek, highlighting the variation of sodium and sulfate in groundwater

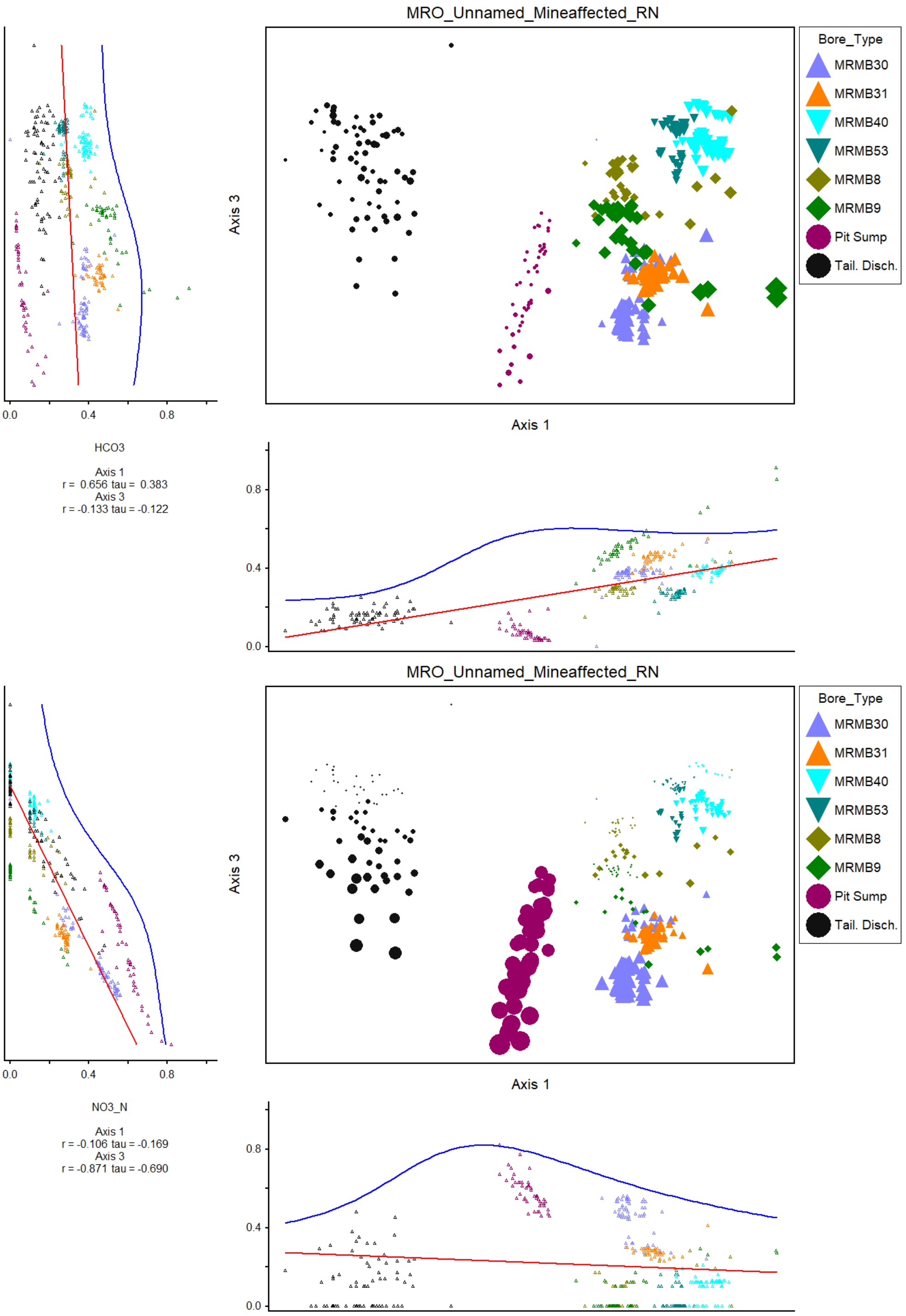


Figure 60: Principal Components 1 and 3 in unnamed creek, highlighting the variation of bicarbonate and nitrate-N in groundwater

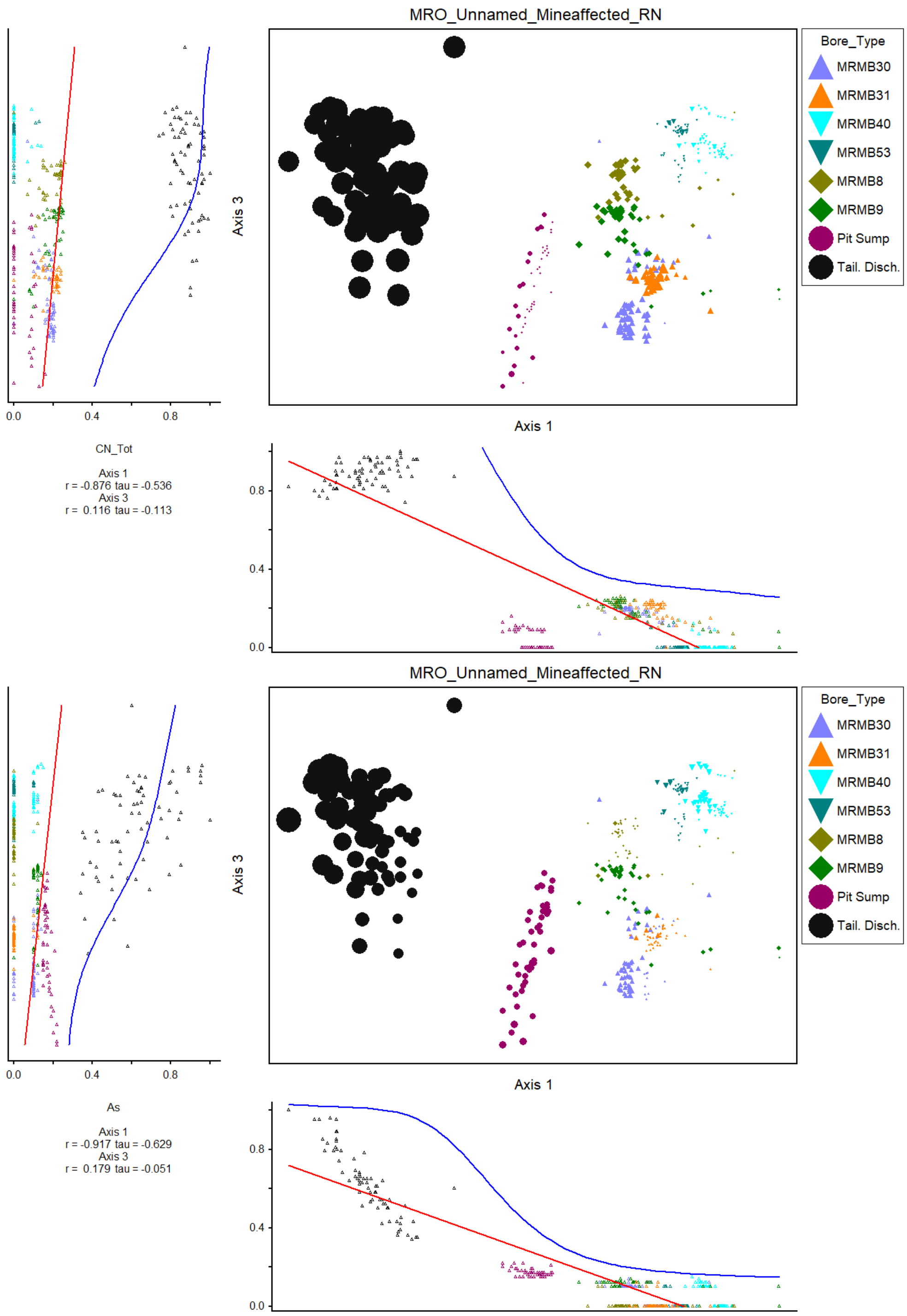


Figure 61: Principal Components 1 and 3 in unnamed creek, highlighting the variation of total cyanide and arsenic in groundwater

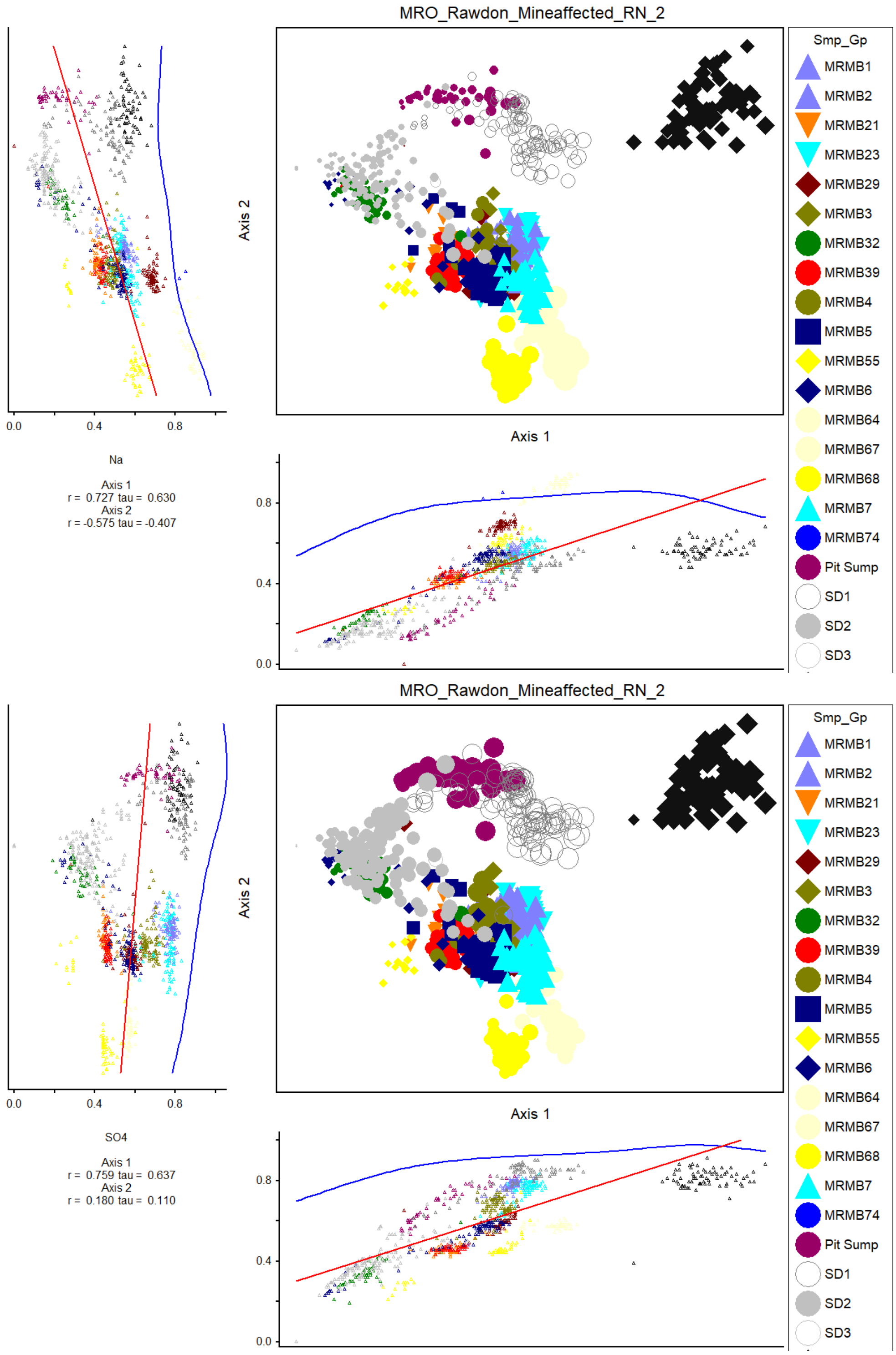


Figure 62: Principal Components 1 and 2 in Rawdon Creek, highlighting the variation of sodium and sulfate in water

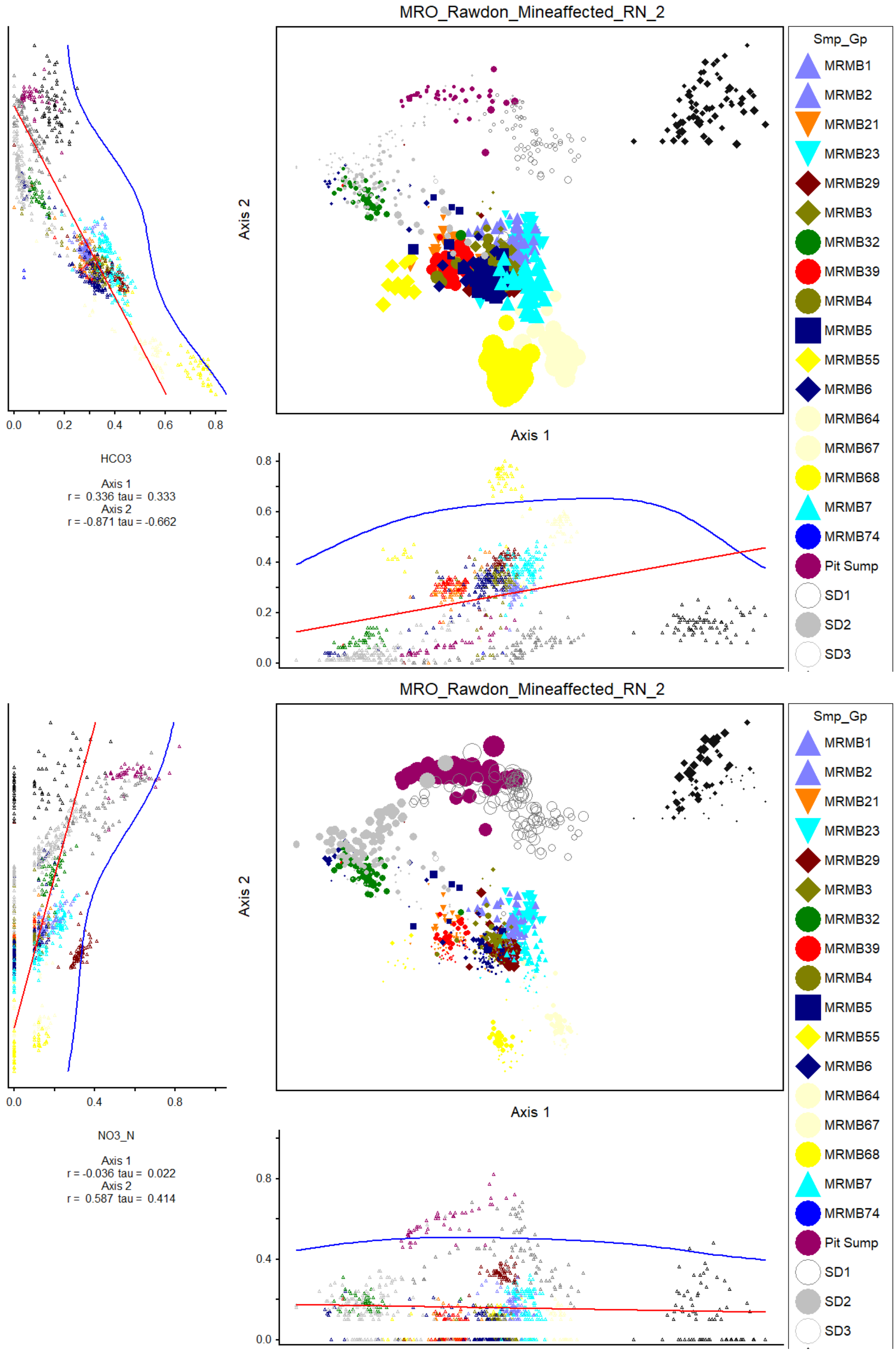


Figure 63: Principal Components 1 and 2 in Rawdon Creek, highlighting the variation of bicarbonate and nitrate-N in water

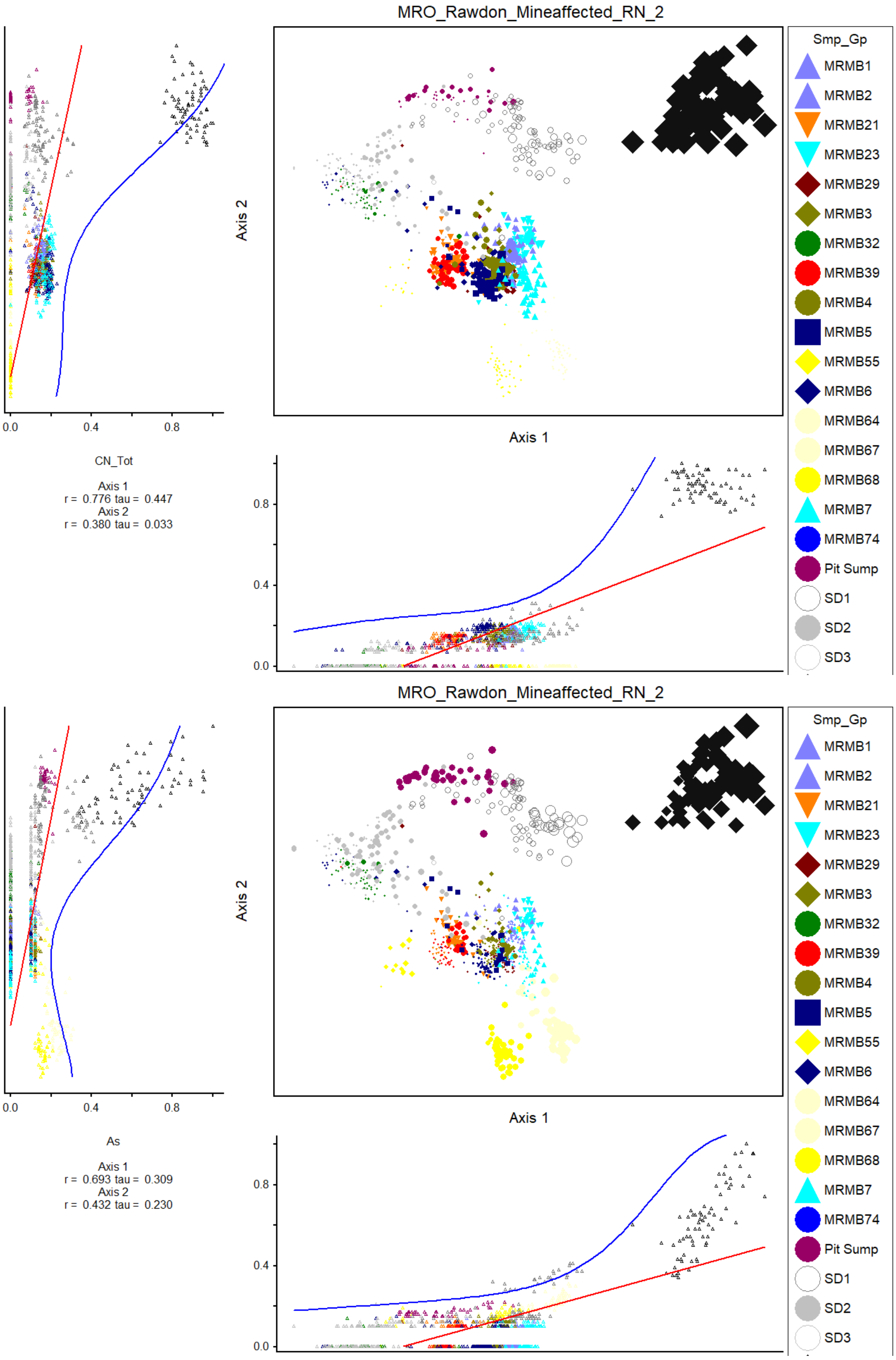


Figure 64: Principal Components 1 and 2 in Rawdon Creek, highlighting the variation of total cyanide and arsenic in water

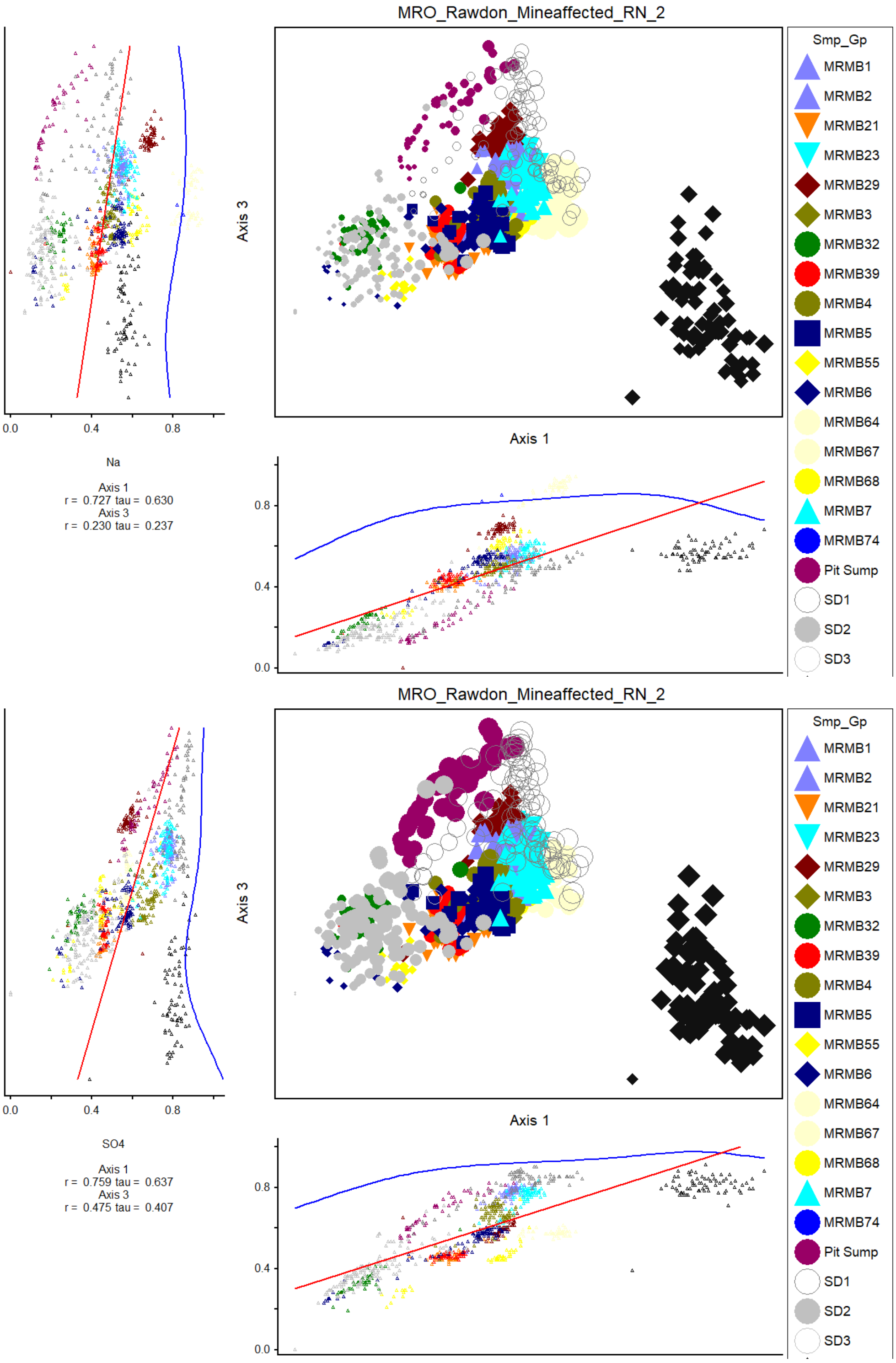


Figure 65: Principal Components 1 and 3 in Rawdon Creek, highlighting the variation of sodium and sulfate in groundwater

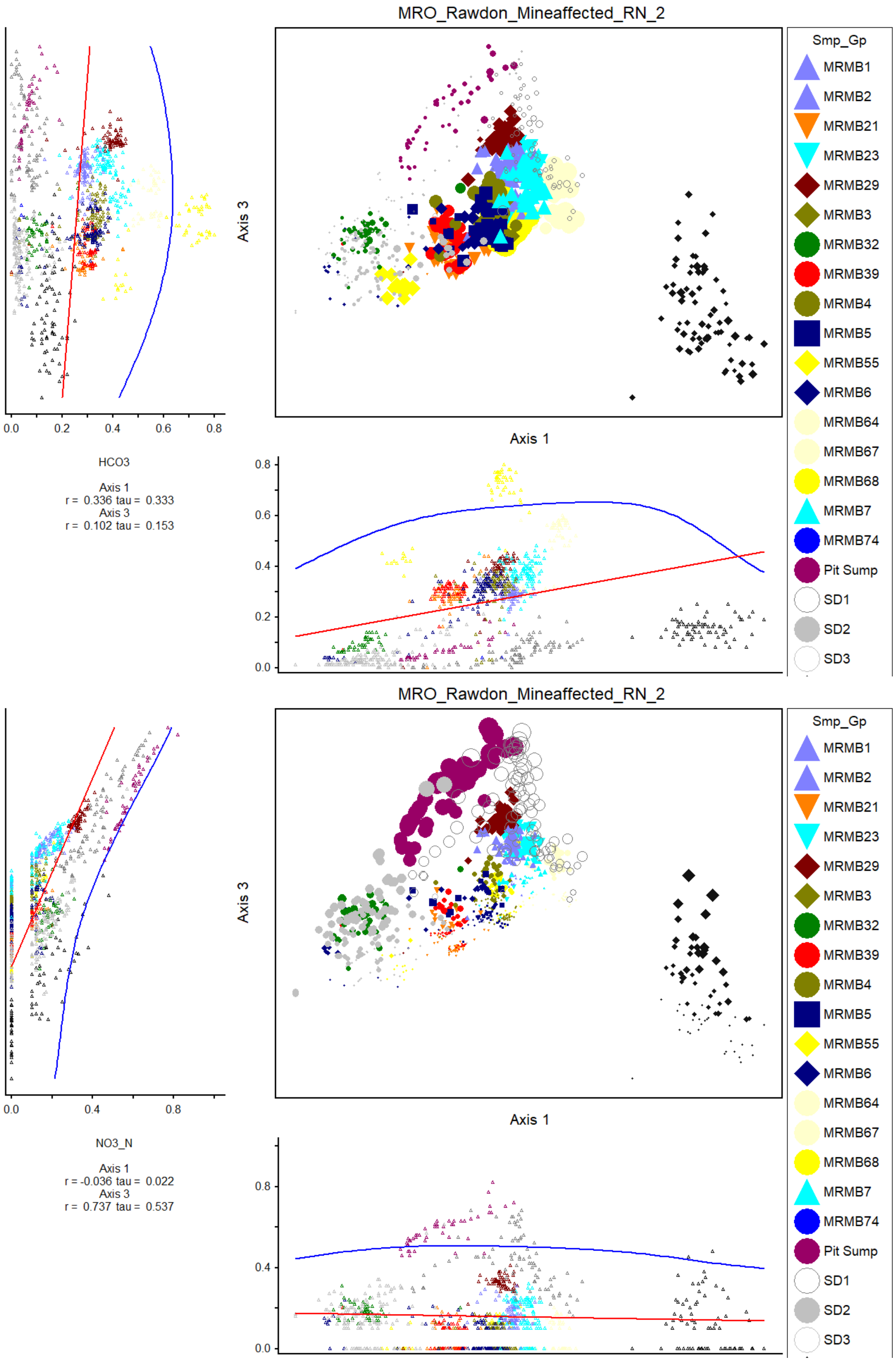


Figure 66: Principal Components 1 and 3 in Rawdon Creek, highlighting the variation of bicarbonate and nitrate-N in groundwater

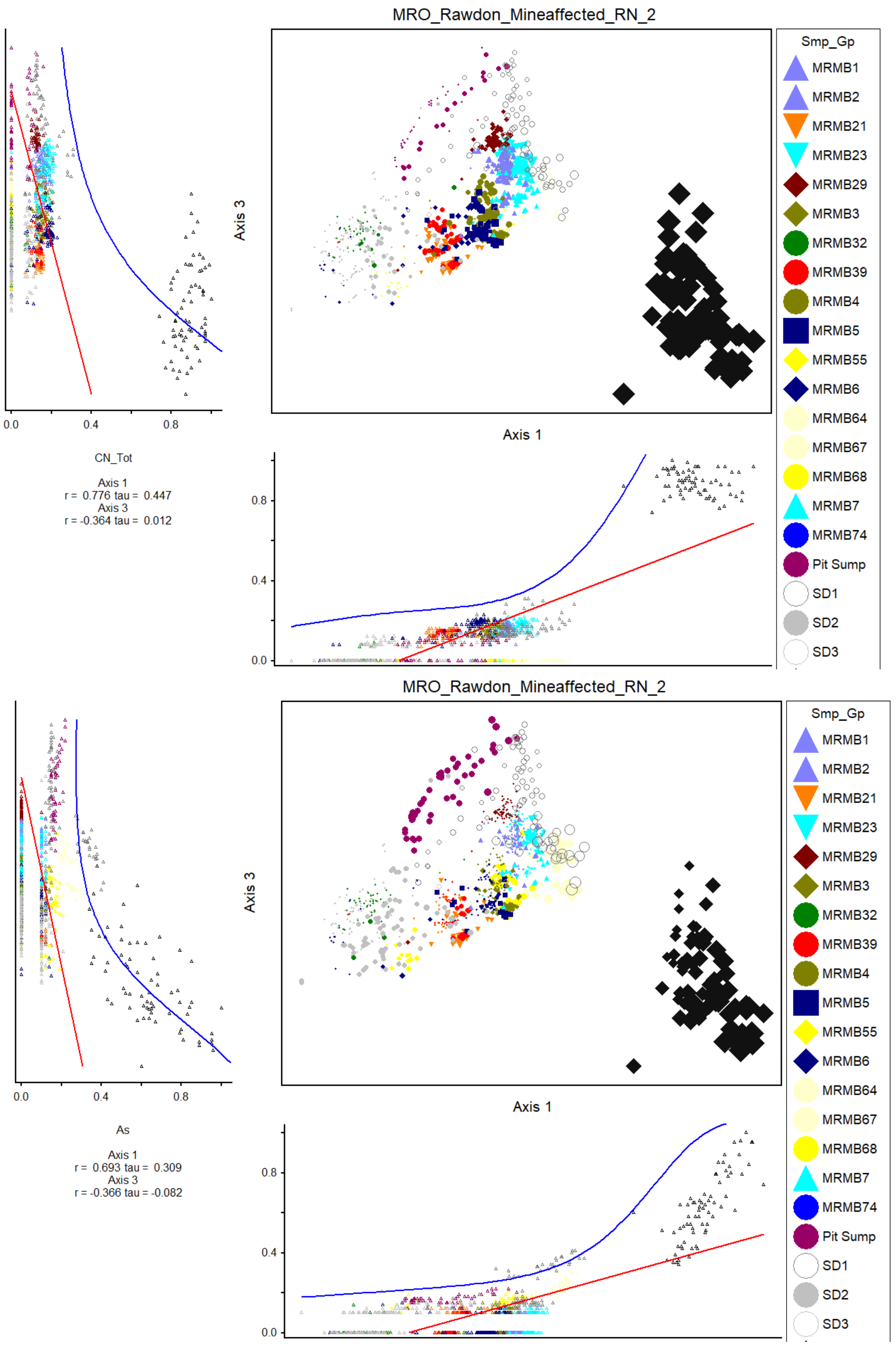


Figure 67: Principal Components 1 and 3 in Rawdon Creek, highlighting the variation of total cyanide and arsenic in groundwater

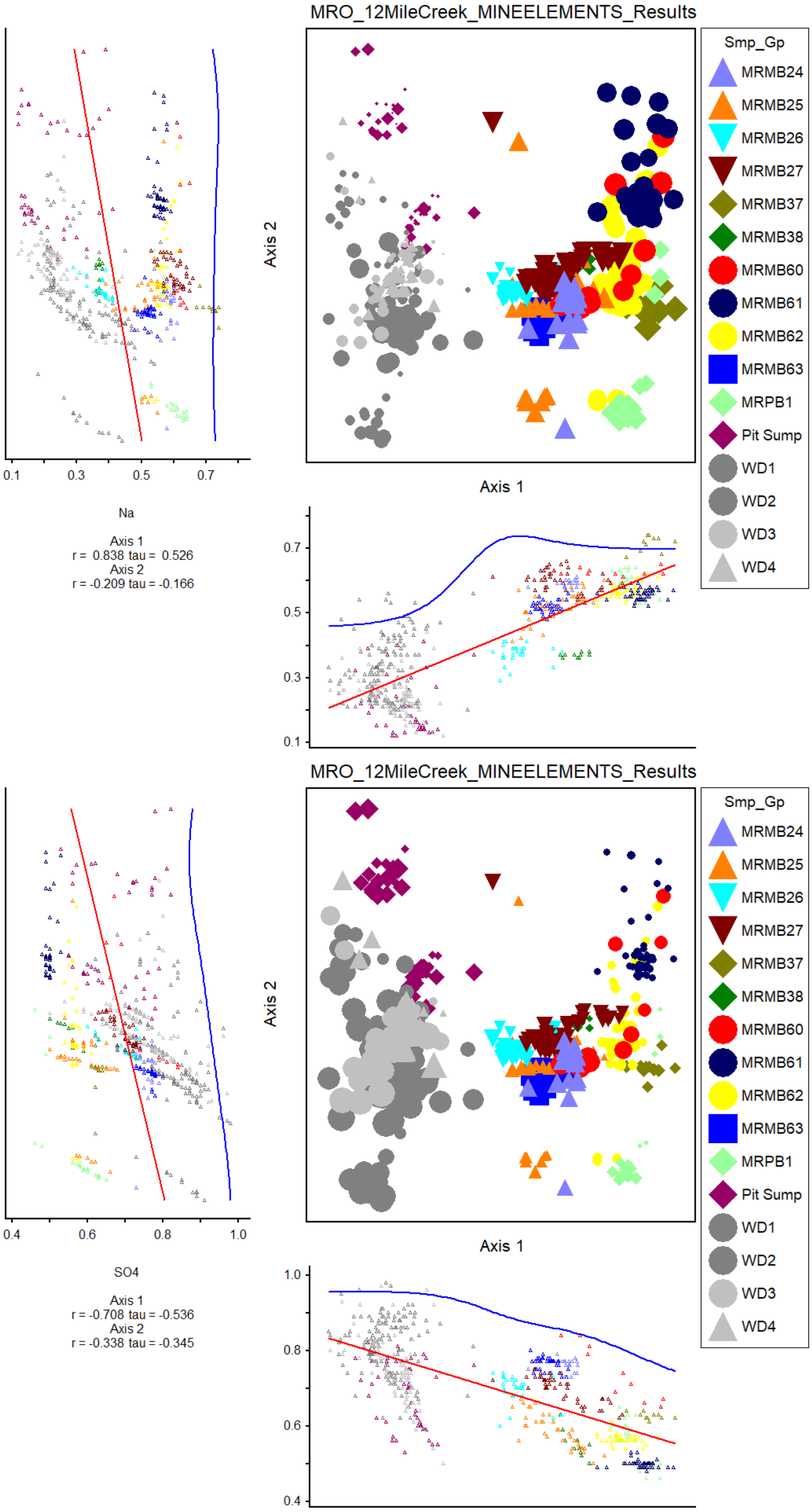


Figure 68: Principal Components 1 and 2 in Twelve Mile Creek, highlighting the variation of sodium and sulfate in water

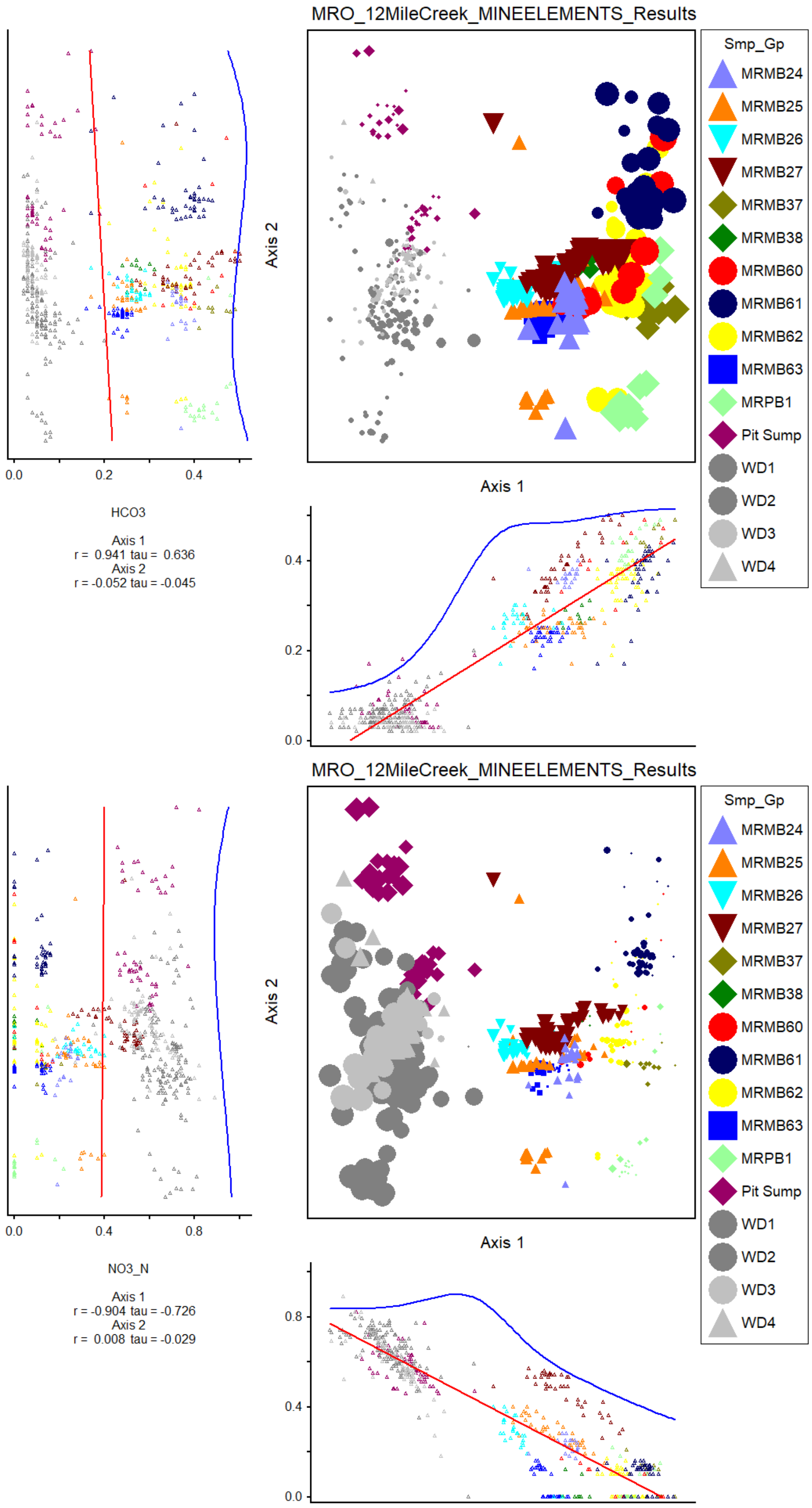


Figure 69: Principal Components 1 and 2 in Twelve Mile Creek, highlighting the variation of bicarbonate and nitrate-N in water

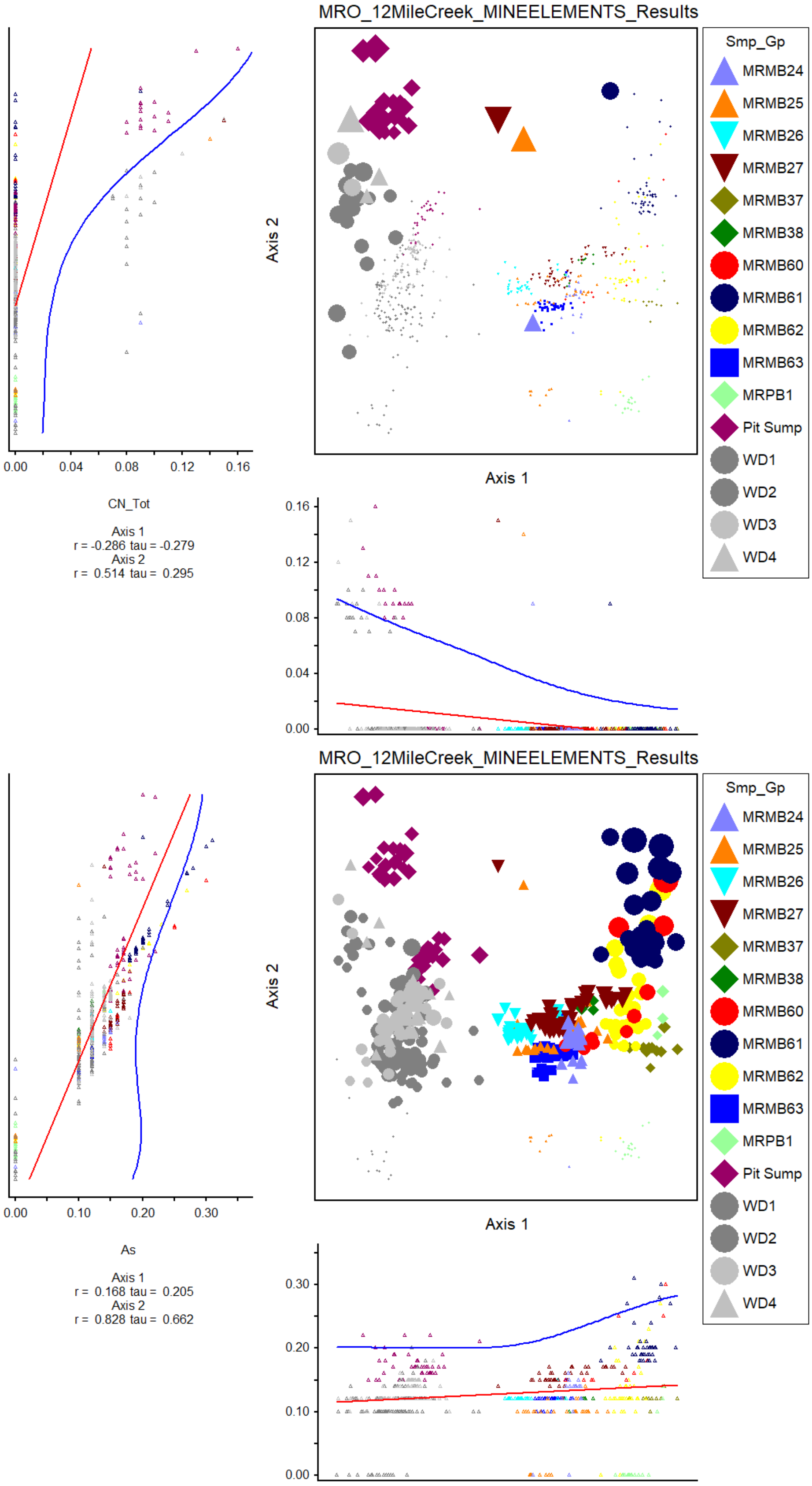


Figure 70: Principal Components 1 and 2 in Twelve Mile Creek, highlighting the variation of total cyanide and arsenic in water

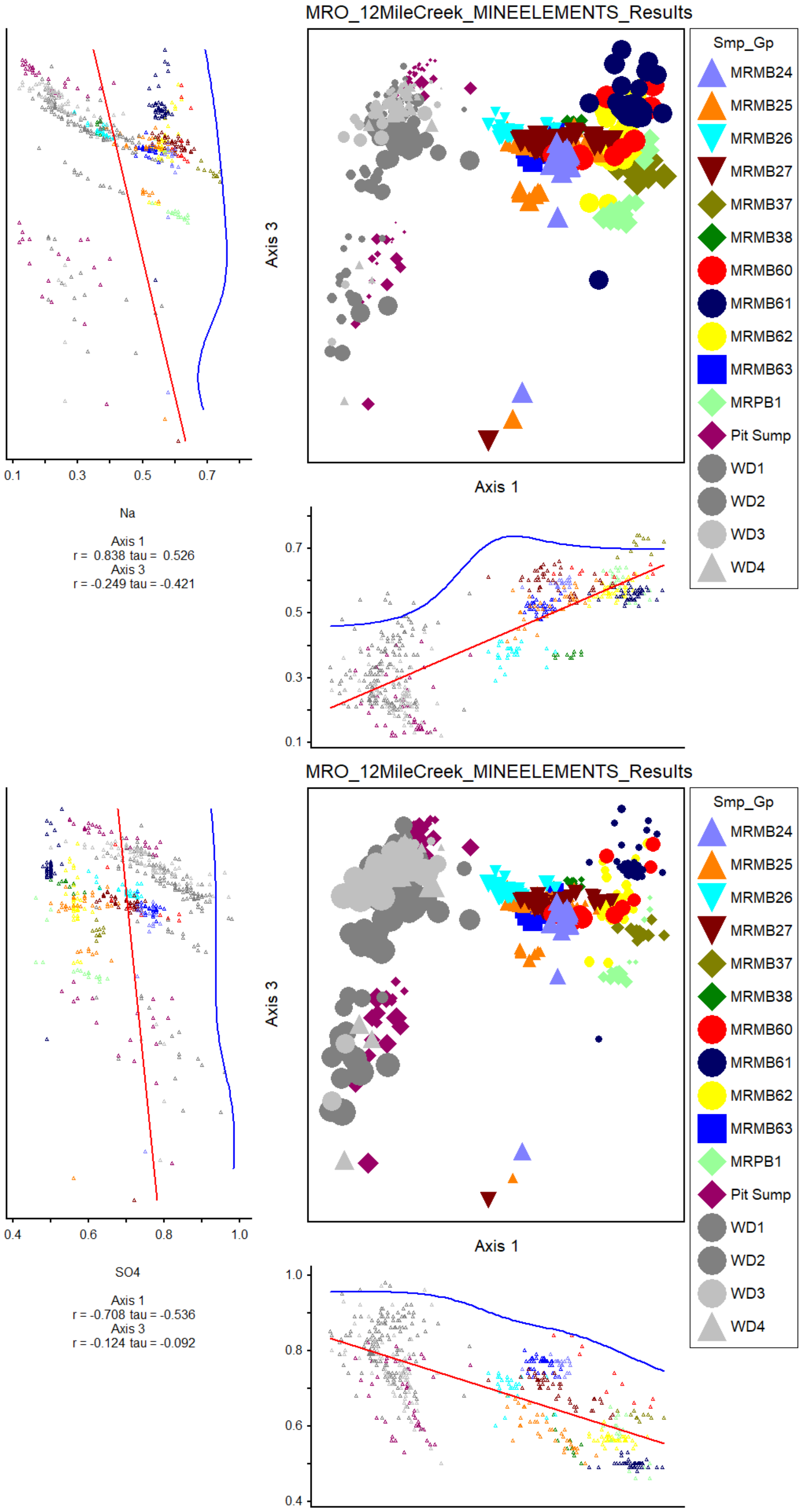


Figure 71: Principal Components 1 and 3 in Twelve Mile Creek, highlighting the variation of sodium and sulfate in groundwater

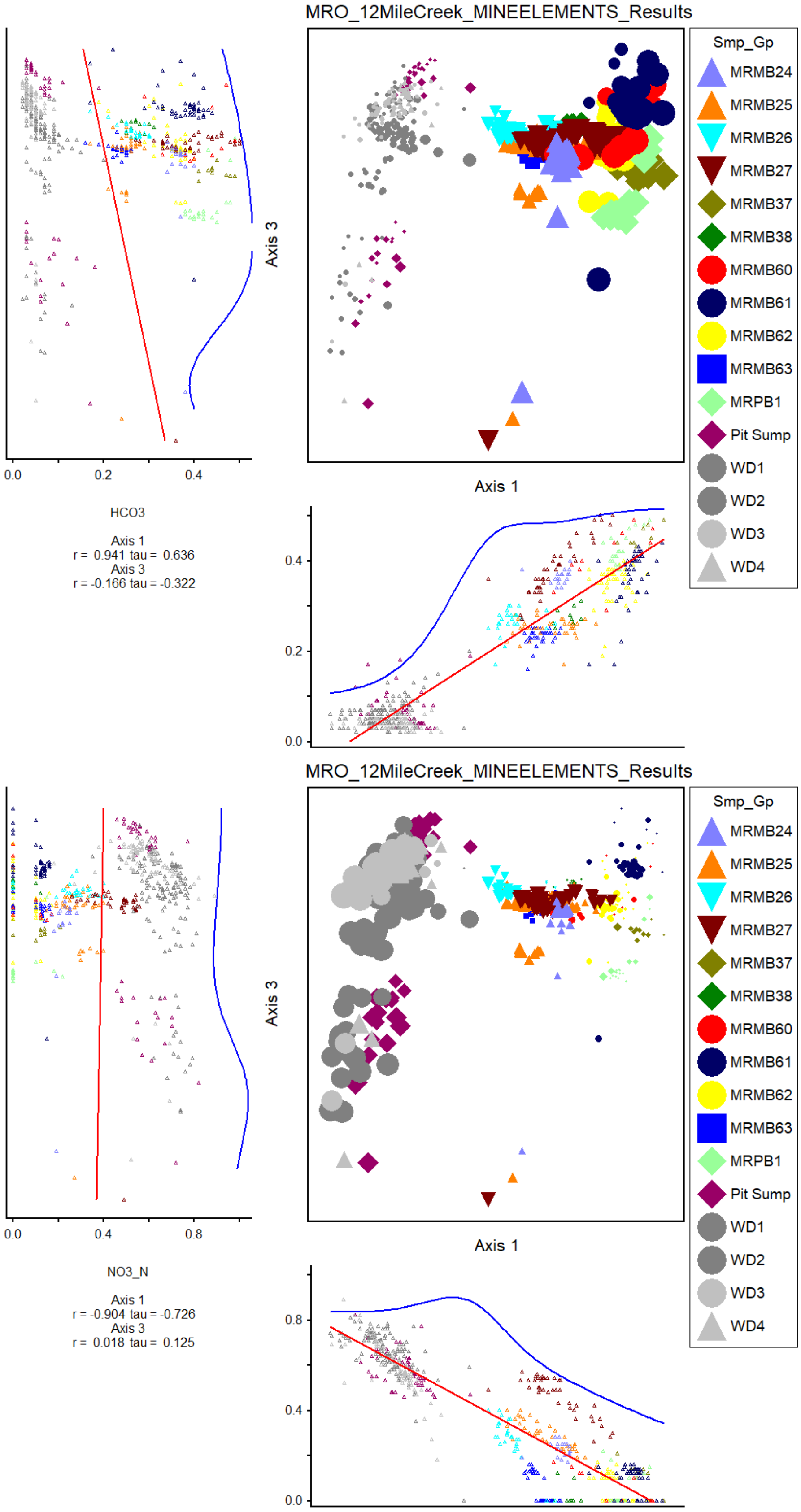


Figure 72: Principal Components 1 and 3 in Twelve Mile Creek, highlighting the variation of bicarbonate and nitrate-N in groundwater

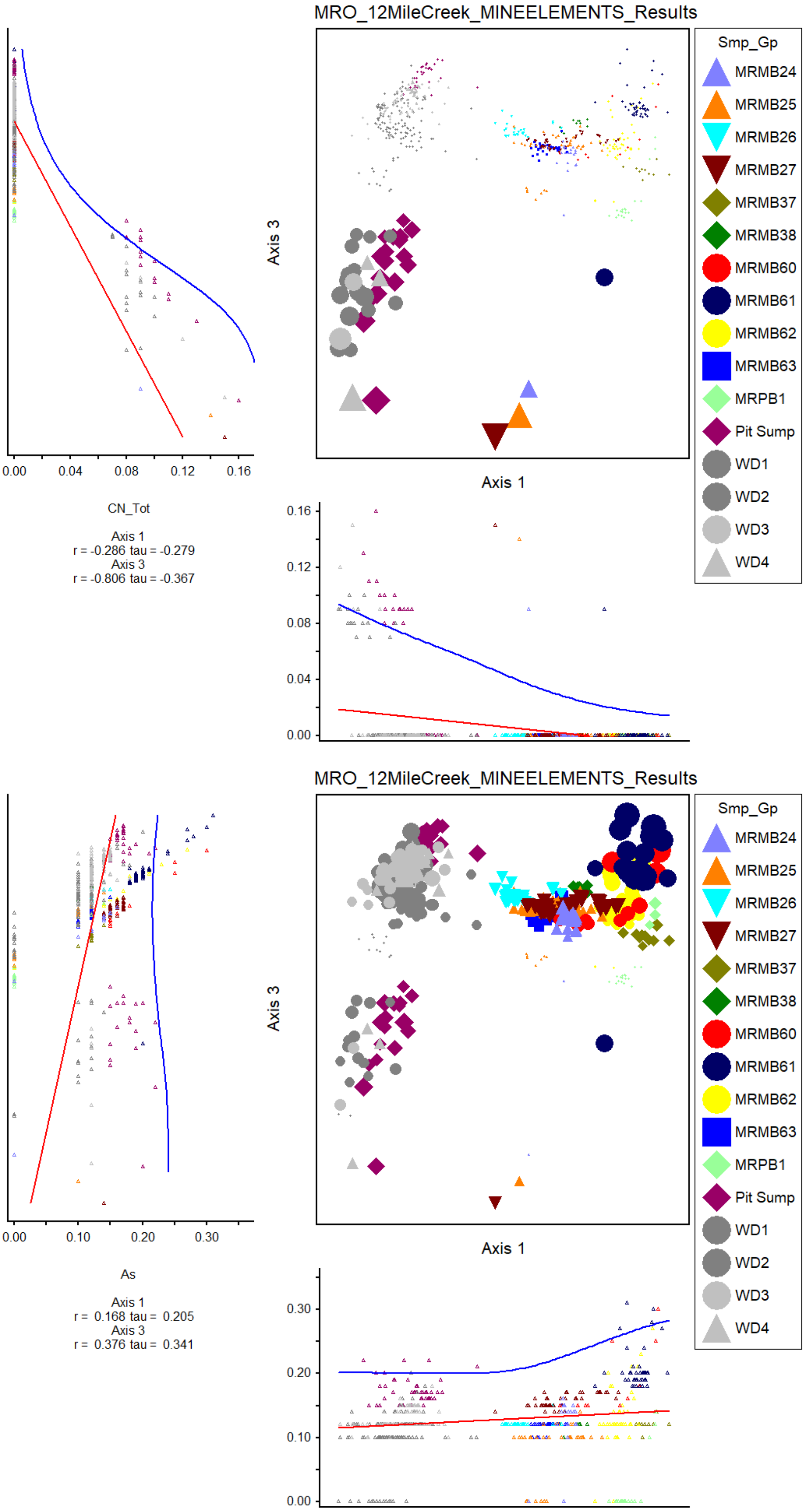


Figure 73: Principal Components 1 and 3 in Twelve Mile Creek, highlighting the variation of total cyanide and arsenic in groundwater

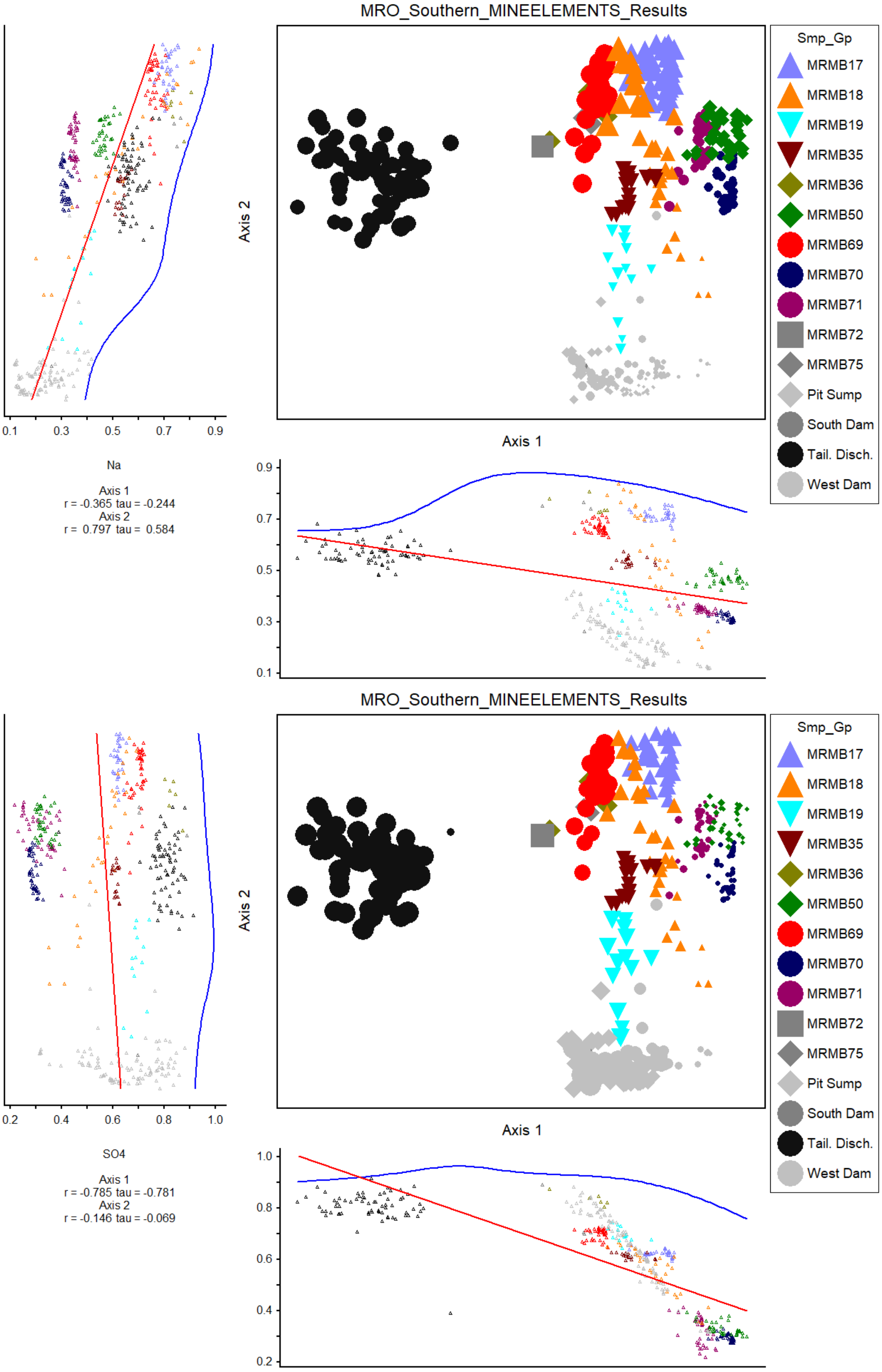


Figure 74: Principal Components 1 and 2 in Mingham Creek, highlighting the variation of sodium and sulfate in groundwater

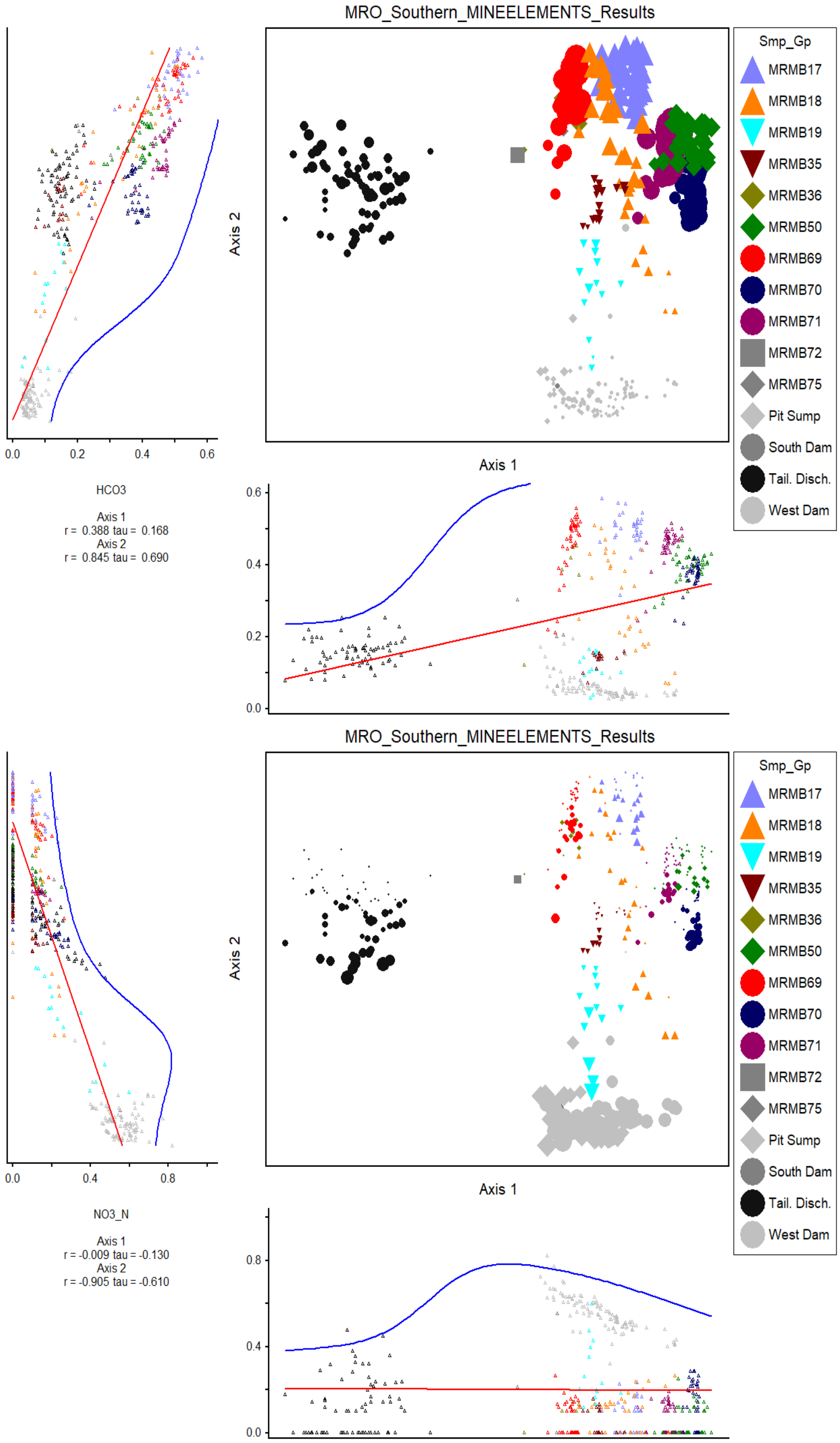


Figure 75: Principal Components 1 and 2 in Mingham Creek, highlighting the variation of bicarbonate and nitrate-N in groundwater

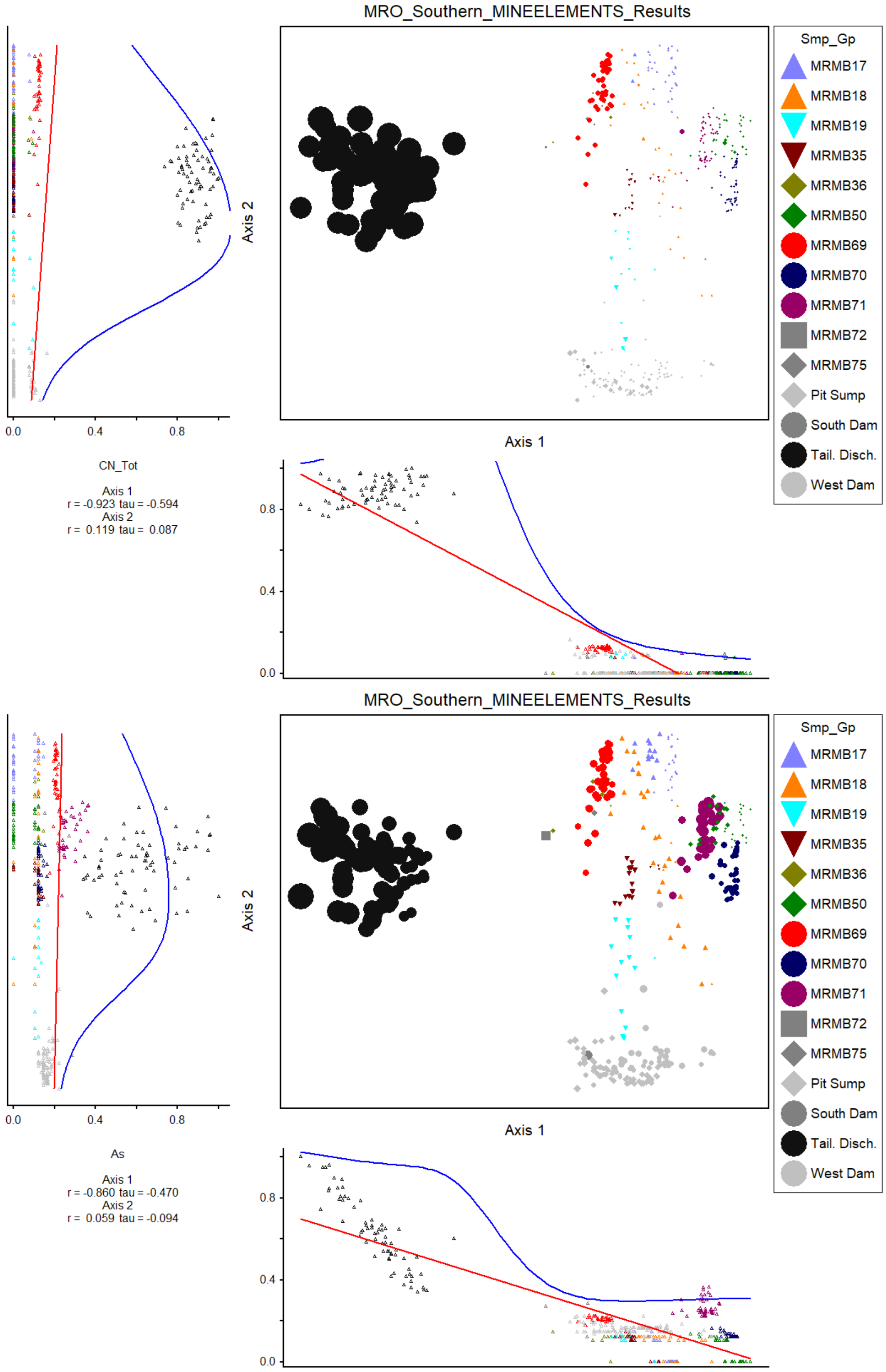


Figure 76: Principal Components 1 and 2 in Mingham Creek, highlighting the variation of total cyanide and arsenic in groundwater

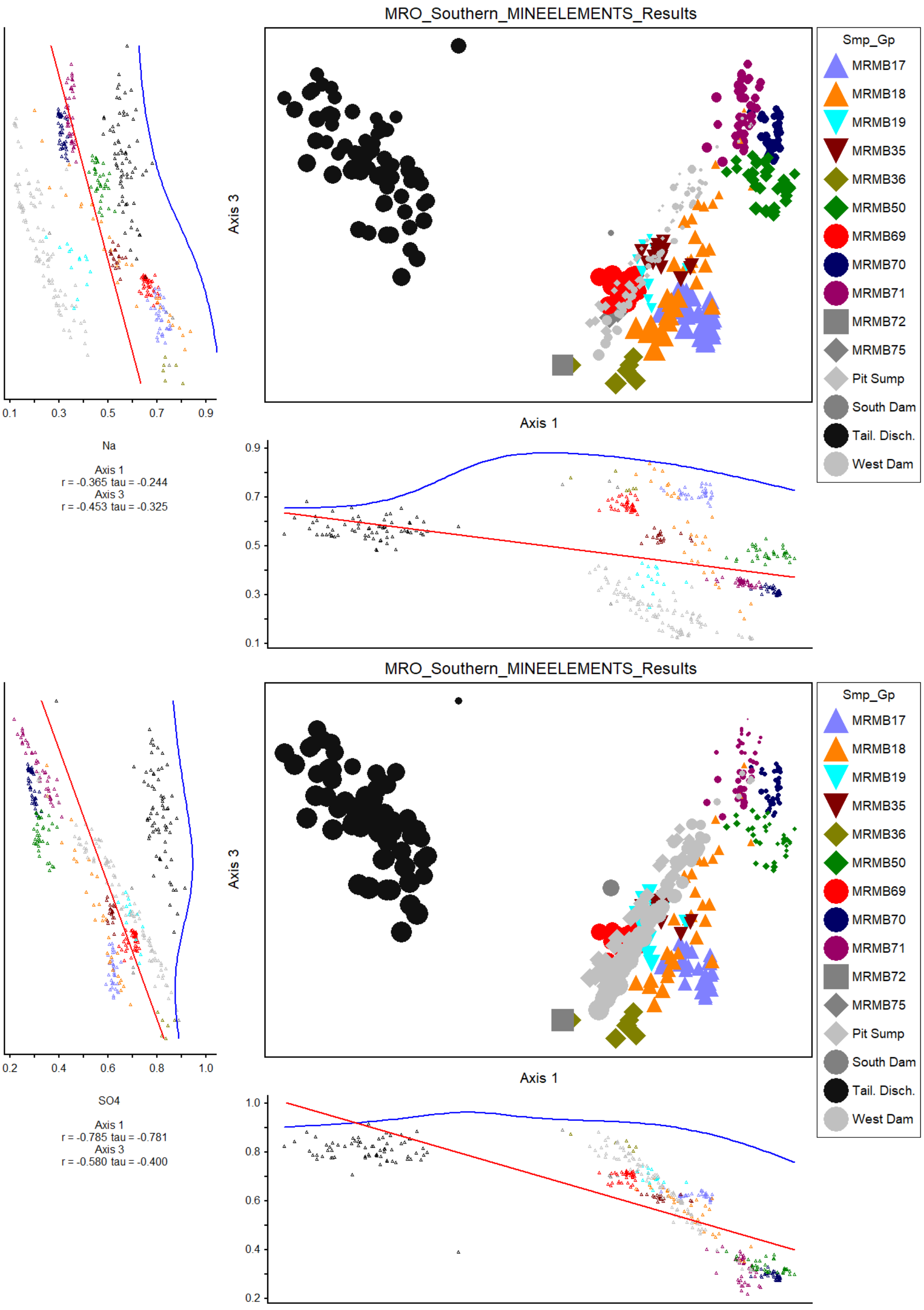


Figure 77: Principal Components 1 and 3 in Mingham Creek, highlighting the variation of sodium and sulfate in groundwater

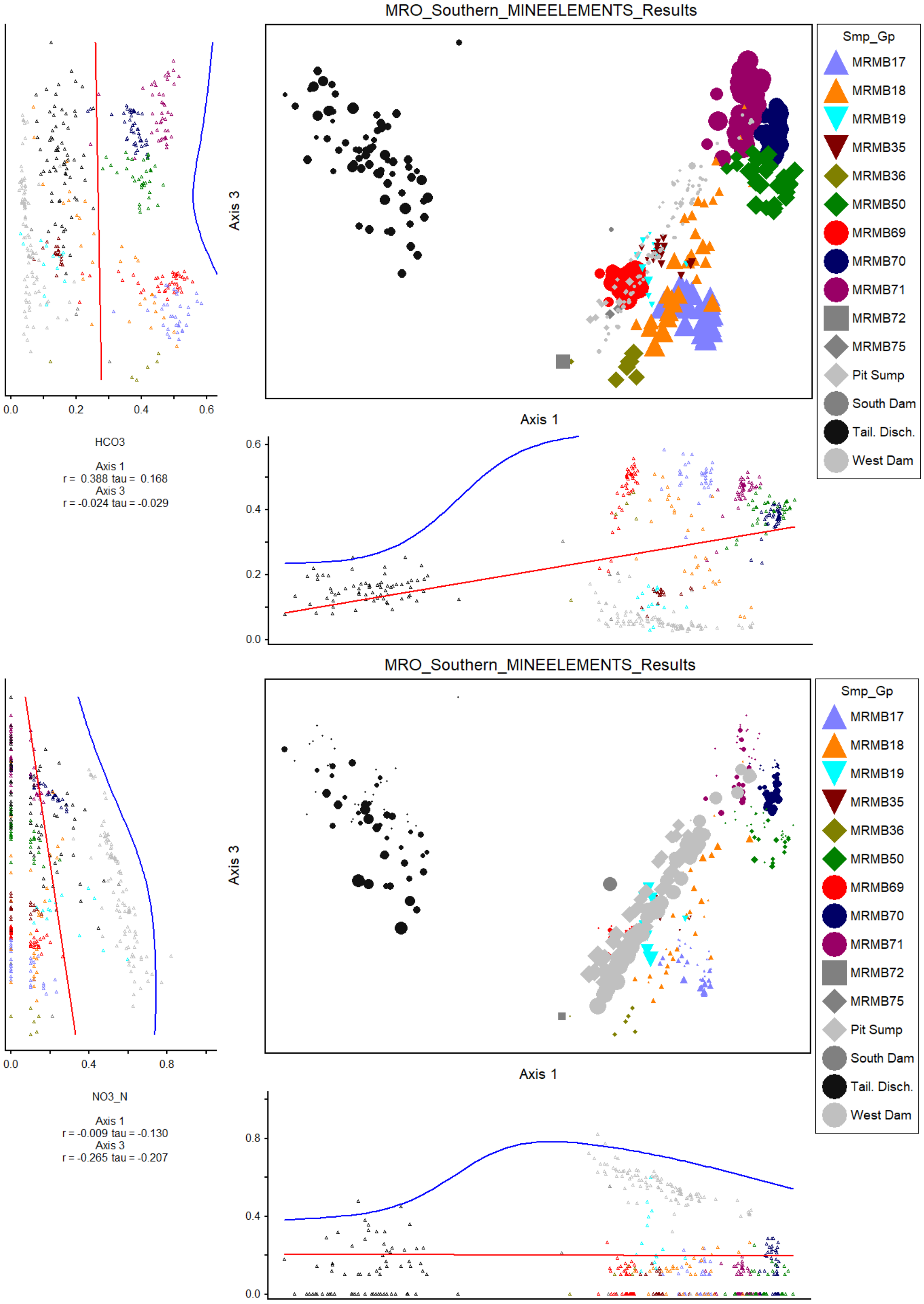


Figure 78: Principal Components 1 and 3 in Mingham Creek, highlighting the variation of bicarbonate and nitrate-N in groundwater

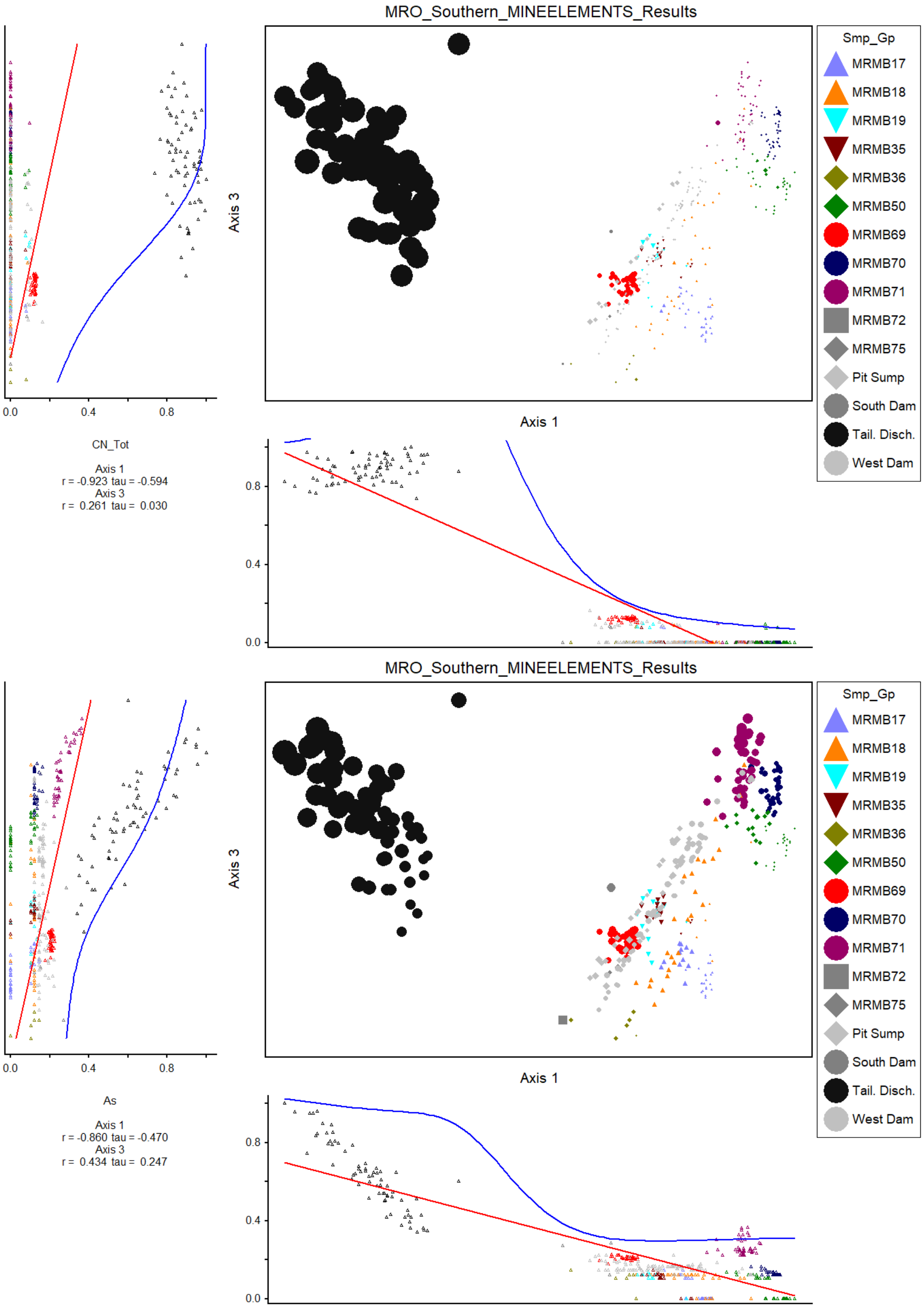


Figure 79: Principal Components 1 and 3 in Mingham Creek, highlighting the variation of total cyanide and arsenic in groundwater

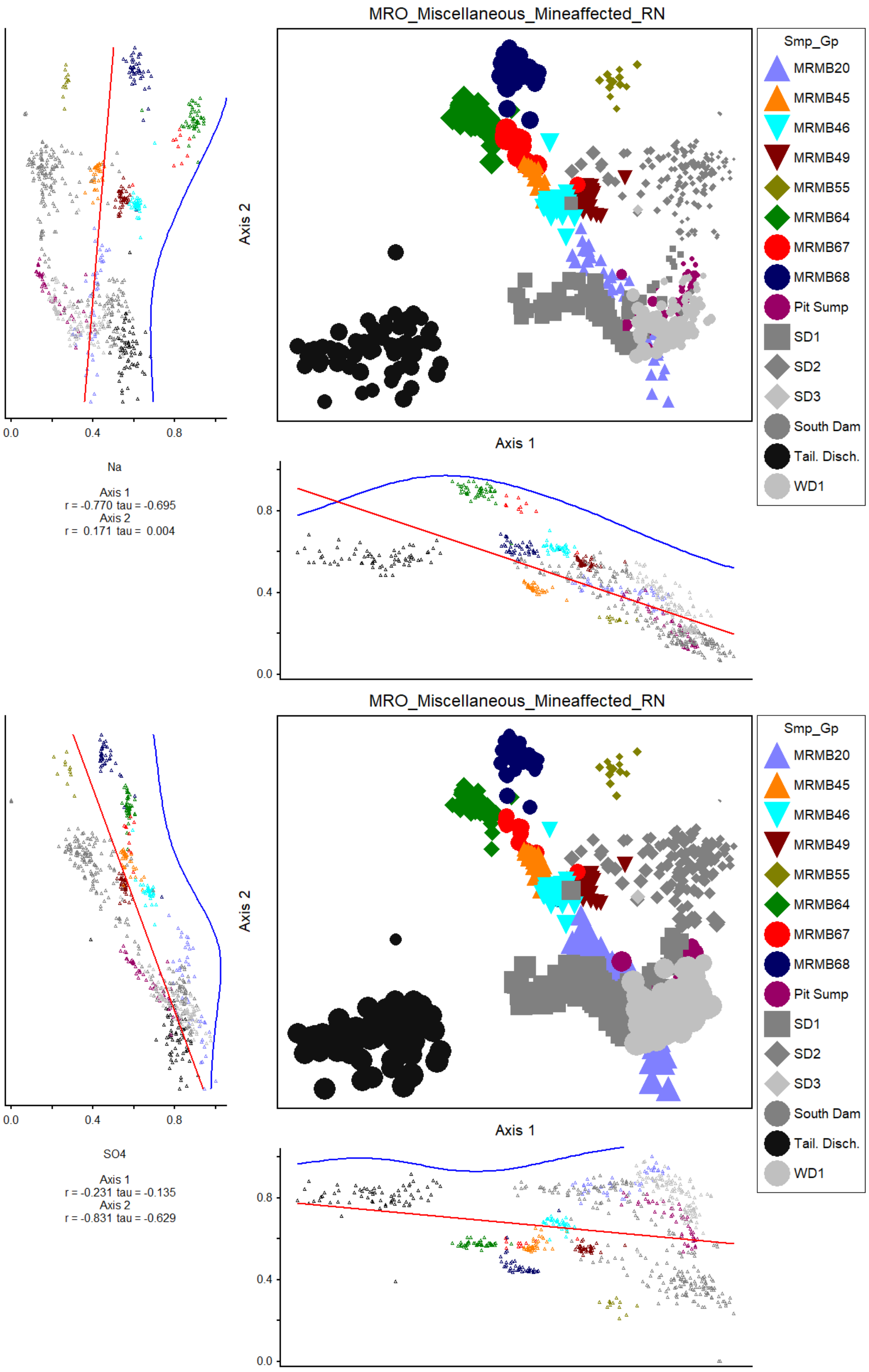


Figure 80: Principal Components 1 and 2 in groundwater below the processing area/access road, highlighting the variation of sodium and sulfate in groundwater

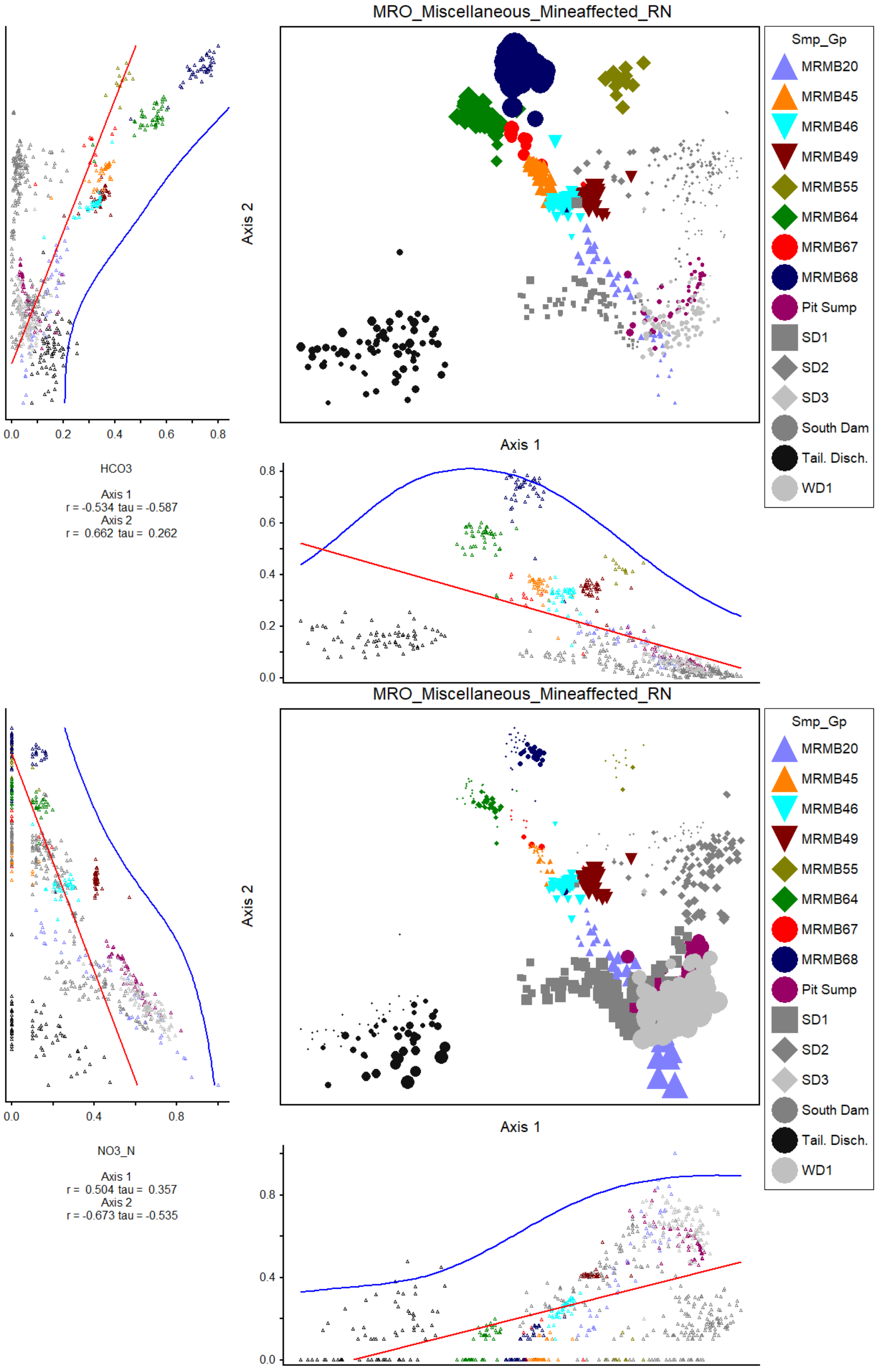


Figure 81: Principal Components 1 and 2 in groundwater below the processing area/access road, highlighting the variation of bicarbonate and nitrate-N in groundwater

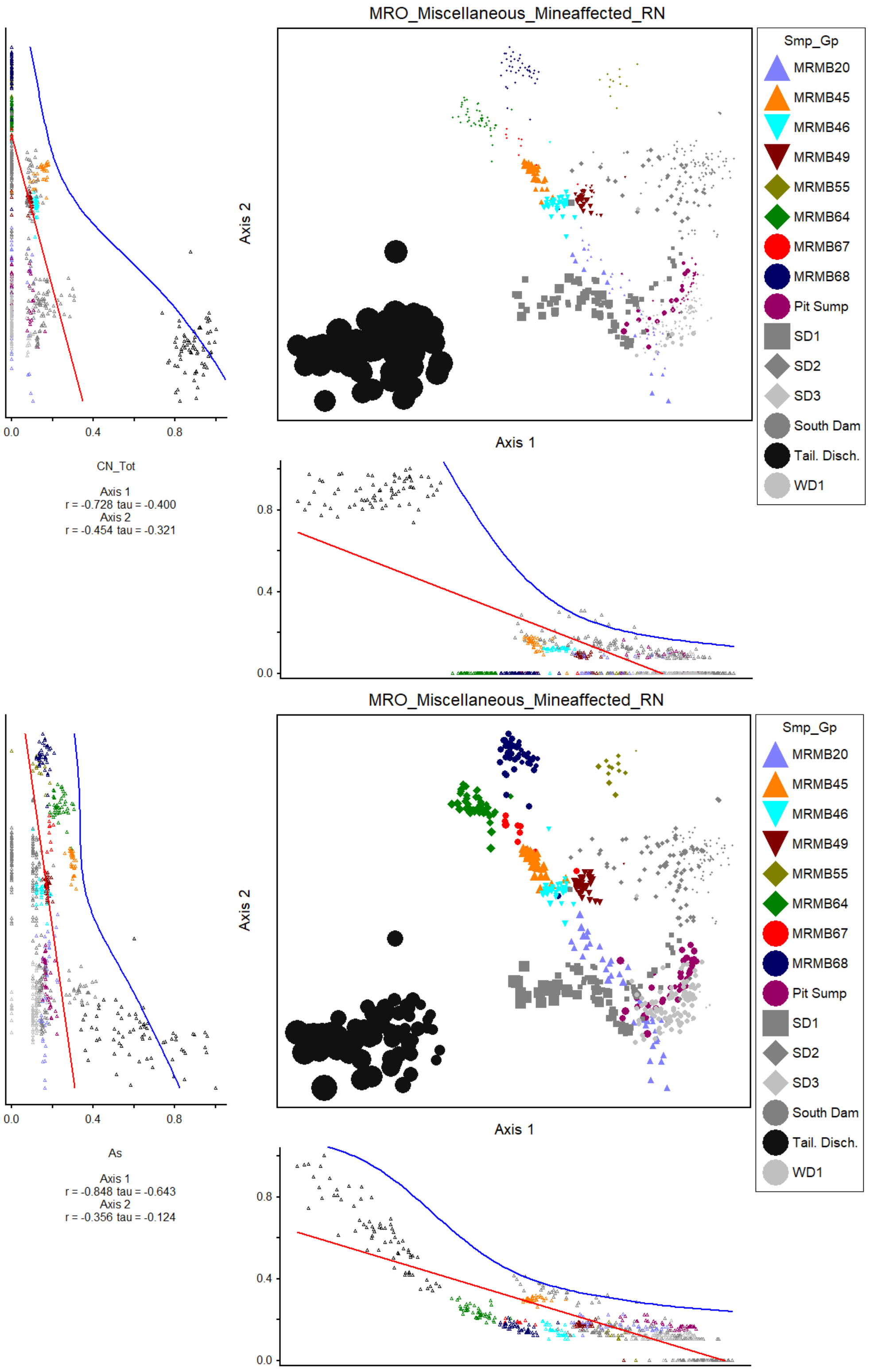


Figure 82: Principal Components 1 and 2 in groundwater below the processing area/access road, highlighting the variation of total cyanide and arsenic in groundwater

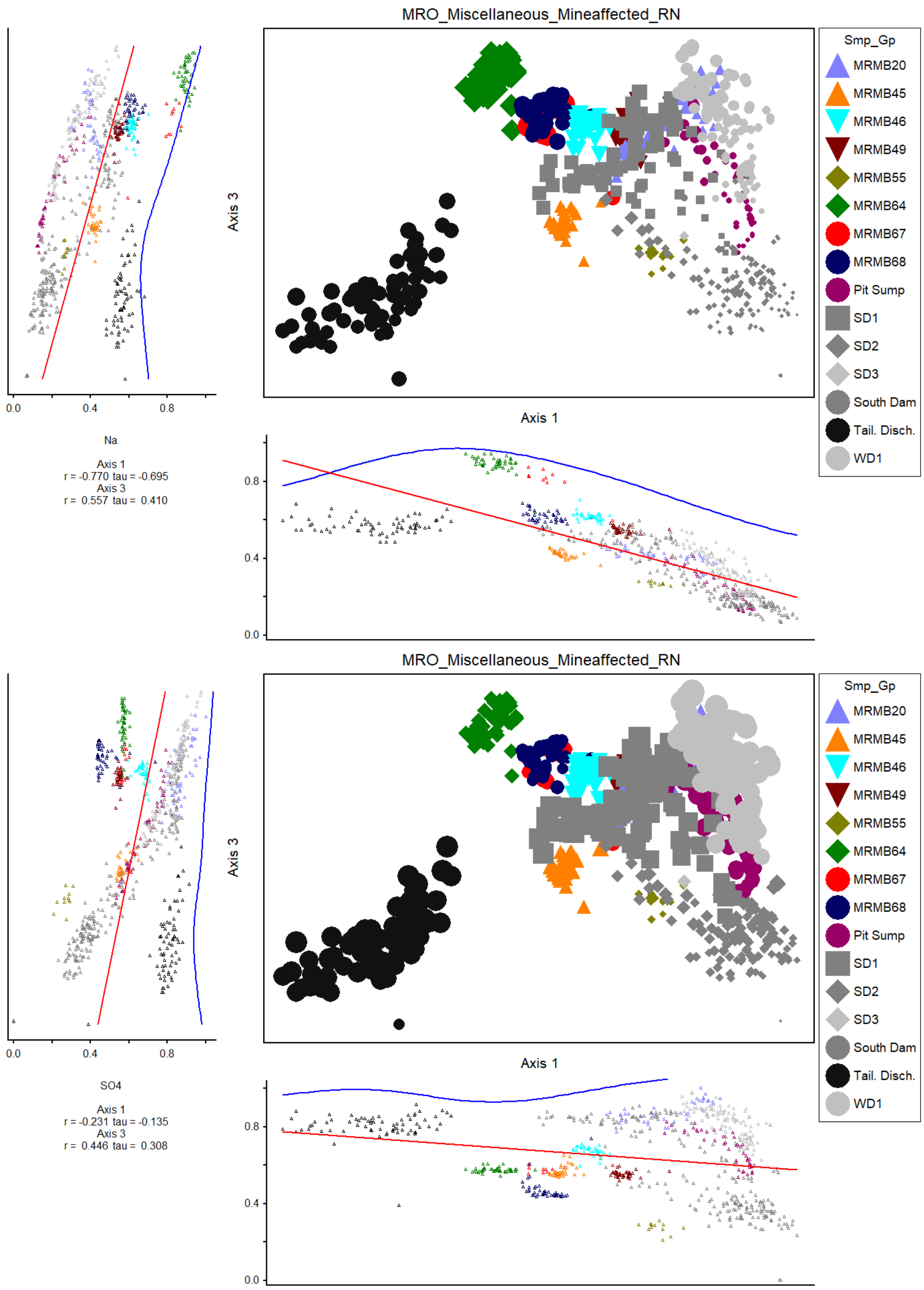


Figure 83: Principal Components 1 and 3 in groundwater below the processing area/access road, highlighting the variation of sodium and sulfate in groundwater

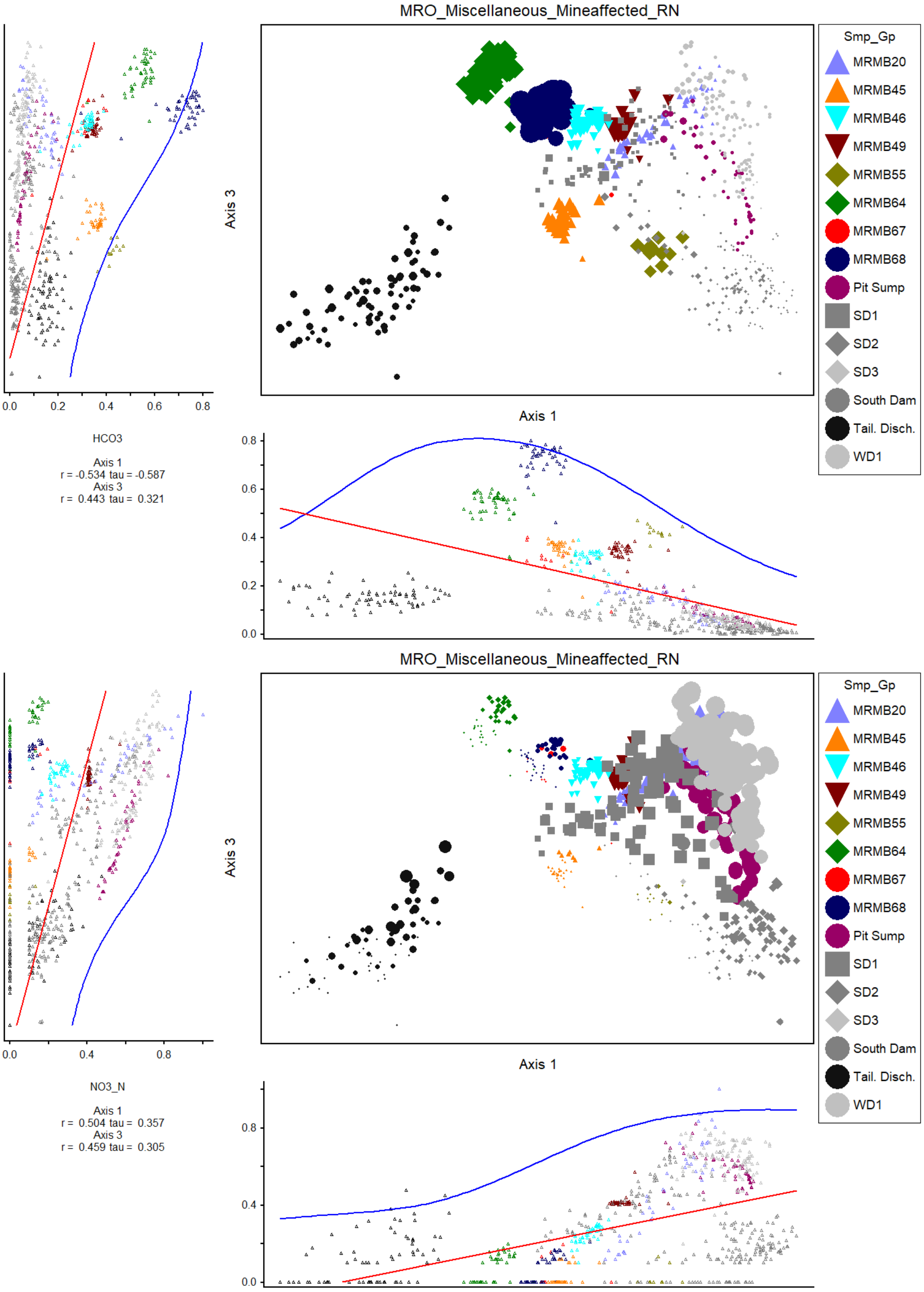


Figure 84: Principal Components 1 and 3 in groundwater below the processing area/access road, highlighting the variation of sodium and sulfate in groundwater

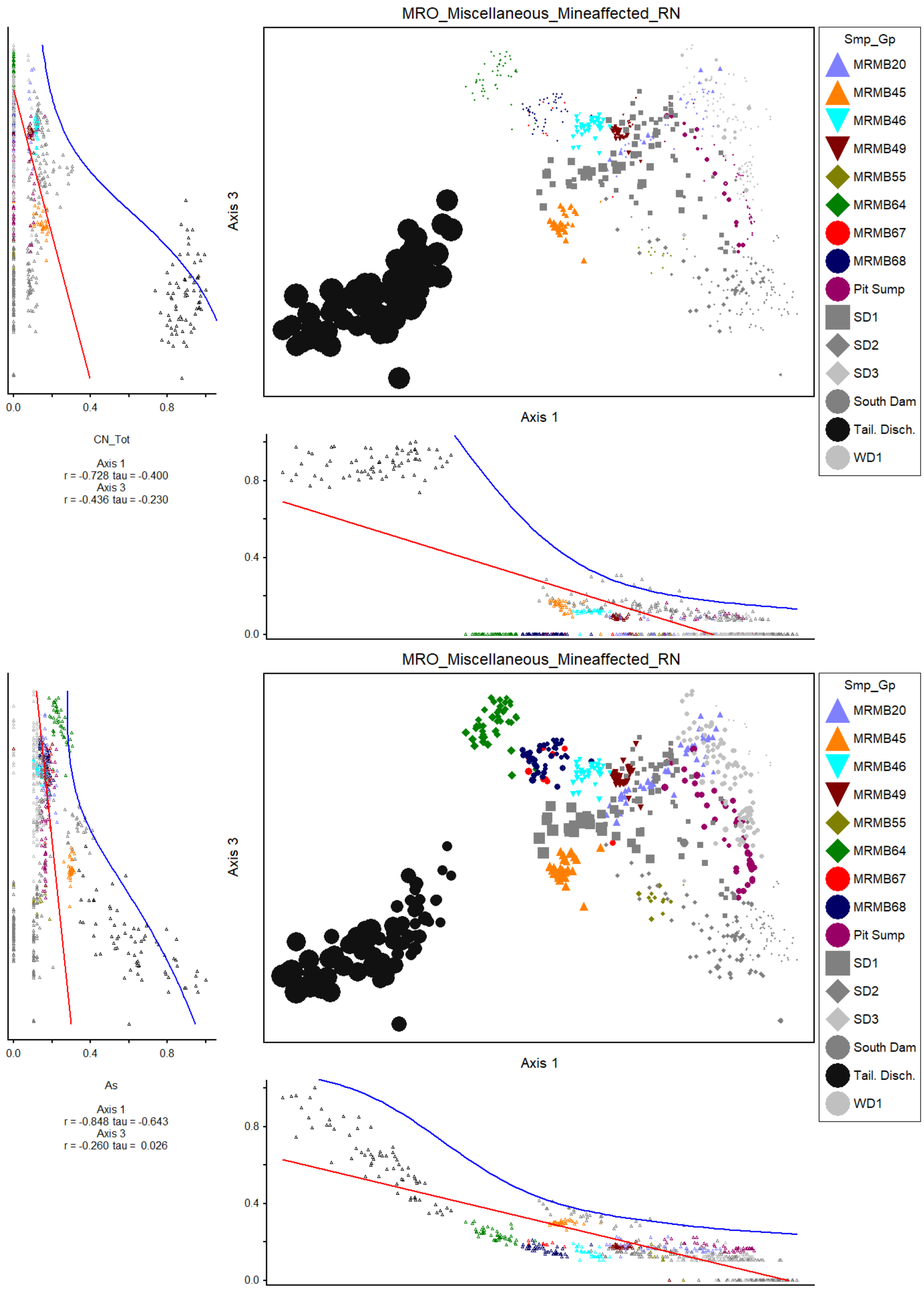
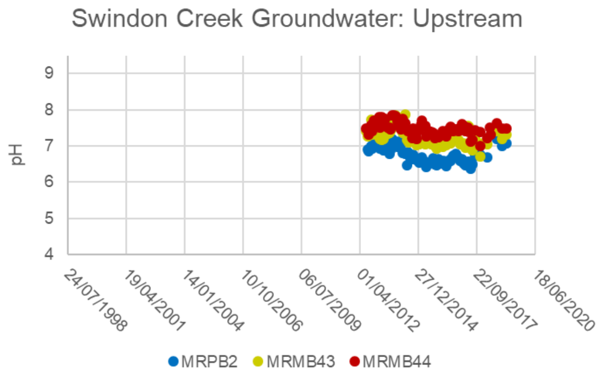
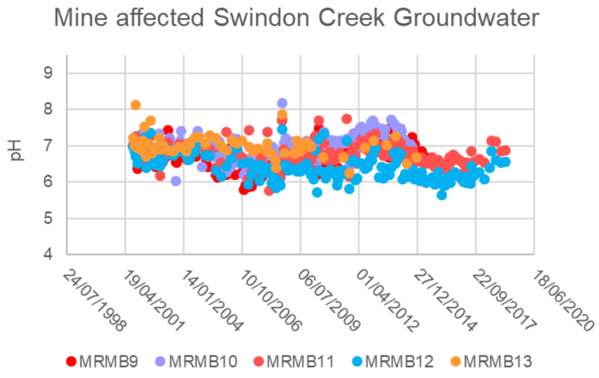


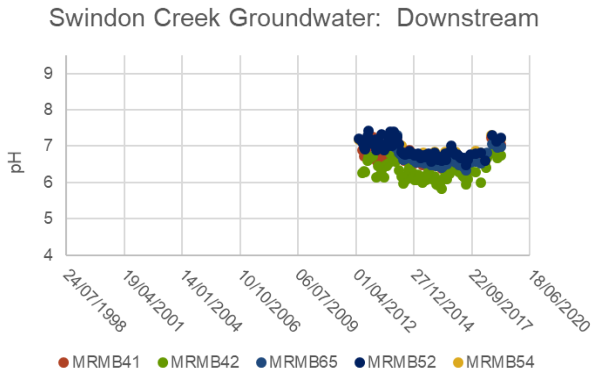
Figure 85: Principal Components 1 and 3 in groundwater below the processing area/access road, highlighting the variation of total cyanide and arsenic in groundwater

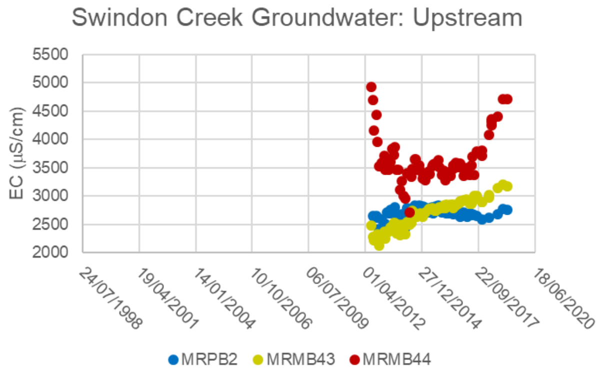
8.4 Historical Groundwater Quality

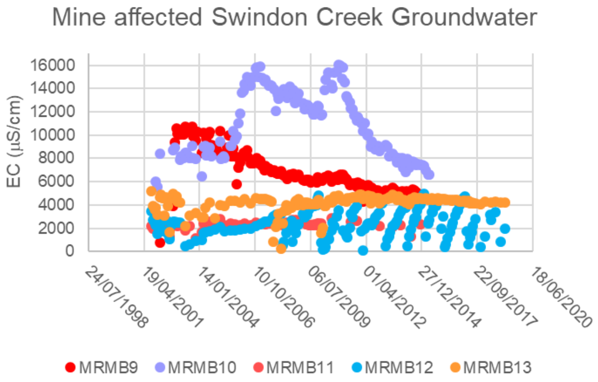
8.4.1 Time Series Charts for Swindon Creek

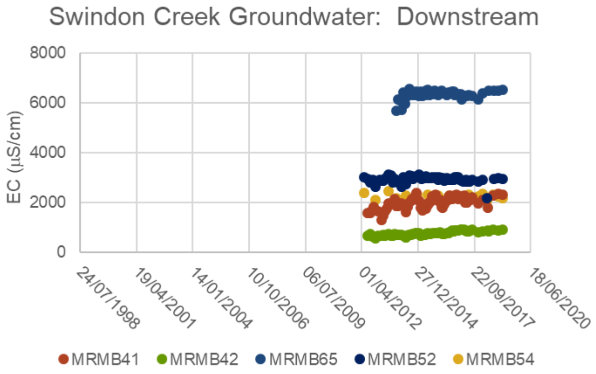


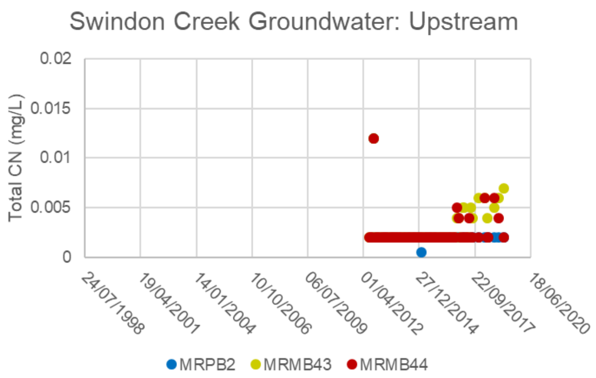


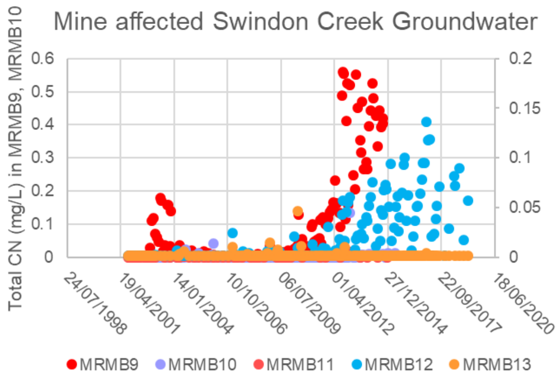


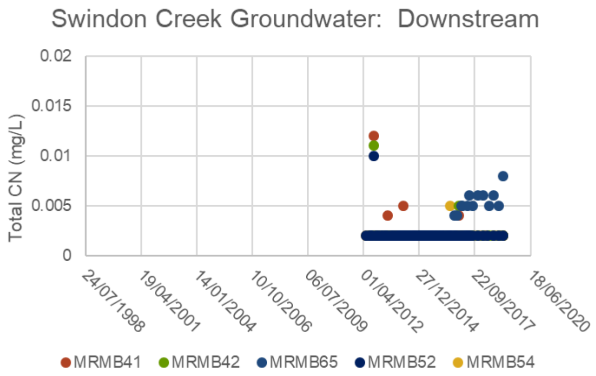


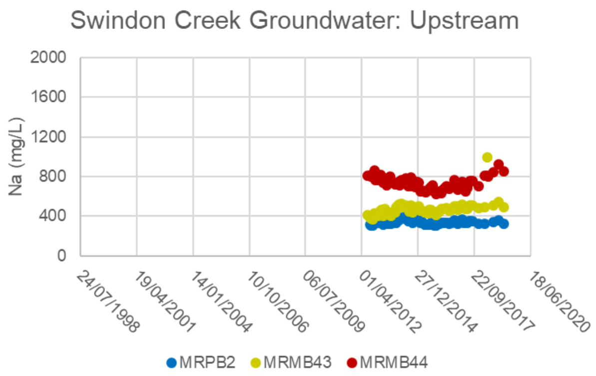


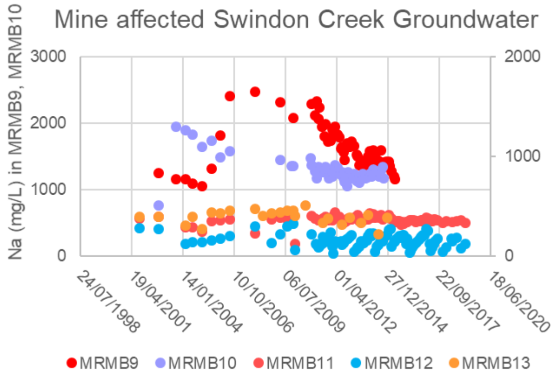


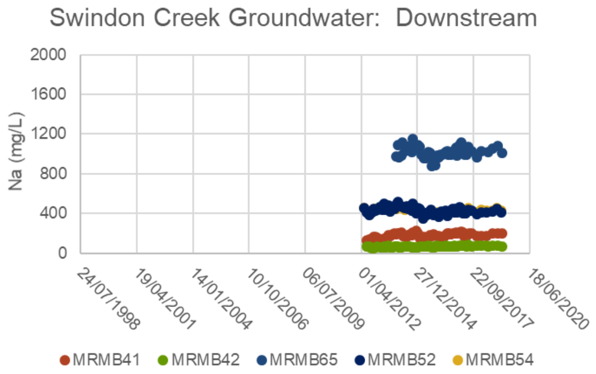

Swindon Creek Groundwater: Upstream
Total CN (mg/L)
0.02
0.015
0.01
0.005
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRPB2 ● MRMB43 ● MRMB44

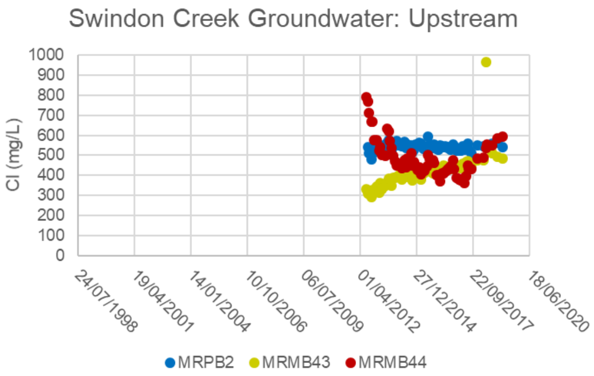

Mine affected Swindon Creek Groundwater
Total CN (mg/L) in MRMB9, MRMB10
0.6
0.5
0.4
0.3
0.2
0.1
0
0.2
0.15
0.1
0.05
0
Total CN (mg/L) in MRMB11, MRMB12, MRMB13
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB9 ● MRMB10 ● MRMB11 ● MRMB12 ● MRMB13

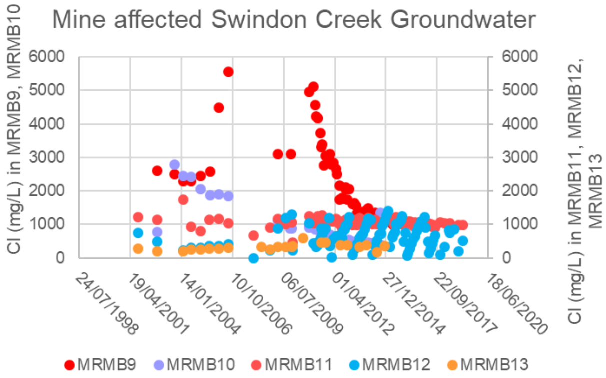

Swindon Creek Groundwater: Downstream
Total CN (mg/L)
0.02
0.015
0.01
0.005
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB41 ● MRMB42 ● MRMB65 ● MRMB52 ● MRMB54

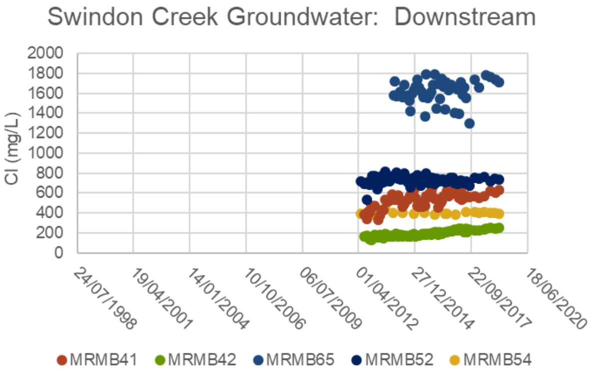

Swindon Creek Groundwater: Upstream
Na (mg/L)
2000
1600
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRPB2 ● MRMB43 ● MRMB44

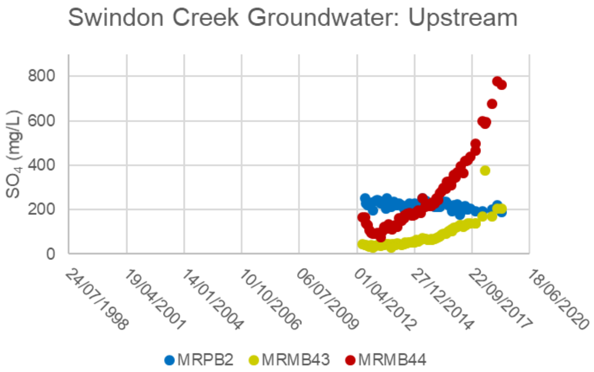

Mine affected Swindon Creek Groundwater
Na (mg/L) in MRMB9, MRMB10
3000
2000
1000
0
2000
1000
0
Na (mg/L) in MRMB11, MRMB12, MRMB13
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB9 ● MRMB10 ● MRMB11 ● MRMB12 ● MRMB13

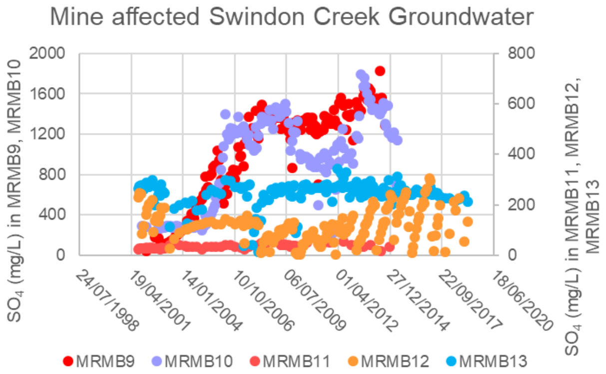

Swindon Creek Groundwater: Downstream
Na (mg/L)
2000
1600
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB41 ● MRMB42 ● MRMB65 ● MRMB52 ● MRMB54

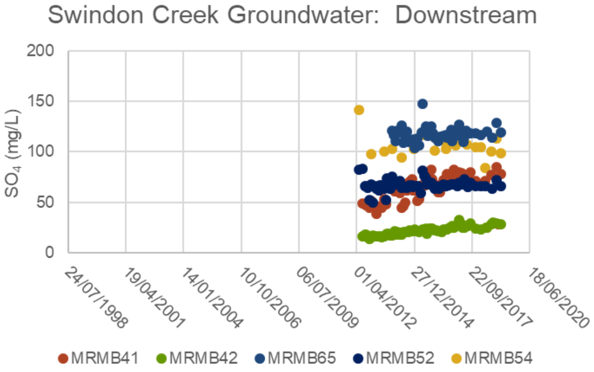

Swindon Creek Groundwater: Upstream
Cl (mg/L)
1000
900
800
700
600
500
400
300
200
100
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRPB2 ● MRMB43 ● MRMB44

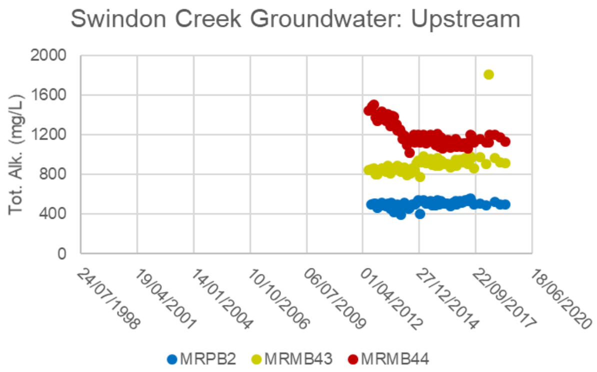

Mine affected Swindon Creek Groundwater
Cl (mg/L) in MRMB9, MRMB10
6000
5000
4000
3000
2000
1000
0
Cl (mg/L) in MRMB11, MRMB12, MRMB13
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB9 ● MRMB10 ● MRMB11 ● MRMB12 ● MRMB13

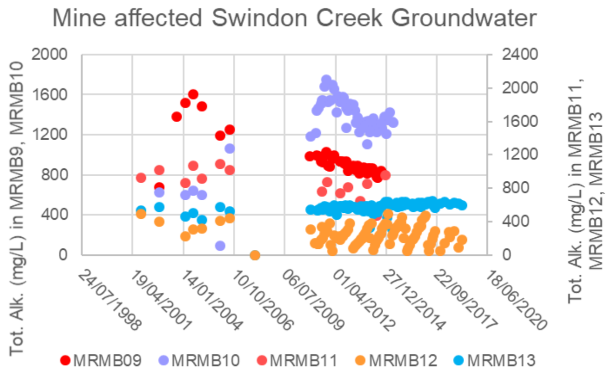

Swindon Creek Groundwater: Downstream
Cl (mg/L)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB41 ● MRMB42 ● MRMB65 ● MRMB52 ● MRMB54

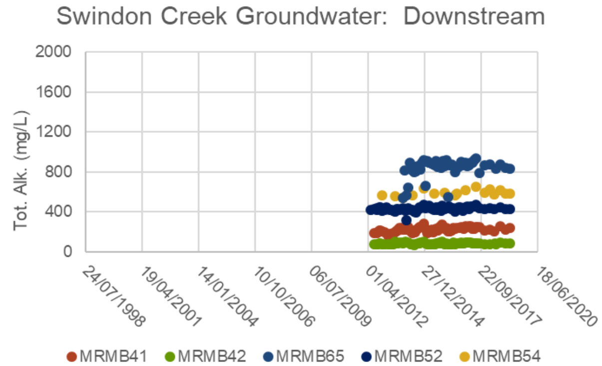

Swindon Creek Groundwater: Upstream
SO₄ (mg/L)
800
600
400
200
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRPB2 ● MRMB43 ● MRMB44

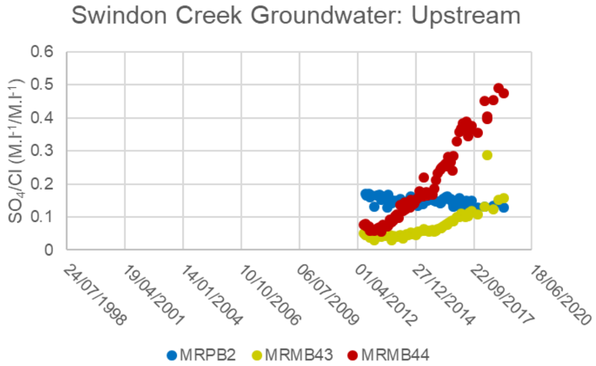

Mine affected Swindon Creek Groundwater
SO₄ (mg/L) in MRMB9, MRMB10
2000
1600
1200
800
400
0
800
600
400
200
0
SO₄ (mg/L) in MRMB11, MRMB12, MRMB13
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB9 ● MRMB10 ● MRMB11 ● MRMB12 ● MRMB13

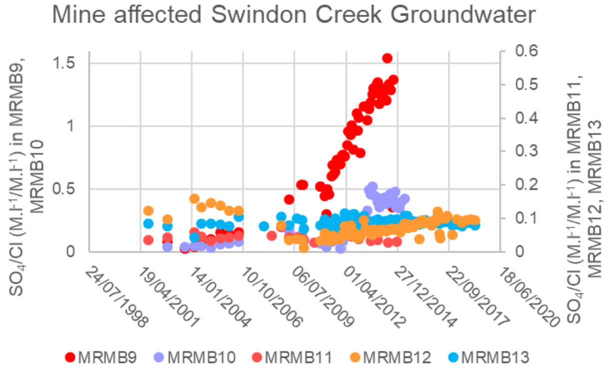

Swindon Creek Groundwater: Downstream
SO₄ (mg/L)
200
150
100
50
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB41 ● MRMB42 ● MRMB65 ● MRMB52 ● MRMB54

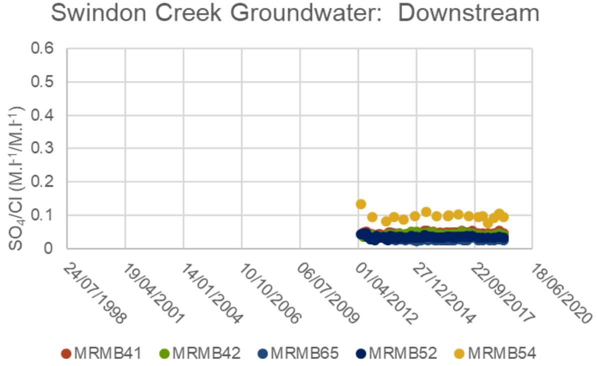

Swindon Creek Groundwater: Upstream
Tot. Alk. (mg/L)
2000
1600
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRPB2 ● MRMB43 ● MRMB44

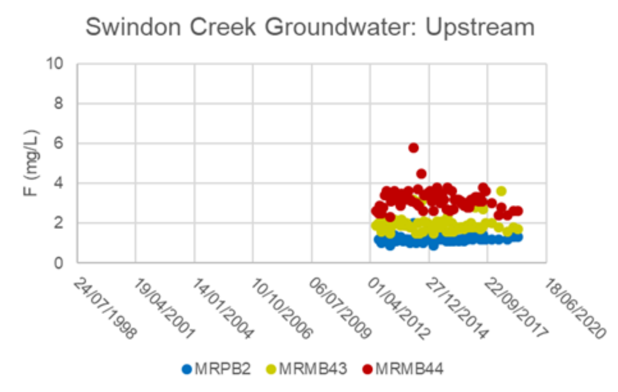

Mine affected Swindon Creek Groundwater
Tot. Alk. (mg/L) in MRMB9, MRMB10
2000
1600
1200
800
400
0
Tot. Alk. (mg/L) in MRMB11, MRMB12, MRMB13
2400
2000
1600
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB09 ● MRMB10 ● MRMB11 ● MRMB12 ● MRMB13

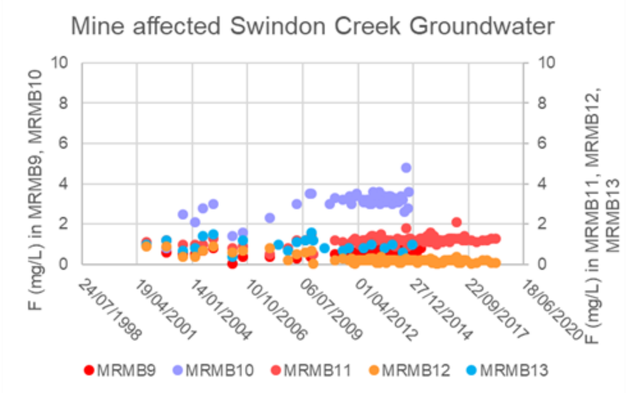

Swindon Creek Groundwater: Downstream
Tot. Alk. (mg/L)
2000
1600
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB41 ● MRMB42 ● MRMB65 ● MRMB52 ● MRMB54

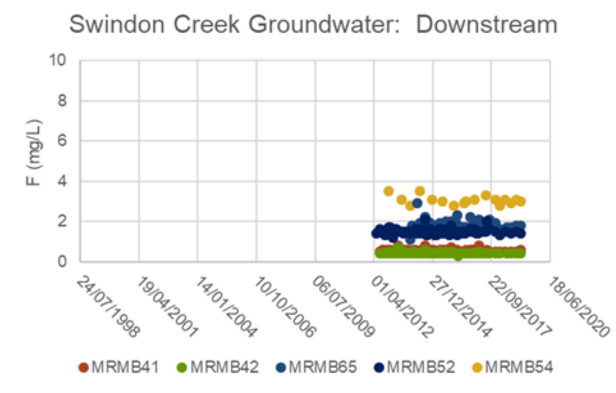

Swindon Creek Groundwater: Upstream
SO4/Cl (M.l-1/M.l-1)
0.6
0.5
0.4
0.3
0.2
0.1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRPB2 ● MRMB43 ● MRMB44

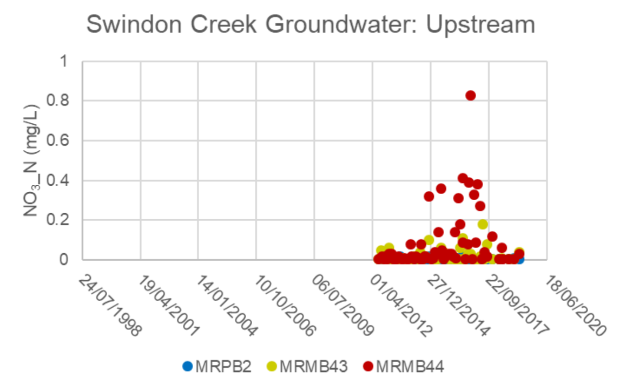

Mine affected Swindon Creek Groundwater
SO4/Cl (M.l-1/M.l-1) in MRMB9, MRMB10
1.5
1
0.5
0
SO4/Cl (M.l-1/M.l-1) in MRMB11, MRMB12, MRMB13
0.6
0.5
0.4
0.3
0.2
0.1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB9 ● MRMB10 ● MRMB11 ● MRMB12 ● MRMB13

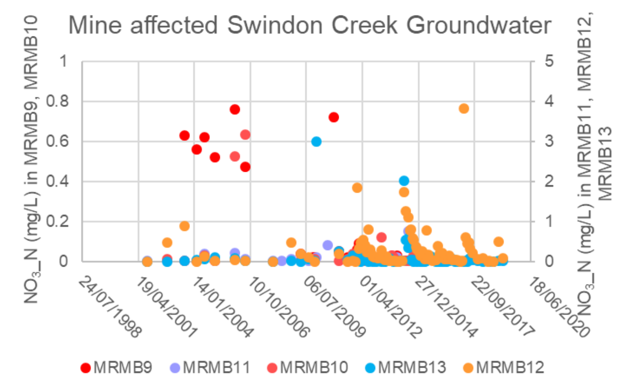

Swindon Creek Groundwater: Downstream
SO4/Cl (M.l-1/M.l-1)
0.6
0.5
0.4
0.3
0.2
0.1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB41 ● MRMB42 ● MRMB65 ● MRMB52 ● MRMB54

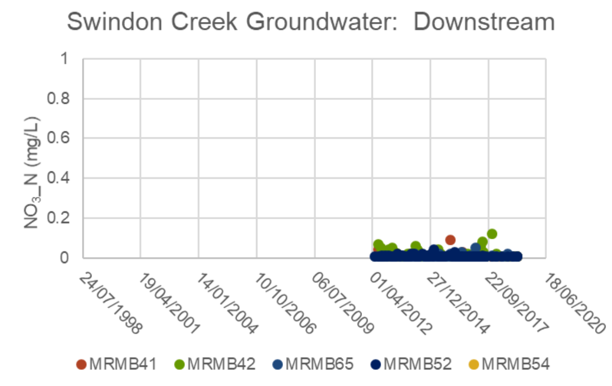

Swindon Creek Groundwater: Upstream
F (mg/L)
10
8
6
4
2
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
●MRPB2 ●MRMB43 ●MRMB44

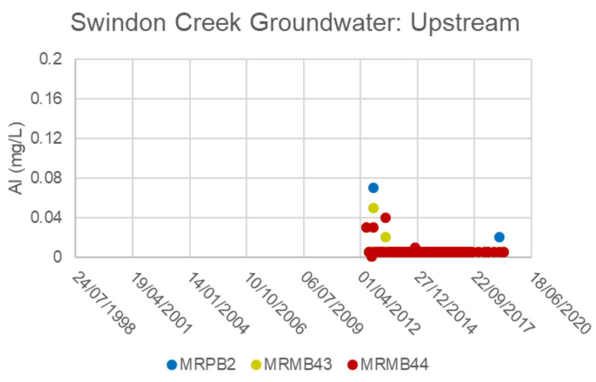

Mine affected Swindon Creek Groundwater
F (mg/L) in MRMB9, MRMB10
F (mg/L) in MRMB11, MRMB12, MRMB13
10
8
6
4
2
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
●MRMB9 ●MRMB10 ●MRMB11 ●MRMB12 ●MRMB13

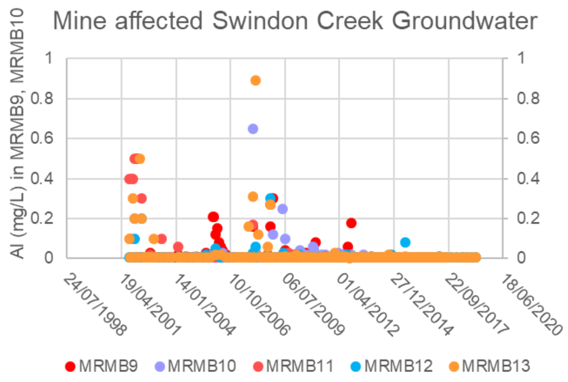

Swindon Creek Groundwater: Downstream
F (mg/L)
10
8
6
4
2
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
●MRMB41 ●MRMB42 ●MRMB65 ●MRMB52 ●MRMB54

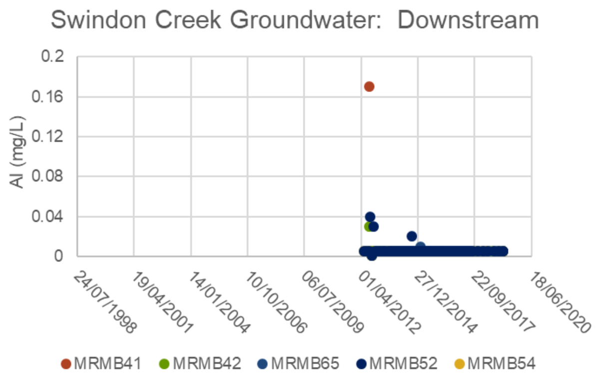

Swindon Creek Groundwater: Upstream
NO3_N (mg/L)
1
0.8
0.6
0.4
0.2
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
●MRPB2 ●MRMB43 ●MRMB44

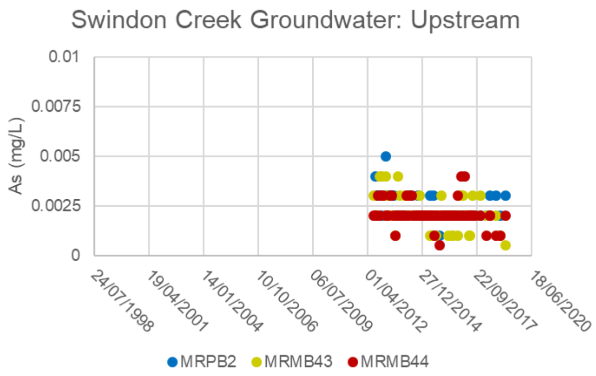

Mine affected Swindon Creek Groundwater
NO3_N (mg/L) in MRMB9, MRMB10
NO3_N (mg/L) in MRMB11, MRMB12, MRMB13
1
0.8
0.6
0.4
0.2
0
5
4
3
2
1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
●MRMB9 ●MRMB11 ●MRMB10 ●MRMB13 ●MRMB12

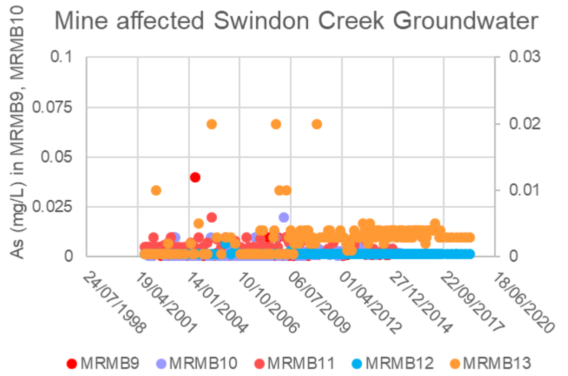

Swindon Creek Groundwater: Downstream
NO3_N (mg/L)
1
0.8
0.6
0.4
0.2
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
●MRMB41 ●MRMB42 ●MRMB65 ●MRMB52 ●MRMB54

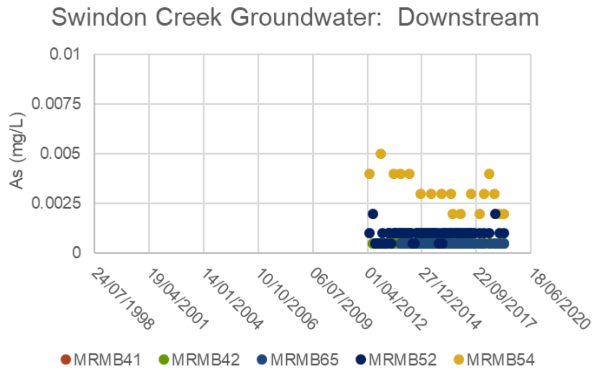

Swindon Creek Groundwater: Upstream
Al (mg/L)
0.2
0.16
0.12
0.08
0.04
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRPB2 ● MRMB43 ● MRMB44

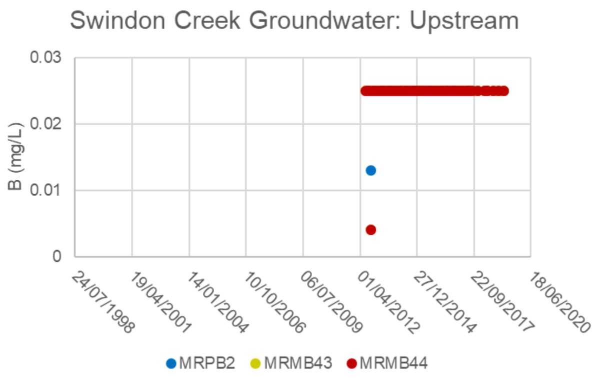

Mine affected Swindon Creek Groundwater
Al (mg/L) in MRMB9, MRMB10
Al (mg/L) in MRMB11, MRMB12, MRMB13
1
0.8
0.6
0.4
0.2
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB9 ● MRMB10 ● MRMB11 ● MRMB12 ● MRMB13

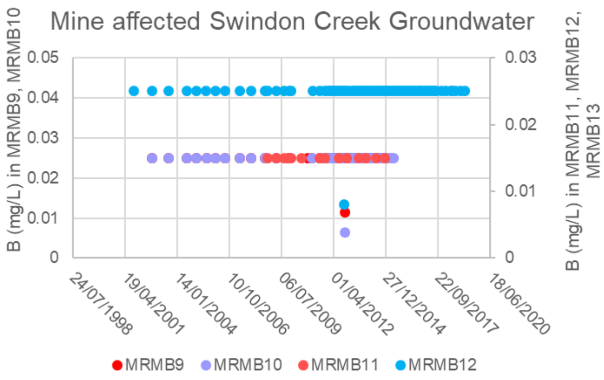

Swindon Creek Groundwater: Downstream
Al (mg/L)
0.2
0.16
0.12
0.08
0.04
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB41 ● MRMB42 ● MRMB65 ● MRMB52 ● MRMB54

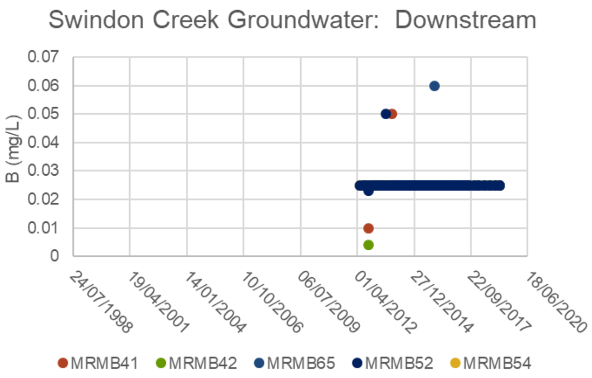

Swindon Creek Groundwater: Upstream
As (mg/L)
0.01
0.0075
0.005
0.0025
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRPB2 ● MRMB43 ● MRMB44

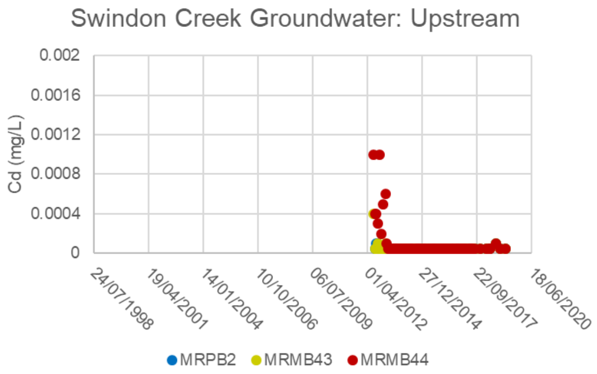

Mine affected Swindon Creek Groundwater
As (mg/L) in MRMB9, MRMB10
As (mg/L) in MRMB11, MRMB12, MRMB13
0.1
0.075
0.05
0.025
0
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB9 ● MRMB10 ● MRMB11 ● MRMB12 ● MRMB13

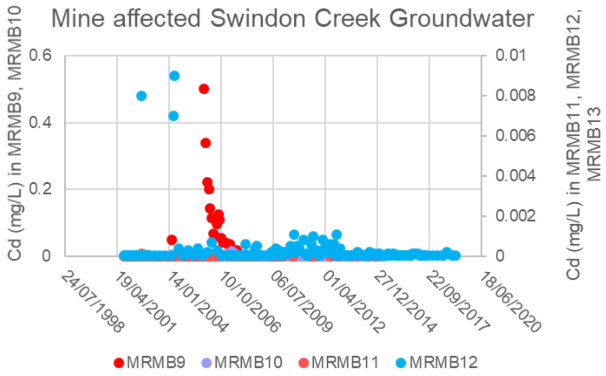

Swindon Creek Groundwater: Downstream
As (mg/L)
0.01
0.0075
0.005
0.0025
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB41 ● MRMB42 ● MRMB65 ● MRMB52 ● MRMB54

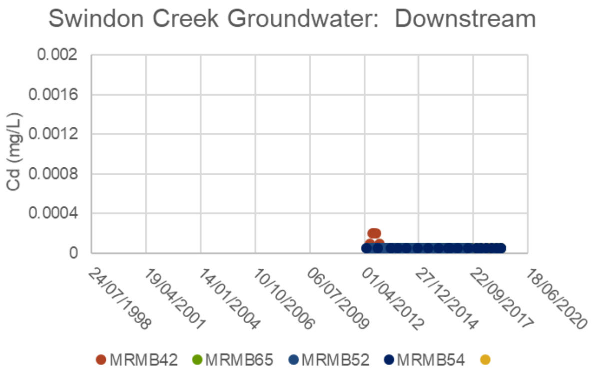

Swindon Creek Groundwater: Upstream
B (mg/L)
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRPB2
● MRMB43
● MRMB44

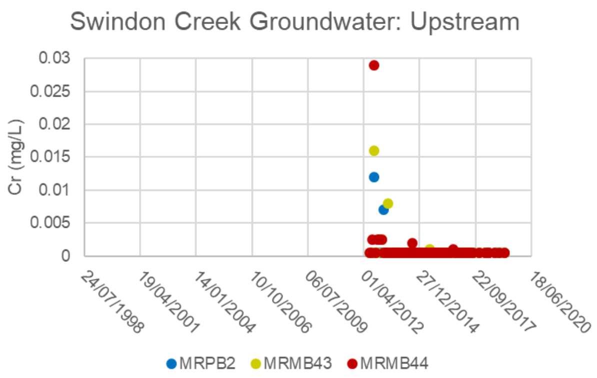

Mine affected Swindon Creek Groundwater
B (mg/L) in MRMB9, MRMB10
B (mg/L) in MRMB11, MRMB12, MRMB13
0.05
0.04
0.03
0.02
0.01
0
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB9
● MRMB10
● MRMB11
● MRMB12

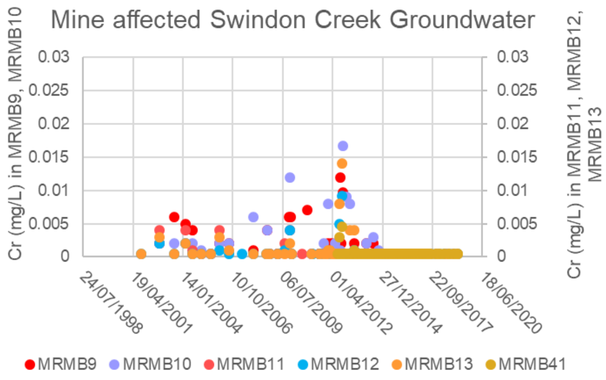

Swindon Creek Groundwater: Downstream
B (mg/L)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB41
● MRMB42
● MRMB65
● MRMB52
● MRMB54

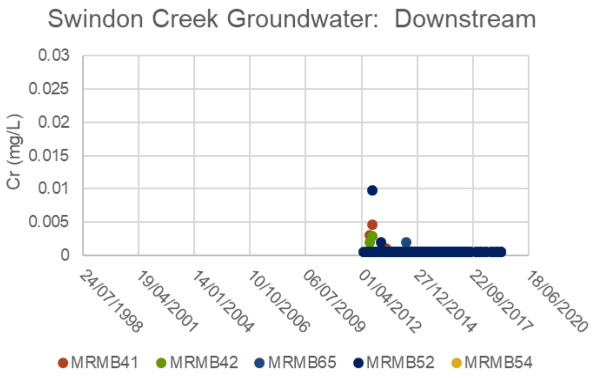

Swindon Creek Groundwater: Upstream
Cd (mg/L)
0.002
0.0016
0.0012
0.0008
0.0004
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRPB2
● MRMB43
● MRMB44

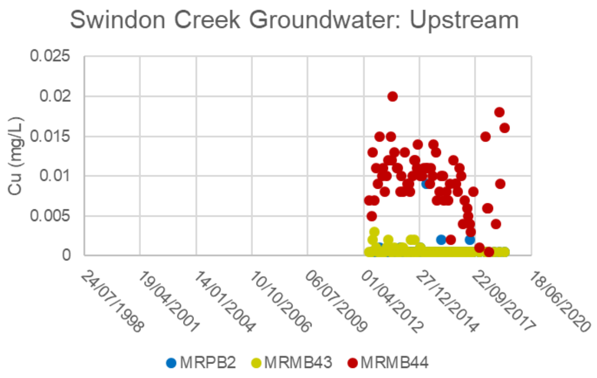

Mine affected Swindon Creek Groundwater
Cd (mg/L) in MRMB9, MRMB10
Cd (mg/L) in MRMB11, MRMB12, MRMB13
0.6
0.4
0.2
0
0.01
0.008
0.006
0.004
0.002
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB9
● MRMB10
● MRMB11
● MRMB12

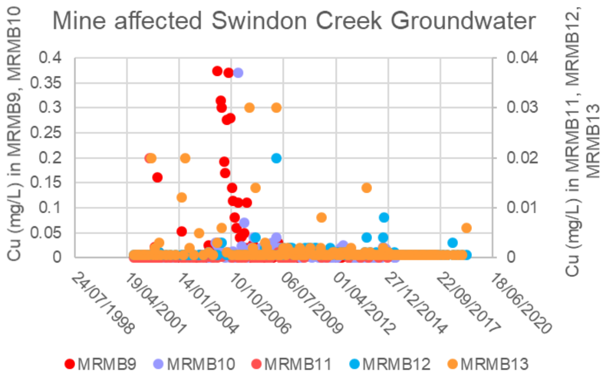

Swindon Creek Groundwater: Downstream
Cd (mg/L)
0.002
0.0016
0.0012
0.0008
0.0004
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB42
● MRMB65
● MRMB52
● MRMB54
●

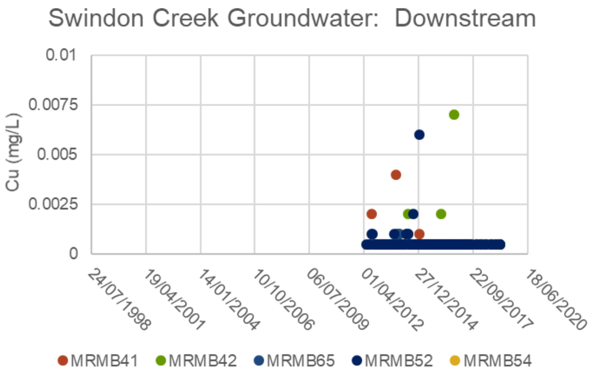

Swindon Creek Groundwater: Upstream
Cr (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRPB2
● MRMB43
● MRMB44

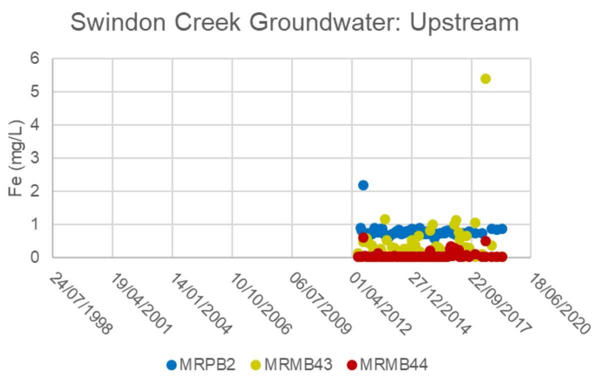

Mine affected Swindon Creek Groundwater
Cr (mg/L) in MRMB9, MRMB10
Cr (mg/L) in MRMB11, MRMB12, MRMB13
0.03
0.025
0.02
0.015
0.01
0.005
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB9
● MRMB10
● MRMB11
● MRMB12
● MRMB13
● MRMB41

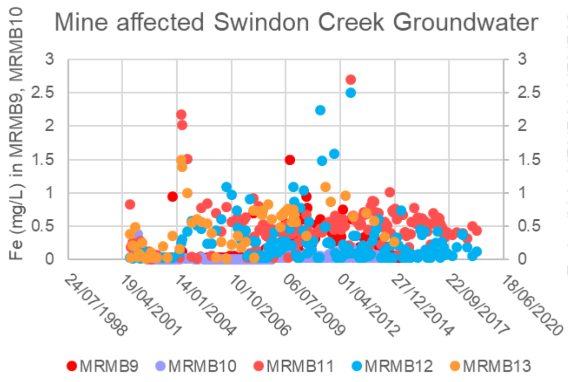

Swindon Creek Groundwater: Downstream
Cr (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB41
● MRMB42
● MRMB65
● MRMB52
● MRMB54

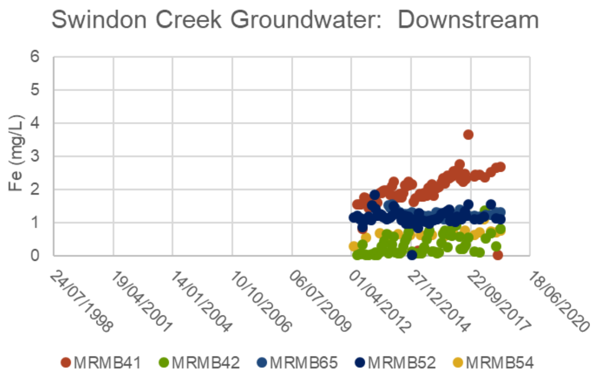

Swindon Creek Groundwater: Upstream
Cu (mg/L)
0.025
0.02
0.015
0.01
0.005
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRPB2
● MRMB43
● MRMB44

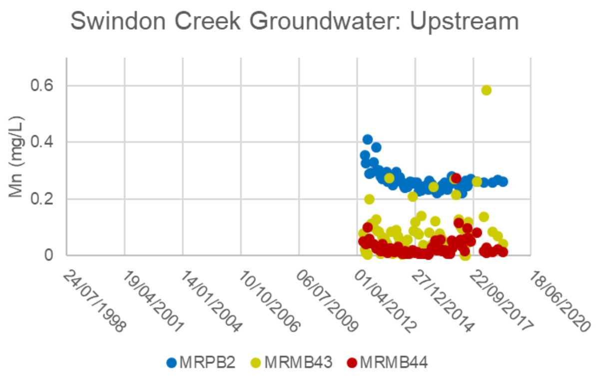

Mine affected Swindon Creek Groundwater
Cu (mg/L) in MRMB9, MRMB10
Cu (mg/L) in MRMB11, MRMB12, MRMB13
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.04
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB9
● MRMB10
● MRMB11
● MRMB12
● MRMB13

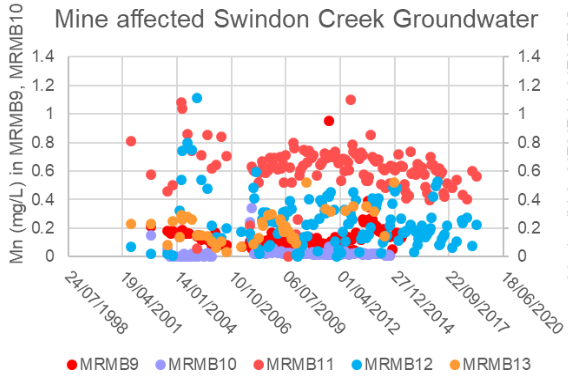

Swindon Creek Groundwater: Downstream
Cu (mg/L)
0.01
0.0075
0.005
0.0025
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB41
● MRMB42
● MRMB65
● MRMB52
● MRMB54

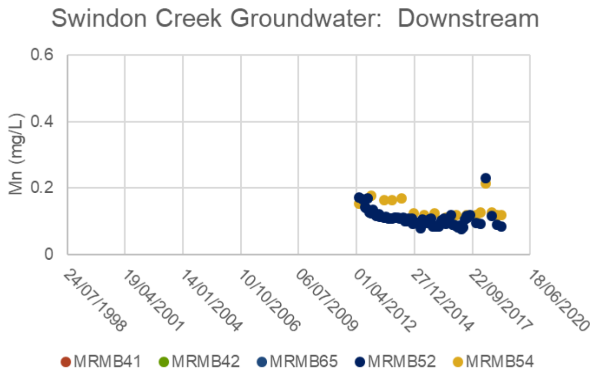

Swindon Creek Groundwater: Upstream
Fe (mg/L)
0
1
2
3
4
5
6
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRPB2
● MRMB43
● MRMB44

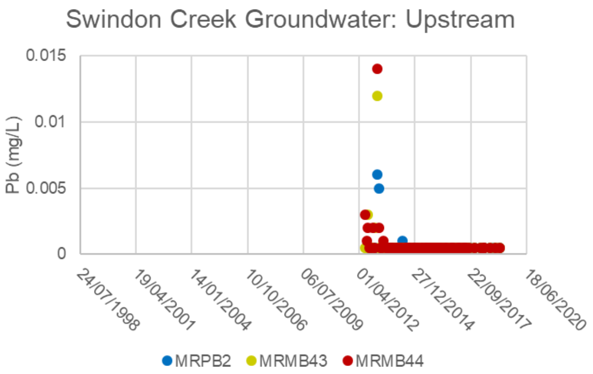

Mine affected Swindon Creek Groundwater
Fe (mg/L) in MRMB9, MRMB10
Fe (mg/L) in MRMB11, MRMB12, MRMB13
0
0.5
1
1.5
2
2.5
3
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB9
● MRMB10
● MRMB11
● MRMB12
● MRMB13

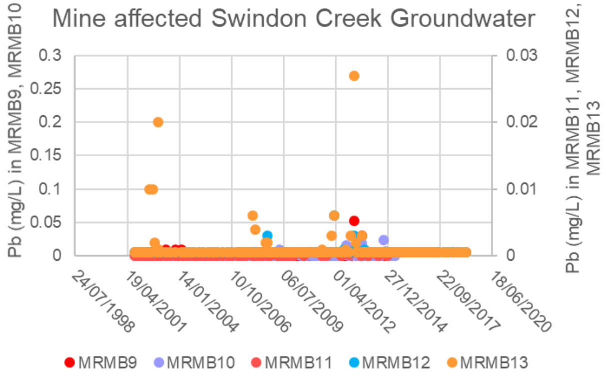

Swindon Creek Groundwater: Downstream
Fe (mg/L)
0
1
2
3
4
5
6
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB41
● MRMB42
● MRMB65
● MRMB52
● MRMB54

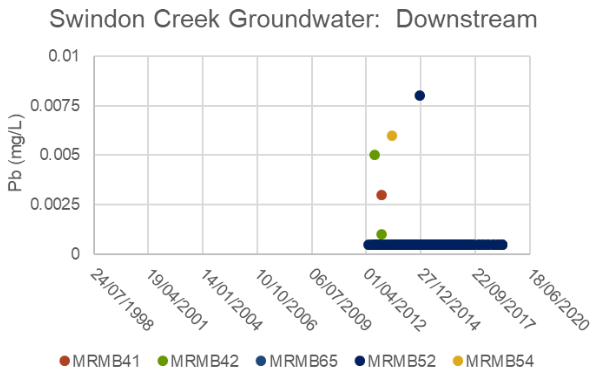

Swindon Creek Groundwater: Upstream
Mn (mg/L)
0
0.2
0.4
0.6
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRPB2
● MRMB43
● MRMB44

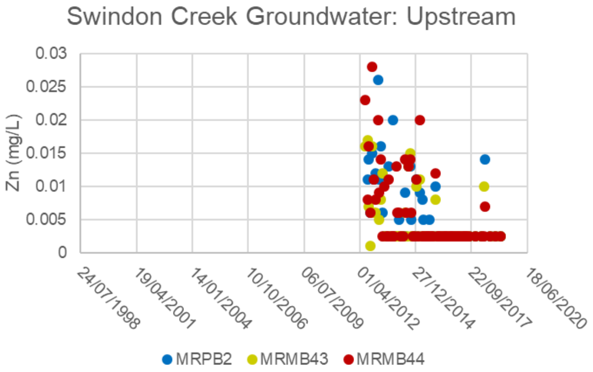

Mine affected Swindon Creek Groundwater
Mn (mg/L) in MRMB9, MRMB10
Mn (mg/L) in MRMB11, MRMB12, MRMB13
0
0.2
0.4
0.6
0.8
1
1.2
1.4
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB9
● MRMB10
● MRMB11
● MRMB12
● MRMB13

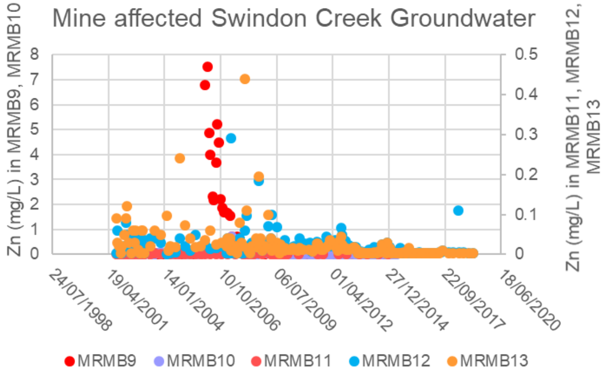

Swindon Creek Groundwater: Downstream
Mn (mg/L)
0
0.2
0.4
0.6
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB41
● MRMB42
● MRMB65
● MRMB52
● MRMB54

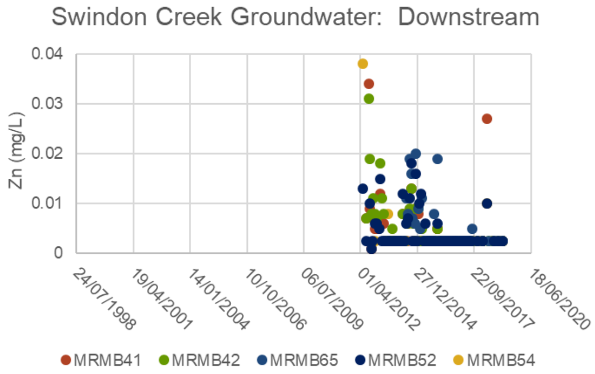

Swindon Creek Groundwater: Upstream

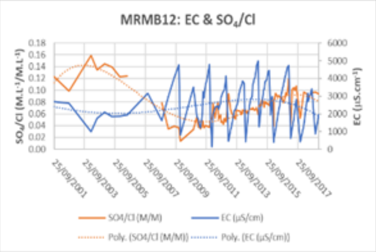

Mine affected Swindon Creek Groundwater

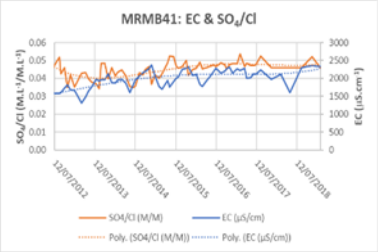

Swindon Creek Groundwater: Downstream

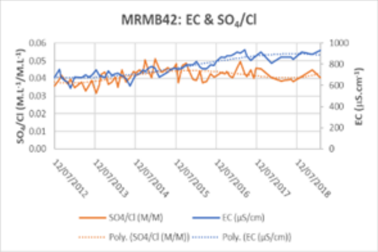

Swindon Creek Groundwater: Upstream

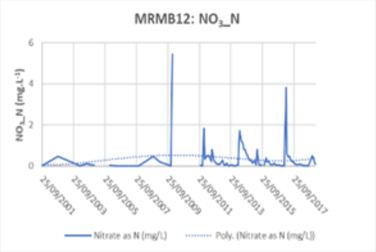

Mine affected Swindon Creek Groundwater

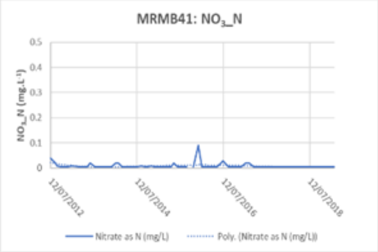

Swindon Creek Groundwater: Downstream

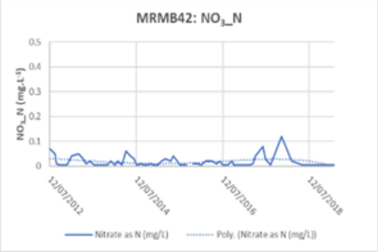

MRMB12: EC & SO4/Cl
SO4/Cl (M.L-1/M.L-1)
EC (µS.cm-1)
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))

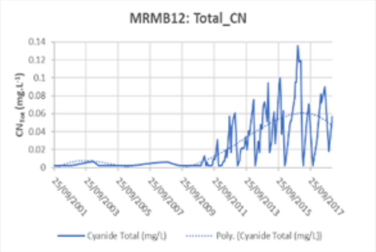

MRMB41: EC & SO4/Cl
SO4/Cl (M.L-1/M.L-1)
EC (µS.cm-1)
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))

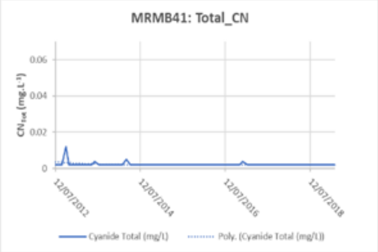

MRMB42: EC & SO4/Cl
SO4/Cl (M.L-1/M.L-1)
EC (µS.cm-1)
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))

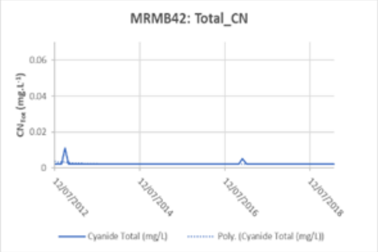

MRMB12: NO3_N
NO3_N (mg.L-1)
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

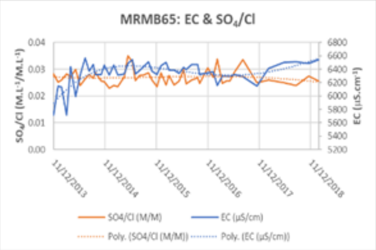

MRMB41: NO3_N
NO3_N (mg.L-1)
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

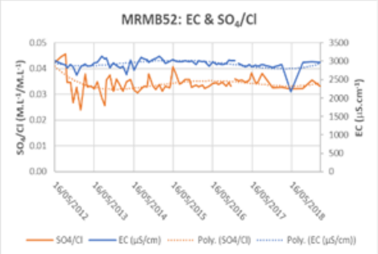

MRMB42: NO3_N
NO3_N (mg.L-1)
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

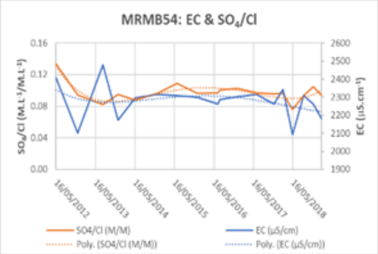

MRMB12: Total_CN
CNtot (mg.L-1)
Cyanide Total (mg/L)
Poly. (Cyanide Total (mg/L))

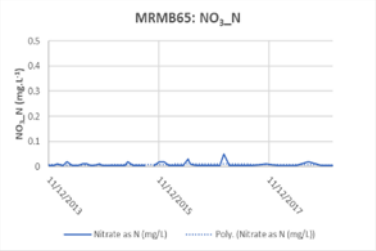

MRMB41: Total_CN
CNtot (mg.L-1)
Cyanide Total (mg/L)
Poly. (Cyanide Total (mg/L))

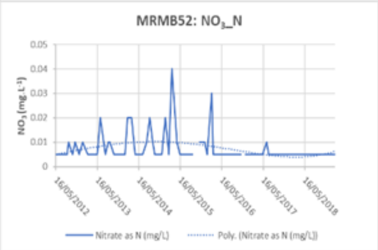

MRMB42: Total_CN
CNtot (mg.L-1)
Cyanide Total (mg/L)
Poly. (Cyanide Total (mg/L))

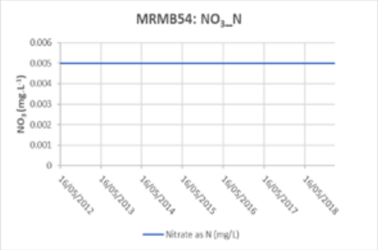

MRMB65: EC & SO4/Cl
SO4/Cl (M.L-1/M.L-1)
EC (µS.cm-1)
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))

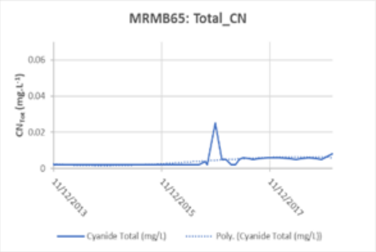

MRMB52: EC & SO4/Cl
SO4/Cl (M.L-1/M.L-1)
EC (µS.cm-1)
SO4/Cl
EC (µS/cm)
Poly. (SO4/Cl)
Poly. (EC (µS/cm))

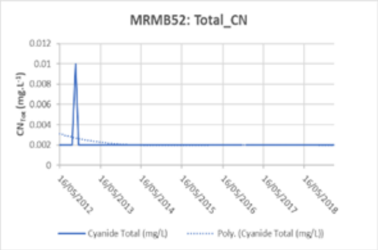

MRMB54: EC & SO4/Cl
SO4/Cl (M.L-1/M.L-1)
EC (µS.cm-1)
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))

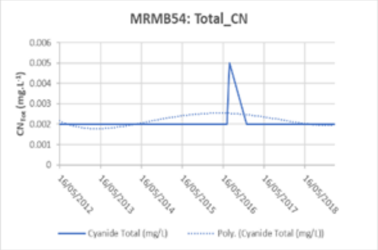

MRMB65: NO3_N
NO3_N (mg.L-1)
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))


MRMB52: NO3_N
NO3 (mg.L-1)
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

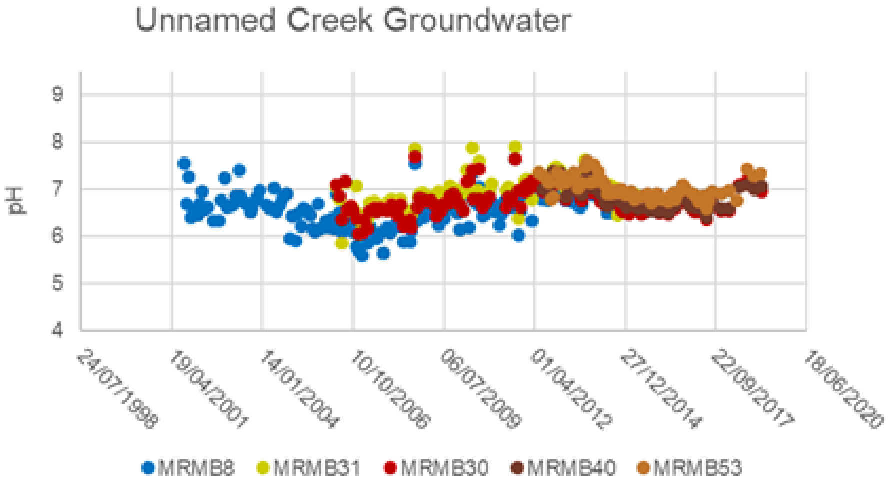

MRMB54: NO3_N
NO3 (mg.L-1)
Nitrate as N (mg/L)

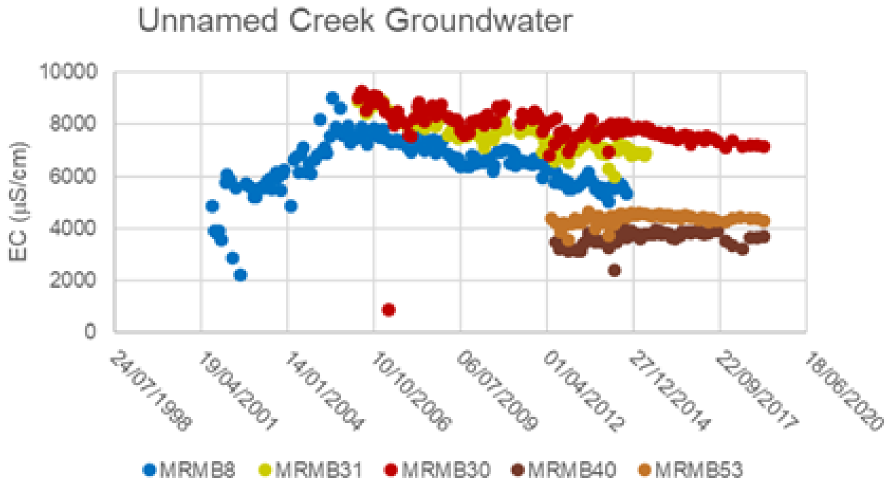

MRMB65: Total_CN
CNtot (mg.L-1)
Cyanide Total (mg/L)
Poly. (Cyanide Total (mg/L))

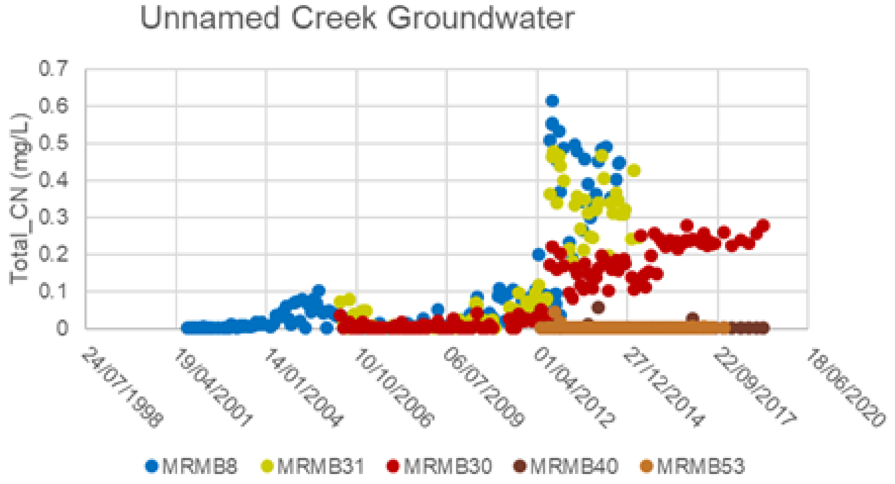

MRMB52: Total_CN
CNtot (mg.L-1)
Cyanide Total (mg/L)
Poly. (Cyanide Total (mg/L))

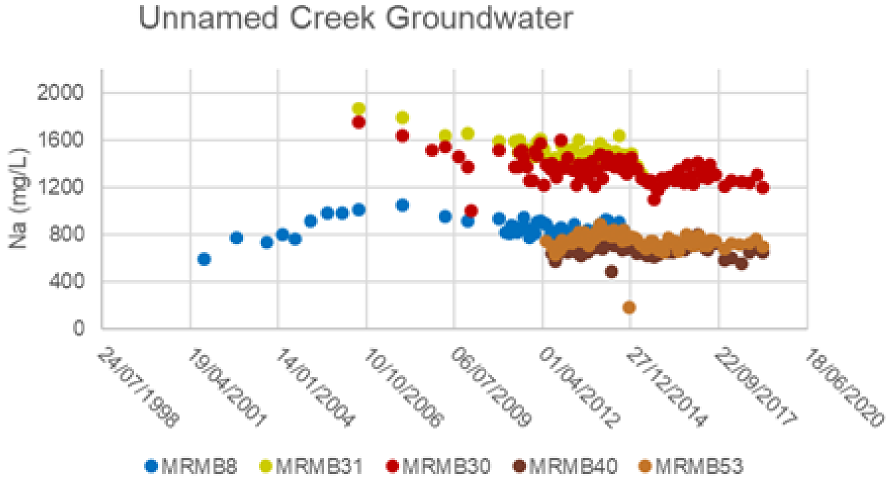

MRMB54: Total_CN
CNtot (mg.L-1)
Cyanide Total (mg/L)
Poly. (Cyanide Total (mg/L))

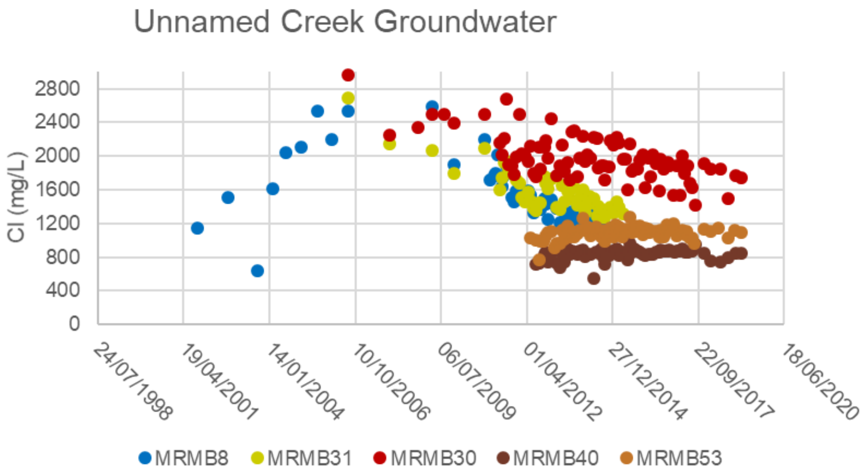
8.4.2 Time Series Charts for Unnamed Creek between Swindon Creek and Rawdon Creek

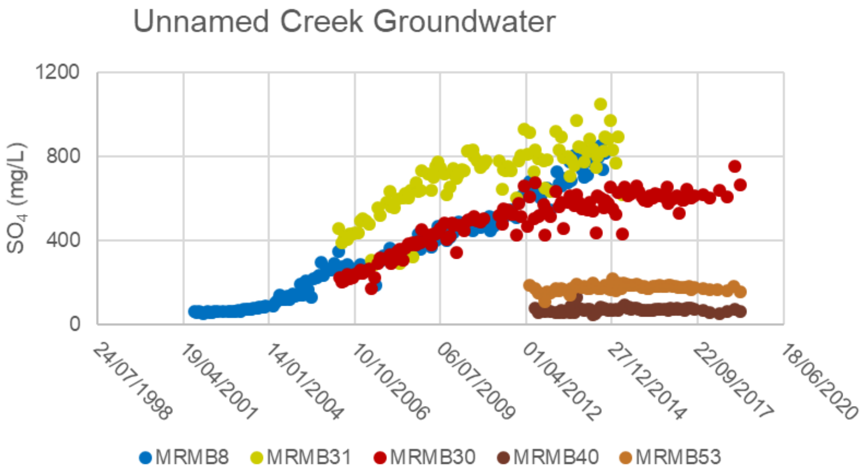


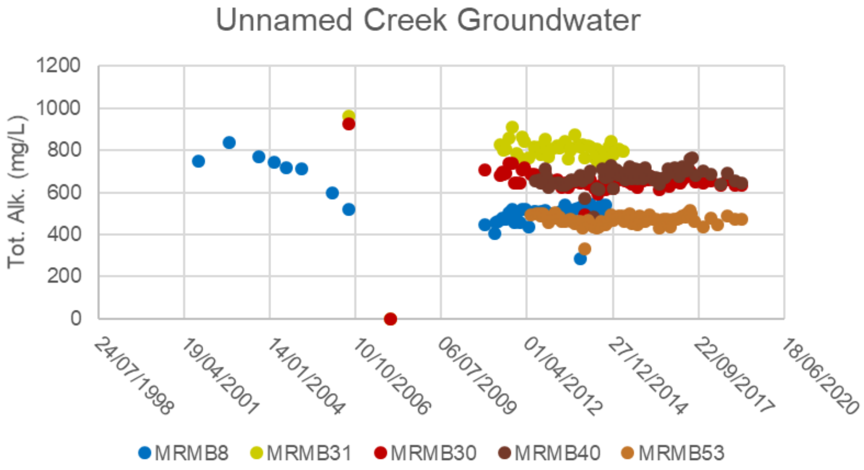


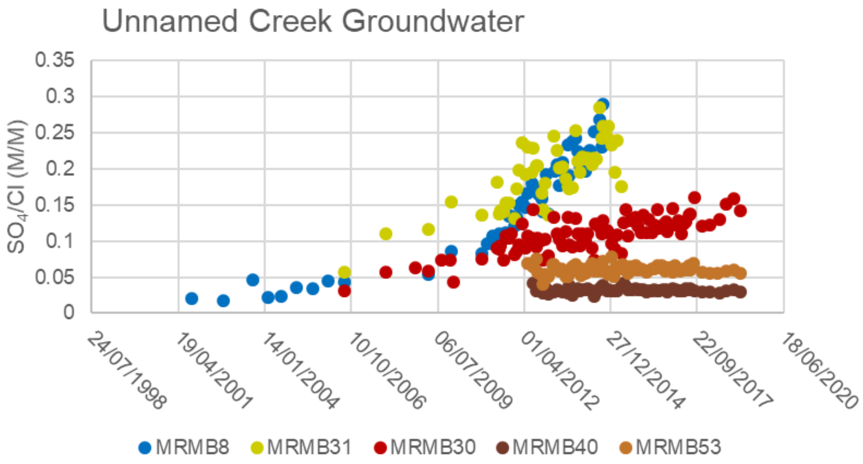


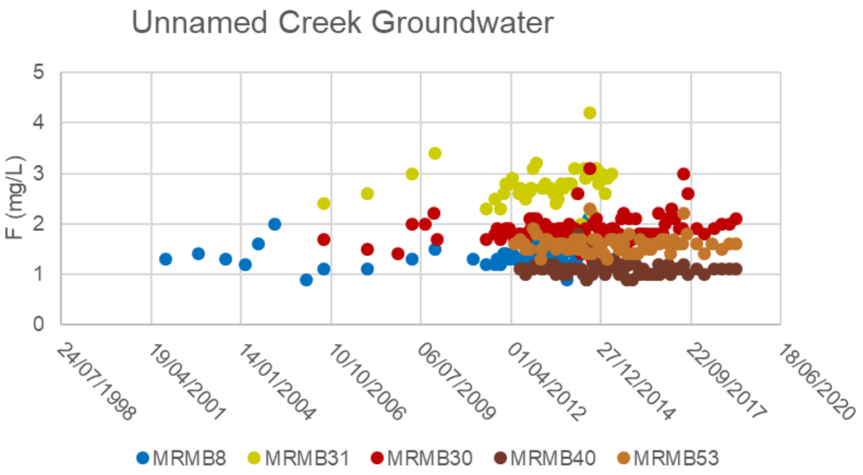


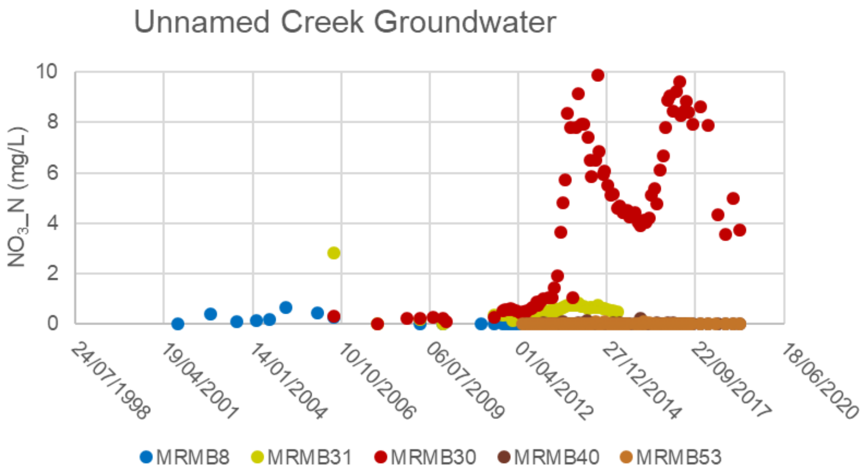

Unnamed Creek Groundwater
Cl (mg/L)
2800
2400
2000
1600
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB8
● MRMB31
● MRMB30
● MRMB40
● MRMB53

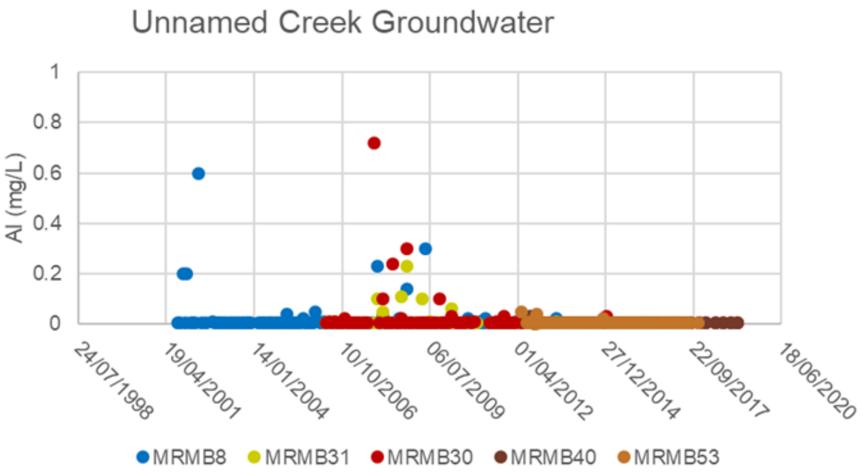

Unnamed Creek Groundwater
SO4 (mg/L)
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB8
● MRMB31
● MRMB30
● MRMB40
● MRMB53

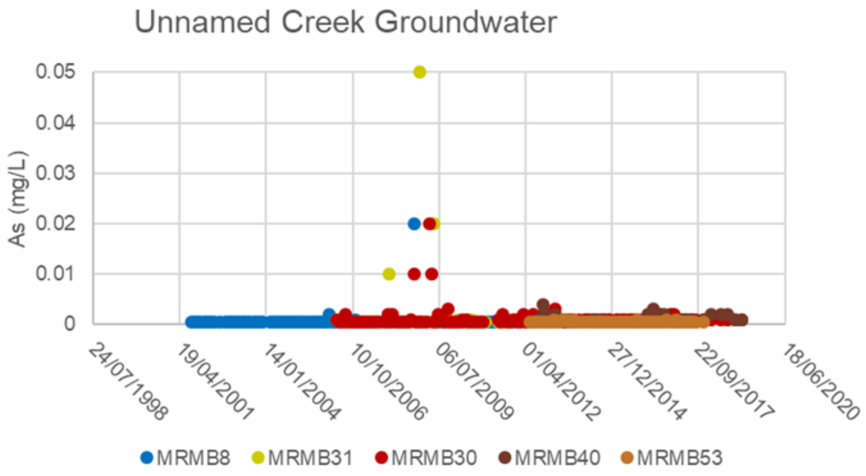

Unnamed Creek Groundwater
Tot. Alk. (mg/L)
1200
1000
800
600
400
200
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB8
● MRMB31
● MRMB30
● MRMB40
● MRMB53

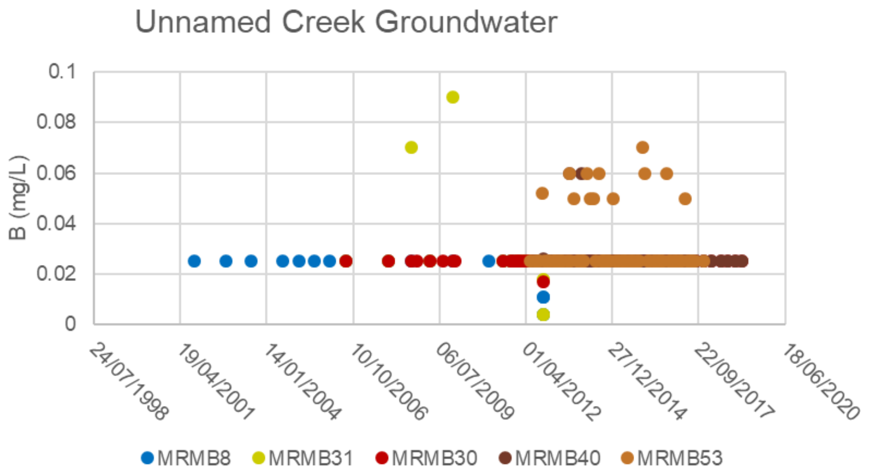

Unnamed Creek Groundwater
SO4/Cl (M/M)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB8
● MRMB31
● MRMB30
● MRMB40
● MRMB53

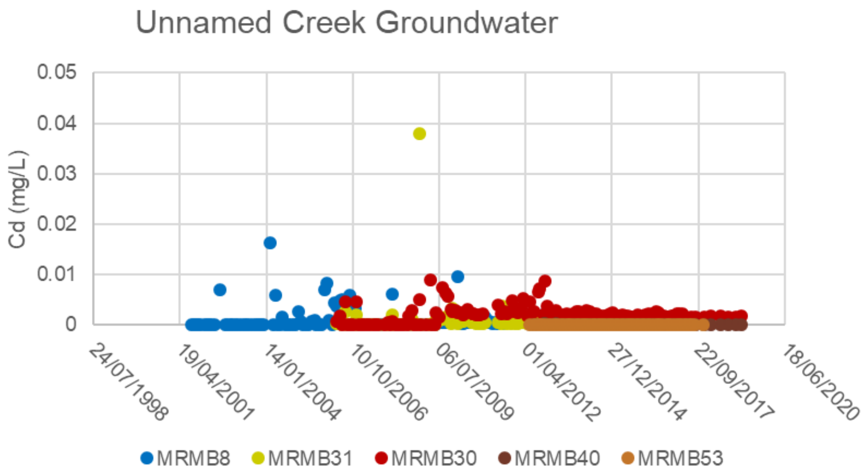

Unnamed Creek Groundwater
F (mg/L)
0
1
2
3
4
5
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB8 ● MRMB31 ● MRMB30 ● MRMB40 ● MRMB53

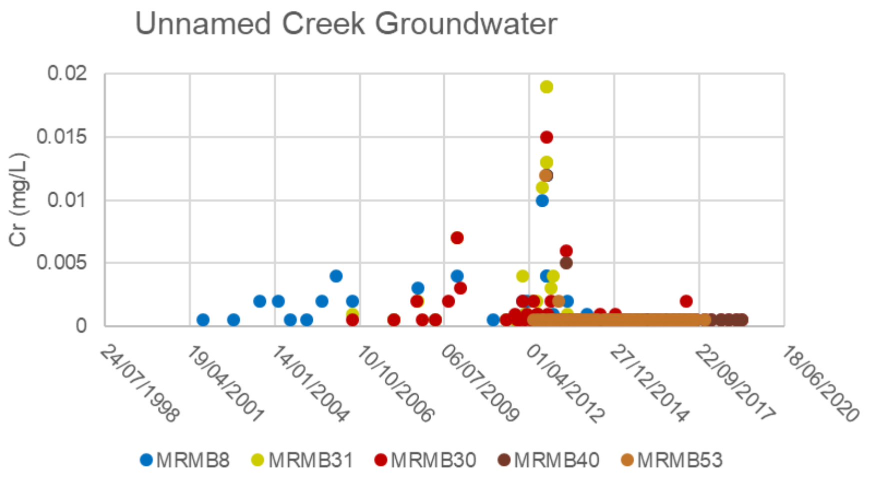

Unnamed Creek Groundwater
NO_3_N (mg/L)
0
2
4
6
8
10
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB8 ● MRMB31 ● MRMB30 ● MRMB40 ● MRMB53

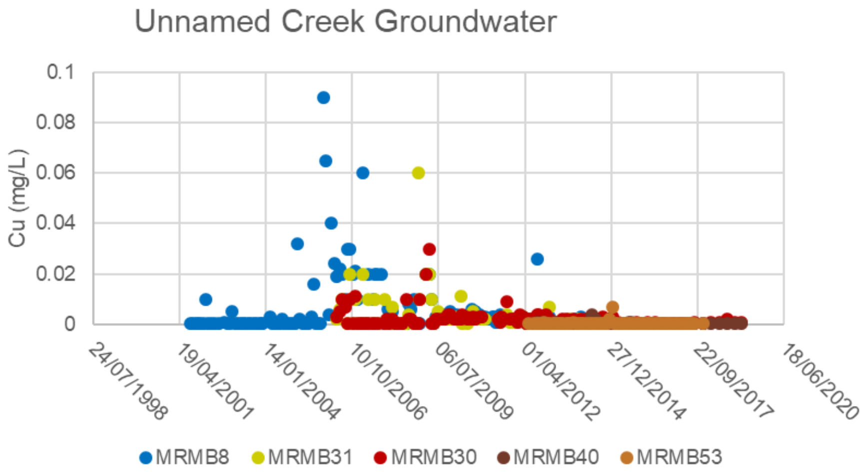

Unnamed Creek Groundwater
Al (mg/L)
0
0.2
0.4
0.6
0.8
1
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB8 ● MRMB31 ● MRMB30 ● MRMB40 ● MRMB53

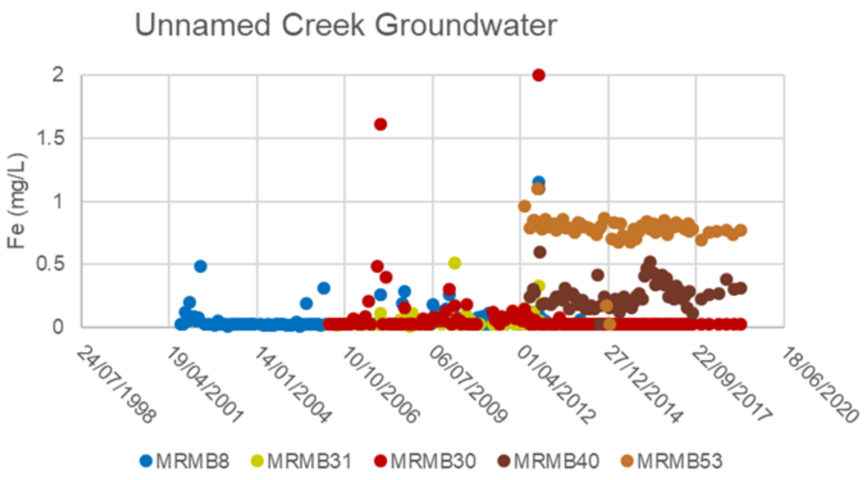

Unnamed Creek Groundwater
As (mg/L)
0
0.01
0.02
0.03
0.04
0.05
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB8 ● MRMB31 ● MRMB30 ● MRMB40 ● MRMB53

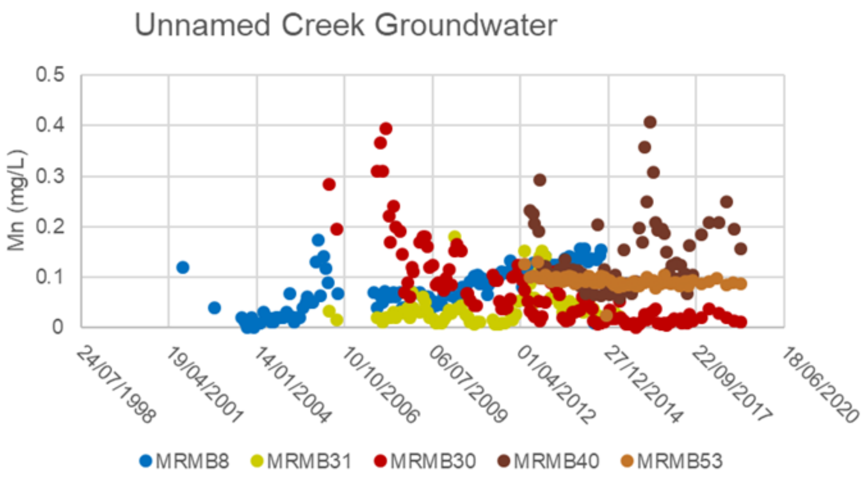

Unnamed Creek Groundwater
B (mg/L)
0.1
0.08
0.06
0.04
0.02
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
MRMB8
MRMB31
MRMB30
MRMB40
MRMB53

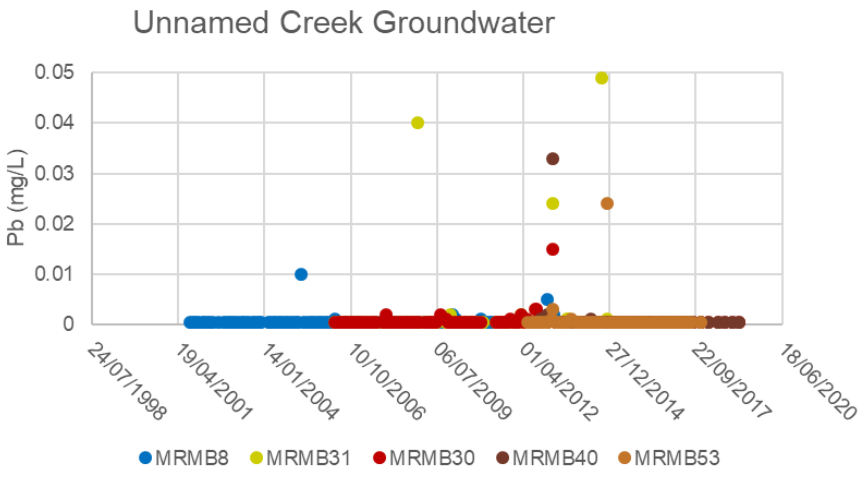

Unnamed Creek Groundwater
Cd (mg/L)
0.05
0.04
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
MRMB8
MRMB31
MRMB30
MRMB40
MRMB53

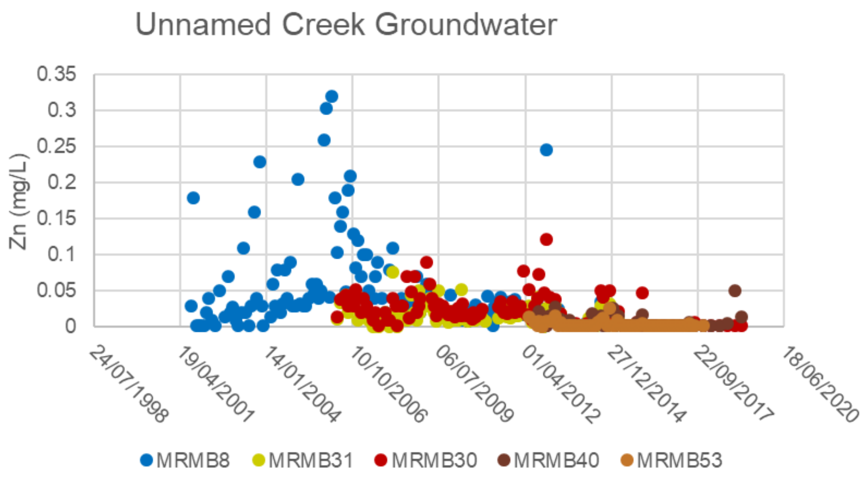

Unnamed Creek Groundwater
Cr (mg/L)
0.02
0.015
0.01
0.005
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
MRMB8
MRMB31
MRMB30
MRMB40
MRMB53


Unnamed Creek Groundwater
Cu (mg/L)
0.1
0.08
0.06
0.04
0.02
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
MRMB8
MRMB31
MRMB30
MRMB40
MRMB53

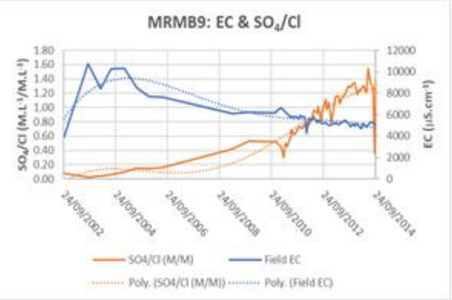

Unnamed Creek Groundwater
Fe (mg/L)
2
1.5
1
0.5
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB8
● MRMB31
● MRMB30
● MRMB40
● MRMB53

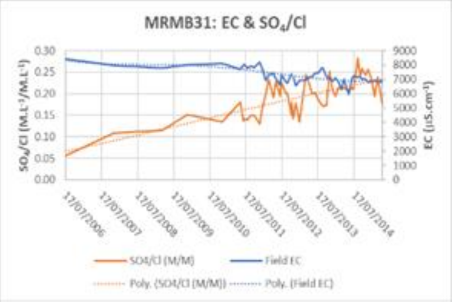

Unnamed Creek Groundwater
Mn (mg/L)
0.5
0.4
0.3
0.2
0.1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB8
● MRMB31
● MRMB30
● MRMB40
● MRMB53

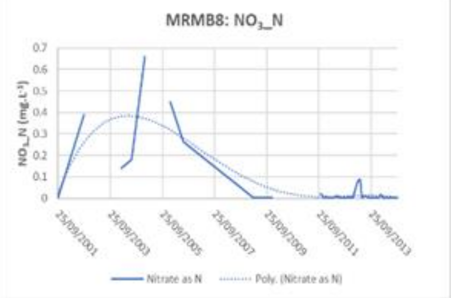

Unnamed Creek Groundwater
Pb (mg/L)
0.05
0.04
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB8
● MRMB31
● MRMB30
● MRMB40
● MRMB53

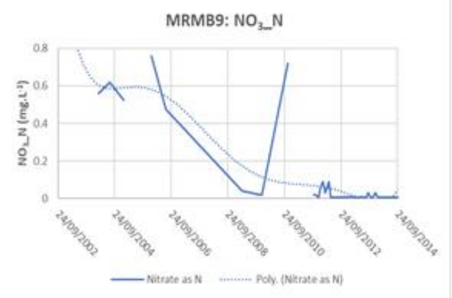

Unnamed Creek Groundwater
Zn (mg/L)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB8
● MRMB31
● MRMB30
● MRMB40
● MRMB53

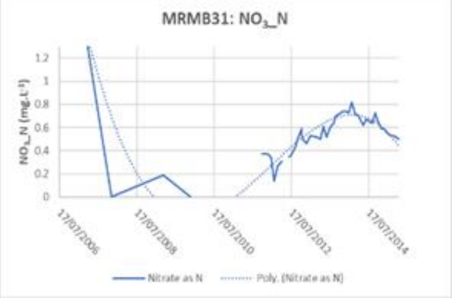

MRMB8: EC & SO$_4$/Cl

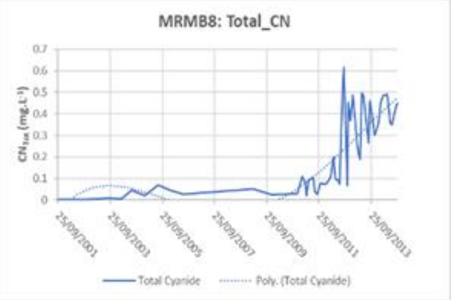

MRMB9: EC & SO$_4$/Cl

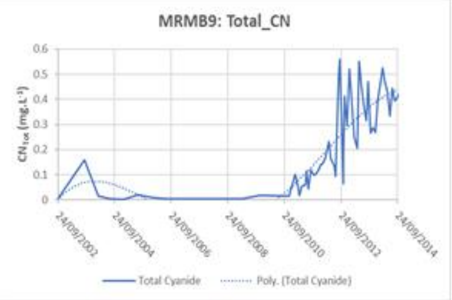

MRMB31: EC & SO$_4$/Cl


MRMB8: NO$_3$_N

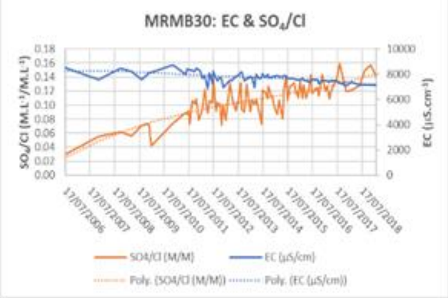

MRMB9: NO$_3$_N

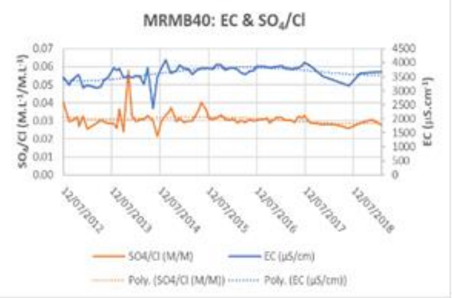

MRMB31: NO$_3$_N

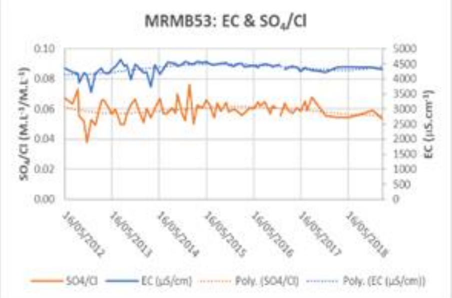

MRMB8: Total_CN

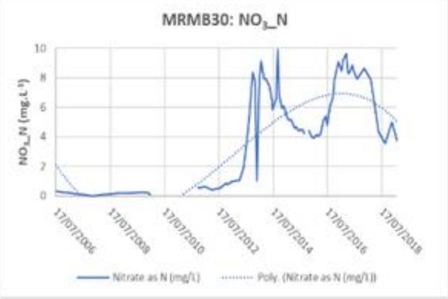

MRMB9: Total_CN

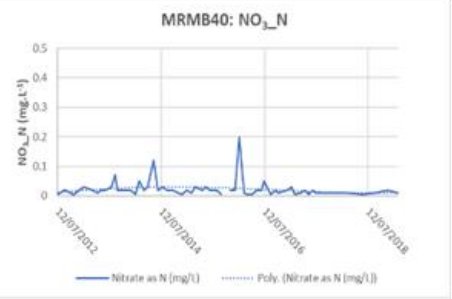

MRMB31: Total_CN

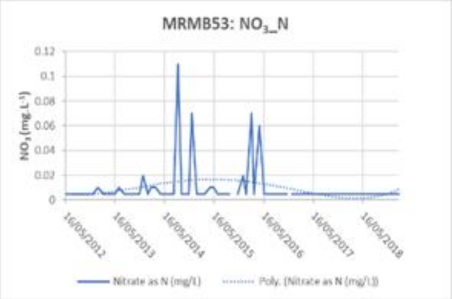

MRMB30: EC & SO$_4$/Cl

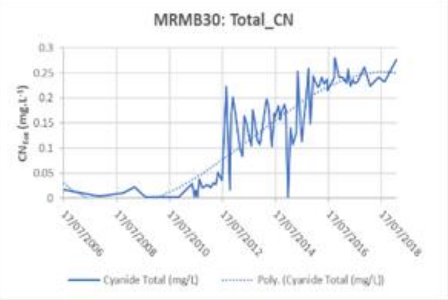

MRMB40: EC & SO$_4$/Cl

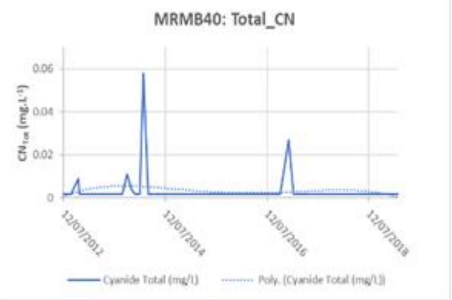

MRMB53: EC & SO$_4$/Cl

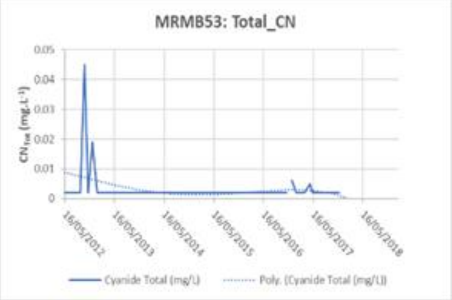

MRMB30: NO$_3$_N


MRMB40: NO$_3$_N

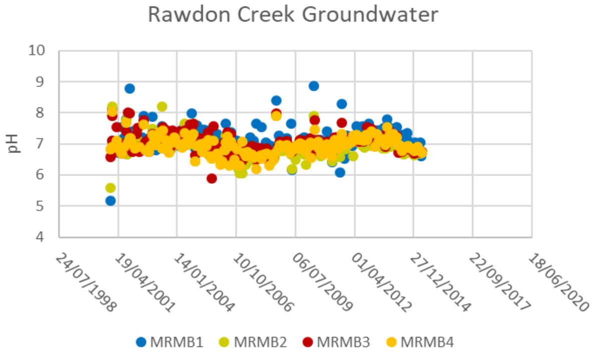

MRMB53: NO$_3$_N

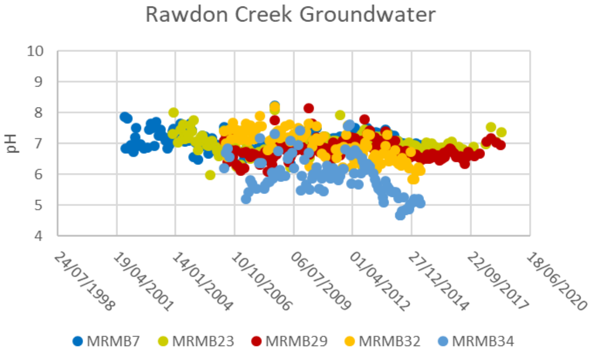

MRMB30: Total_CN

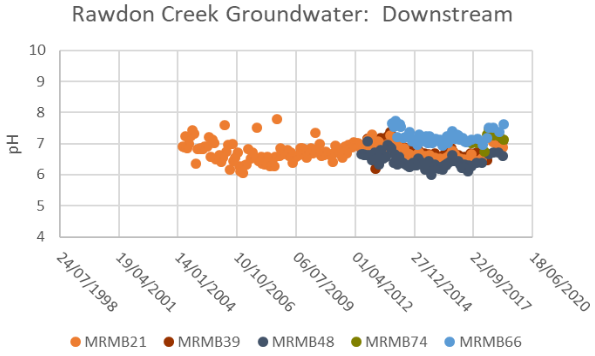

MRMB40: Total_CN

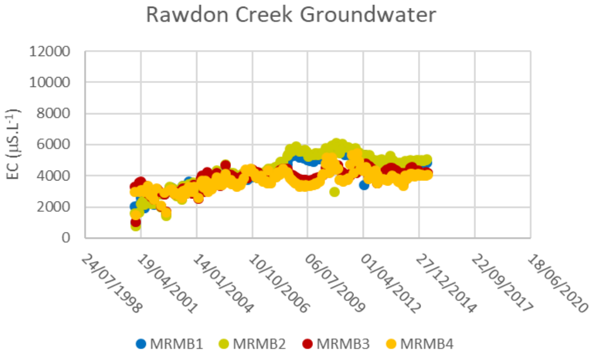

MRMB53: Total_CN

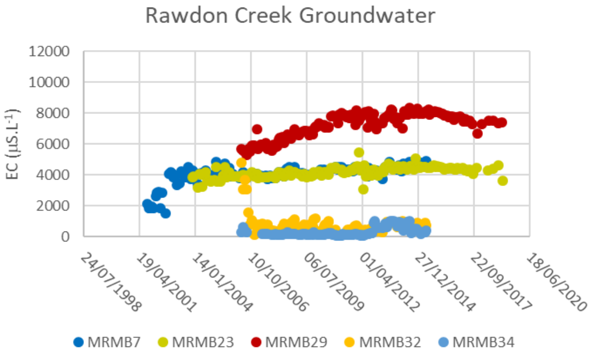
8.4.3 Time Series Charts for Rawdon Creek

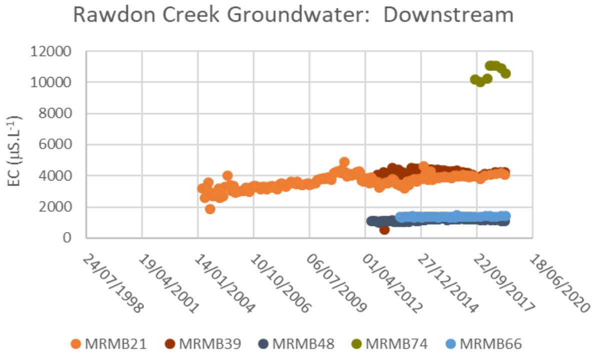


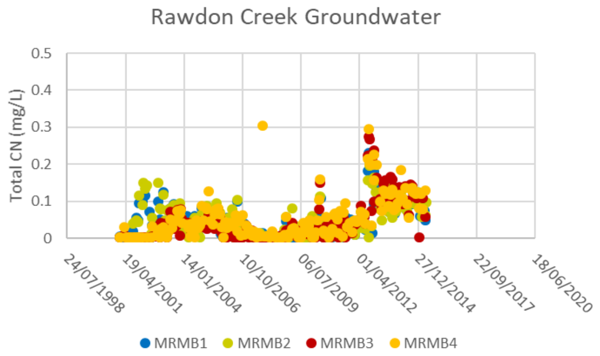


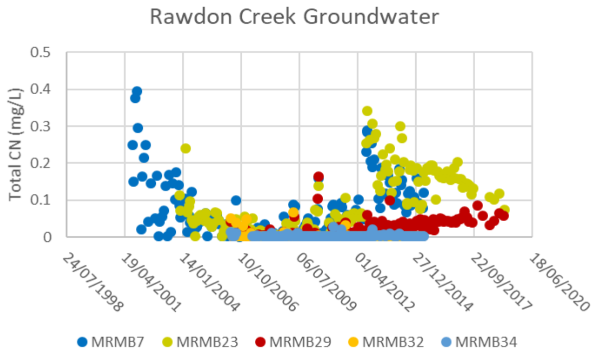


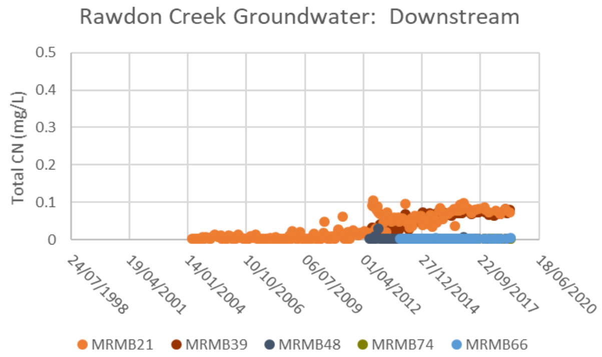


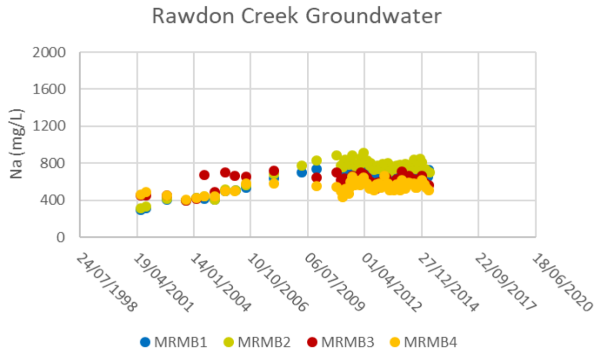


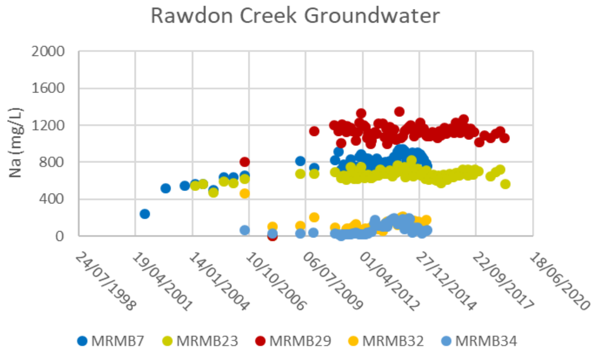


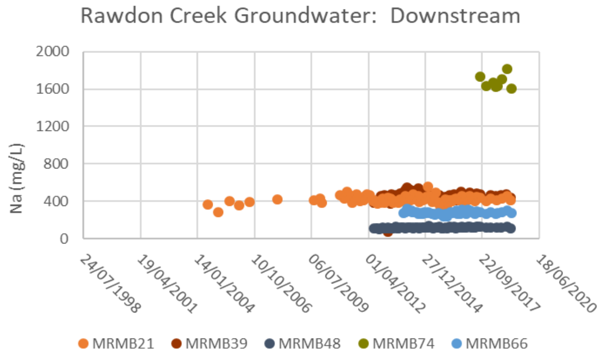

Rawdon Creek Groundwater
Total CN (mg/L)
0.5
0.4
0.3
0.2
0.1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB1 ● MRMB2 ● MRMB3 ● MRMB4

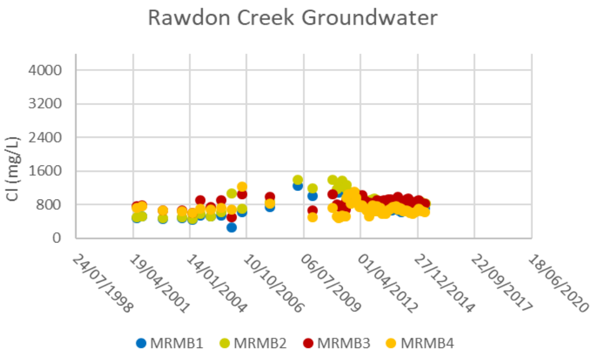

Rawdon Creek Groundwater
Total CN (mg/L)
0.5
0.4
0.3
0.2
0.1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB7 ● MRMB23 ● MRMB29 ● MRMB32 ● MRMB34

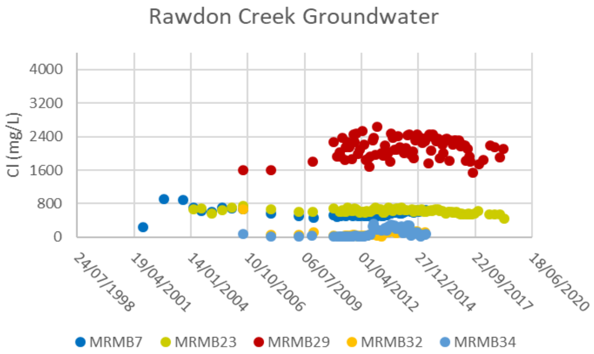

Rawdon Creek Groundwater: Downstream
Total CN (mg/L)
0.5
0.4
0.3
0.2
0.1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB21 ● MRMB39 ● MRMB48 ● MRMB74 ● MRMB66

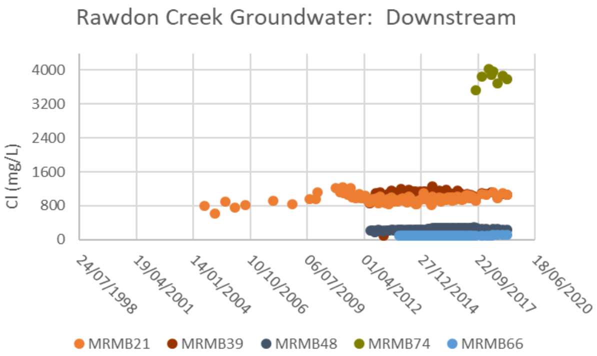

Rawdon Creek Groundwater
Na (mg/L)
2000
1600
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB1 ● MRMB2 ● MRMB3 ● MRMB4

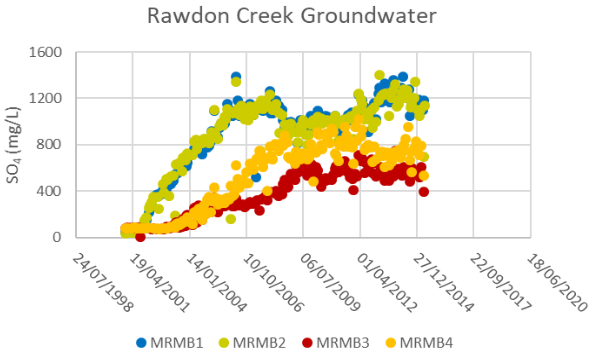

Rawdon Creek Groundwater
Na (mg/L)
2000
1600
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB7 ● MRMB23 ● MRMB29 ● MRMB32 ● MRMB34

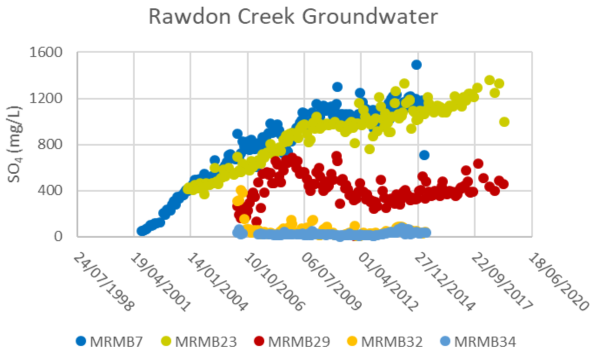

Rawdon Creek Groundwater: Downstream
Na (mg/L)
2000
1600
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB21 ● MRMB39 ● MRMB48 ● MRMB74 ● MRMB66

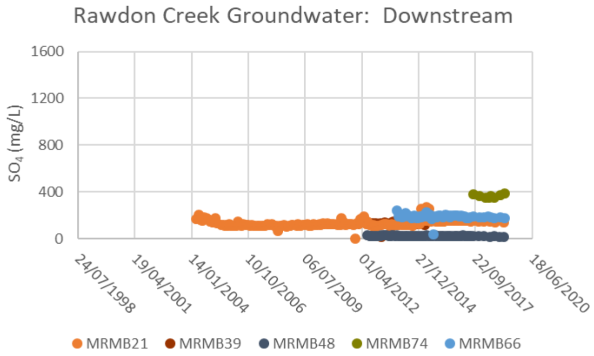

Rawdon Creek Groundwater
Cl (mg/L)
4000
3200
2400
1600
800
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB1 ● MRMB2 ● MRMB3 ● MRMB4

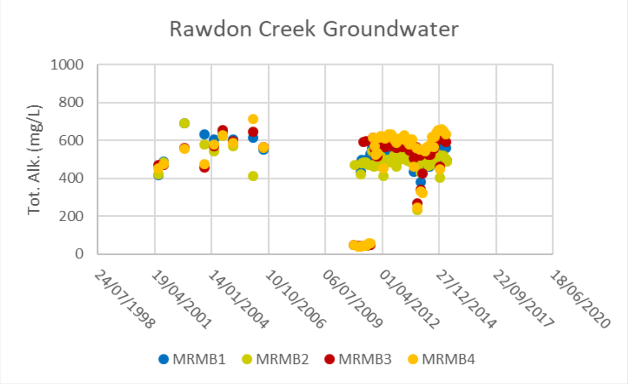

Rawdon Creek Groundwater
Cl (mg/L)
4000
3200
2400
1600
800
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB7 ● MRMB23 ● MRMB29 ● MRMB32 ● MRMB34

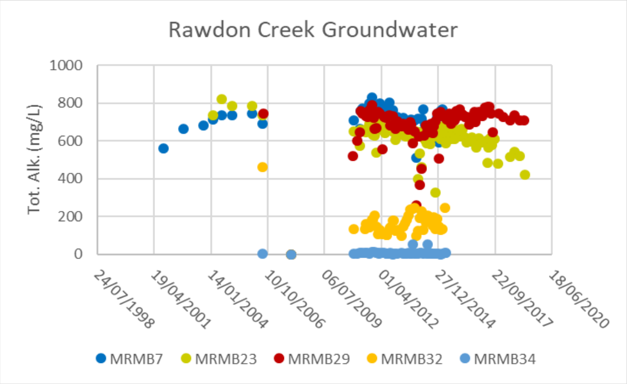

Rawdon Creek Groundwater: Downstream
Cl (mg/L)
4000
3200
2400
1600
800
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB21 ● MRMB39 ● MRMB48 ● MRMB74 ● MRMB66

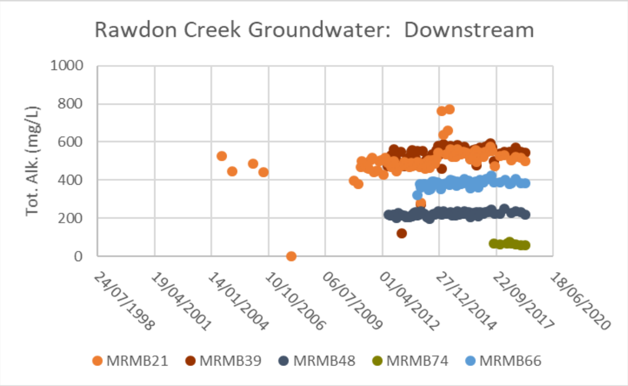

Rawdon Creek Groundwater
SO₄ (mg/L)
1600
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB1 ● MRMB2 ● MRMB3 ● MRMB4

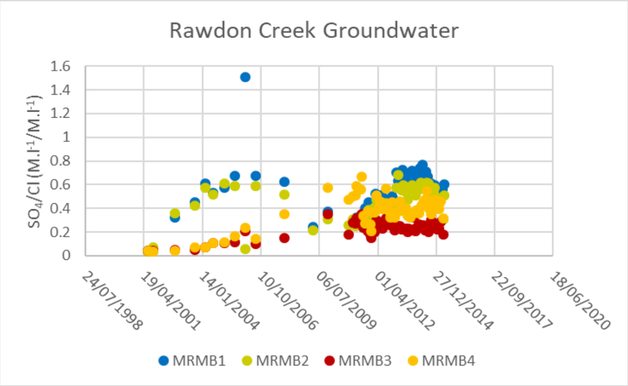

Rawdon Creek Groundwater
SO₄ (mg/L)
1600
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB7 ● MRMB23 ● MRMB29 ● MRMB32 ● MRMB34

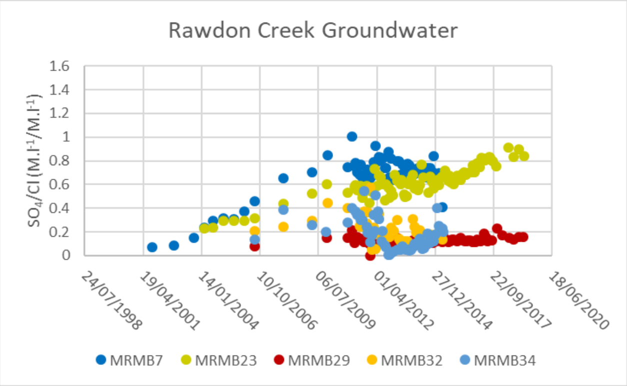

Rawdon Creek Groundwater: Downstream
SO₄ (mg/L)
1600
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB21 ● MRMB39 ● MRMB48 ● MRMB74 ● MRMB66

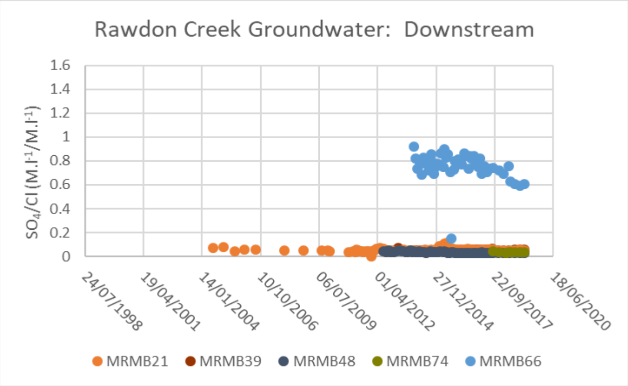

Rawdon Creek Groundwater
Tot. Alk. (mg/L)
1000
800
600
400
200
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB1
● MRMB2
● MRMB3
● MRMB4

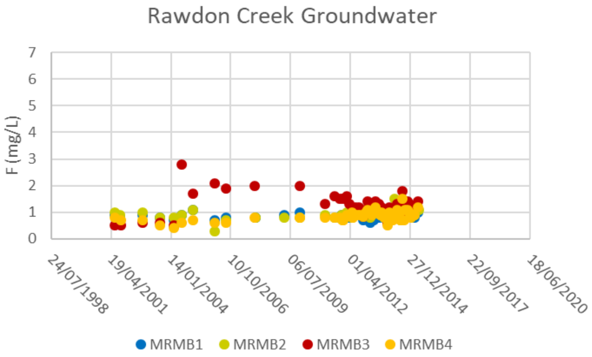

Rawdon Creek Groundwater
Tot. Alk. (mg/L)
1000
800
600
400
200
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB7
● MRMB23
● MRMB29
● MRMB32
● MRMB34

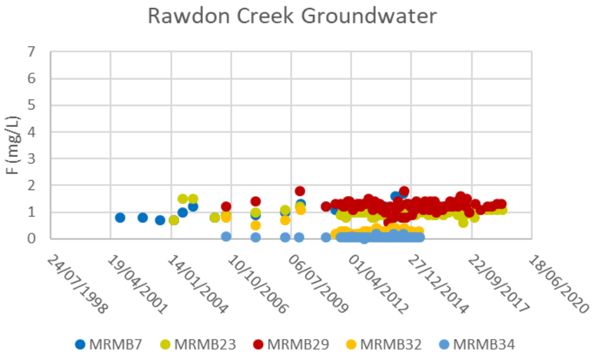

Rawdon Creek Groundwater: Downstream
Tot. Alk. (mg/L)
1000
800
600
400
200
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB21
● MRMB39
● MRMB48
● MRMB74
● MRMB66

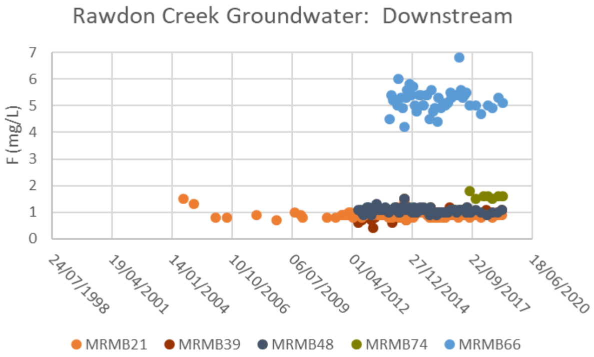

Rawdon Creek Groundwater
$SO_4/Cl\,(M.l^{-1}/M.l^{-1})$
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB1
● MRMB2
● MRMB3
● MRMB4

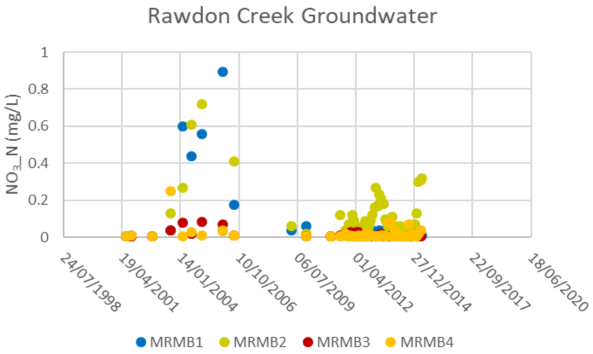

Rawdon Creek Groundwater
$SO_4/Cl\,(M.l^{-1}/M.l^{-1})$
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB7
● MRMB23
● MRMB29
● MRMB32
● MRMB34

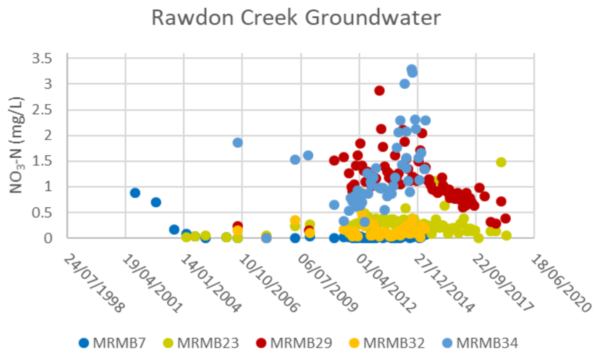

Rawdon Creek Groundwater: Downstream
$SO_4/Cl\,(M.l^{-1}/M.l^{-1})$
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB21
● MRMB39
● MRMB48
● MRMB74
● MRMB66

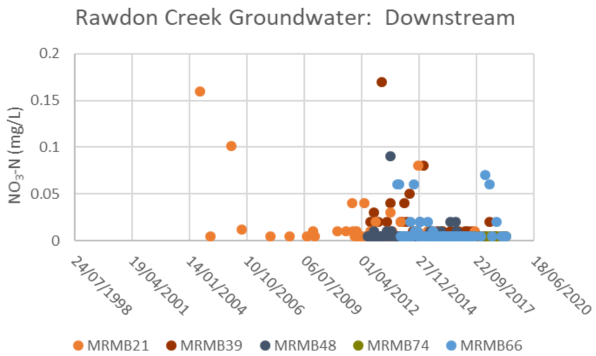

Rawdon Creek Groundwater
F (mg/L)
0
1
2
3
4
5
6
7
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB1 ● MRMB2 ● MRMB3 ● MRMB4

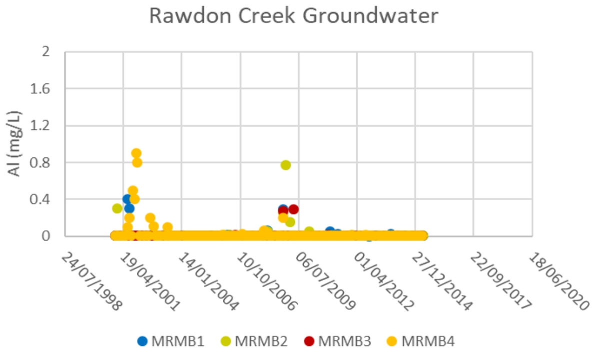

Rawdon Creek Groundwater
F (mg/L)
0
1
2
3
4
5
6
7
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB7 ● MRMB23 ● MRMB29 ● MRMB32 ● MRMB34

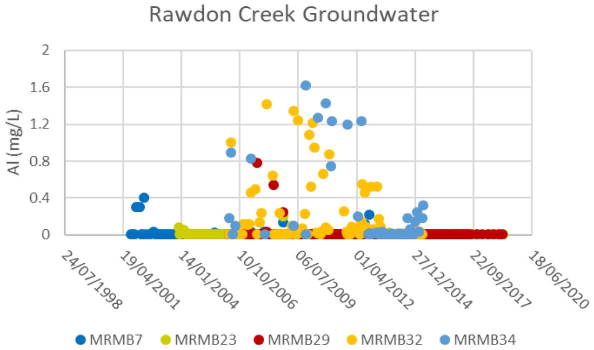

Rawdon Creek Groundwater: Downstream
F (mg/L)
0
1
2
3
4
5
6
7
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB21 ● MRMB39 ● MRMB48 ● MRMB74 ● MRMB66

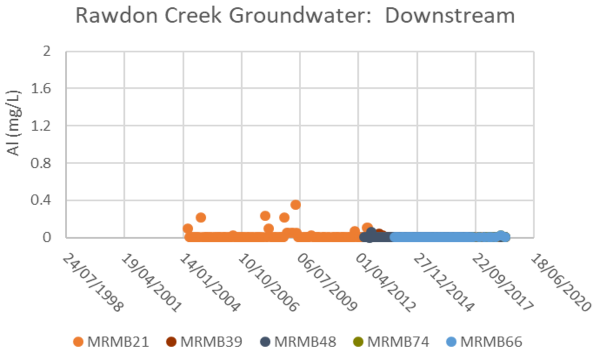

Rawdon Creek Groundwater
NO_3_N (mg/L)
0
0.2
0.4
0.6
0.8
1
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB1 ● MRMB2 ● MRMB3 ● MRMB4

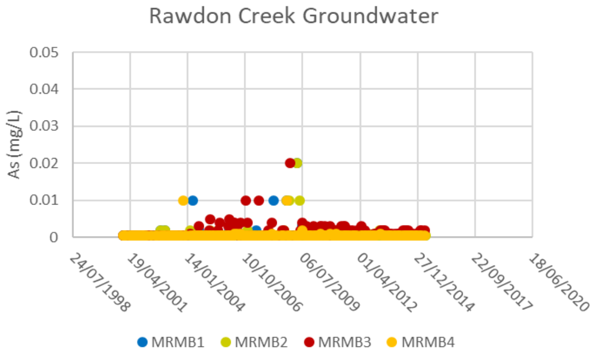

Rawdon Creek Groundwater
NO_3-N (mg/L)
0
0.5
1
1.5
2
2.5
3
3.5
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB7 ● MRMB23 ● MRMB29 ● MRMB32 ● MRMB34

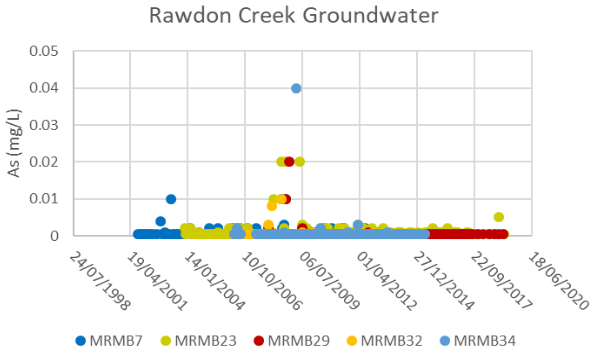

Rawdon Creek Groundwater: Downstream
NO_3-N (mg/L)
0
0.05
0.1
0.15
0.2
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB21 ● MRMB39 ● MRMB48 ● MRMB74 ● MRMB66

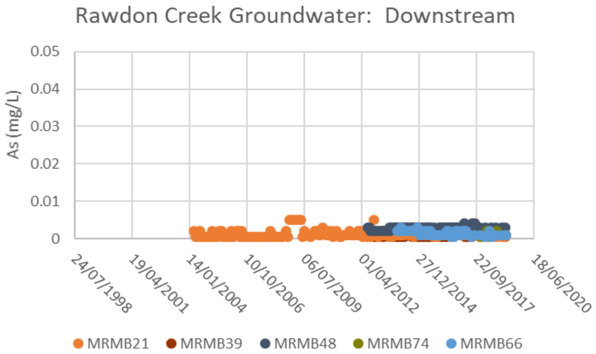

Rawdon Creek Groundwater

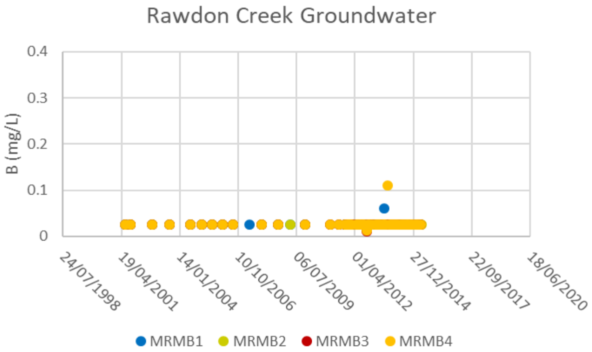

Rawdon Creek Groundwater

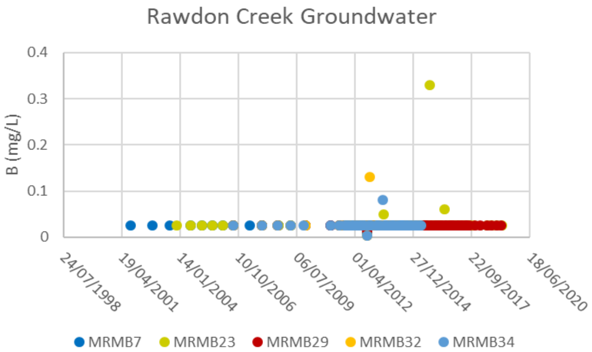

Rawdon Creek Groundwater: Downstream

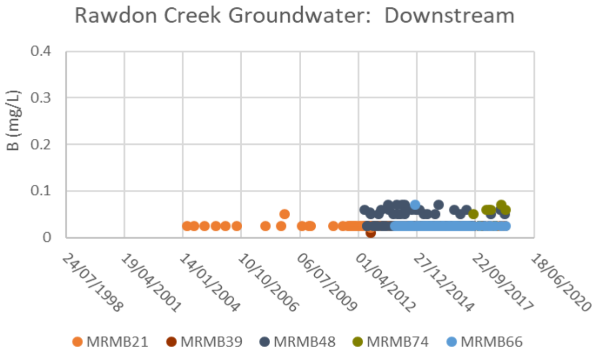

Rawdon Creek Groundwater

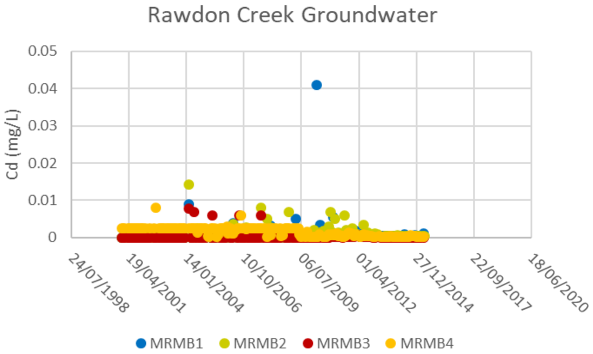

Rawdon Creek Groundwater

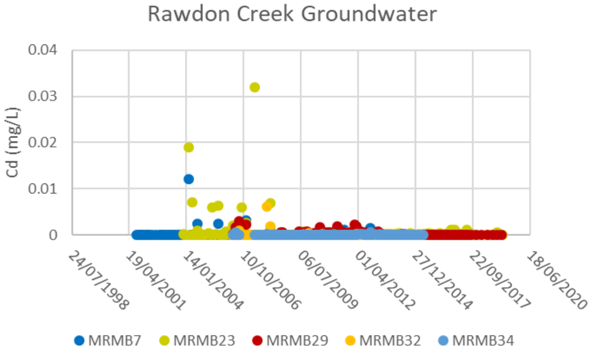

Rawdon Creek Groundwater: Downstream

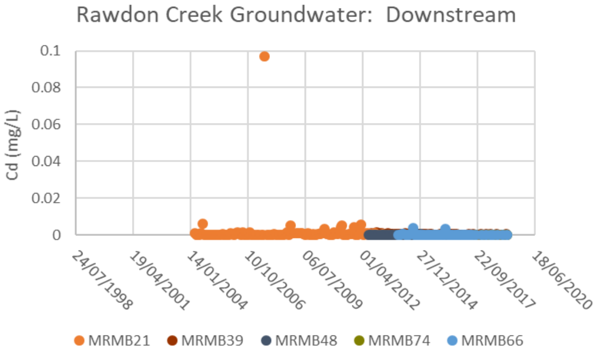

Rawdon Creek Groundwater
B (mg/L)
0.4
0.3
0.2
0.1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB1 ● MRMB2 ● MRMB3 ● MRMB4

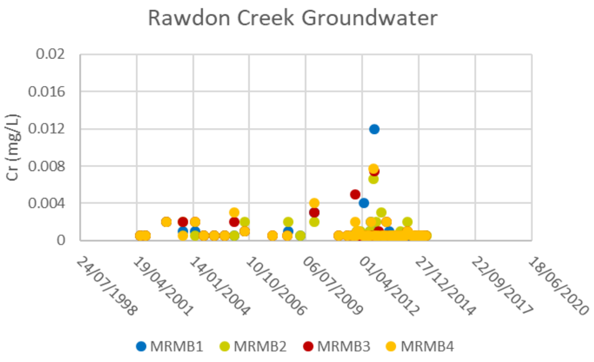

Rawdon Creek Groundwater
B (mg/L)
0.4
0.3
0.2
0.1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB7 ● MRMB23 ● MRMB29 ● MRMB32 ● MRMB34

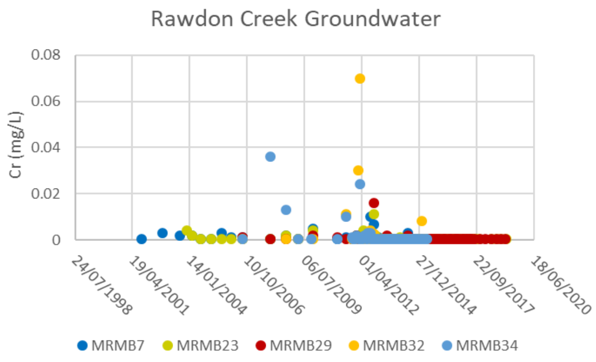

Rawdon Creek Groundwater: Downstream
B (mg/L)
0.4
0.3
0.2
0.1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB21 ● MRMB39 ● MRMB48 ● MRMB74 ● MRMB66

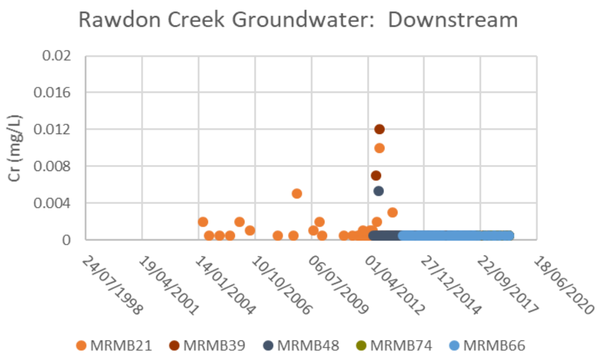

Rawdon Creek Groundwater
Cd (mg/L)
0.05
0.04
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB1 ● MRMB2 ● MRMB3 ● MRMB4

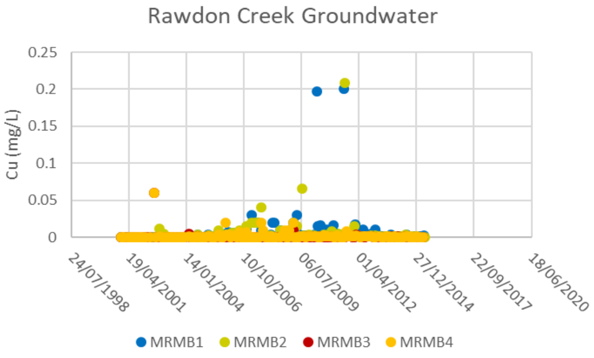

Rawdon Creek Groundwater
Cd (mg/L)
0.04
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB7 ● MRMB23 ● MRMB29 ● MRMB32 ● MRMB34

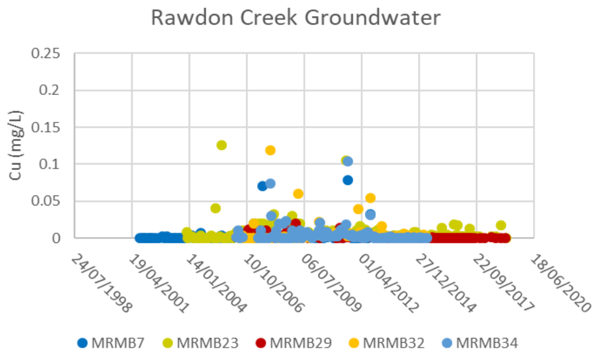

Rawdon Creek Groundwater: Downstream
Cd (mg/L)
0.1
0.08
0.06
0.04
0.02
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB21 ● MRMB39 ● MRMB48 ● MRMB74 ● MRMB66

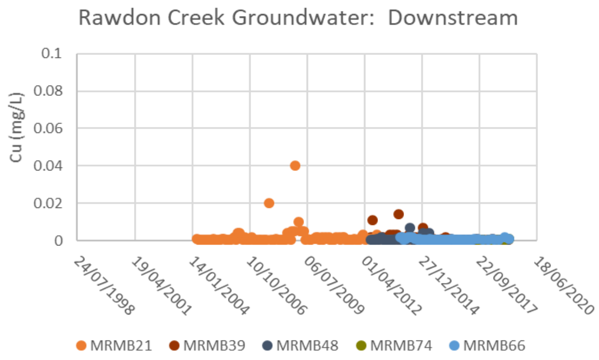

Rawdon Creek Groundwater
Cr (mg/L)
0.02
0.016
0.012
0.008
0.004
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB1 ● MRMB2 ● MRMB3 ● MRMB4

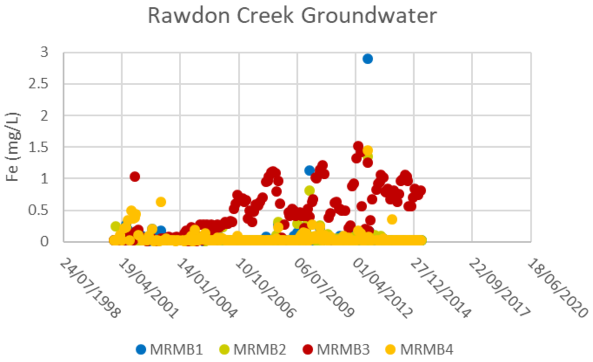

Rawdon Creek Groundwater
Cr (mg/L)
0.08
0.06
0.04
0.02
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB7 ● MRMB23 ● MRMB29 ● MRMB32 ● MRMB34

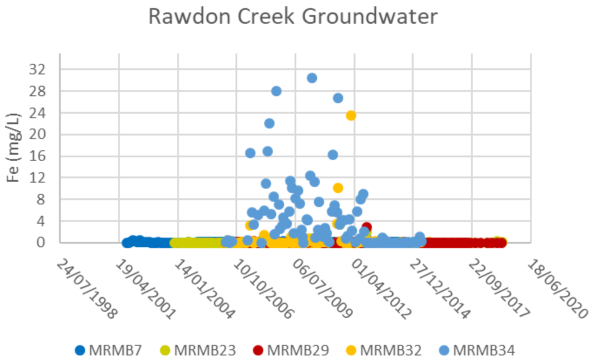

Rawdon Creek Groundwater: Downstream
Cr (mg/L)
0.02
0.016
0.012
0.008
0.004
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB21 ● MRMB39 ● MRMB48 ● MRMB74 ● MRMB66

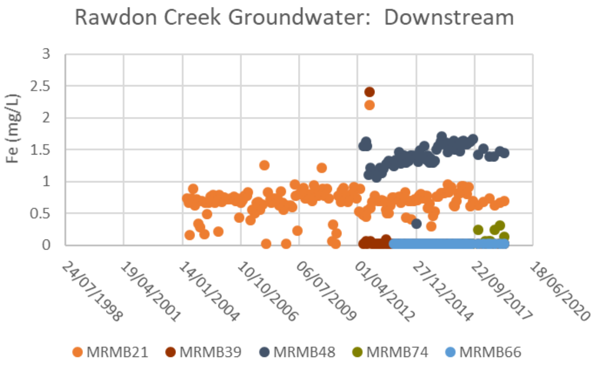

Rawdon Creek Groundwater
Cu (mg/L)
0.25
0.2
0.15
0.1
0.05
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB1 ● MRMB2 ● MRMB3 ● MRMB4

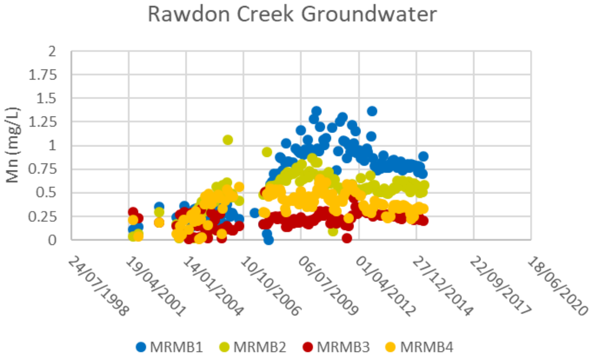

Rawdon Creek Groundwater
Cu (mg/L)
0.25
0.2
0.15
0.1
0.05
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB7 ● MRMB23 ● MRMB29 ● MRMB32 ● MRMB34

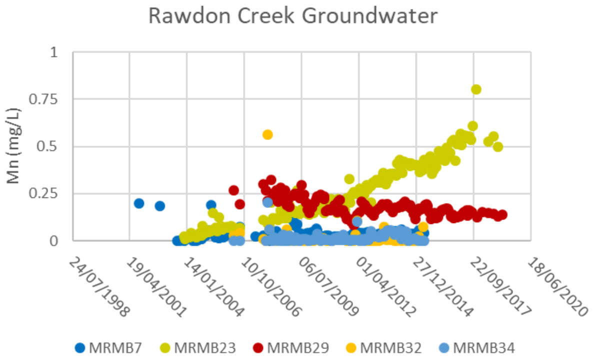

Rawdon Creek Groundwater: Downstream
Cu (mg/L)
0.1
0.08
0.06
0.04
0.02
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB21 ● MRMB39 ● MRMB48 ● MRMB74 ● MRMB66

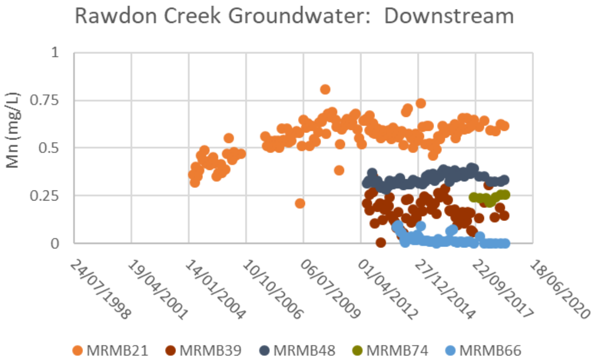

Rawdon Creek Groundwater

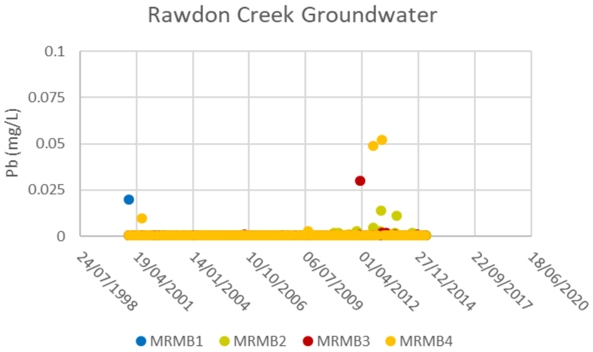

Rawdon Creek Groundwater

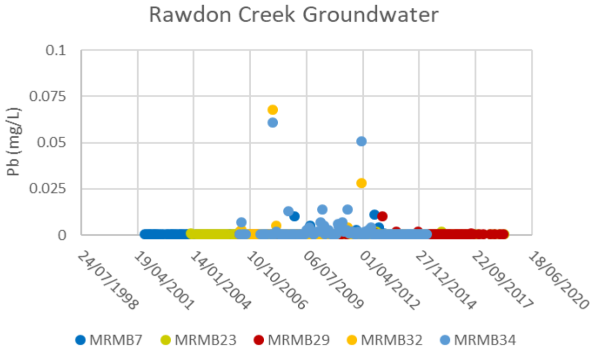

Rawdon Creek Groundwater: Downstream

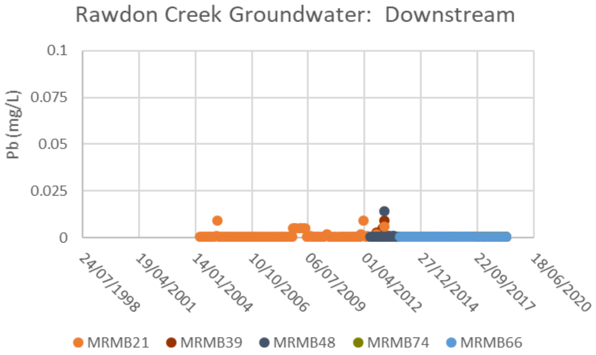

Rawdon Creek Groundwater

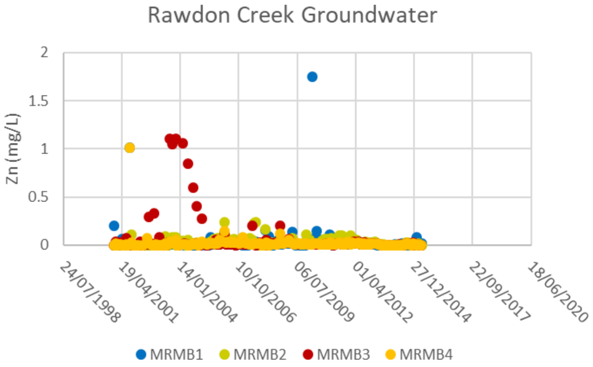

Rawdon Creek Groundwater

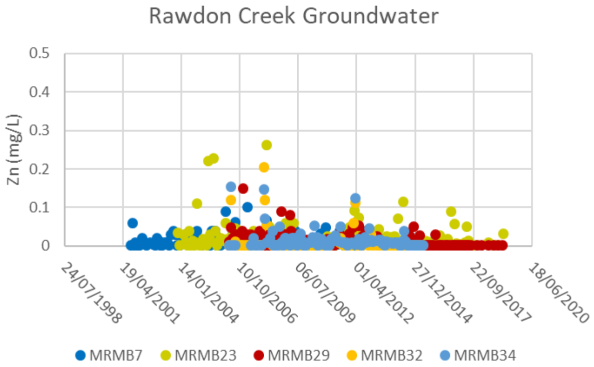

Rawdon Creek Groundwater: Downstream

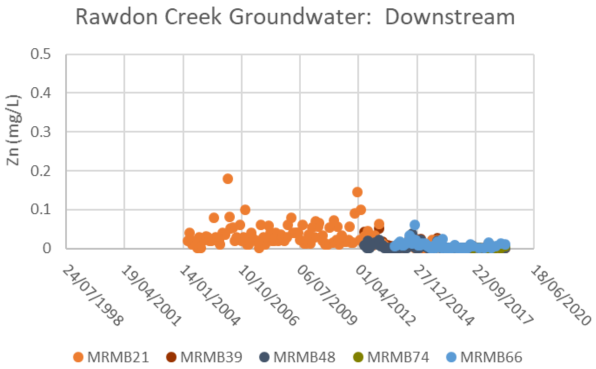

Rawdon Creek Groundwater
Pb (mg/L)
0.1
0.075
0.05
0.025
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB1
● MRMB2
● MRMB3
● MRMB4

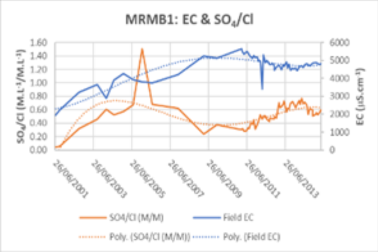

Rawdon Creek Groundwater
Pb (mg/L)
0.1
0.075
0.05
0.025
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB7
● MRMB23
● MRMB29
● MRMB32
● MRMB34

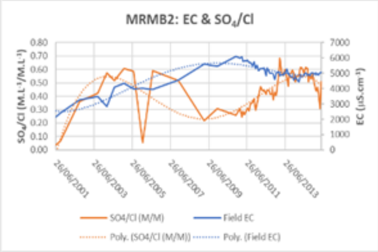

Rawdon Creek Groundwater: Downstream
Pb (mg/L)
0.1
0.075
0.05
0.025
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB21
● MRMB39
● MRMB48
● MRMB74
● MRMB66

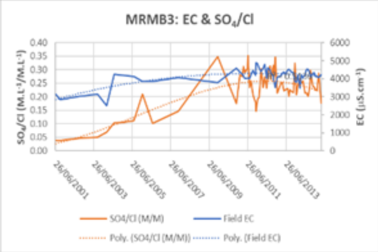

Rawdon Creek Groundwater
Zn (mg/L)
2
1.5
1
0.5
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB1
● MRMB2
● MRMB3
● MRMB4

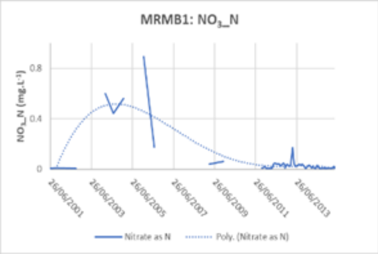

Rawdon Creek Groundwater
Zn (mg/L)
0.5
0.4
0.3
0.2
0.1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB7
● MRMB23
● MRMB29
● MRMB32
● MRMB34

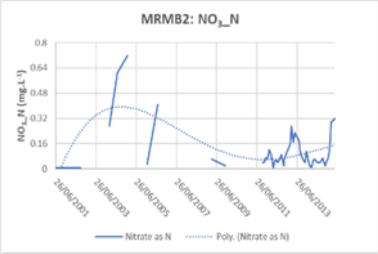

Rawdon Creek Groundwater: Downstream
Zn (mg/L)
0.5
0.4
0.3
0.2
0.1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB21
● MRMB39
● MRMB48
● MRMB74
● MRMB66

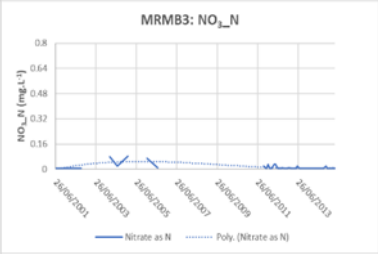

MRMB1: EC & SO$_4$/Cl
SO$_4$/Cl (M.L^{-1}/M.L^{-1})
EC (µS.cm^{-1})
26/06/2001
26/06/2003
26/06/2005
26/06/2007
26/06/2009
26/06/2011
26/06/2013
SO4/Cl (M/M)
Field EC
Poly. (SO4/Cl (M/M))
Poly. (Field EC)

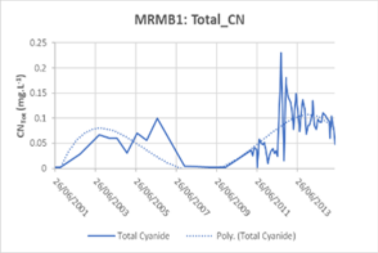

MRMB2: EC & SO$_4$/Cl
SO$_4$/Cl (M.L^{-1}/M.L^{-1})
EC (µS.cm^{-1})
26/06/2001
26/06/2003
26/06/2005
26/06/2007
26/06/2009
26/06/2011
26/06/2013
SO4/Cl (M/M)
Field EC
Poly. (SO4/Cl (M/M))
Poly. (Field EC)

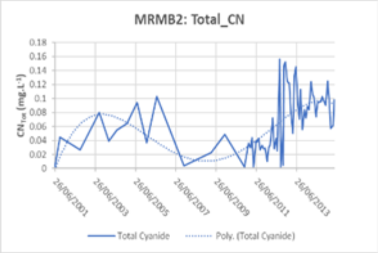

MRMB3: EC & SO$_4$/Cl
SO$_4$/Cl (M.L^{-1}/M.L^{-1})
EC (µS.cm^{-1})
26/06/2001
26/06/2003
26/06/2005
26/06/2007
26/06/2009
26/06/2011
26/06/2013
SO4/Cl (M/M)
Field EC
Poly. (SO4/Cl (M/M))
Poly. (Field EC)

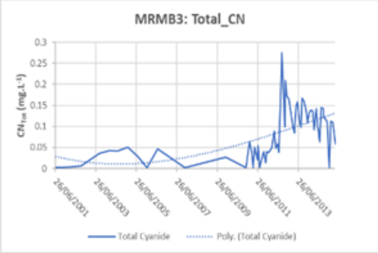

MRMB1: NO$_3$_N
NO$_3$_N (mg.L^{-1})
26/06/2001
26/06/2003
26/06/2005
26/06/2007
26/06/2009
26/06/2011
26/06/2013
Nitrate as N
Poly. (Nitrate as N)

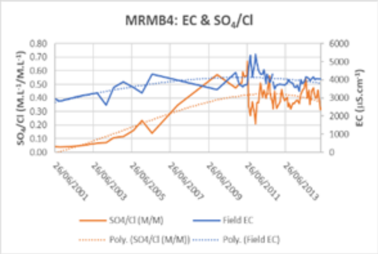

MRMB2: NO$_3$_N
NO$_3$_N (mg.L^{-1})
26/06/2001
26/06/2003
26/06/2005
26/06/2007
26/06/2009
26/06/2011
26/06/2013
Nitrate as N
Poly. (Nitrate as N)

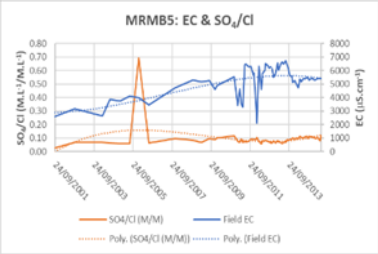

MRMB3: NO$_3$_N
NO$_3$_N (mg.L^{-1})
26/06/2001
26/06/2003
26/06/2005
26/06/2007
26/06/2009
26/06/2011
26/06/2013
Nitrate as N
Poly. (Nitrate as N)

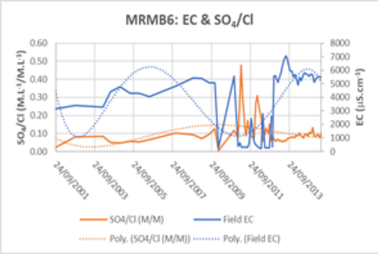

MRMB1: Total_CN
CN$_{tot}$ (mg.L^{-1})
26/06/2001
26/06/2003
26/06/2005
26/06/2007
26/06/2009
26/06/2011
26/06/2013
Total Cyanide
Poly. (Total Cyanide)

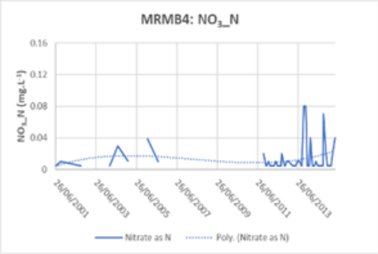

MRMB2: Total_CN
CN$_{tot}$ (mg.L^{-1})
26/06/2001
26/06/2003
26/06/2005
26/06/2007
26/06/2009
26/06/2011
26/06/2013
Total Cyanide
Poly. (Total Cyanide)

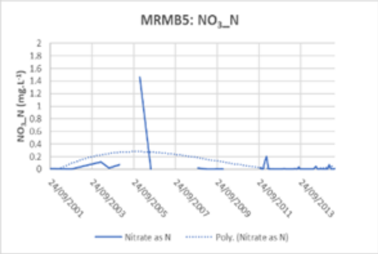

MRMB3: Total_CN
CN$_{tot}$ (mg.L^{-1})
26/06/2001
26/06/2003
26/06/2005
26/06/2007
26/06/2009
26/06/2011
26/06/2013
Total Cyanide
Poly. (Total Cyanide)

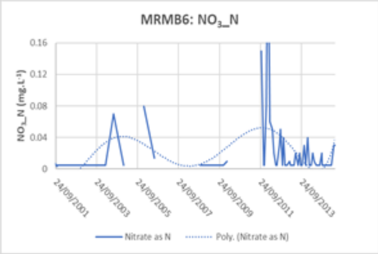

MRMB4: EC & SO$_4$/Cl
SO$_4$/Cl (M.L^{-1}/M.L^{-1})
EC (µS.cm^{-1})
26/06/2001
26/06/2003
26/06/2005
26/06/2007
26/06/2009
26/06/2011
26/06/2013
SO4/Cl (M/M)
Field EC
Poly. (SO4/Cl (M/M))
Poly. (Field EC)

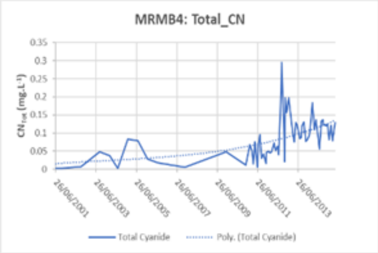

MRMB5: EC & SO$_4$/Cl
SO$_4$/Cl (M.L^{-1}/M.L^{-1})
EC (µS.cm^{-1})
24/09/2001
24/09/2003
24/09/2005
24/09/2007
24/09/2009
24/09/2011
24/09/2013
SO4/Cl (M/M)
Field EC
Poly. (SO4/Cl (M/M))
Poly. (Field EC)

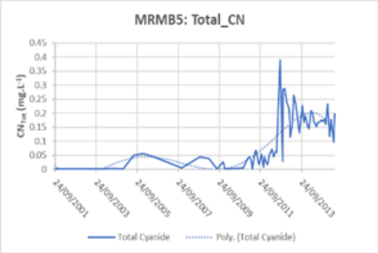

MRMB6: EC & SO$_4$/Cl
SO$_4$/Cl (M.L^{-1}/M.L^{-1})
EC (µS.cm^{-1})
24/09/2001
24/09/2003
24/09/2005
24/09/2007
24/09/2009
24/09/2011
24/09/2013
SO4/Cl (M/M)
Field EC
Poly. (SO4/Cl (M/M))
Poly. (Field EC)

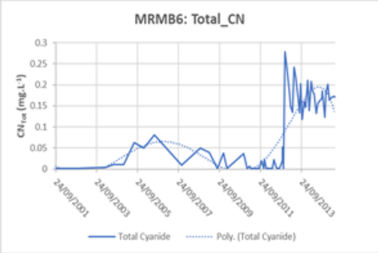

MRMB4: NO$_3$_N
NO$_3$_N (mg.L^{-1})
26/06/2001
26/06/2003
26/06/2005
26/06/2007
26/06/2009
26/06/2011
26/06/2013
Nitrate as N
Poly. (Nitrate as N)

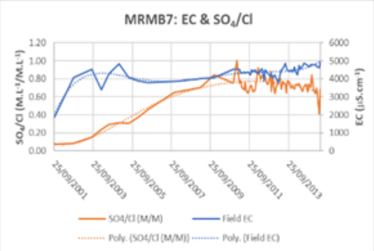

MRMB5: NO$_3$_N
NO$_3$_N (mg.L^{-1})
24/09/2001
24/09/2003
24/09/2005
24/09/2007
24/09/2009
24/09/2011
24/09/2013
Nitrate as N
Poly. (Nitrate as N)

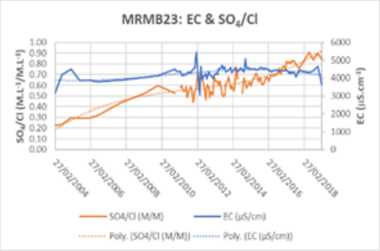

MRMB6: NO$_3$_N
NO$_3$_N (mg.L^{-1})
24/09/2001
24/09/2003
24/09/2005
24/09/2007
24/09/2009
24/09/2011
24/09/2013
Nitrate as N
Poly. (Nitrate as N)

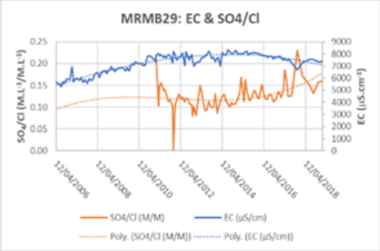

MRMB4: Total_CN
CN$_{tot}$ (mg.L^{-1})
26/06/2001
26/06/2003
26/06/2005
26/06/2007
26/06/2009
26/06/2011
26/06/2013
Total Cyanide
Poly. (Total Cyanide)

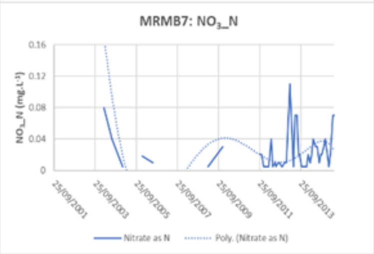

MRMB5: Total_CN
CN$_{tot}$ (mg.L^{-1})
24/09/2001
24/09/2003
24/09/2005
24/09/2007
24/09/2009
24/09/2011
24/09/2013
Total Cyanide
Poly. (Total Cyanide)

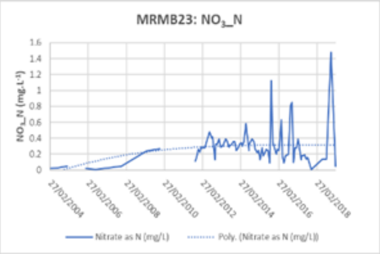

MRMB6: Total_CN
CN$_{tot}$ (mg.L^{-1})
24/09/2001
24/09/2003
24/09/2005
24/09/2007
24/09/2009
24/09/2011
24/09/2013
Total Cyanide
Poly. (Total Cyanide)

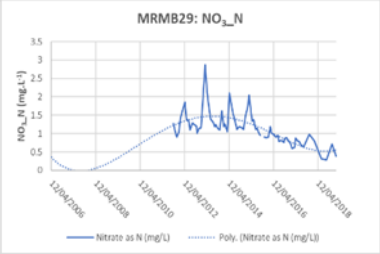

MRMB7: EC & SO_4/Cl

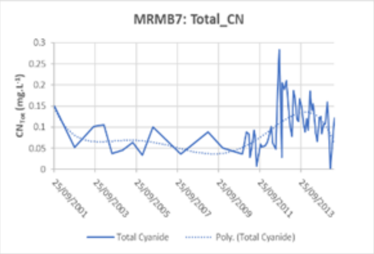

MRMB23: EC & SO_4/Cl

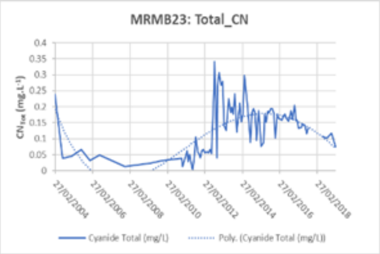

MRMB29: EC & SO4/Cl

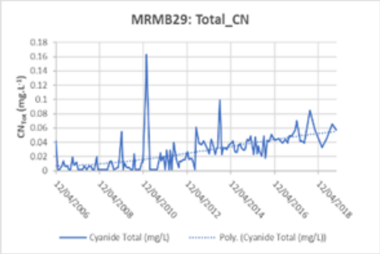

MRMB7: NO_3_N

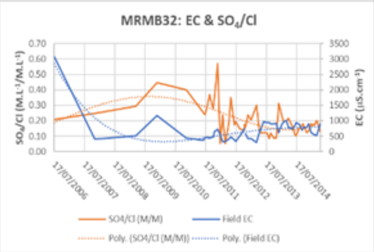

MRMB23: NO_3_N

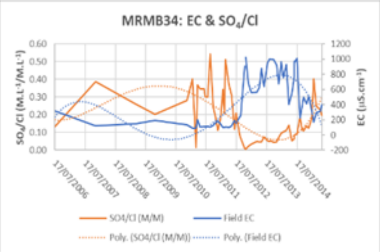

MRMB29: NO_3_N

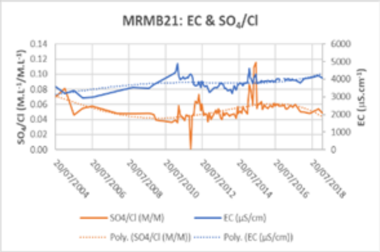

MRMB7: Total_CN

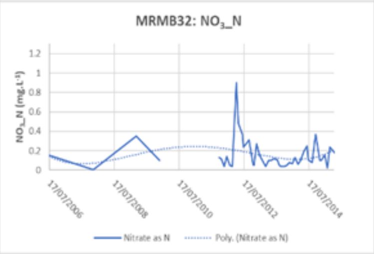

MRMB23: Total_CN

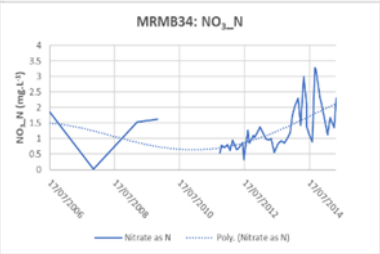

MRMB29: Total_CN

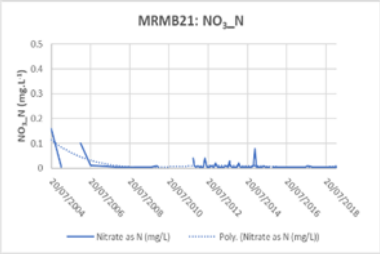

MRMB32: EC & SO_4/Cl

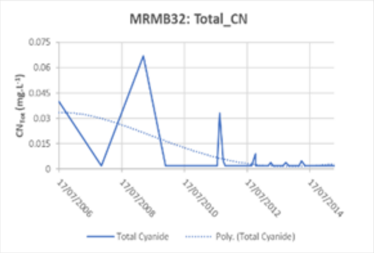

MRMB34: EC & SO_4/Cl

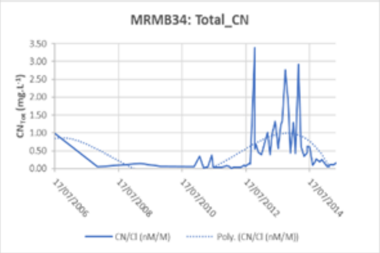

MRMB21: EC & SO_4/Cl

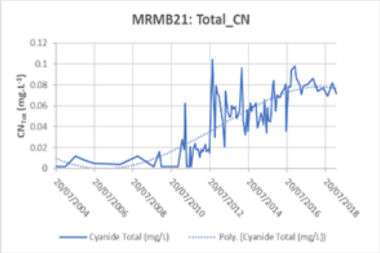

MRMB32: NO_3_N

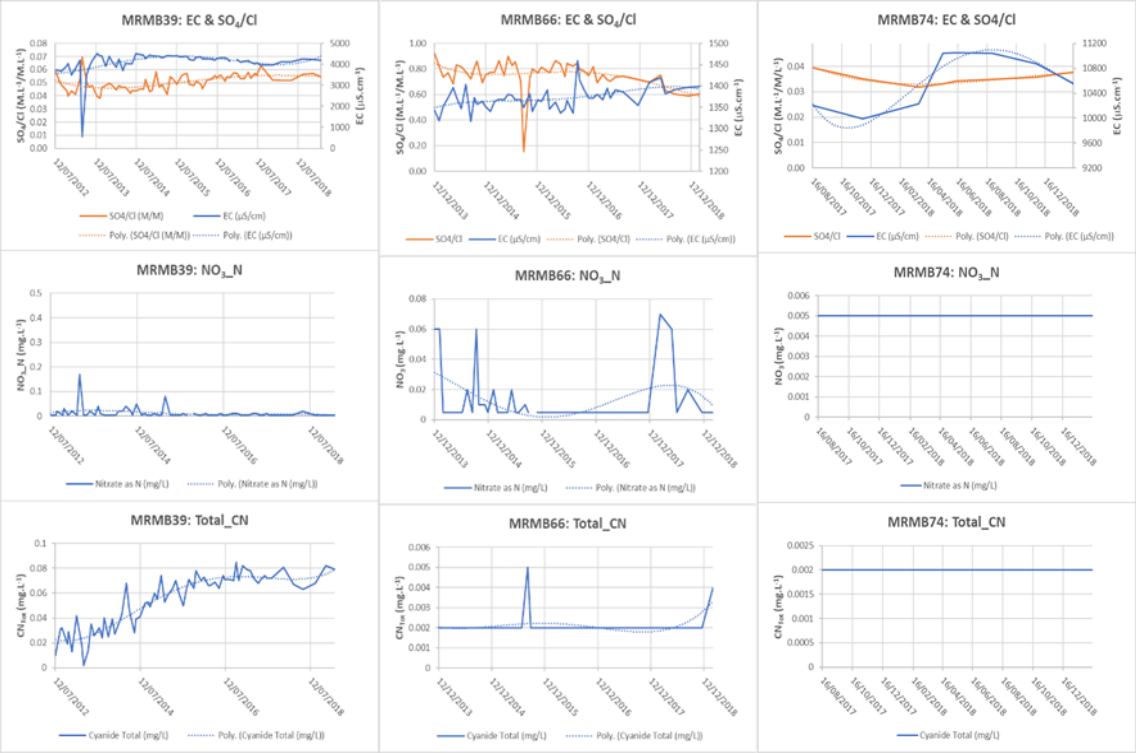

MRMB34: NO_3_N


MRMB21: NO_3_N

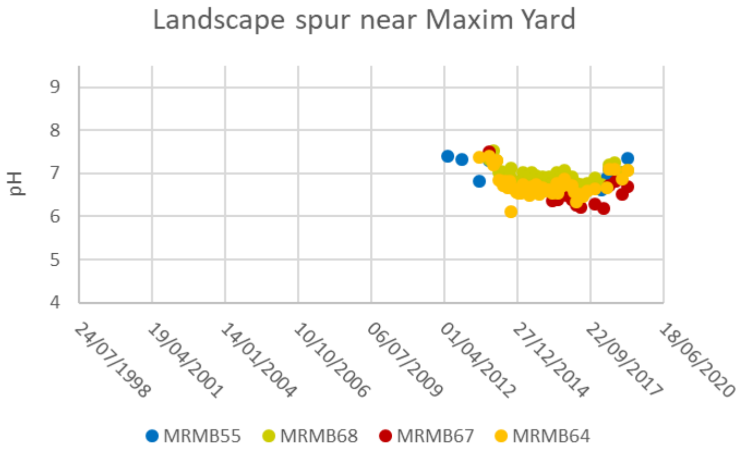

MRMB32: Total_CN

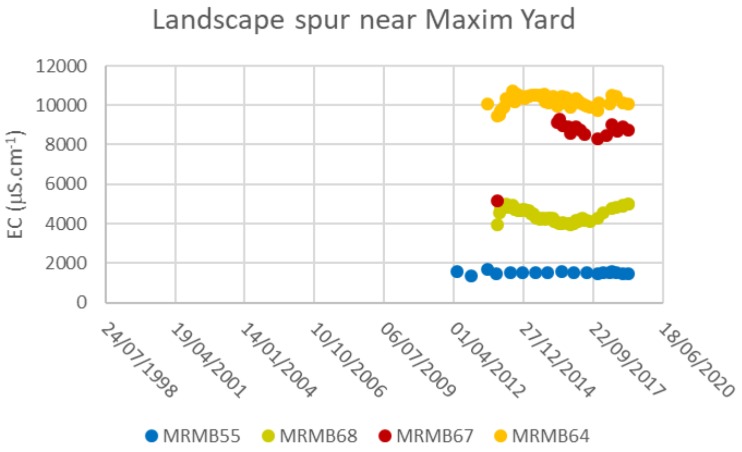

MRMB34: Total_CN

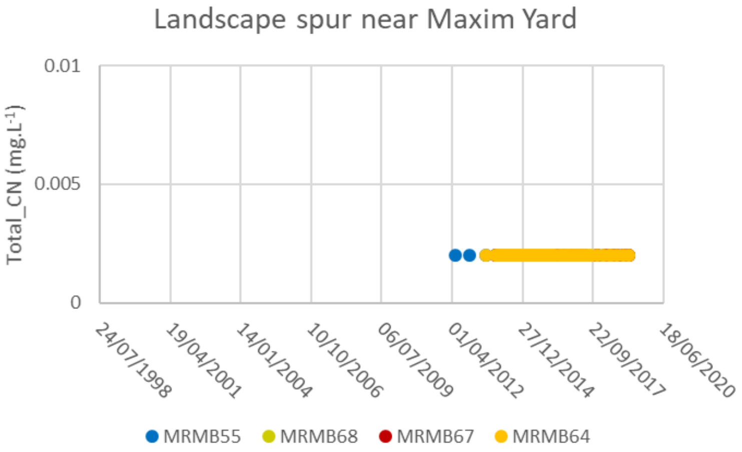

MRMB21: Total_CN

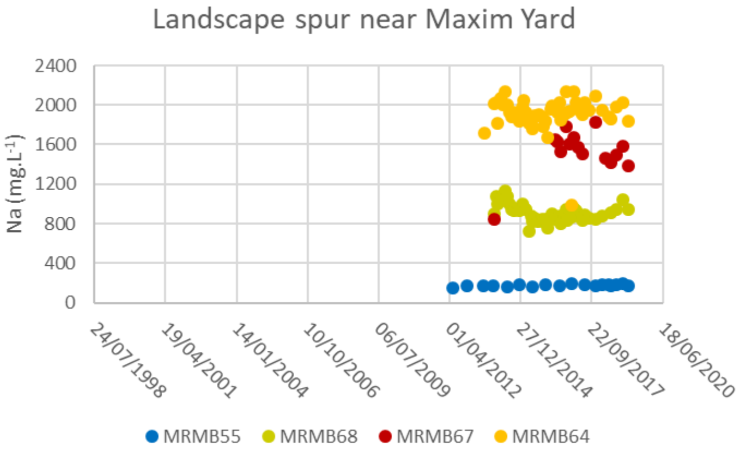

MRMB39: EC & SO_4/Cl
SO_4/Cl (M.L⁻¹/M.L⁻¹)
EC (µS.cm⁻¹)
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))
MRMB66: EC & SO_4/Cl
SO4/Cl
EC (µS/cm)
Poly. (SO4/Cl)
Poly. (EC (µS/cm))
MRMB74: EC & SO4/Cl
MRMB39: NO_3_N
NO_3_N (mg.L⁻¹)
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))
MRMB66: NO_3_N
NO_3 (mg.L⁻¹)
MRMB74: NO_3_N
MRMB39: Total_CN
CN_{tot} (mg.L⁻¹)
Cyanide Total (mg/L)
Poly. (Cyanide Total (mg/L))
MRMB66: Total_CN
MRMB74: Total_CN
12/07/2012
12/07/2013
12/07/2014
12/07/2015
12/07/2016
12/07/2017
12/07/2018
12/12/2013
12/12/2014
12/12/2015
12/12/2016
12/12/2017
12/12/2018
16/08/2017
16/10/2017
16/12/2017
16/02/2018
16/04/2018
16/06/2018
16/08/2018
16/10/2018
16/12/2018

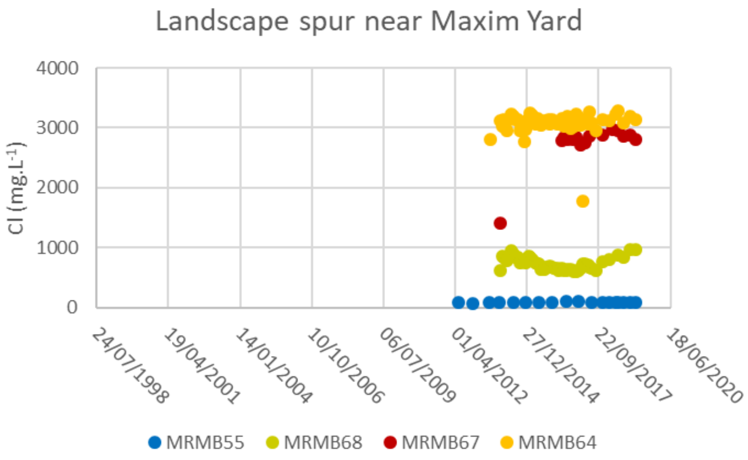
8.4.4 Time Series Charts for Landscape Spur

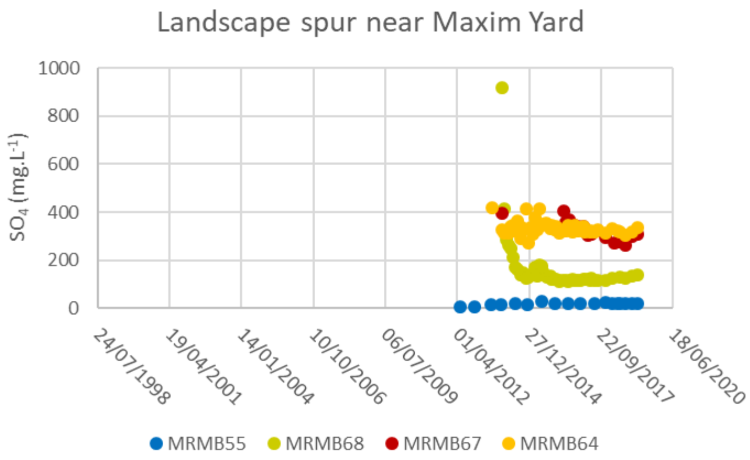


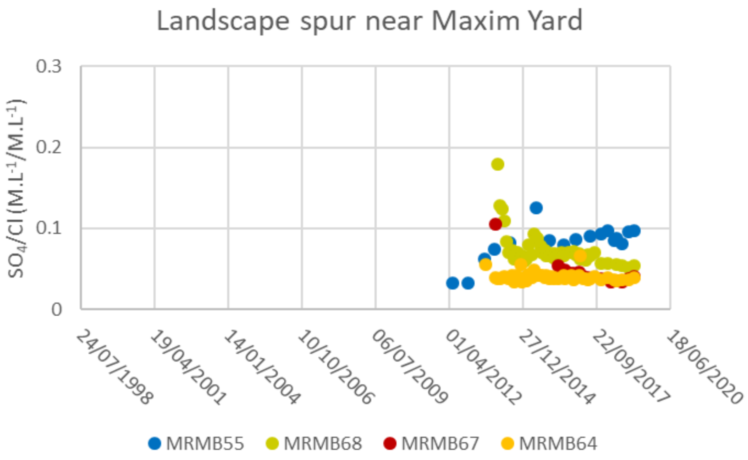


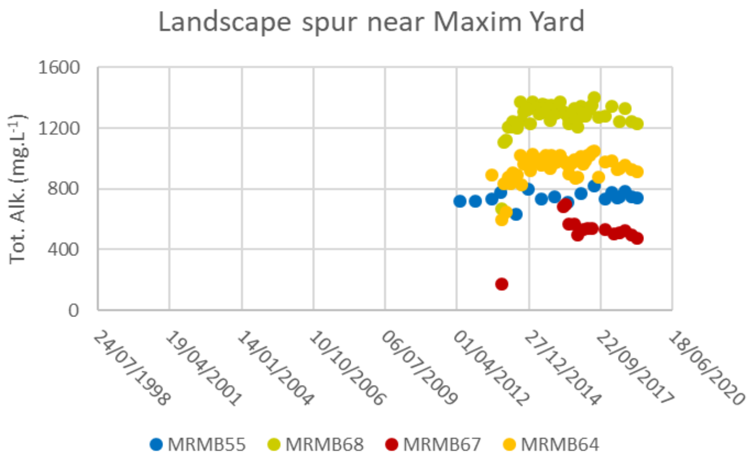


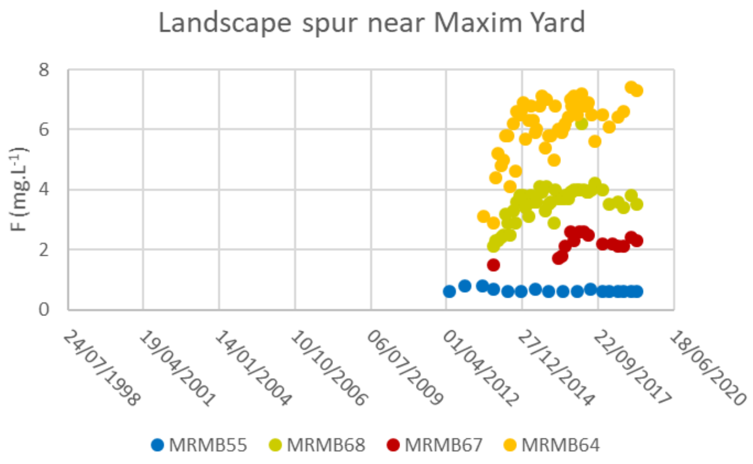


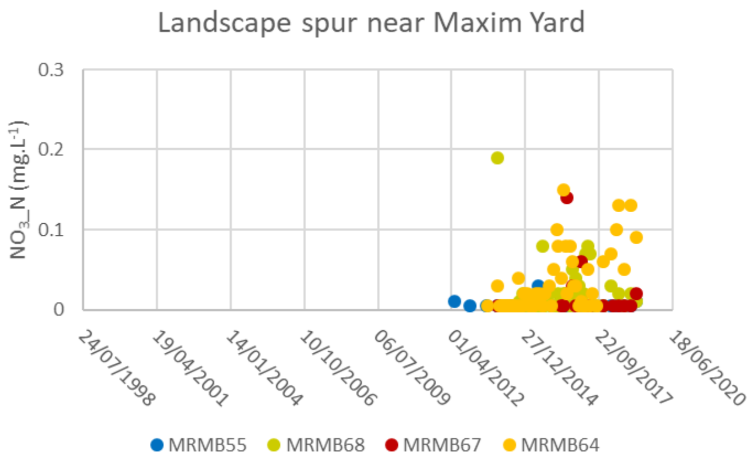

Landscape spur near Maxim Yard

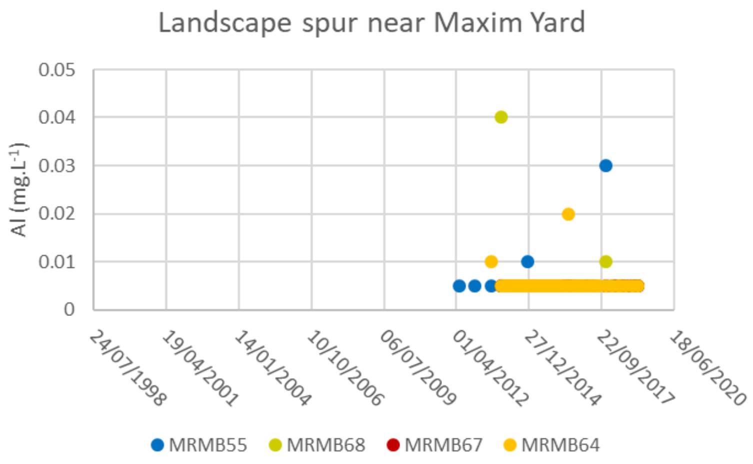

Landscape spur near Maxim Yard

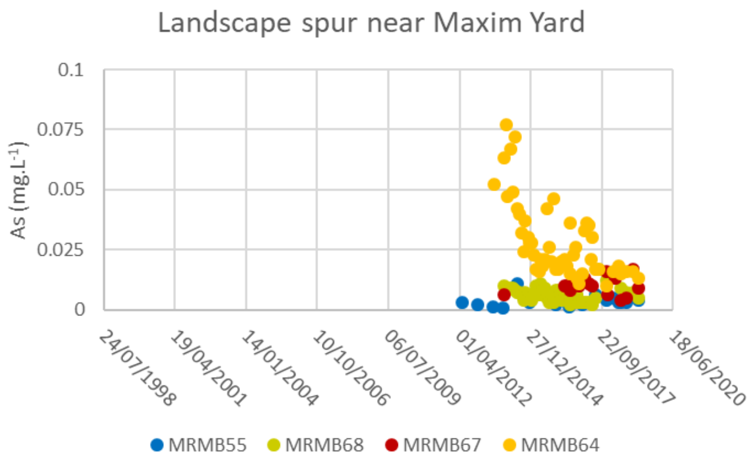

Landscape spur near Maxim Yard

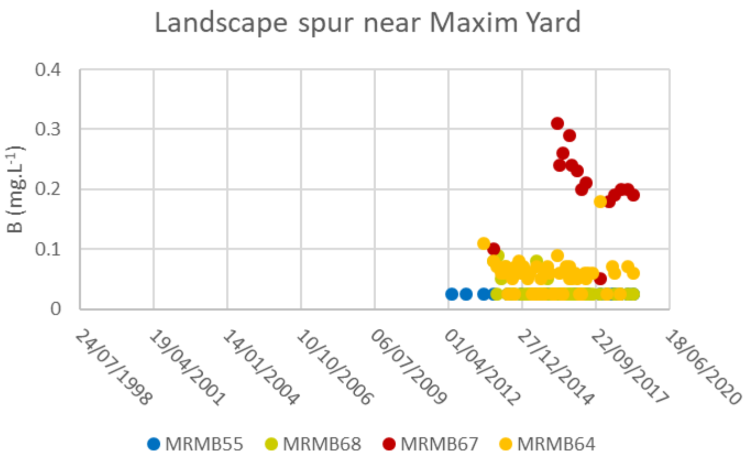

Landscape spur near Maxim Yard

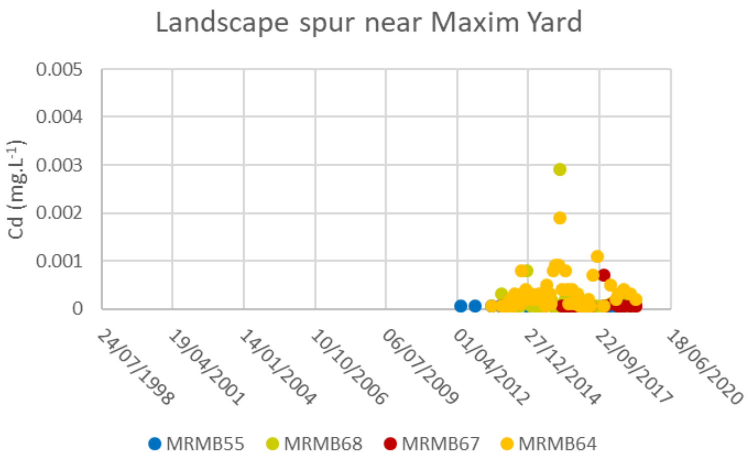

Landscape spur near Maxim Yard
F (mg.L^{-1})
8
6
4
2
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB55
● MRMB68
● MRMB67
● MRMB64

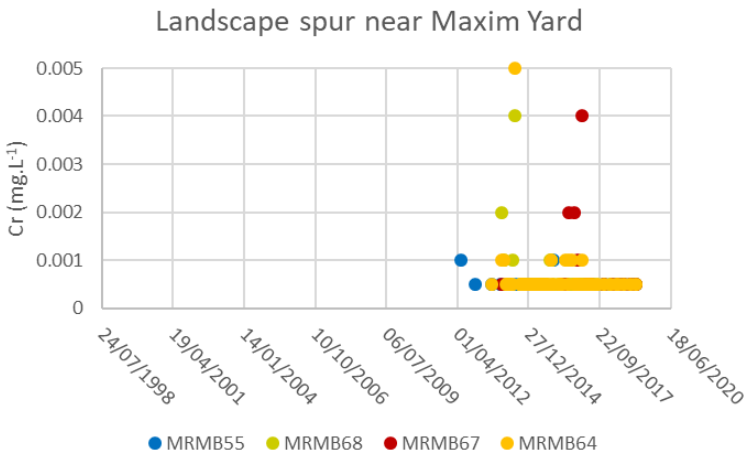

Landscape spur near Maxim Yard
NO$_3$_N (mg.L^{-1})
0.3
0.2
0.1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB55
● MRMB68
● MRMB67
● MRMB64

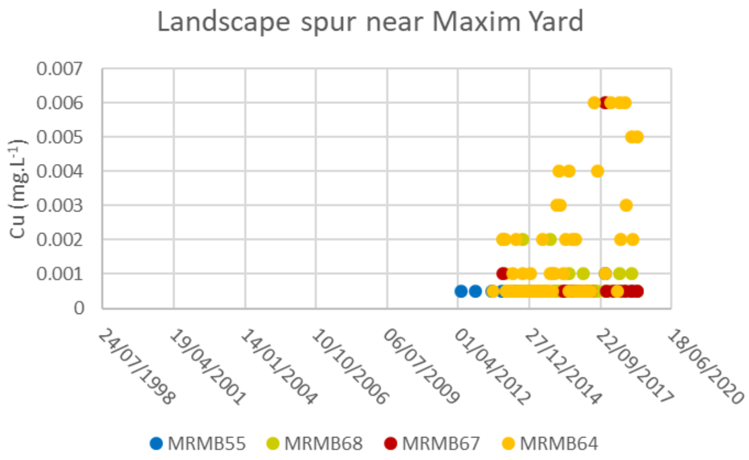

Landscape spur near Maxim Yard
Al (mg.L^{-1})
0.05
0.04
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB55
● MRMB68
● MRMB67
● MRMB64

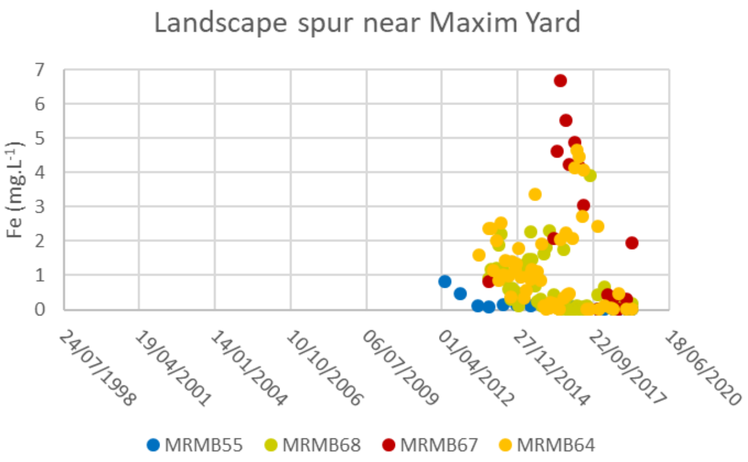

Landscape spur near Maxim Yard
As (mg.L^{-1})
0.1
0.075
0.05
0.025
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB55
● MRMB68
● MRMB67
● MRMB64

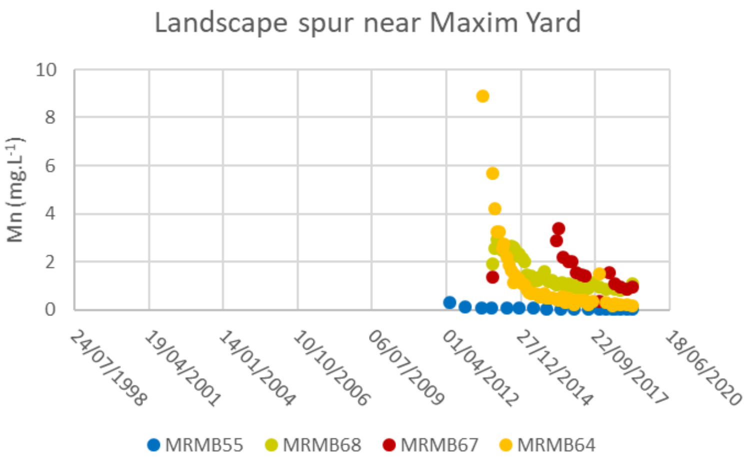

Landscape spur near Maxim Yard
B (mg.L-1)
0.4
0.3
0.2
0.1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB55 ● MRMB68 ● MRMB67 ● MRMB64

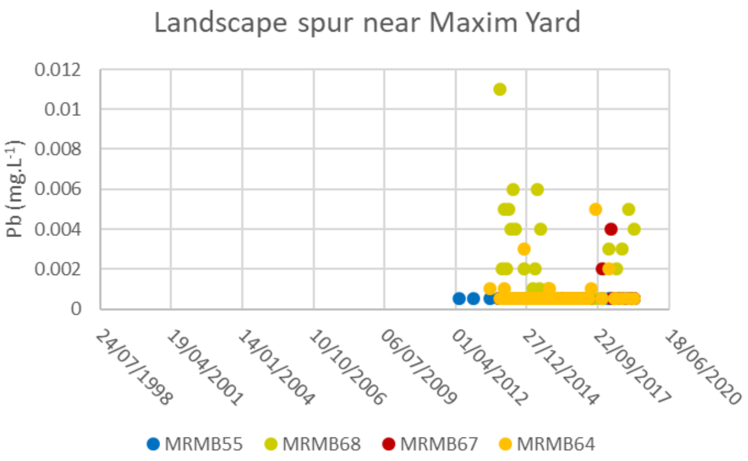

Landscape spur near Maxim Yard
Cd (mg.L-1)
0.005
0.004
0.003
0.002
0.001
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB55 ● MRMB68 ● MRMB67 ● MRMB64

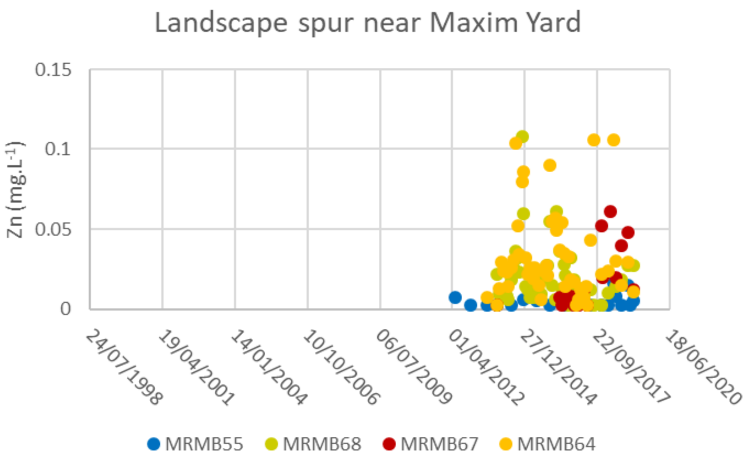

Landscape spur near Maxim Yard
Cr (mg.L-1)
0.005
0.004
0.003
0.002
0.001
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB55 ● MRMB68 ● MRMB67 ● MRMB64

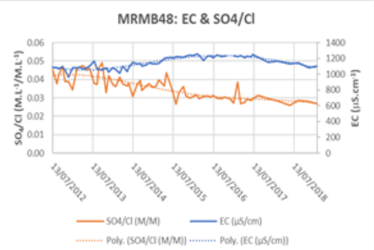

Landscape spur near Maxim Yard
Cu (mg.L-1)
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB55 ● MRMB68 ● MRMB67 ● MRMB64

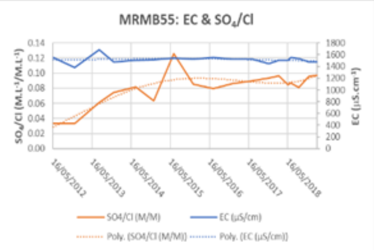

Landscape spur near Maxim Yard
Fe (mg.L-1)
7
6
5
4
3
2
1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB55
● MRMB68
● MRMB67
● MRMB64

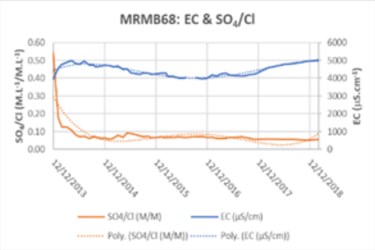

Landscape spur near Maxim Yard
Mn (mg.L-1)
10
8
6
4
2
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB55
● MRMB68
● MRMB67
● MRMB64

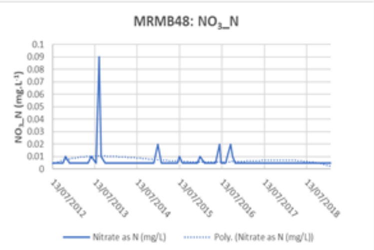

Landscape spur near Maxim Yard
Pb (mg.L-1)
0.012
0.01
0.008
0.006
0.004
0.002
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB55
● MRMB68
● MRMB67
● MRMB64

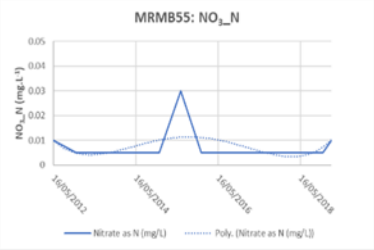

Landscape spur near Maxim Yard
Zn (mg.L-1)
0.15
0.1
0.05
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB55
● MRMB68
● MRMB67
● MRMB64

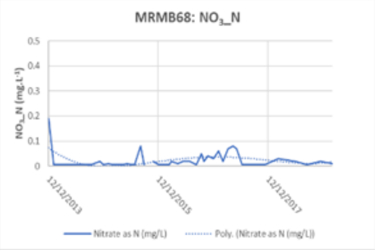

MRMB48: EC & SO4/Cl
SO4/Cl (M.L⁻¹/M.L⁻¹)
EC (µS.cm⁻¹)
0.00 0.01 0.02 0.03 0.04 0.05 0.06
0 200 400 600 800 1000 1200 1400
13/07/2012 13/07/2013 13/07/2014 13/07/2015 13/07/2016 13/07/2017 13/07/2018
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))

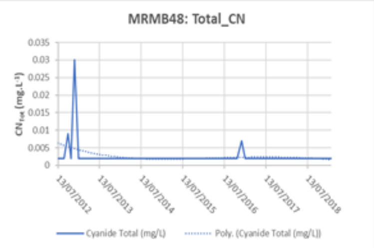

MRMB55: EC & SO4/Cl
SO4/Cl (M.L⁻¹/M.L⁻¹)
EC (µS.cm⁻¹)
0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14
0 200 400 600 800 1000 1200 1400 1600 1800
16/05/2012 16/05/2013 16/05/2014 16/05/2015 16/05/2016 16/05/2017 16/05/2018
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))

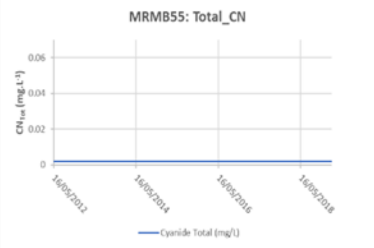

MRMB68: EC & SO4/Cl
SO4/Cl (M.L⁻¹/M.L⁻¹)
EC (µS.cm⁻¹)
0.00 0.10 0.20 0.30 0.40 0.50 0.60
0 1000 2000 3000 4000 5000 6000
12/12/2013 12/12/2014 12/12/2015 12/12/2016 12/12/2017 12/12/2018
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))

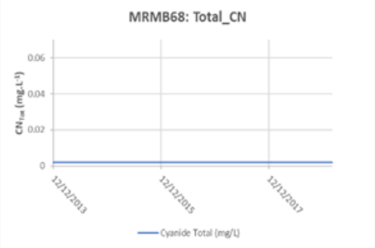

MRMB48: NO3_N
NO3_N (mg.L⁻¹)
0 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1
13/07/2012 13/07/2013 13/07/2014 13/07/2015 13/07/2016 13/07/2017 13/07/2018
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

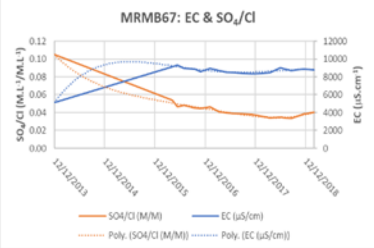

MRMB55: NO3_N
NO3_N (mg.L⁻¹)
0 0.01 0.02 0.03 0.04 0.05
16/05/2012 16/05/2014 16/05/2016 16/05/2018
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

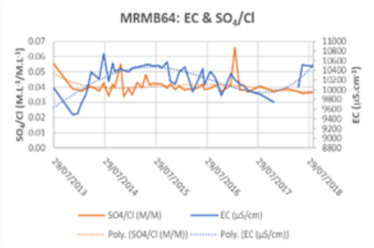

MRMB68: NO3_N
NO3_N (mg.L⁻¹)
0 0.1 0.2 0.3 0.4 0.5
12/12/2013 12/12/2015 12/12/2017
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

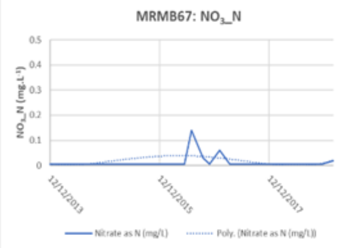

MRMB48: Total_CN
CNTot (mg.L⁻¹)
0 0.005 0.01 0.015 0.02 0.025 0.03 0.035
13/07/2012 13/07/2013 13/07/2014 13/07/2015 13/07/2016 13/07/2017 13/07/2018
Cyanide Total (mg/L)
Poly. (Cyanide Total (mg/L))

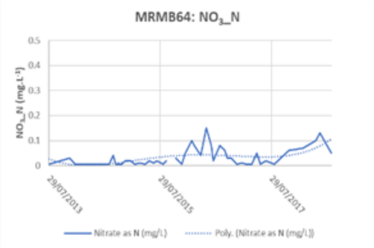

MRMB55: Total_CN
CNTot (mg.L⁻¹)
0 0.02 0.04 0.06
16/05/2012 16/05/2014 16/05/2016 16/05/2018
Cyanide Total (mg/L)

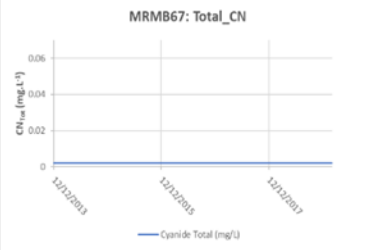

MRMB68: Total_CN
CNTot (mg.L⁻¹)
0 0.02 0.04 0.06
12/12/2013 12/12/2015 12/12/2017
Cyanide Total (mg/L)

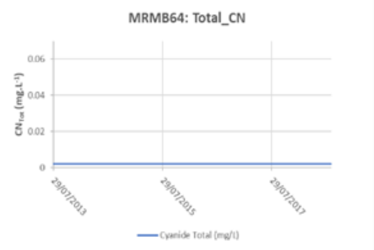

MRMB67: EC & SO4/Cl
SO4/Cl (M.L⁻¹/M.L⁻¹)
EC (µS.cm⁻¹)
0.00 0.02 0.04 0.06 0.08 0.10 0.12
0 2000 4000 6000 8000 10000 12000
12/12/2013 12/12/2014 12/12/2015 12/12/2016 12/12/2017 12/12/2018
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))


MRMB64: EC & SO4/Cl
SO4/Cl (M.L⁻¹/M.L⁻¹)
EC (µS.cm⁻¹)
0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07
8800 9000 9200 9400 9600 9800 10000 10200 10400 10600 10800 11000
29/07/2013 29/07/2014 29/07/2015 29/07/2016 29/07/2017 29/07/2018
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))

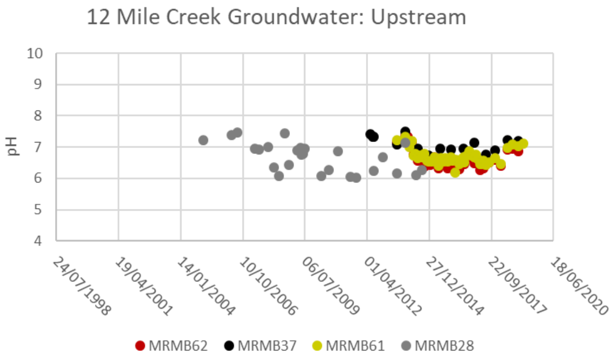

MRMB67: NO3_N
NO3_N (mg.L⁻¹)
0 0.1 0.2 0.3 0.4 0.5
12/12/2013 12/12/2015 12/12/2017
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

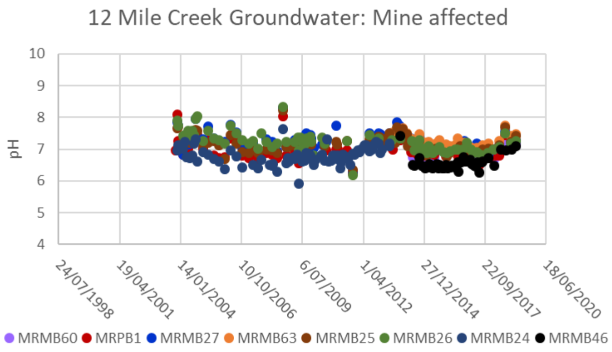

MRMB64: NO3_N
NO3_N (mg.L⁻¹)
0 0.1 0.2 0.3 0.4 0.5
29/07/2013 29/07/2015 29/07/2017
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

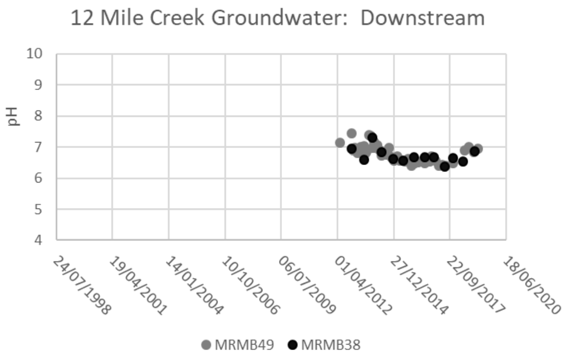

MRMB67: Total_CN
CNTot (mg.L⁻¹)
0 0.02 0.04 0.06
12/12/2013 12/12/2015 12/12/2017
Cyanide Total (mg/L)

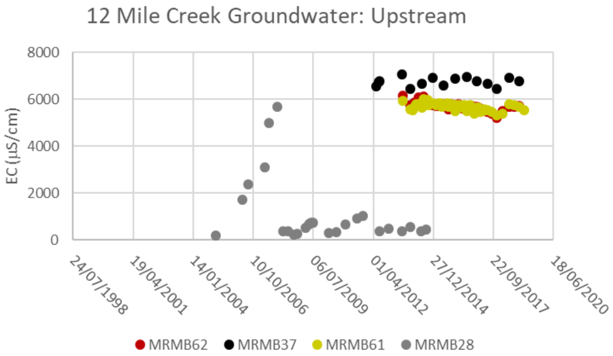

MRMB64: Total_CN
CNTot (mg.L⁻¹)
0 0.02 0.04 0.06
29/07/2013 29/07/2015 29/07/2017
Cyanide Total (mg/L)

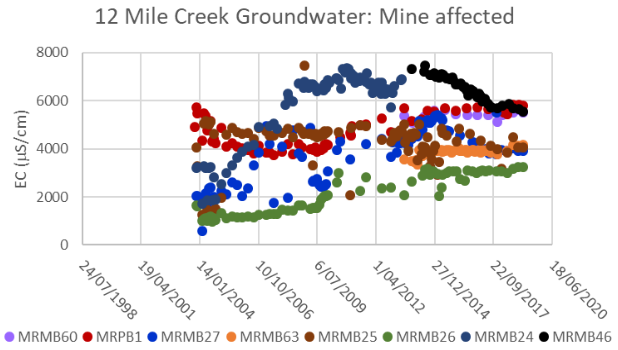
8.4.5 Time Series Charts for Twelve Mile Creek

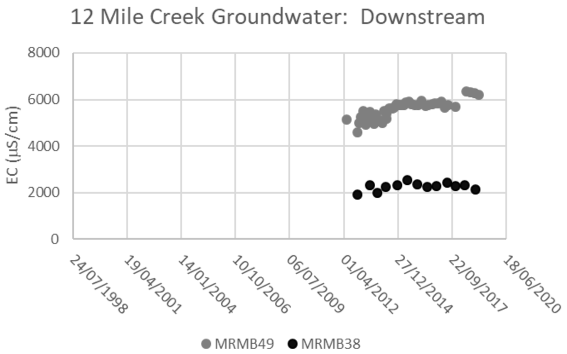


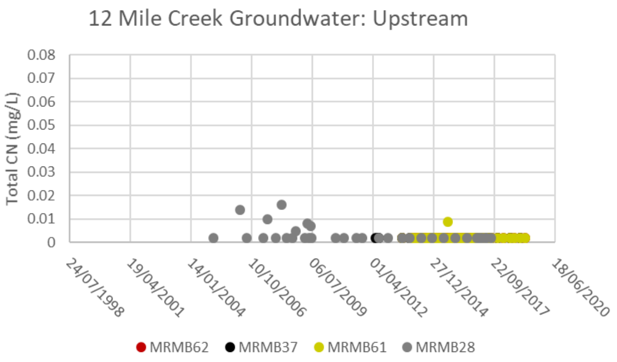


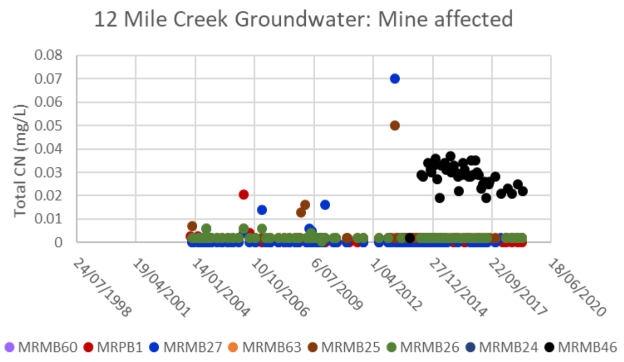


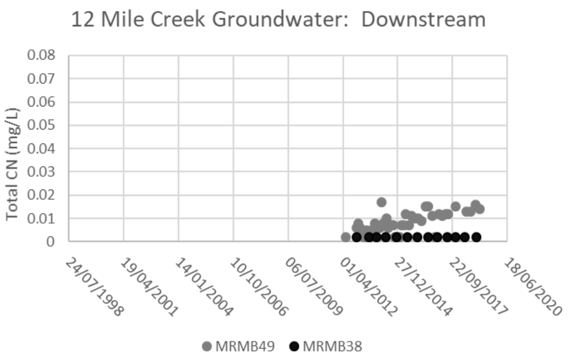


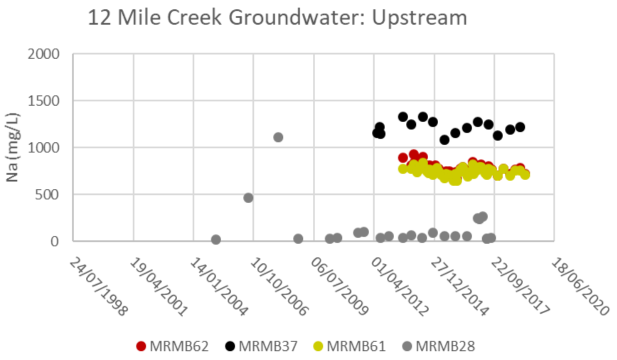


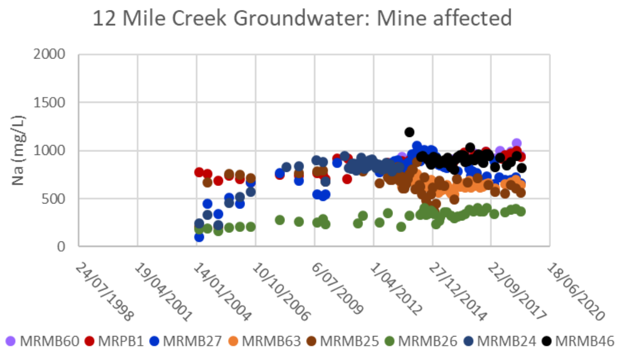


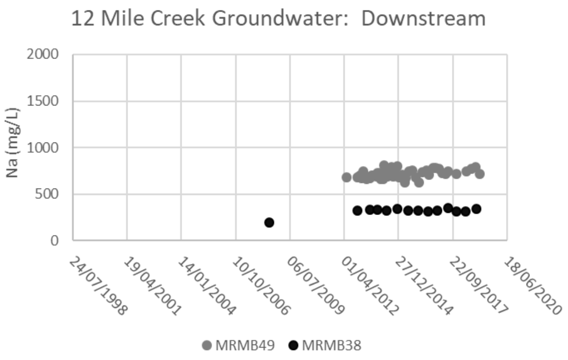

12 Mile Creek Groundwater: Upstream

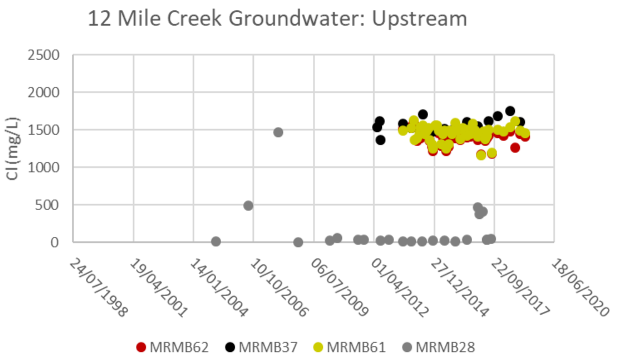

12 Mile Creek Groundwater: Mine affected

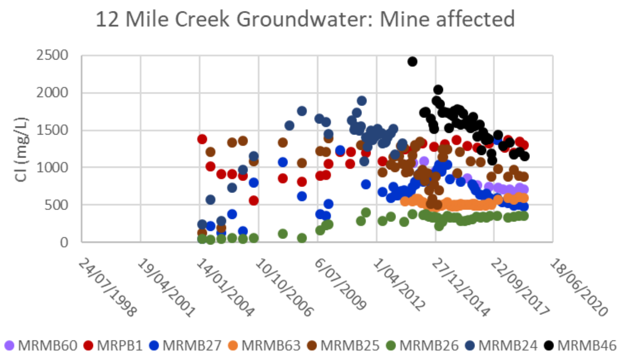

12 Mile Creek Groundwater: Downstream

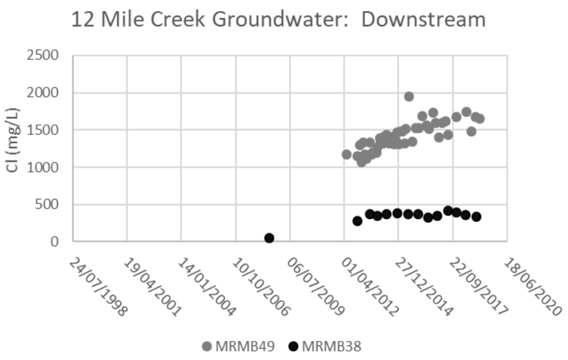

12 Mile Creek Groundwater: Upstream

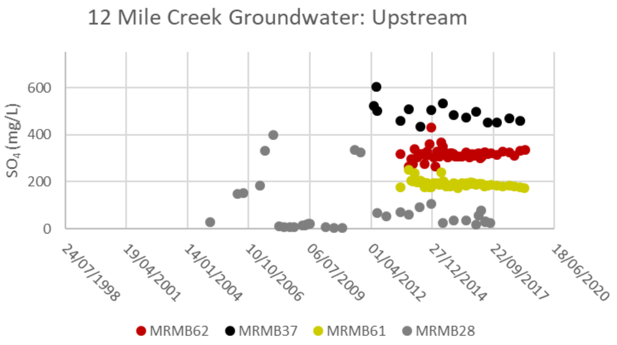

12 Mile Creek Groundwater: Mine affected

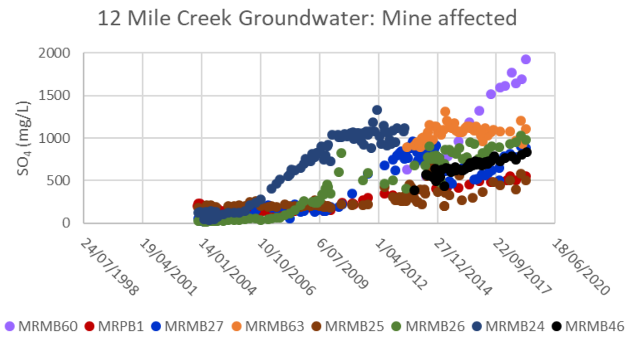

12 Mile Creek Groundwater: Downstream

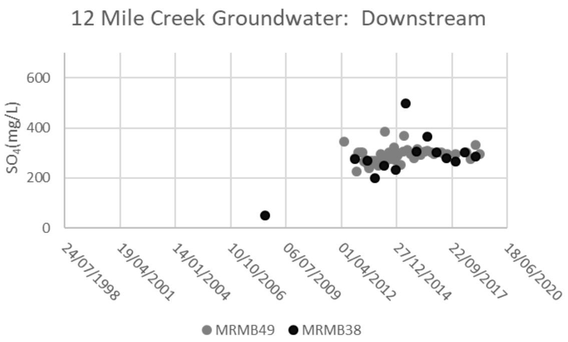

12 Mile Creek Groundwater: Upstream

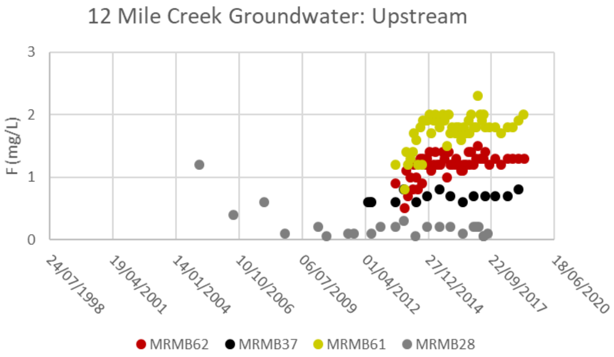

12 Mile Creek Groundwater: Mine affected

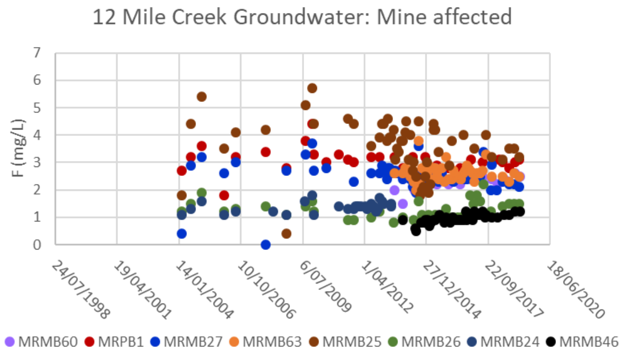

12 Mile Creek Groundwater: Downstream

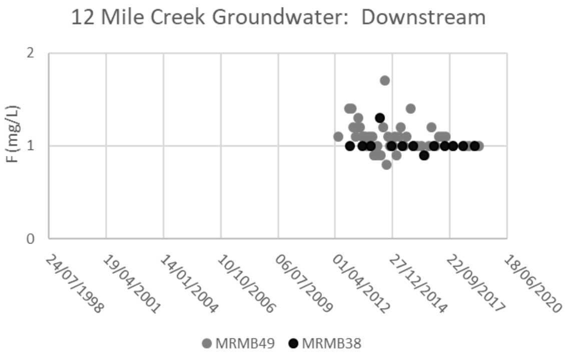

12 Mile Creek Groundwater: Upstream

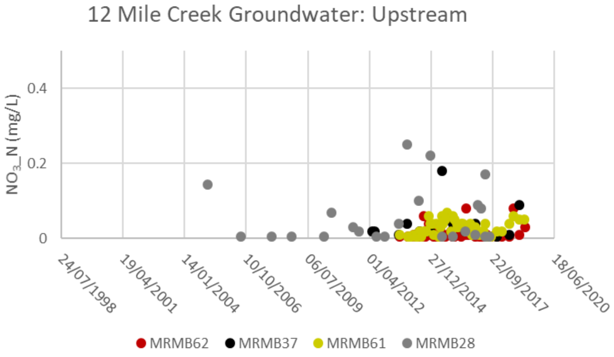

12 Mile Creek Groundwater: Mine affected

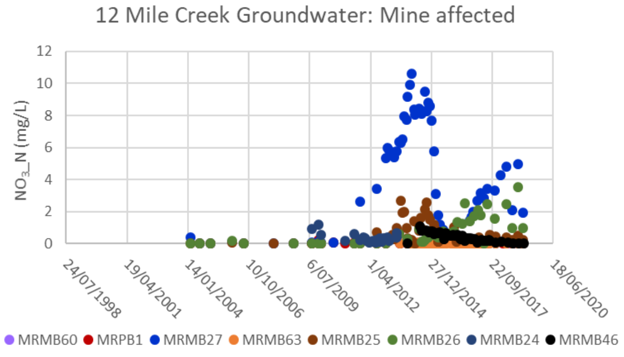

12 Mile Creek Groundwater: Downstream

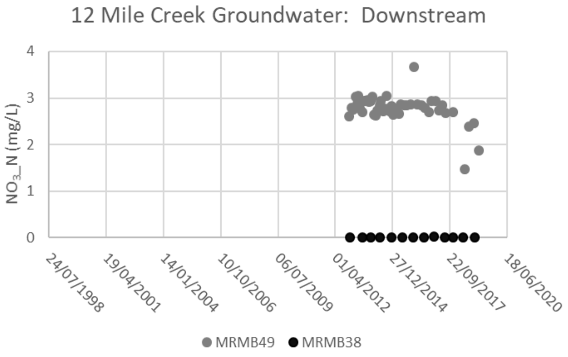

12 Mile Creek Groundwater: Upstream

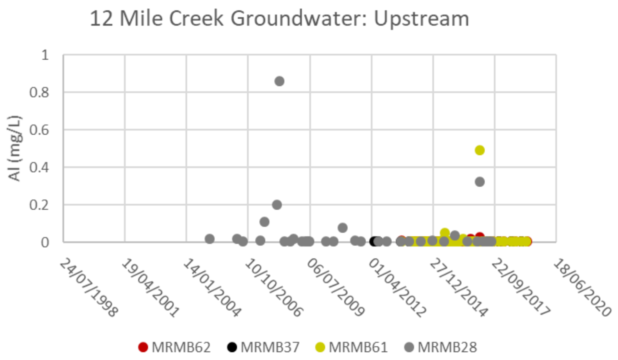

12 Mile Creek Groundwater: Mine affected

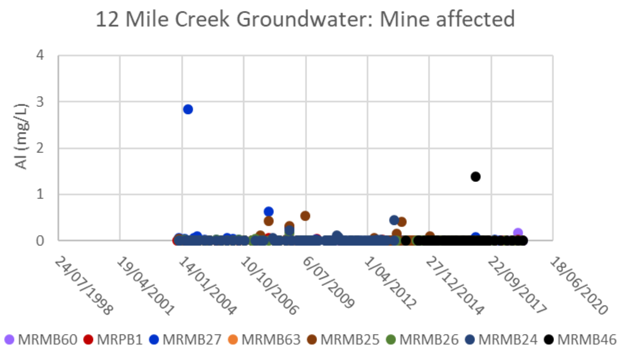

12 Mile Creek Groundwater: Downstream

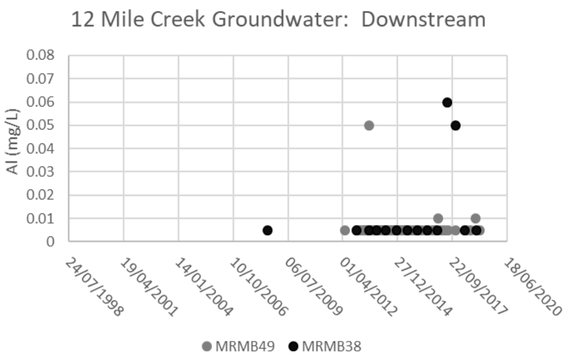

12 Mile Creek Groundwater: Upstream

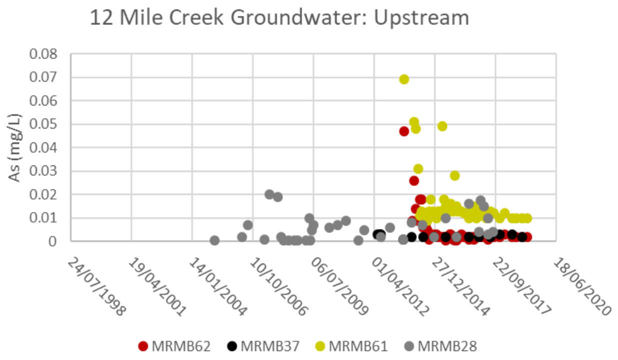

12 Mile Creek Groundwater: Mine affected

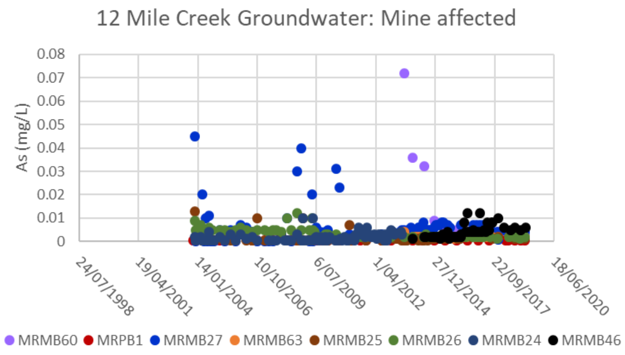

12 Mile Creek Groundwater: Downstream

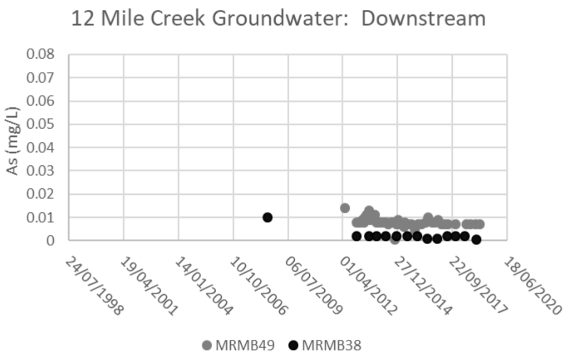

12 Mile Creek Groundwater: Upstream
Al (mg/L)
1
0.8
0.6
0.4
0.2
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
MRMB62
MRMB37
MRMB61
MRMB28

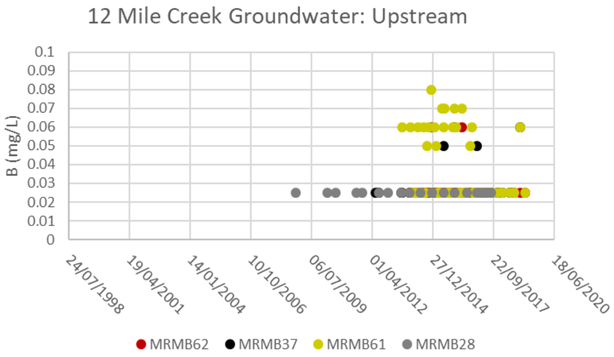

12 Mile Creek Groundwater: Mine affected
Al (mg/L)
4
3
2
1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
22/09/2017
18/06/2020
MRMB60
MRPB1
MRMB27
MRMB63
MRMB25
MRMB26
MRMB24
MRMB46

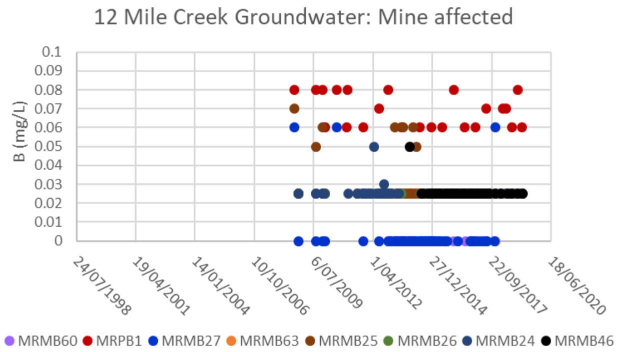

12 Mile Creek Groundwater: Downstream
Al (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
MRMB49
MRMB38

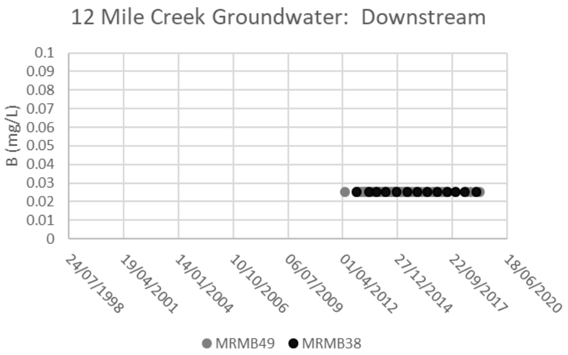

12 Mile Creek Groundwater: Upstream
As (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
MRMB62
MRMB37
MRMB61
MRMB28

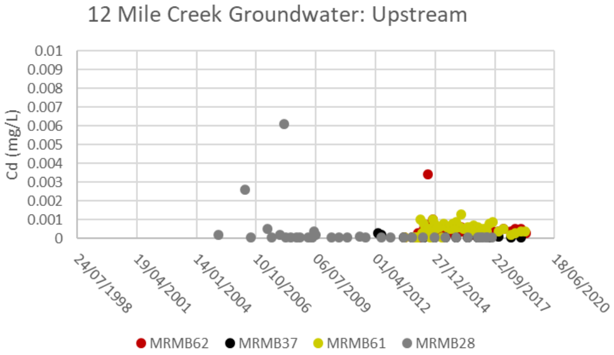

12 Mile Creek Groundwater: Mine affected
As (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
22/09/2017
18/06/2020
MRMB60
MRPB1
MRMB27
MRMB63
MRMB25
MRMB26
MRMB24
MRMB46

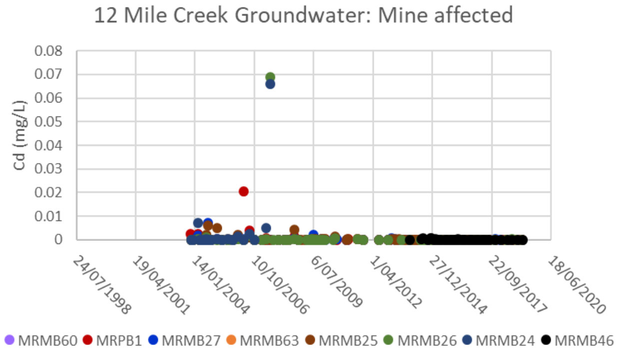

12 Mile Creek Groundwater: Downstream
As (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
MRMB49
MRMB38

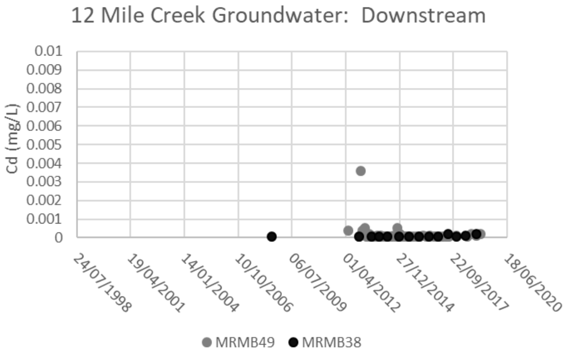

12 Mile Creek Groundwater: Upstream
B (mg/L)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB62 ● MRMB37 ● MRMB61 ● MRMB28

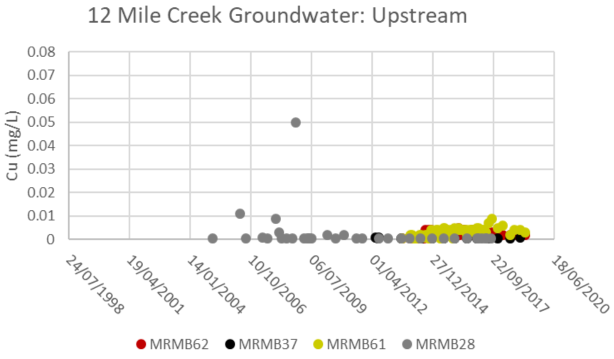

12 Mile Creek Groundwater: Mine affected
B (mg/L)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB60 ● MRPB1 ● MRMB27 ● MRMB63 ● MRMB25 ● MRMB26 ● MRMB24 ● MRMB46

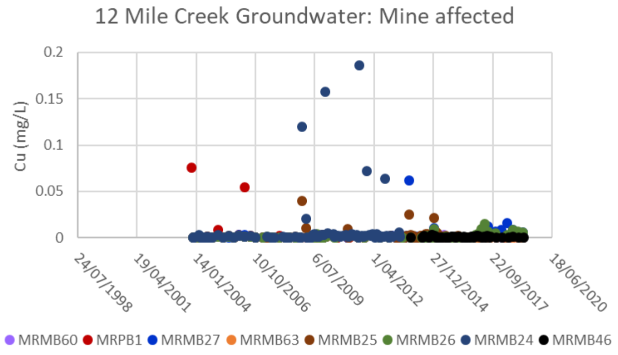

12 Mile Creek Groundwater: Downstream
B (mg/L)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB49 ● MRMB38

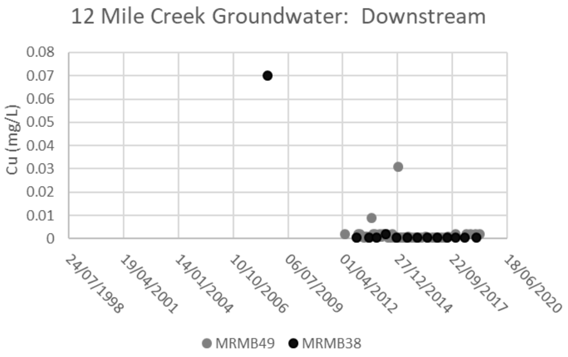

12 Mile Creek Groundwater: Upstream
Cd (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB62 ● MRMB37 ● MRMB61 ● MRMB28

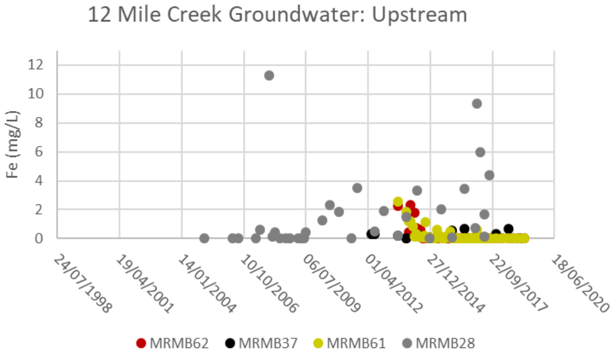

12 Mile Creek Groundwater: Mine affected
Cd (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB60 ● MRPB1 ● MRMB27 ● MRMB63 ● MRMB25 ● MRMB26 ● MRMB24 ● MRMB46

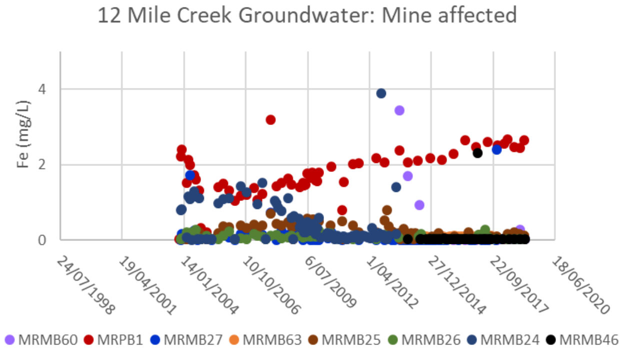

12 Mile Creek Groundwater: Downstream
Cd (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB49 ● MRMB38

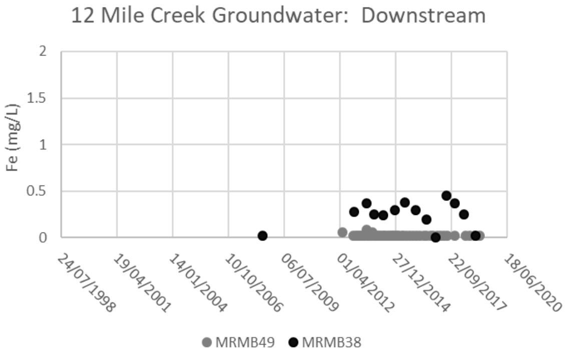

12 Mile Creek Groundwater: Upstream
Cu (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB62 ● MRMB37 ● MRMB61 ● MRMB28

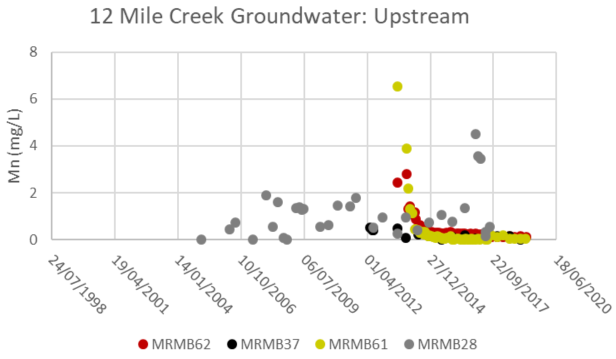

12 Mile Creek Groundwater: Mine affected
Cu (mg/L)
0.2
0.15
0.1
0.05
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB60 ● MRPB1 ● MRMB27 ● MRMB63 ● MRMB25 ● MRMB26 ● MRMB24 ● MRMB46

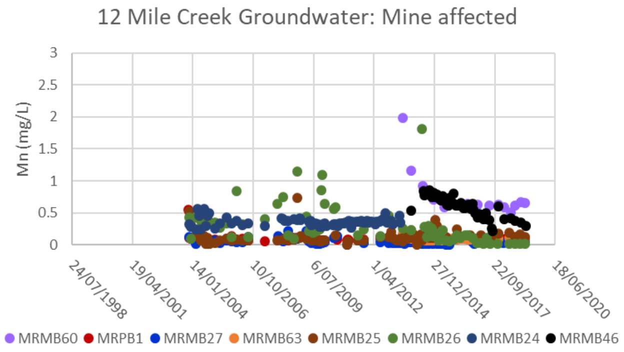

12 Mile Creek Groundwater: Downstream
Cu (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB49 ● MRMB38

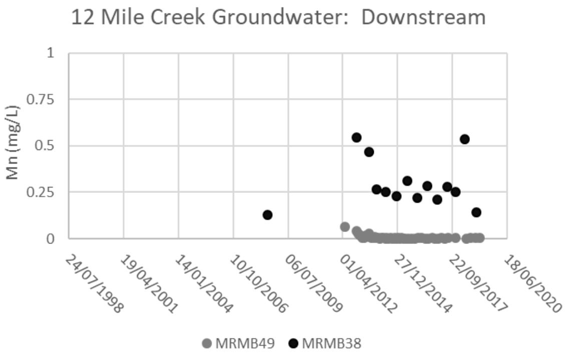

12 Mile Creek Groundwater: Upstream
Fe (mg/L)
12
10
8
6
4
2
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB62 ● MRMB37 ● MRMB61 ● MRMB28

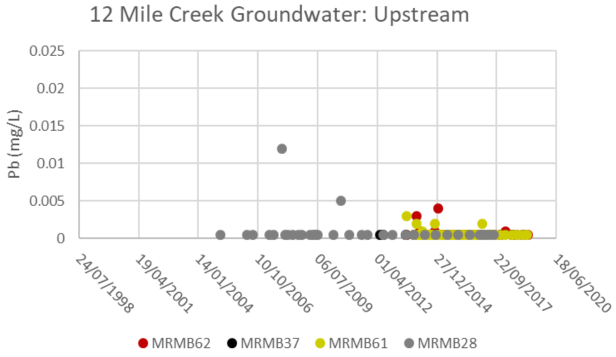

12 Mile Creek Groundwater: Mine affected
Fe (mg/L)
4
2
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB60 ● MRPB1 ● MRMB27 ● MRMB63 ● MRMB25 ● MRMB26 ● MRMB24 ● MRMB46

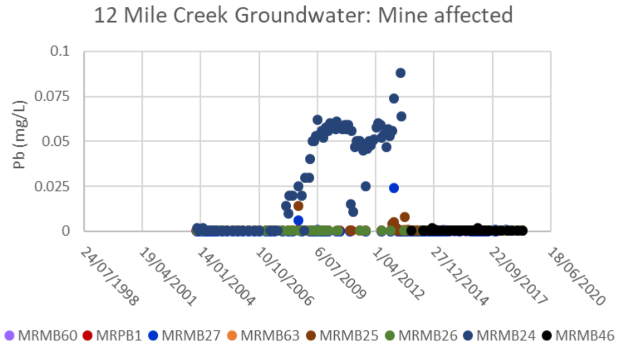

12 Mile Creek Groundwater: Downstream
Fe (mg/L)
2
1.5
1
0.5
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB49 ● MRMB38

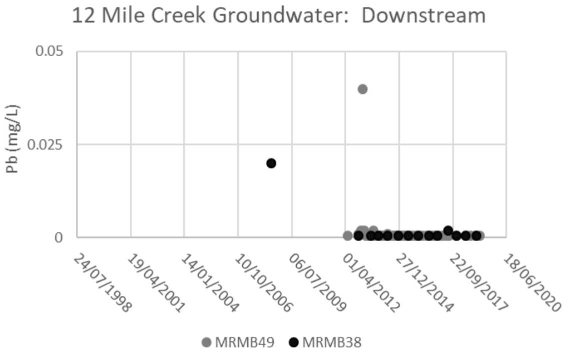

12 Mile Creek Groundwater: Upstream
Mn (mg/L)
8
6
4
2
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB62
● MRMB37
● MRMB61
● MRMB28

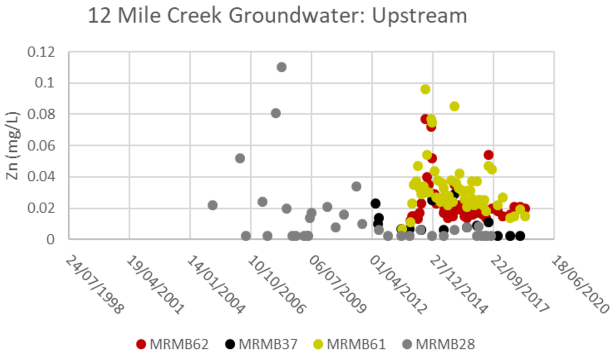

12 Mile Creek Groundwater: Mine affected
Mn (mg/L)
3
2.5
2
1.5
1
0.5
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB60
● MRPB1
● MRMB27
● MRMB63
● MRMB25
● MRMB26
● MRMB24
● MRMB46

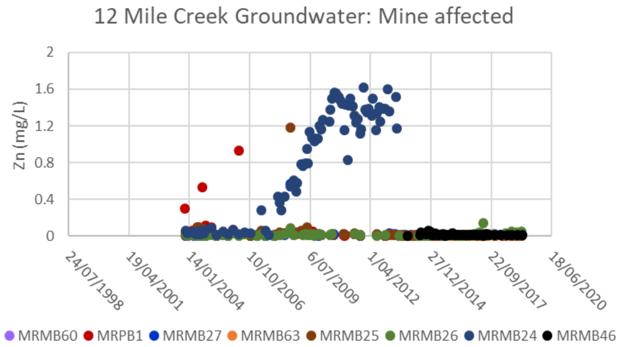

12 Mile Creek Groundwater: Downstream
Mn (mg/L)
1
0.75
0.5
0.25
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB49
● MRMB38

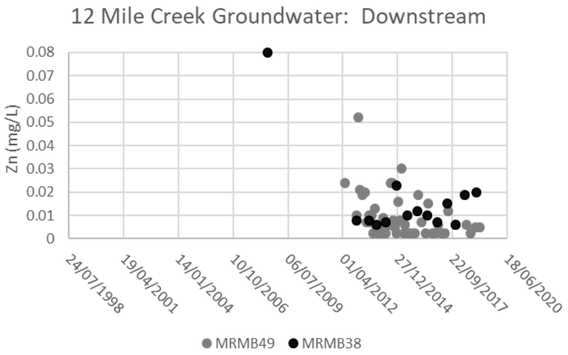

12 Mile Creek Groundwater: Upstream
Pb (mg/L)
0.025
0.02
0.015
0.01
0.005
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB62
● MRMB37
● MRMB61
● MRMB28

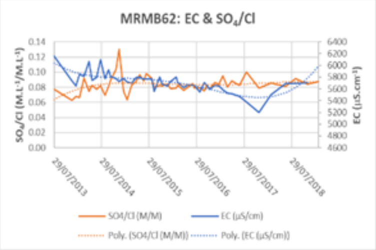

12 Mile Creek Groundwater: Mine affected
Pb (mg/L)
0.1
0.075
0.05
0.025
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB60
● MRPB1
● MRMB27
● MRMB63
● MRMB25
● MRMB26
● MRMB24
● MRMB46

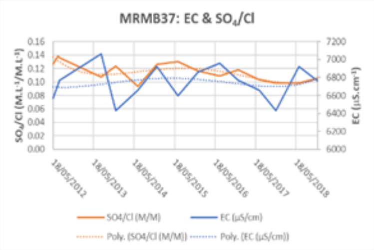

12 Mile Creek Groundwater: Downstream
Pb (mg/L)
0.05
0.025
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB49
● MRMB38

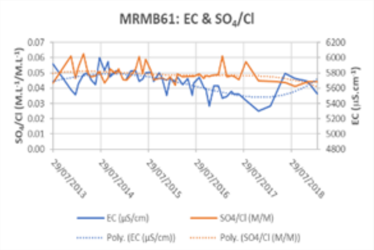

12 Mile Creek Groundwater: Upstream

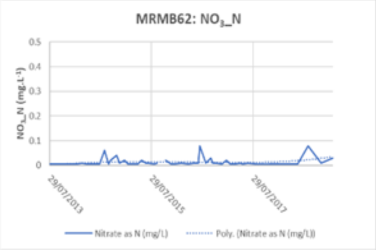

12 Mile Creek Groundwater: Mine affected

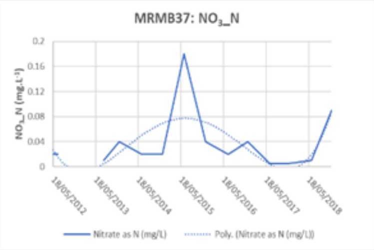

12 Mile Creek Groundwater: Downstream

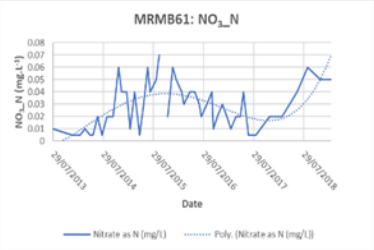

MRMB62: EC & SO₄/Cl
SO₄/Cl (M.L⁻¹/M.L⁻¹)
EC (µS.cm⁻¹)
0.14 0.12 0.10 0.08 0.06 0.04 0.02 0.00
6400 6200 6000 5800 5600 5400 5200 5000 4800 4600
29/07/2013 29/07/2014 29/07/2015 29/07/2016 29/07/2017 29/07/2018
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))

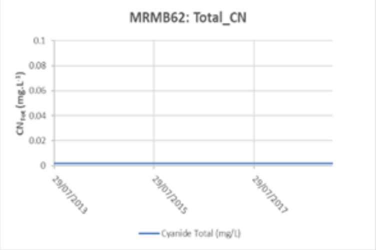

MRMB37: EC & SO₄/Cl
SO₄/Cl (M.L⁻¹/M.L⁻¹)
EC (µS.cm⁻¹)
0.16 0.14 0.12 0.10 0.08 0.06 0.04 0.02 0.00
7200 7000 6800 6600 6400 6200 6000
18/05/2012 18/05/2013 18/05/2014 18/05/2015 18/05/2016 18/05/2017 18/05/2018
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))

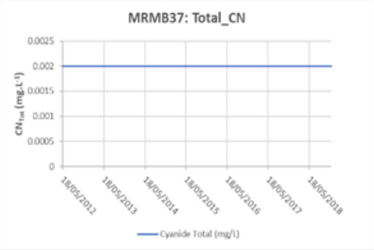

MRMB61: EC & SO₄/Cl
SO₄/Cl (M.L⁻¹/M.L⁻¹)
EC (µS.cm⁻¹)
0.07 0.06 0.05 0.04 0.03 0.02 0.01 0.00
6200 6000 5800 5600 5400 5200 5000 4800
29/07/2013 29/07/2014 29/07/2015 29/07/2016 29/07/2017 29/07/2018
EC (µS/cm)
SO4/Cl (M/M)
Poly. (EC (µS/cm))
Poly. (SO4/Cl (M/M))

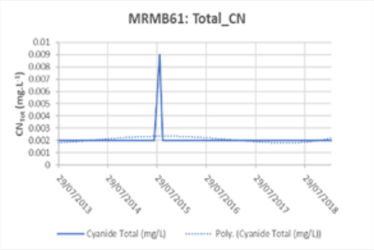

MRMB62: NO₃_N
NO₃_N (mg.L⁻¹)
0.5 0.4 0.3 0.2 0.1 0
29/07/2013 29/07/2015 29/07/2017
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

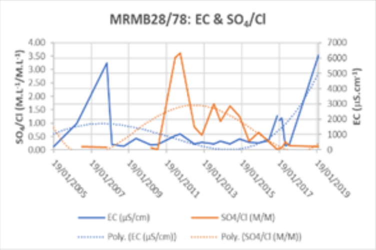

MRMB37: NO₃_N
NO₃_N (mg.L⁻¹)
0.2 0.16 0.12 0.08 0.04 0
18/05/2012 18/05/2013 18/05/2014 18/05/2015 18/05/2016 18/05/2017 18/05/2018
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

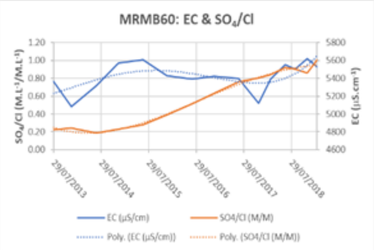

MRMB61: NO₃_N
NO₃_N (mg.L⁻¹)
0.08 0.07 0.06 0.05 0.04 0.03 0.02 0.01 0
29/07/2013 29/07/2014 29/07/2015 29/07/2016 29/07/2017 29/07/2018
Date
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

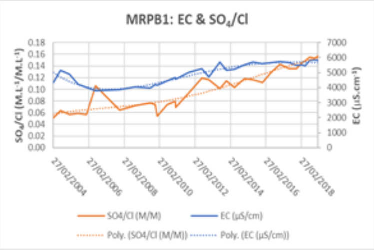

MRMB62: Total_CN
CN_tot (mg.L⁻¹)
0.1 0.08 0.06 0.04 0.02 0
29/07/2013 29/07/2015 29/07/2017
Cyanide Total (mg/L)

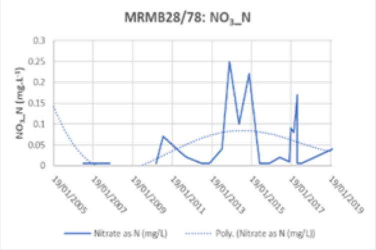

MRMB37: Total_CN
CN_tot (mg.L⁻¹)
0.0025 0.002 0.0015 0.001 0.0005 0
18/05/2012 18/05/2013 18/05/2014 18/05/2015 18/05/2016 18/05/2017 18/05/2018
Cyanide Total (mg/L)

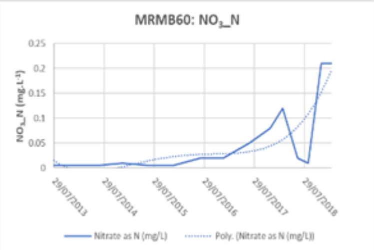

MRMB61: Total_CN
CN_tot (mg.L⁻¹)
0.01 0.009 0.008 0.007 0.006 0.005 0.004 0.003 0.002 0.001 0
29/07/2013 29/07/2014 29/07/2015 29/07/2016 29/07/2017 29/07/2018
Cyanide Total (mg/L)
Poly. (Cyanide Total (mg/L))

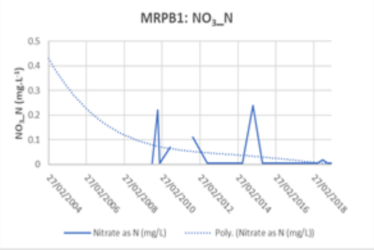

MRMB28/78: EC & SO₄/Cl
SO₄/Cl (M.L⁻¹/M.L⁻¹)
EC (µS.cm⁻¹)
4.00 3.50 3.00 2.50 2.00 1.50 1.00 0.50 0.00
7000 6000 5000 4000 3000 2000 1000 0
19/01/2005 19/01/2007 19/01/2009 19/01/2011 19/01/2013 19/01/2015 19/01/2017 19/01/2019
EC (µS/cm)
SO4/Cl (M/M)
Poly. (EC (µS/cm))
Poly. (SO4/Cl (M/M))

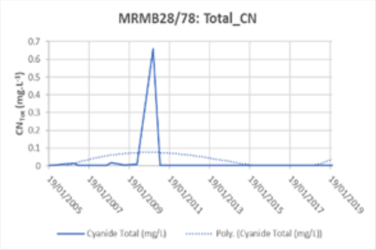

MRMB60: EC & SO₄/Cl
SO₄/Cl (M.L⁻¹/M.L⁻¹)
EC (µS.cm⁻¹)
1.20 1.00 0.80 0.60 0.40 0.20 0.00
5800 5600 5400 5200 5000 4800 4600
29/07/2013 29/07/2014 29/07/2015 29/07/2016 29/07/2017 29/07/2018
EC (µS/cm)
SO4/Cl (M/M)
Poly. (EC (µS/cm))
Poly. (SO4/Cl (M/M))

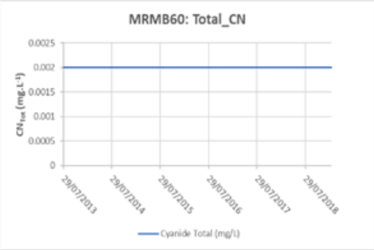

MRPB1: EC & SO₄/Cl
SO₄/Cl (M.L⁻¹/M.L⁻¹)
EC (µS.cm⁻¹)
0.18 0.16 0.14 0.12 0.10 0.08 0.06 0.04 0.02 0.00
7000 6000 5000 4000 3000 2000 1000 0
27/02/2004 27/02/2006 27/02/2008 27/02/2010 27/02/2012 27/02/2014 27/02/2016 27/02/2018
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))

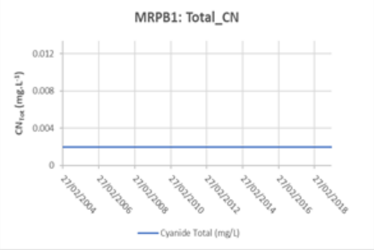

MRMB28/78: NO₃_N
NO₃_N (mg.L⁻¹)
0.3 0.25 0.2 0.15 0.1 0.05 0
19/01/2005 19/01/2007 19/01/2009 19/01/2011 19/01/2013 19/01/2015 19/01/2017 19/01/2019
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

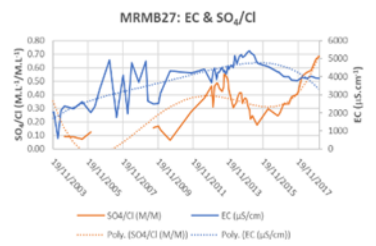

MRMB60: NO₃_N
NO₃_N (mg.L⁻¹)
0.25 0.2 0.15 0.1 0.05 0
29/07/2013 29/07/2014 29/07/2015 29/07/2016 29/07/2017 29/07/2018
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

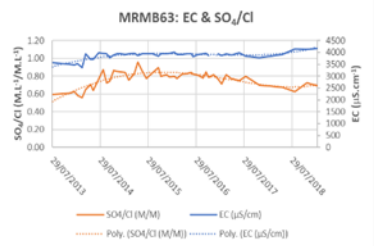

MRPB1: NO₃_N
NO₃_N (mg.L⁻¹)
0.5 0.4 0.3 0.2 0.1 0
27/02/2004 27/02/2006 27/02/2008 27/02/2010 27/02/2012 27/02/2014 27/02/2016 27/02/2018
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

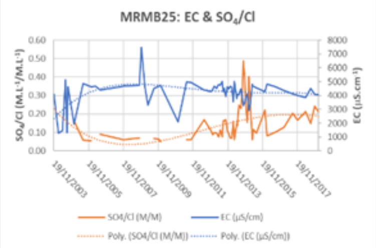

MRMB28/78: Total_CN
CN_tot (mg.L⁻¹)
0.7 0.6 0.5 0.4 0.3 0.2 0.1 0
19/01/2005 19/01/2007 19/01/2009 19/01/2011 19/01/2013 19/01/2015 19/01/2017 19/01/2019
Cyanide Total (mg/L)
Poly. (Cyanide Total (mg/L))

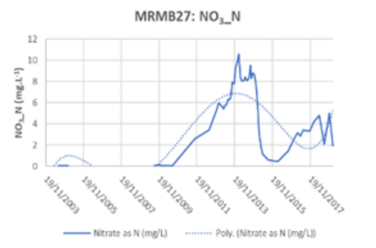

MRMB60: Total_CN
CN_tot (mg.L⁻¹)
0.0025 0.002 0.0015 0.001 0.0005 0
29/07/2013 29/07/2014 29/07/2015 29/07/2016 29/07/2017 29/07/2018
Cyanide Total (mg/L)

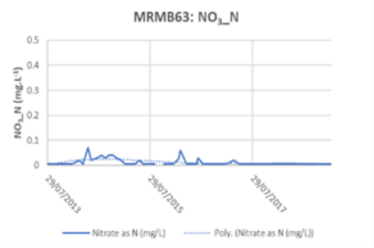

MRPB1: Total_CN
CN_tot (mg.L⁻¹)
0.012 0.008 0.004 0
27/02/2004 27/02/2006 27/02/2008 27/02/2010 27/02/2012 27/02/2014 27/02/2016 27/02/2018
Cyanide Total (mg/L)

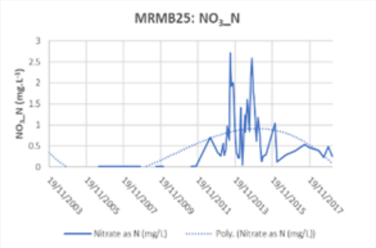

MRMB27: EC & SO$_4$/Cl
SO$_4$/Cl (M.L^{-1}/M.L^{-1})
EC (µS.cm^{-1})
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))

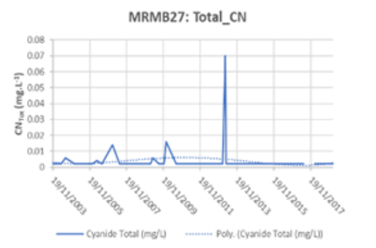

MRMB63: EC & SO$_4$/Cl
SO$_4$/Cl (M.L^{-1}/M.L^{-1})
EC (µS.cm^{-1})
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))

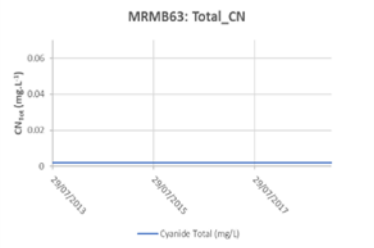

MRMB25: EC & SO$_4$/Cl
SO$_4$/Cl (M.L^{-1}/M.L^{-1})
EC (µS.cm^{-1})
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))

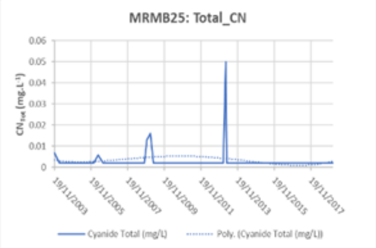

MRMB27: NO$_3$_N
NO$_3$_N (mg.L^{-1})
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

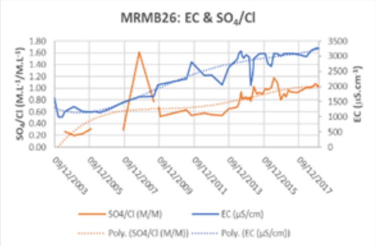

MRMB63: NO$_3$_N
NO$_3$_N (mg.L^{-1})
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

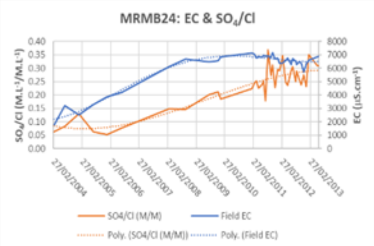

MRMB25: NO$_3$_N
NO$_3$_N (mg.L^{-1})
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

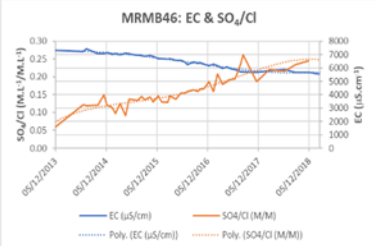

MRMB27: Total_CN
CN$_{tot}$ (mg.L^{-1})
Cyanide Total (mg/L)
Poly. (Cyanide Total (mg/L))

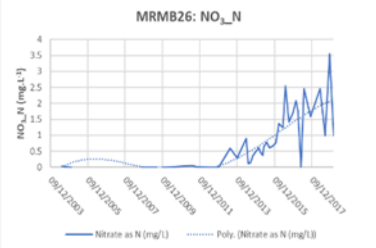

MRMB63: Total_CN
CN$_{tot}$ (mg.L^{-1})
Cyanide Total (mg/L)

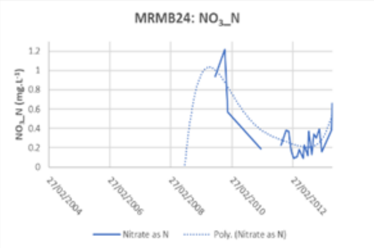

MRMB25: Total_CN
CN$_{tot}$ (mg.L^{-1})
Cyanide Total (mg/L)
Poly. (Cyanide Total (mg/L))

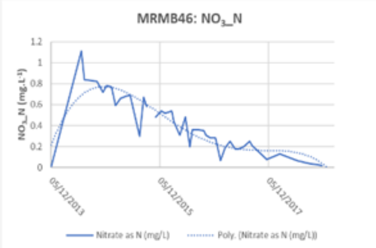

MRMB26: EC & SO$_4$/Cl
SO$_4$/Cl (M.L^{-1}/M.L^{-1})
EC (µS.cm^{-1})
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))

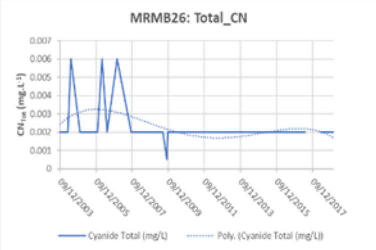

MRMB24: EC & SO$_4$/Cl
SO$_4$/Cl (M.L^{-1}/M.L^{-1})
EC (µS.cm^{-1})
SO4/Cl (M/M)
Field EC
Poly. (SO4/Cl (M/M))
Poly. (Field EC)

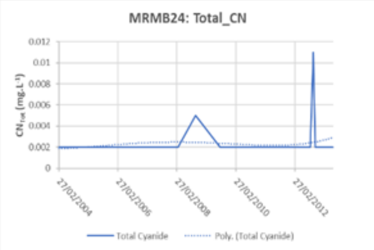

MRMB46: EC & SO$_4$/Cl
SO$_4$/Cl (M.L^{-1}/M.L^{-1})
EC (µS.cm^{-1})
EC (µS/cm)
SO4/Cl (M/M)
Poly. (EC (µS/cm))
Poly. (SO4/Cl (M/M))

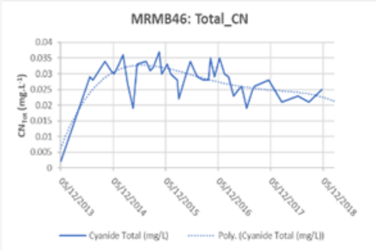

MRMB26: NO$_3$_N
NO$_3$_N (mg.L^{-1})
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

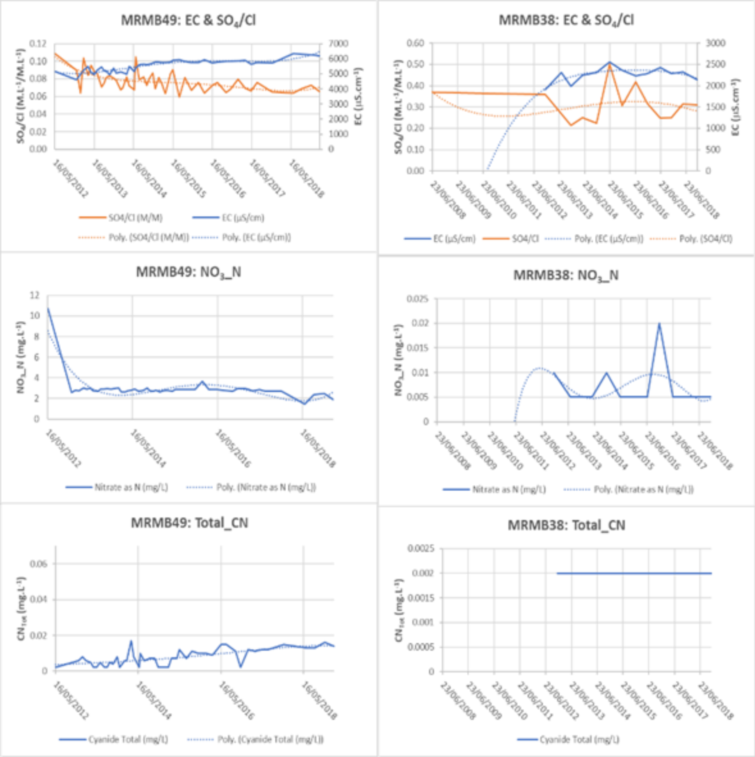

MRMB24: NO$_3$_N
NO$_3$_N (mg.L^{-1})
Nitrate as N
Poly. (Nitrate as N)


MRMB46: NO$_3$_N
NO$_3$_N (mg.L^{-1})
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

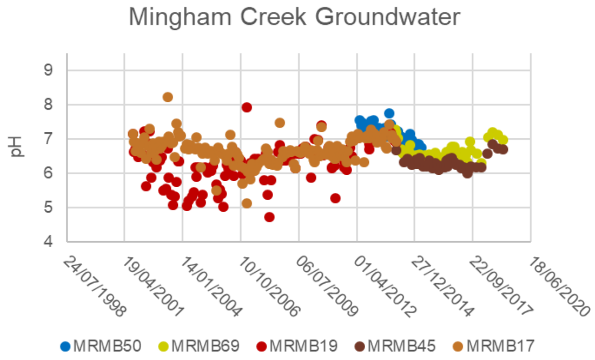

MRMB26: Total_CN
CN$_{tot}$ (mg.L^{-1})
Cyanide Total (mg/L)
Poly. (Cyanide Total (mg/L))

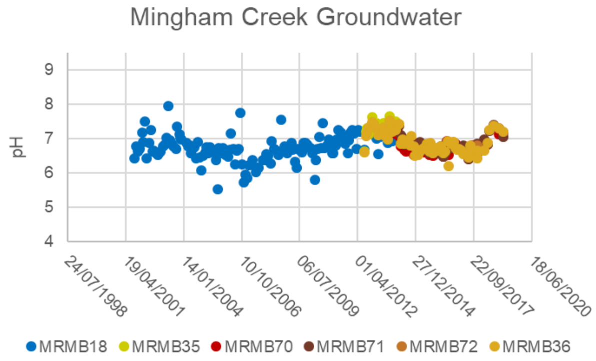

MRMB24: Total_CN
CN$_{tot}$ (mg.L^{-1})
Total Cyanide
Poly. (Total Cyanide)

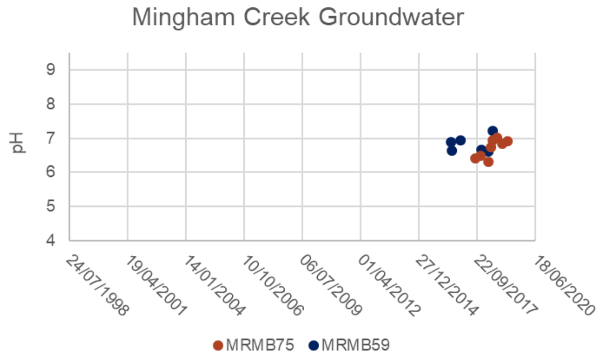

MRMB46: Total_CN
CN$_{tot}$ (mg.L^{-1})
Cyanide Total (mg/L)
Poly. (Cyanide Total (mg/L))

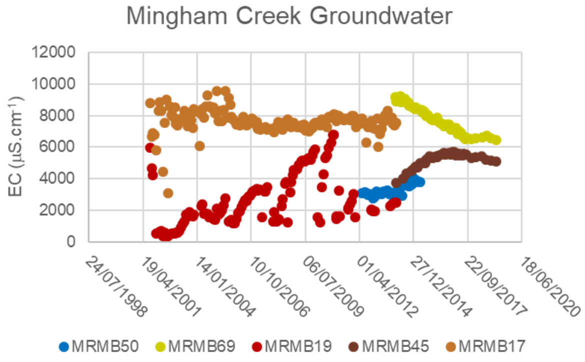

MRMB49: EC & SO$_4$/Cl
SO$_4$/Cl (M.L^{-1}/M.L^{-1})
EC (µS.cm^{-1})
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0
1000
2000
3000
4000
5000
6000
7000
16/05/2012
16/05/2013
16/05/2014
16/05/2015
16/05/2016
16/05/2017
16/05/2018
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))
MRMB38: EC & SO$_4$/Cl
SO$_4$/Cl (M.L^{-1}/M.L^{-1})
EC (µS.cm^{-1})
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0
500
1000
1500
2000
2500
3000
23/06/2008
23/06/2009
23/06/2010
23/06/2011
23/06/2012
23/06/2013
23/06/2014
23/06/2015
23/06/2016
23/06/2017
23/06/2018
EC (µS/cm)
SO4/Cl
Poly. (EC (µS/cm))
Poly. (SO4/Cl)
MRMB49: NO$_3$_N
NO$_3$_N (mg.L^{-1})
0
2
4
6
8
10
12
16/05/2012
16/05/2014
16/05/2016
16/05/2018
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))
MRMB38: NO$_3$_N
NO$_3$_N (mg.L^{-1})
0
0.005
0.01
0.015
0.02
0.025
23/06/2008
23/06/2009
23/06/2010
23/06/2011
23/06/2012
23/06/2013
23/06/2014
23/06/2015
23/06/2016
23/06/2017
23/06/2018
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))
MRMB49: Total_CN
CN$_{tot}$ (mg.L^{-1})
0
0.02
0.04
0.06
16/05/2012
16/05/2014
16/05/2016
16/05/2018
Cyanide Total (mg/L)
Poly. (Cyanide Total (mg/L))
MRMB38: Total_CN
CN$_{tot}$ (mg.L^{-1})
0
0.0005
0.001
0.0015
0.002
0.0025
23/06/2008
23/06/2009
23/06/2010
23/06/2011
23/06/2012
23/06/2013
23/06/2014
23/06/2015
23/06/2016
23/06/2017
23/06/2018
Cyanide Total (mg/L)

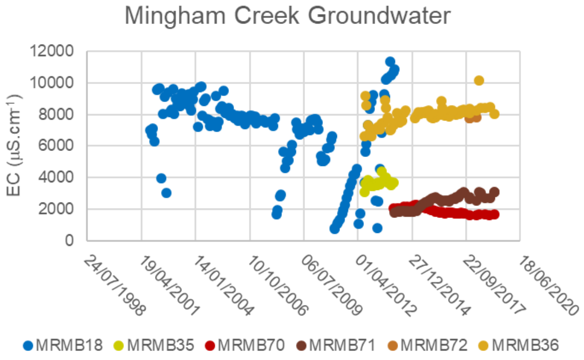
8.4.6 Time Series Charts for Mingham Creek

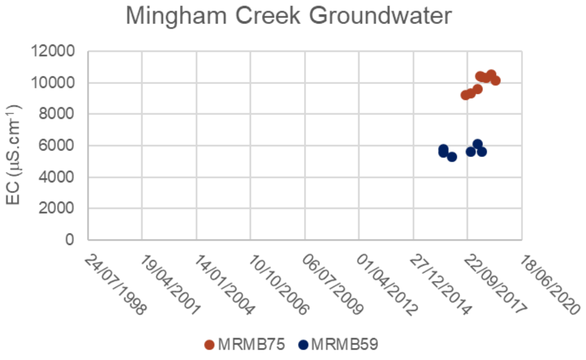

Mingham Creek Groundwater

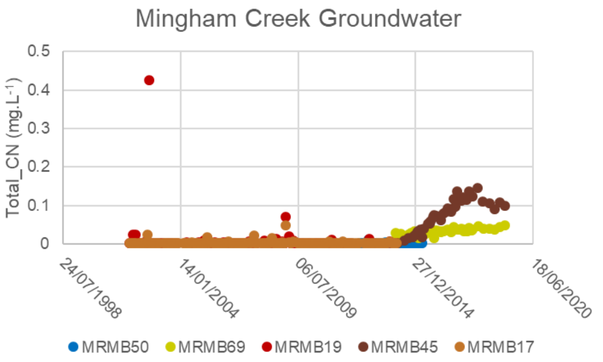

Mingham Creek Groundwater

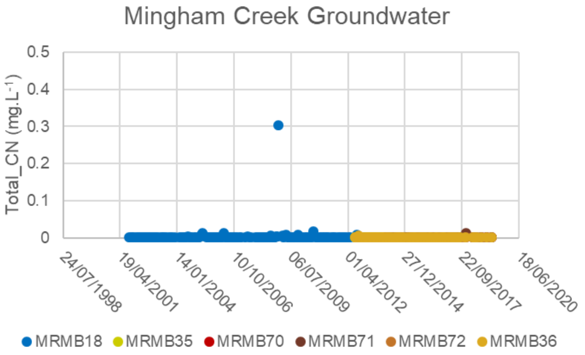

Mingham Creek Groundwater

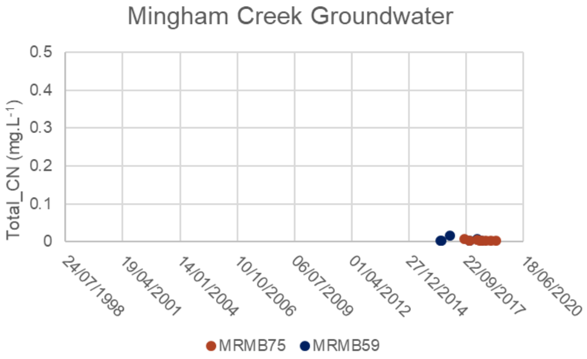

Mingham Creek Groundwater

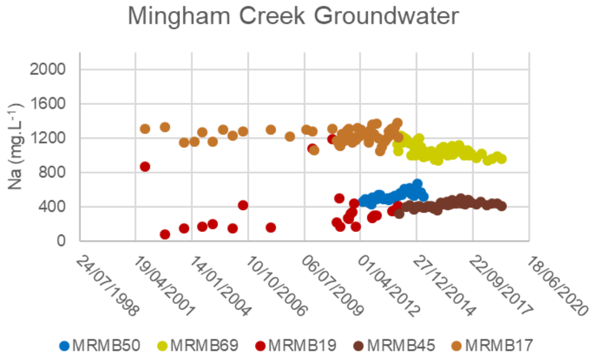

Mingham Creek Groundwater

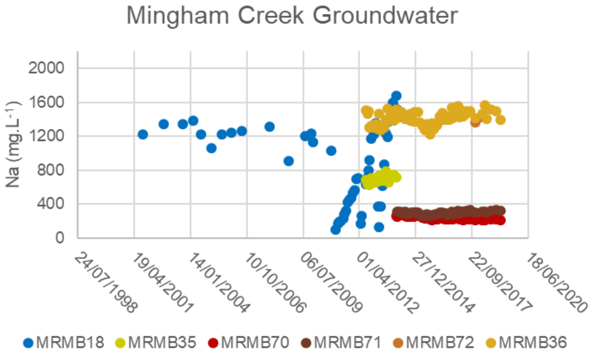

Mingham Creek Groundwater

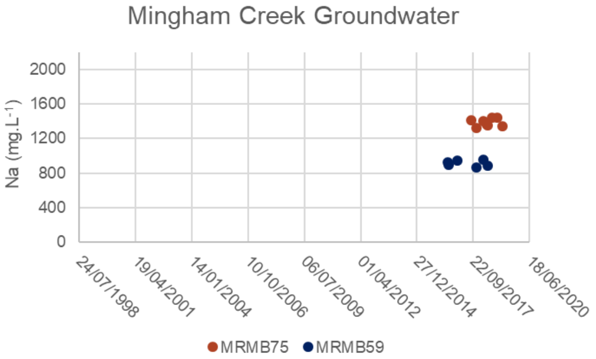

Mingham Creek Groundwater
Total_CN (mg.L-1)
0.5
0.4
0.3
0.2
0.1
0
24/07/1998
14/01/2004
06/07/2009
27/12/2014
18/06/2020
● MRMB50 ● MRMB69 ● MRMB19 ● MRMB45 ● MRMB17

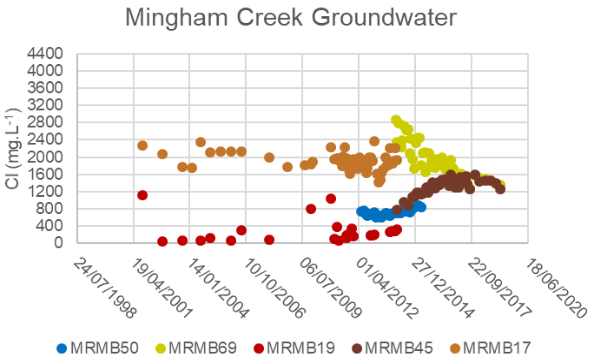

Mingham Creek Groundwater
Total_CN (mg.L-1)
0.5
0.4
0.3
0.2
0.1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB18 ● MRMB35 ● MRMB70 ● MRMB71 ● MRMB72 ● MRMB36

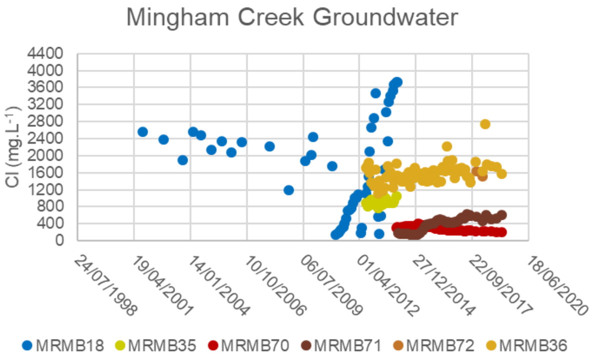

Mingham Creek Groundwater
Total_CN (mg.L-1)
0.5
0.4
0.3
0.2
0.1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB75 ● MRMB59

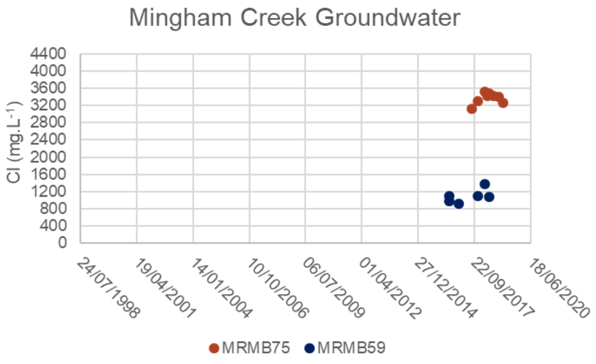

Mingham Creek Groundwater
Na (mg.L-1)
2000
1600
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB50 ● MRMB69 ● MRMB19 ● MRMB45 ● MRMB17

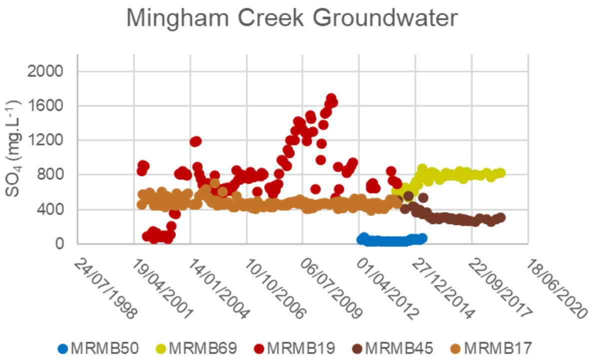

Mingham Creek Groundwater
Na (mg.L-1)
2000
1600
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB18 ● MRMB35 ● MRMB70 ● MRMB71 ● MRMB72 ● MRMB36

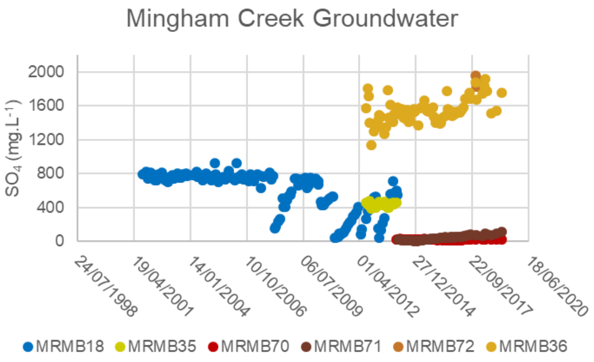

Mingham Creek Groundwater
Na (mg.L-1)
2000
1600
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB75 ● MRMB59

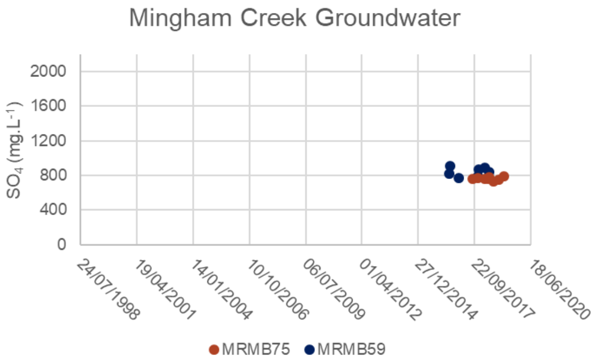

Mingham Creek Groundwater
Cl (mg.L⁻¹)
4400
4000
3600
3200
2800
2400
2000
1600
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB50 ● MRMB69 ● MRMB19 ● MRMB45 ● MRMB17

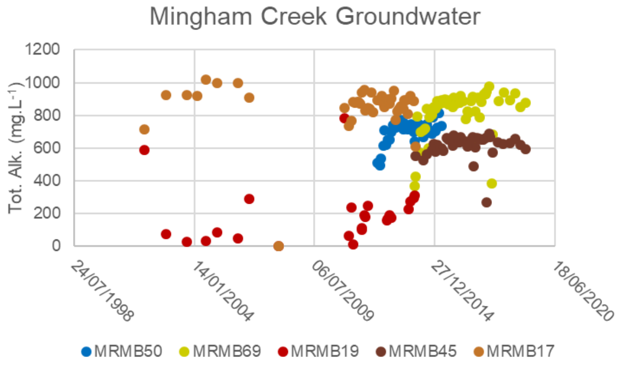

Mingham Creek Groundwater
Cl (mg.L⁻¹)
4400
4000
3600
3200
2800
2400
2000
1600
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB18 ● MRMB35 ● MRMB70 ● MRMB71 ● MRMB72 ● MRMB36

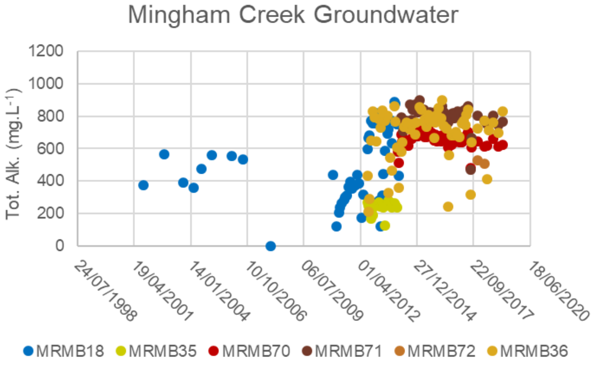

Mingham Creek Groundwater
Cl (mg.L⁻¹)
4400
4000
3600
3200
2800
2400
2000
1600
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB75 ● MRMB59

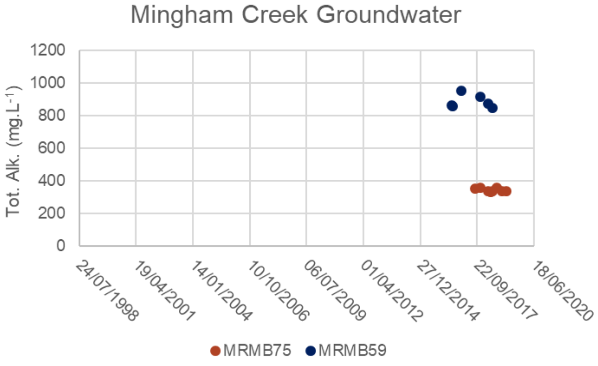

Mingham Creek Groundwater
SO₄ (mg.L⁻¹)
2000
1600
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB50 ● MRMB69 ● MRMB19 ● MRMB45 ● MRMB17

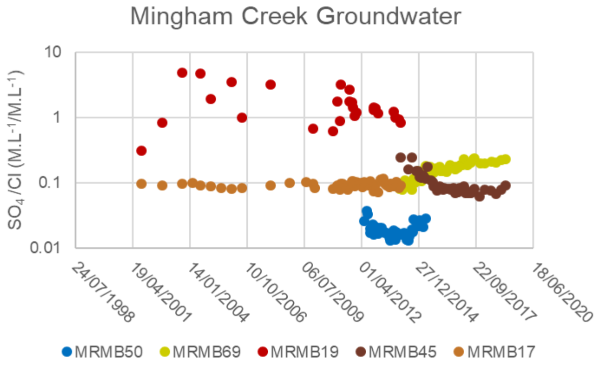

Mingham Creek Groundwater
SO₄ (mg.L⁻¹)
2000
1600
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB18 ● MRMB35 ● MRMB70 ● MRMB71 ● MRMB72 ● MRMB36

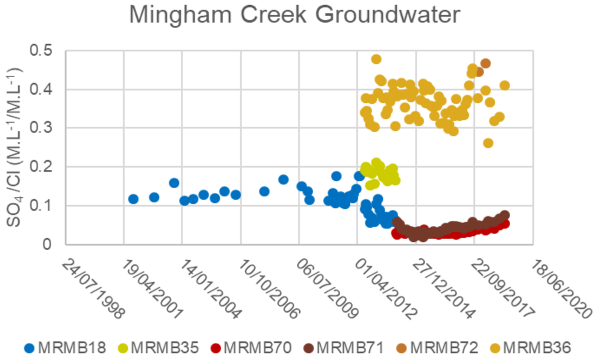

Mingham Creek Groundwater
SO₄ (mg.L⁻¹)
2000
1600
1200
800
400
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB75 ● MRMB59

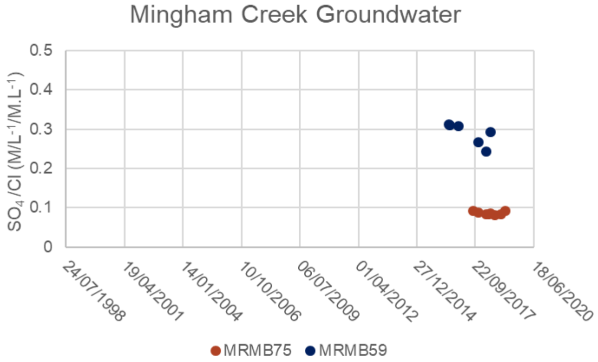

Mingham Creek Groundwater
Tot. Alk. (mg.L^{-1})
1200
1000
800
600
400
200
0
24/07/1998
14/01/2004
06/07/2009
27/12/2014
18/06/2020
● MRMB50
● MRMB69
● MRMB19
● MRMB45
● MRMB17

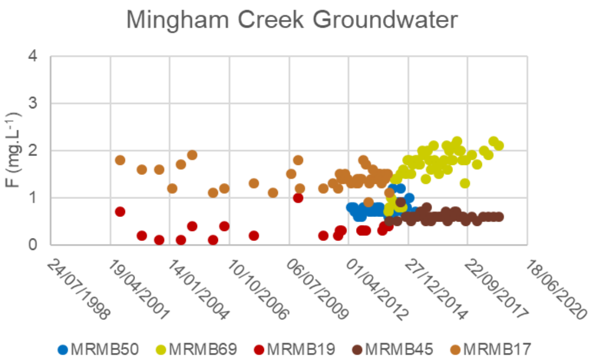

Mingham Creek Groundwater
Tot. Alk. (mg.L^{-1})
1200
1000
800
600
400
200
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB18
● MRMB35
● MRMB70
● MRMB71
● MRMB72
● MRMB36

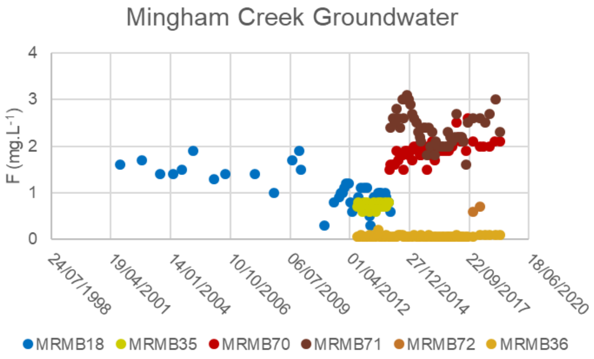

Mingham Creek Groundwater
Tot. Alk. (mg.L^{-1})
1200
1000
800
600
400
200
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB75
● MRMB59

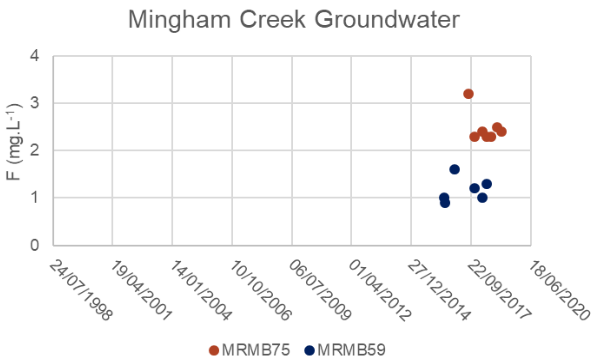

Mingham Creek Groundwater
SO$_4$/Cl (M.L^{-1}/M.L^{-1})
10
1
0.1
0.01
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB50
● MRMB69
● MRMB19
● MRMB45
● MRMB17

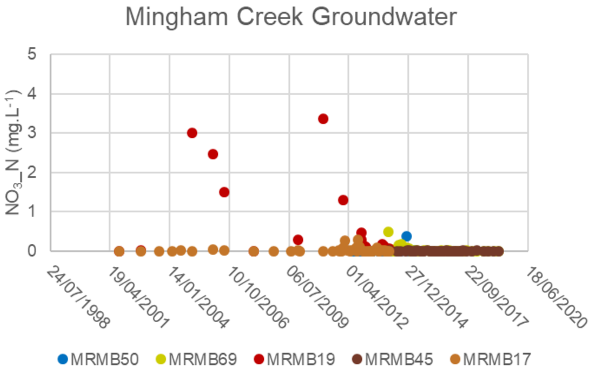

Mingham Creek Groundwater
SO$_4$/Cl (M.L^{-1}/M.L^{-1})
0.5
0.4
0.3
0.2
0.1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB18
● MRMB35
● MRMB70
● MRMB71
● MRMB72
● MRMB36

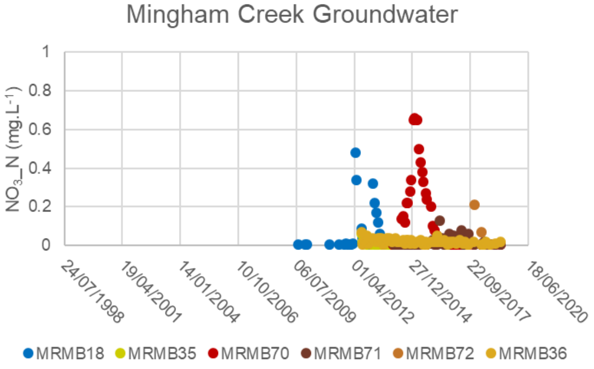

Mingham Creek Groundwater
SO$_4$/Cl (M/L^{-1}/M.L^{-1})
0.5
0.4
0.3
0.2
0.1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB75
● MRMB59

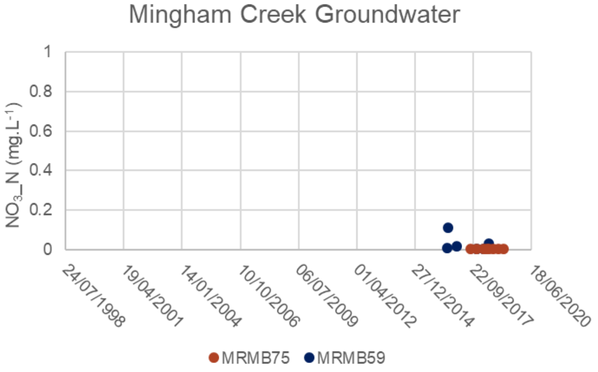

Mingham Creek Groundwater
F (mg.L-1)
0
1
2
3
4
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
●MRMB50 ●MRMB69 ●MRMB19 ●MRMB45 ●MRMB17

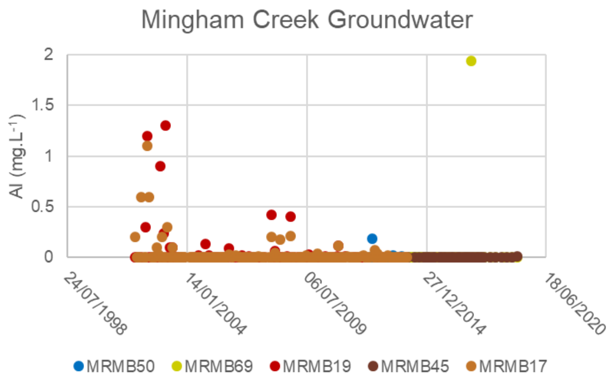

Mingham Creek Groundwater
F (mg.L-1)
0
1
2
3
4
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
●MRMB18 ●MRMB35 ●MRMB70 ●MRMB71 ●MRMB72 ●MRMB36

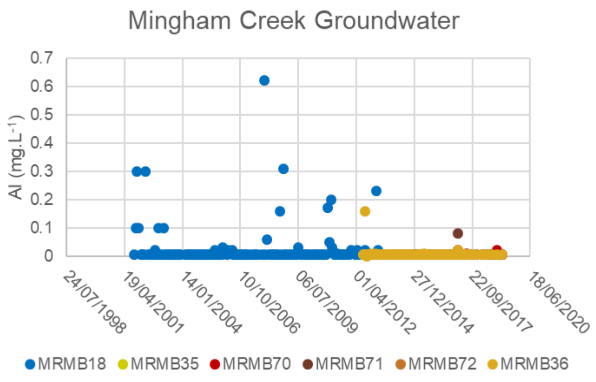

Mingham Creek Groundwater
F (mg.L-1)
0
1
2
3
4
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
●MRMB75 ●MRMB59

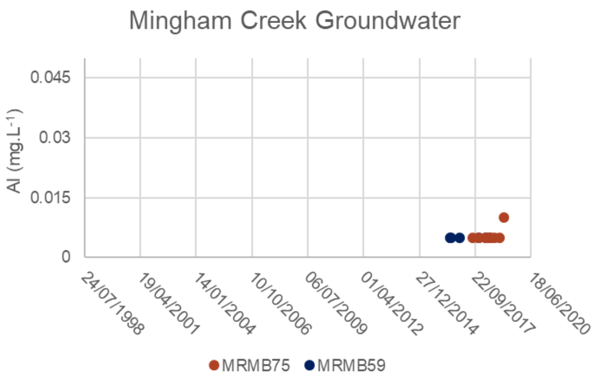

Mingham Creek Groundwater
NO3_N (mg.L-1)
0
1
2
3
4
5
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
●MRMB50 ●MRMB69 ●MRMB19 ●MRMB45 ●MRMB17

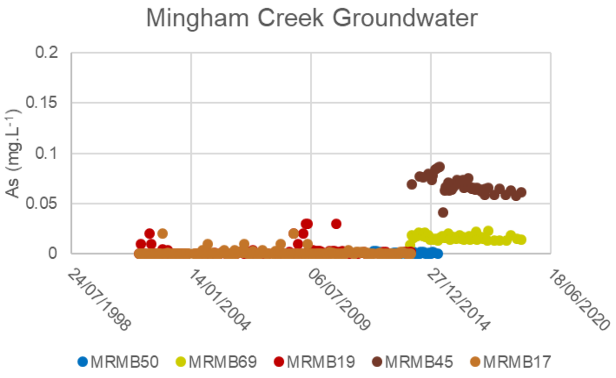

Mingham Creek Groundwater
NO3_N (mg.L-1)
0
0.2
0.4
0.6
0.8
1
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
●MRMB18 ●MRMB35 ●MRMB70 ●MRMB71 ●MRMB72 ●MRMB36

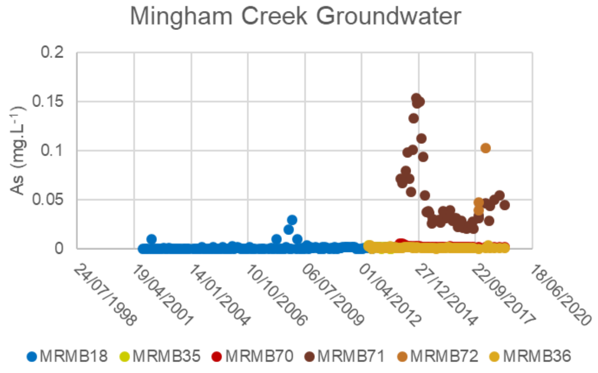

Mingham Creek Groundwater
NO3_N (mg.L-1)
0
0.2
0.4
0.6
0.8
1
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
●MRMB75 ●MRMB59

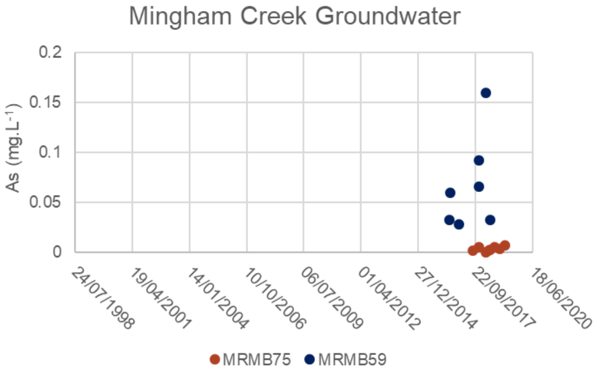

Mingham Creek Groundwater
Al (mg.L^{-1})
2
1.5
1
0.5
0
24/07/1998
14/01/2004
06/07/2009
27/12/2014
18/06/2020
● MRMB50 ● MRMB69 ● MRMB19 ● MRMB45 ● MRMB17

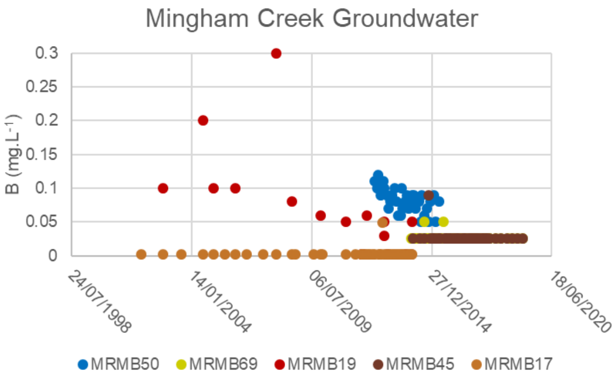

Mingham Creek Groundwater
Al (mg.L^{-1})
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB18 ● MRMB35 ● MRMB70 ● MRMB71 ● MRMB72 ● MRMB36

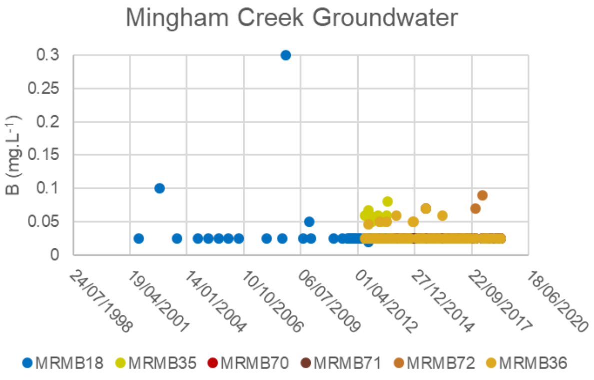

Mingham Creek Groundwater
Al (mg.L^{-1})
0.045
0.03
0.015
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB75 ● MRMB59

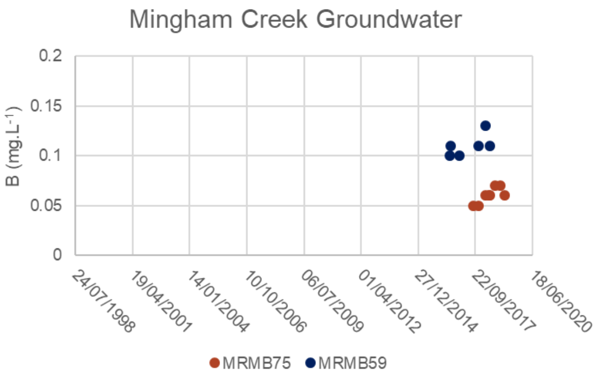

Mingham Creek Groundwater
As (mg.L^{-1})
0.2
0.15
0.1
0.05
0
24/07/1998
14/01/2004
06/07/2009
27/12/2014
18/06/2020
● MRMB50 ● MRMB69 ● MRMB19 ● MRMB45 ● MRMB17

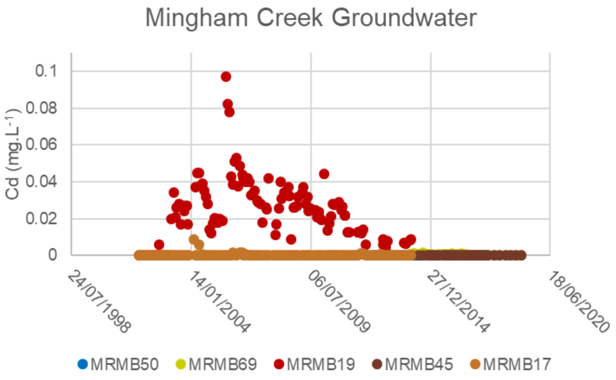

Mingham Creek Groundwater
As (mg.L^{-1})
0.2
0.15
0.1
0.05
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB18 ● MRMB35 ● MRMB70 ● MRMB71 ● MRMB72 ● MRMB36

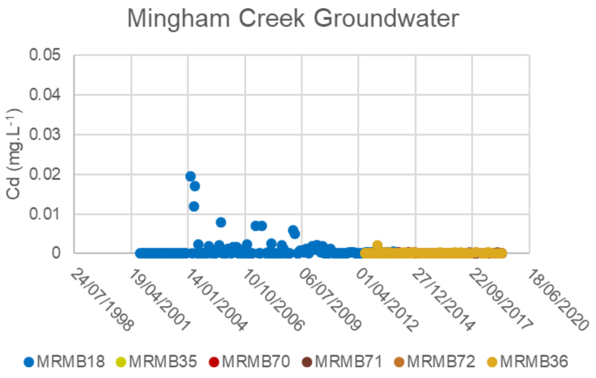

Mingham Creek Groundwater
As (mg.L^{-1})
0.2
0.15
0.1
0.05
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
● MRMB75 ● MRMB59

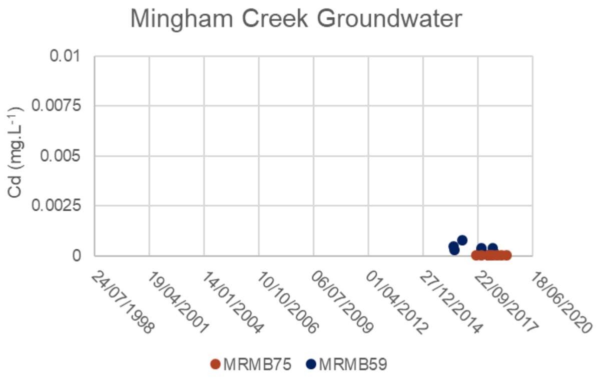

Mingham Creek Groundwater
B (mg.L-1)
0.3
0.25
0.2
0.15
0.1
0.05
0
24/07/1998
14/01/2004
06/07/2009
27/12/2014
18/06/2020
●MRMB50 ●MRMB69 ●MRMB19 ●MRMB45 ●MRMB17

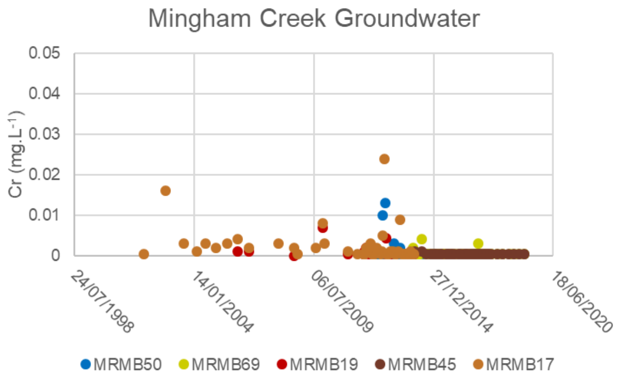

Mingham Creek Groundwater
B (mg.L-1)
0.3
0.25
0.2
0.15
0.1
0.05
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
●MRMB18 ●MRMB35 ●MRMB70 ●MRMB71 ●MRMB72 ●MRMB36

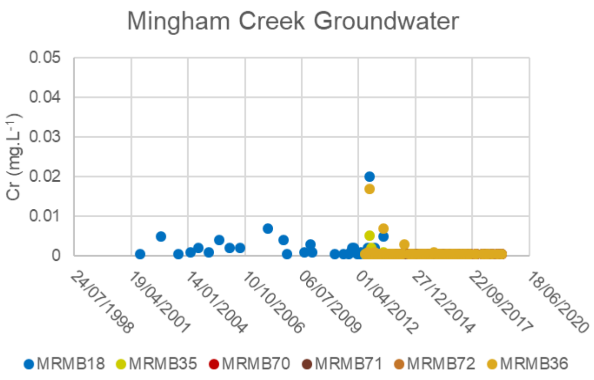

Mingham Creek Groundwater
B (mg.L-1)
0.2
0.15
0.1
0.05
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
●MRMB75 ●MRMB59

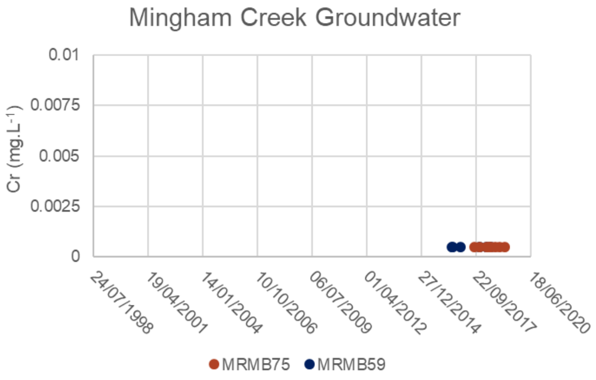

Mingham Creek Groundwater
Cd (mg.L-1)
0.1
0.08
0.06
0.04
0.02
0
24/07/1998
14/01/2004
06/07/2009
27/12/2014
18/06/2020
●MRMB50 ●MRMB69 ●MRMB19 ●MRMB45 ●MRMB17

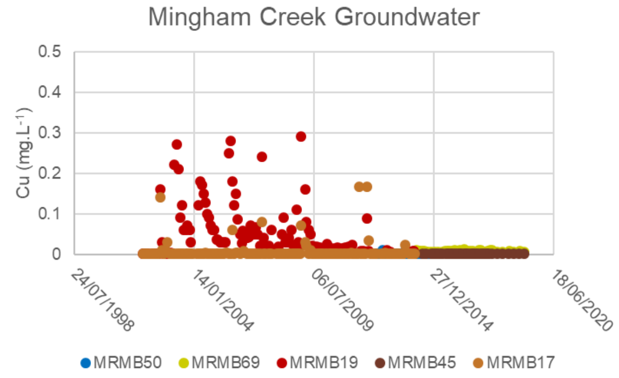

Mingham Creek Groundwater
Cd (mg.L-1)
0.05
0.04
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
●MRMB18 ●MRMB35 ●MRMB70 ●MRMB71 ●MRMB72 ●MRMB36

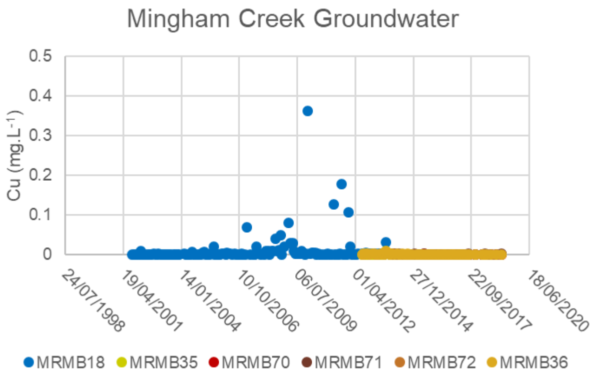

Mingham Creek Groundwater
Cd (mg.L-1)
0.01
0.0075
0.005
0.0025
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
●MRMB75 ●MRMB59

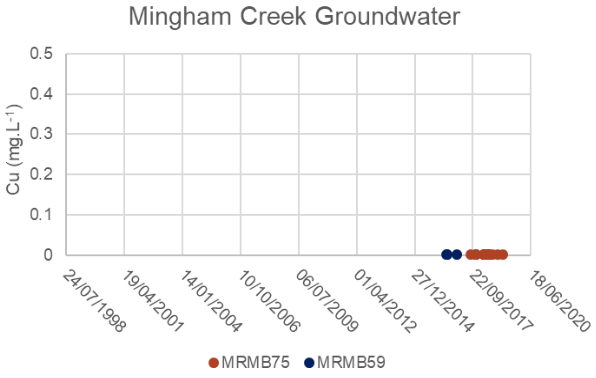

Mingham Creek Groundwater
Cr (mg.L^{-1})
0.05
0.04
0.03
0.02
0.01
0
24/07/1998
14/01/2004
06/07/2009
27/12/2014
18/06/2020
MRMB50
MRMB69
MRMB19
MRMB45
MRMB17

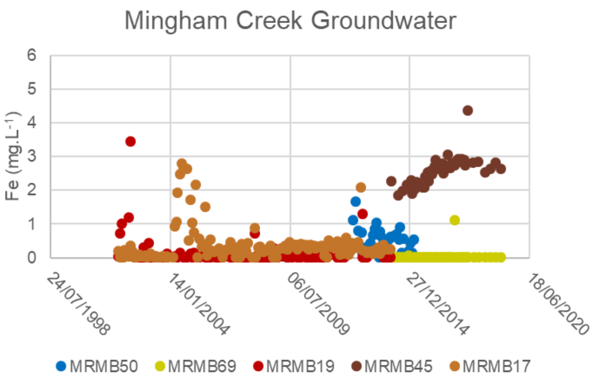

Mingham Creek Groundwater
Cr (mg.L^{-1})
0.05
0.04
0.03
0.02
0.01
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
MRMB18
MRMB35
MRMB70
MRMB71
MRMB72
MRMB36

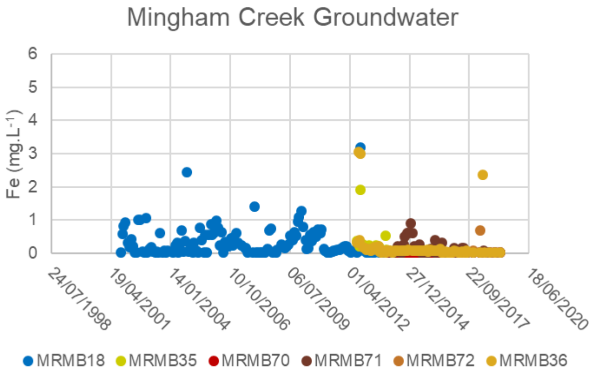

Mingham Creek Groundwater
Cr (mg.L^{-1})
0.01
0.0075
0.005
0.0025
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
MRMB75
MRMB59

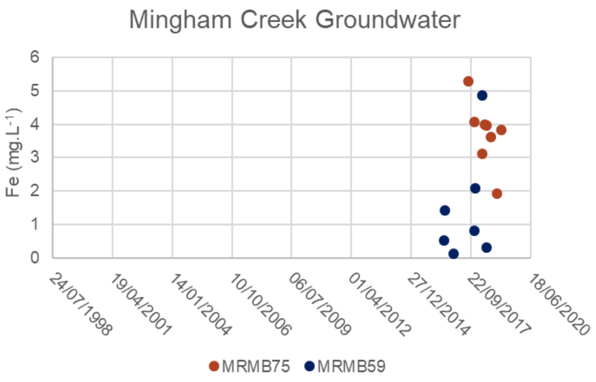

Mingham Creek Groundwater
Cu (mg.L^{-1})
0.5
0.4
0.3
0.2
0.1
0
24/07/1998
14/01/2004
06/07/2009
27/12/2014
18/06/2020
MRMB50
MRMB69
MRMB19
MRMB45
MRMB17

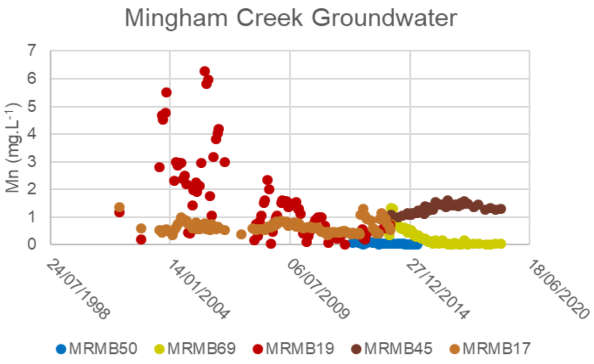

Mingham Creek Groundwater
Cu (mg.L^{-1})
0.5
0.4
0.3
0.2
0.1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
MRMB18
MRMB35
MRMB70
MRMB71
MRMB72
MRMB36

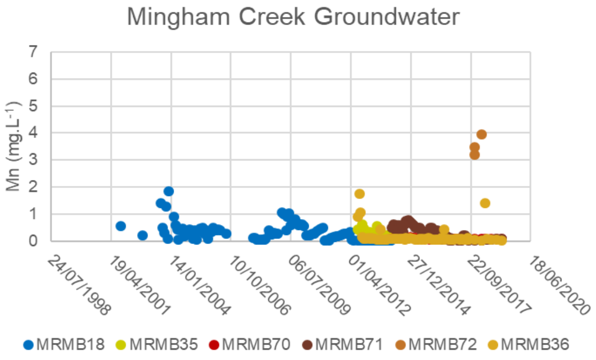

Mingham Creek Groundwater
Cu (mg.L^{-1})
0.5
0.4
0.3
0.2
0.1
0
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
MRMB75
MRMB59

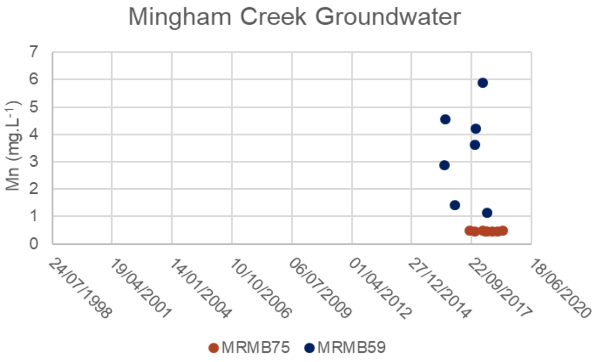

Mingham Creek Groundwater
Fe (mg.L-1)
0
1
2
3
4
5
6
24/07/1998
14/01/2004
06/07/2009
27/12/2014
18/06/2020
MRMB50
MRMB69
MRMB19
MRMB45
MRMB17

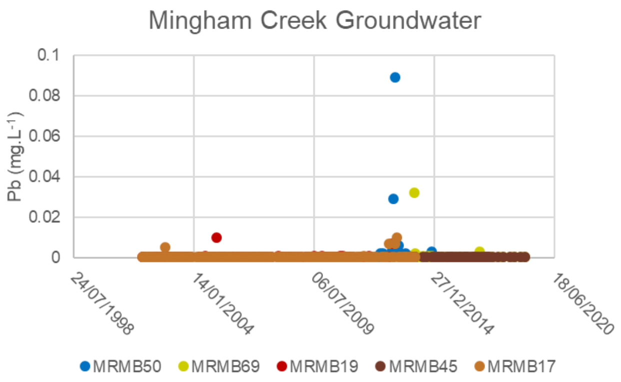

Mingham Creek Groundwater
Fe (mg.L-1)
0
1
2
3
4
5
6
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
MRMB18
MRMB35
MRMB70
MRMB71
MRMB72
MRMB36

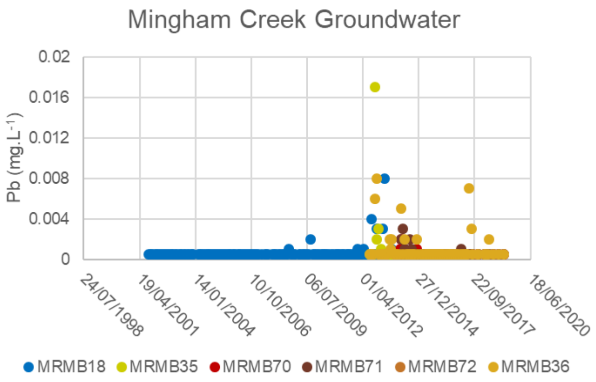

Mingham Creek Groundwater
Fe (mg.L-1)
0
1
2
3
4
5
6
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
MRMB75
MRMB59

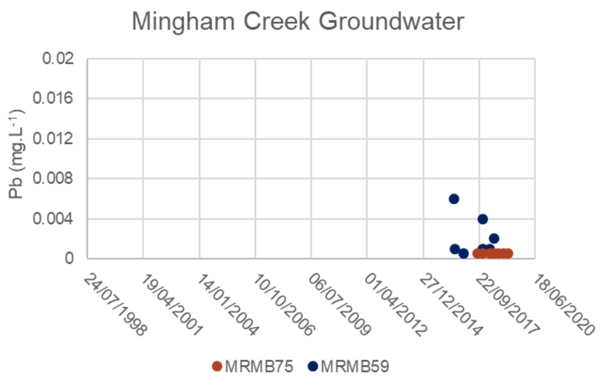

Mingham Creek Groundwater
Mn (mg.L-1)
0
1
2
3
4
5
6
7
24/07/1998
14/01/2004
06/07/2009
27/12/2014
18/06/2020
MRMB50
MRMB69
MRMB19
MRMB45
MRMB17

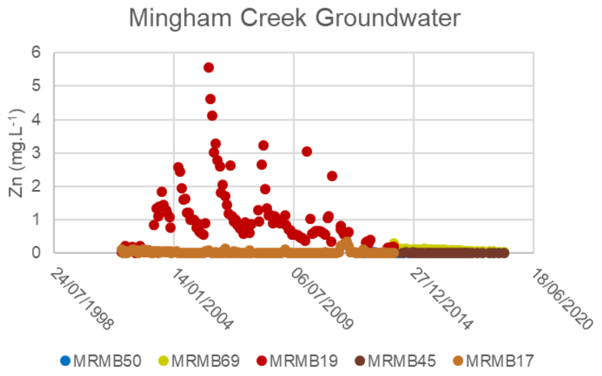

Mingham Creek Groundwater
Mn (mg.L-1)
0
1
2
3
4
5
6
7
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
MRMB18
MRMB35
MRMB70
MRMB71
MRMB72
MRMB36

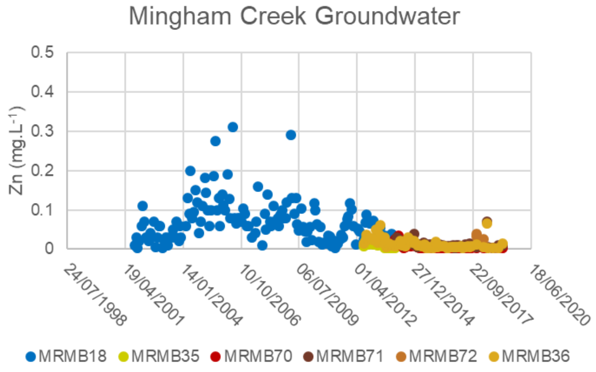

Mingham Creek Groundwater
Mn (mg.L-1)
0
1
2
3
4
5
6
7
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
22/09/2017
18/06/2020
MRMB75
MRMB59

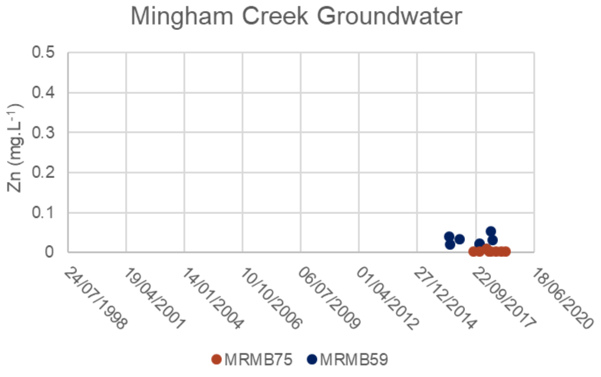

Mingham Creek Groundwater

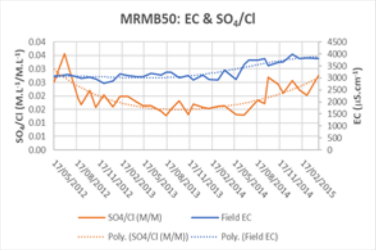

Mingham Creek Groundwater

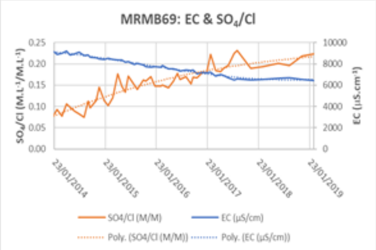

Mingham Creek Groundwater

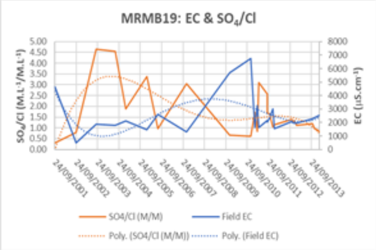

Mingham Creek Groundwater

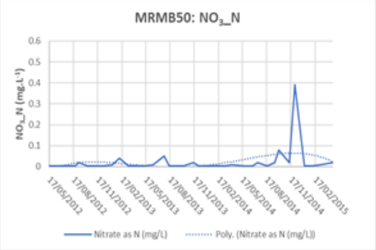

Mingham Creek Groundwater

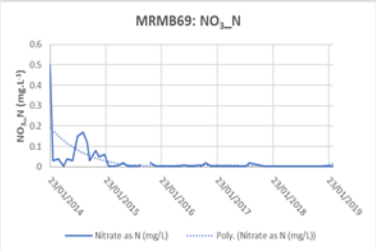

Mingham Creek Groundwater

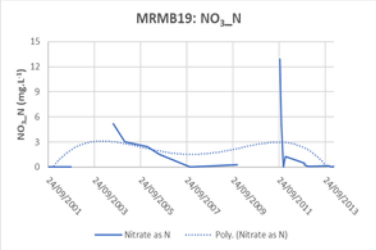

MRMB50: EC & SO4/Cl
SO4/Cl (M.L⁻¹/M.L⁻¹)
EC (µS.cm⁻¹)
SO4/Cl (M/M)
Field EC
Poly. (SO4/Cl (M/M))
Poly. (Field EC)

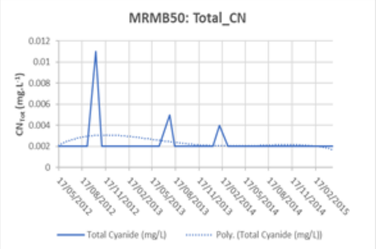

MRMB69: EC & SO4/Cl
SO4/Cl (M.L⁻¹/M.L⁻¹)
EC (µS.cm⁻¹)
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))

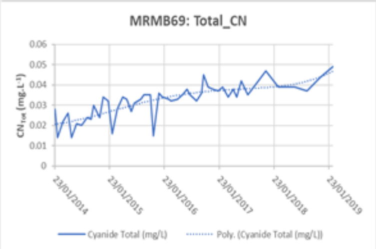

MRMB19: EC & SO4/Cl
SO4/Cl (M.L⁻¹/M.L⁻¹)
EC (µS.cm⁻¹)
SO4/Cl (M/M)
Field EC
Poly. (SO4/Cl (M/M))
Poly. (Field EC)

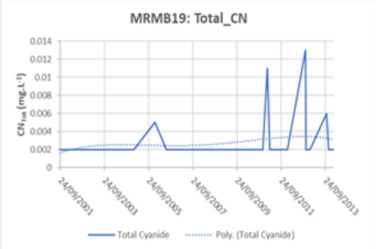

MRMB50: NO3_N
NO3_N (mg.L⁻¹)
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

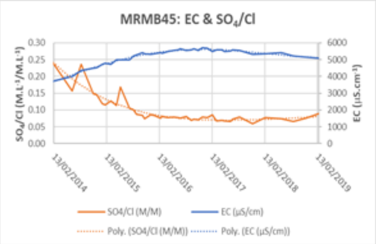

MRMB69: NO3_N
NO3_N (mg.L⁻¹)
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

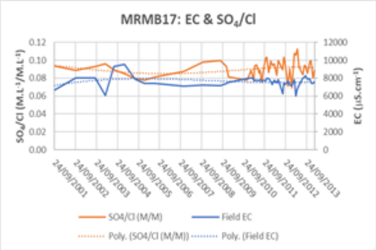

MRMB19: NO3_N
NO3_N (mg.L⁻¹)
Nitrate as N
Poly. (Nitrate as N)

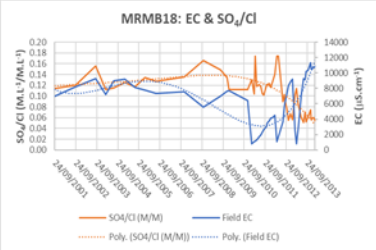

MRMB50: Total_CN
CNtot (mg.L⁻¹)
Total Cyanide (mg/L)
Poly. (Total Cyanide (mg/L))

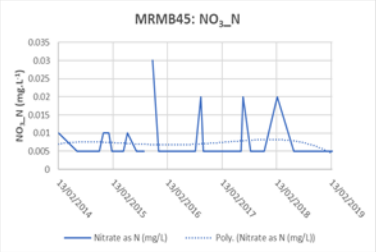

MRMB69: Total_CN
CNtot (mg.L⁻¹)
Cyanide Total (mg/L)
Poly. (Cyanide Total (mg/L))

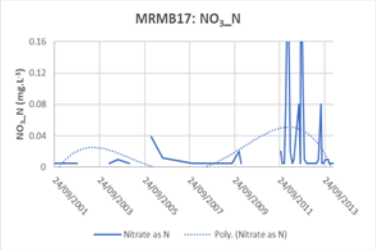

MRMB19: Total_CN
CNtot (mg.L⁻¹)
Total Cyanide
Poly. (Total Cyanide)

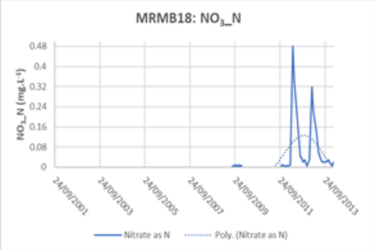

MRMB45: EC & SO4/Cl
SO4/Cl (M.L⁻¹/M.L⁻¹)
EC (µS.cm⁻¹)
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))

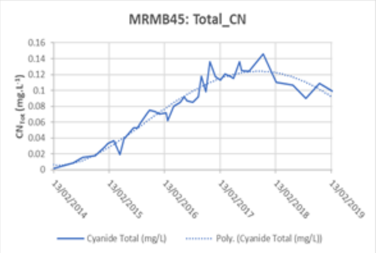

MRMB17: EC & SO4/Cl
SO4/Cl (M.L⁻¹/M.L⁻¹)
EC (µS.cm⁻¹)
SO4/Cl (M/M)
Field EC
Poly. (SO4/Cl (M/M))
Poly. (Field EC)

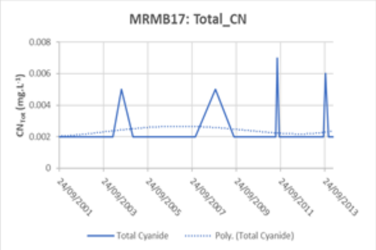

MRMB18: EC & SO4/Cl
SO4/Cl (M.L⁻¹/M.L⁻¹)
EC (µS.cm⁻¹)
SO4/Cl (M/M)
Field EC
Poly. (SO4/Cl (M/M))
Poly. (Field EC)

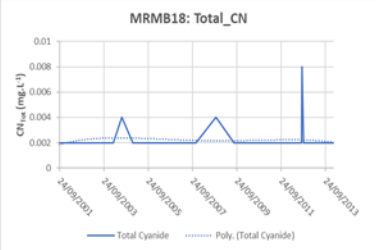

MRMB45: NO3_N
NO3_N (mg.L⁻¹)
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

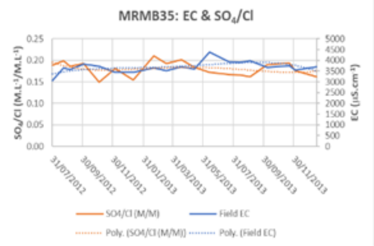

MRMB17: NO3_N
NO3_N (mg.L⁻¹)
Nitrate as N
Poly. (Nitrate as N)

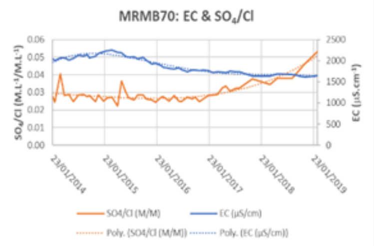

MRMB18: NO3_N
NO3_N (mg.L⁻¹)
Nitrate as N
Poly. (Nitrate as N)

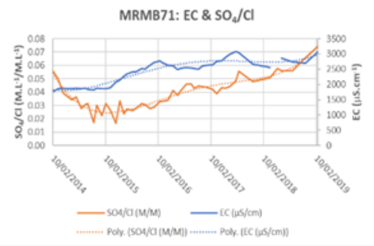

MRMB45: Total_CN
CNtot (mg.L⁻¹)
Cyanide Total (mg/L)
Poly. (Cyanide Total (mg/L))

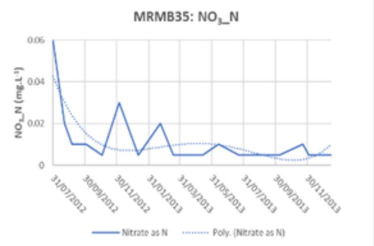

MRMB17: Total_CN
CNtot (mg.L⁻¹)
Total Cyanide
Poly. (Total Cyanide)

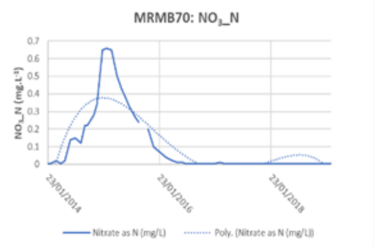

MRMB18: Total_CN
CNtot (mg.L⁻¹)
Total Cyanide
Poly. (Total Cyanide)

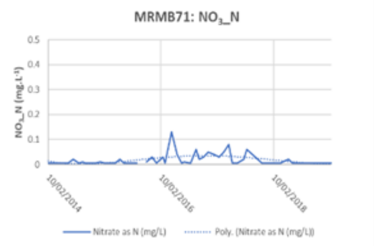

MRMB35: EC & SO4/Cl
SO4/Cl (M.L-1/M.L-1)
EC (µS.cm-1)
0.00 0.05 0.10 0.15 0.20 0.25
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000
31/07/2012 30/09/2012 30/11/2012 31/01/2013 31/03/2013 31/05/2013 31/07/2013 30/09/2013 30/11/2013
SO4/Cl (M/M)
Field EC
Poly. (SO4/Cl (M/M))
Poly. (Field EC)

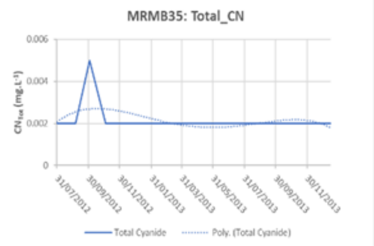

MRMB70: EC & SO4/Cl
SO4/Cl (M.L-1/M.L-1)
EC (µS.cm-1)
0.00 0.01 0.02 0.03 0.04 0.05 0.06
0 500 1000 1500 2000 2500
23/01/2014 23/01/2015 23/01/2016 23/01/2017 23/01/2018 23/01/2019
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))

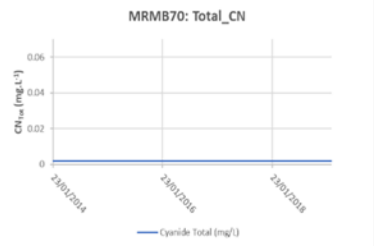

MRMB71: EC & SO4/Cl
SO4/Cl (M.L-1/M.L-1)
EC (µS.cm-1)
0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08
0 500 1000 1500 2000 2500 3000 3500
10/02/2014 10/02/2015 10/02/2016 10/02/2017 10/02/2018 10/02/2019
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))

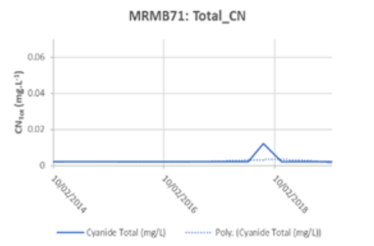

MRMB35: NO3_N
NO3_N (mg.L-1)
0 0.02 0.04 0.06
31/07/2012 30/09/2012 30/11/2012 31/01/2013 31/03/2013 31/05/2013 31/07/2013 30/09/2013 30/11/2013
Nitrate as N
Poly. (Nitrate as N)

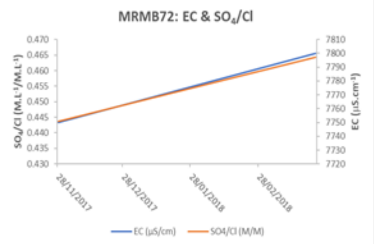

MRMB70: NO3_N
NO3_N (mg.L-1)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7
23/01/2014 23/01/2016 23/01/2018
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

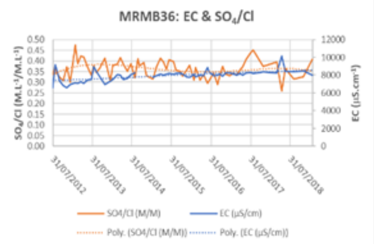

MRMB71: NO3_N
NO3_N (mg.L-1)
0 0.1 0.2 0.3 0.4 0.5
10/02/2014 10/02/2016 10/02/2018
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

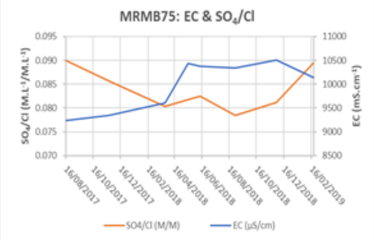

MRMB35: Total_CN
CNTot (mg.L-1)
0 0.002 0.004 0.006
31/07/2012 30/09/2012 30/11/2012 31/01/2013 31/03/2013 31/05/2013 31/07/2013 30/09/2013 30/11/2013
Total Cyanide
Poly. (Total Cyanide)

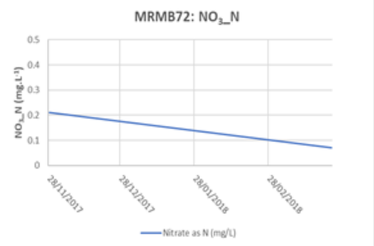

MRMB70: Total_CN
CNTot (mg.L-1)
0 0.02 0.04 0.06
23/01/2014 23/01/2016 23/01/2018
Cyanide Total (mg/L)

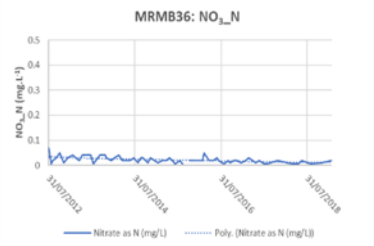

MRMB71: Total_CN
CNTot (mg.L-1)
0 0.02 0.04 0.06
10/02/2014 10/02/2016 10/02/2018
Cyanide Total (mg/L)
Poly. (Cyanide Total (mg/L))

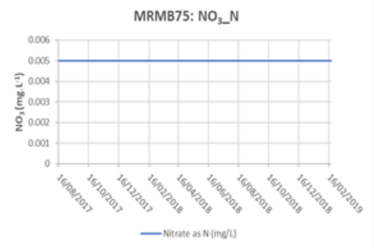

MRMB72: EC & SO4/Cl
SO4/Cl (M.L-1/M.L-1)
EC (µS.cm-1)
0.430 0.435 0.440 0.445 0.450 0.455 0.460 0.465 0.470
7720 7730 7740 7750 7760 7770 7780 7790 7800 7810
28/11/2017 28/12/2017 28/01/2018 28/02/2018
EC (µS/cm)
SO4/Cl (M/M)

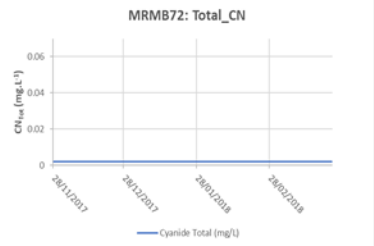

MRMB36: EC & SO4/Cl
SO4/Cl (M.L-1/M.L-1)
EC (µS.cm-1)
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
0 2000 4000 6000 8000 10000 12000
31/07/2012 31/07/2013 31/07/2014 31/07/2015 31/07/2016 31/07/2017 31/07/2018
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))

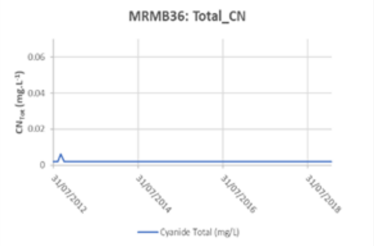

MRMB75: EC & SO4/Cl
SO4/Cl (M.L-1/M.L-1)
EC (mS.cm-1)
0.070 0.075 0.080 0.085 0.090 0.095
8500 9000 9500 10000 10500 11000
16/08/2017 16/10/2017 16/12/2017 16/02/2018 16/04/2018 16/06/2018 16/08/2018 16/10/2018 16/12/2018 16/02/2019
SO4/Cl (M/M)
EC (µS/cm)

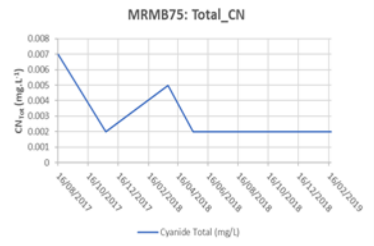

MRMB72: NO3_N
NO3_N (mg.L-1)
0 0.1 0.2 0.3 0.4 0.5
28/11/2017 28/12/2017 28/01/2018 28/02/2018
Nitrate as N (mg/L)

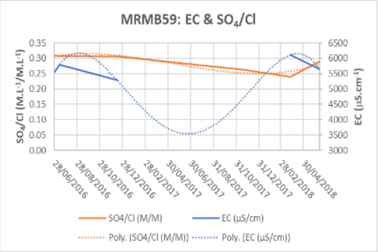

MRMB36: NO3_N
NO3_N (mg.L-1)
0 0.1 0.2 0.3 0.4 0.5
31/07/2012 31/07/2014 31/07/2016 31/07/2018
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))

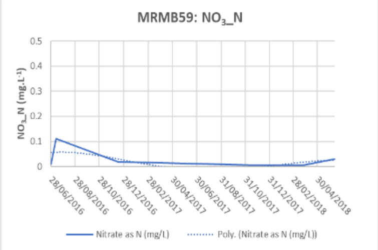

MRMB75: NO3_N
NO3 (mg.L-1)
0 0.001 0.002 0.003 0.004 0.005 0.006
16/08/2017 16/10/2017 16/12/2017 16/02/2018 16/04/2018 16/06/2018 16/08/2018 16/10/2018 16/12/2018 16/02/2019
Nitrate as N (mg/L)

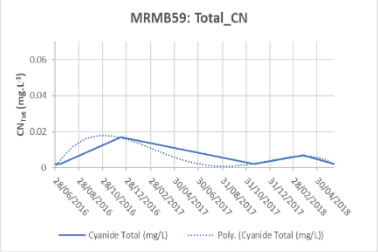

MRMB72: Total_CN
CNTot (mg.L-1)
0 0.02 0.04 0.06
28/11/2017 28/12/2017 28/01/2018 28/02/2018
Cyanide Total (mg/L)


MRMB36: Total_CN
CNTot (mg.L-1)
0 0.02 0.04 0.06
31/07/2012 31/07/2014 31/07/2016 31/07/2018
Cyanide Total (mg/L)


MRMB75: Total_CN
CNTot (mg.L-1)
0 0.001 0.002 0.003 0.004 0.005 0.006 0.007 0.008
16/08/2017 16/10/2017 16/12/2017 16/02/2018 16/04/2018 16/06/2018 16/08/2018 16/10/2018 16/12/2018 16/02/2019
Cyanide Total (mg/L)


MRMB59: EC & SO_4/Cl
SO_4/Cl ($M.L^{-1}/M.L^{-1}$)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
6500
6000
5500
5000
4500
4000
3500
3000
EC ($\mu S.cm^{-1}$)
28/06/2016
28/08/2016
28/10/2016
28/12/2016
28/02/2017
30/04/2017
30/06/2017
31/08/2017
31/10/2017
31/12/2017
28/02/2018
30/04/2018
SO4/Cl (M/M)
EC (µS/cm)
Poly. (SO4/Cl (M/M))
Poly. (EC (µS/cm))


MRMB59: NO_3_N
NO_3_N ($mg.L^{-1}$)
0.5
0.4
0.3
0.2
0.1
0
28/06/2016
28/08/2016
28/10/2016
28/12/2016
28/02/2017
30/04/2017
30/06/2017
31/08/2017
31/10/2017
31/12/2017
28/02/2018
30/04/2018
Nitrate as N (mg/L)
Poly. (Nitrate as N (mg/L))


MRMB59: Total_CN
CN_{Tot} ($mg.L^{-1}$)
0.06
0.04
0.02
0
28/06/2016
28/08/2016
28/10/2016
28/12/2016
28/02/2017
30/04/2017
30/06/2017
31/08/2017
31/10/2017
31/12/2017
28/02/2018
30/04/2018
Cyanide Total (mg/L)
Poly. (Cyanide Total (mg/L))

8.5 Site Information

8.5.1 Updated Timeline of Events

Date	Events	Exceedences	Incidents
31/12/2000	Stage 1 TSF lift commenced construction to a crest level of RL137 m. The TSF was originally designed as a valley type storage, formed by the primary embankment at the Northern (downstream) end of the site, an upstream embankment (Southern end) and saddleback embankment (western end). The Starter Embankment Crest was formed using rock fill (run-of-mine waste rock) with a clay fill core, and associated filter zone within the upstream embankment face.		
15/01/2001	Commenced tailings discharge into the TSF.		
26/03/2001			Equigold NL detected Tot. CN in groundwater monitoring bores downstream of the TSF and advised EPA of the detectable cyanide concentration on 20/04/01.
07/05/2001			Stock entry into TSF.
14/06/2001			Infringement Notice 000781 to Equigold NL: Failure to fence off area around Tailings Dam to prevent stock entry (Offence Code EPA04)
26/08/2001	Equigold advised the EPA that the required corrective actions to minimise seepage from the TSF were completed. Permanent flow pumps with meters installed were commissioned, and warning signs of cyanide risk were erected.		
10/10/2001			Equigold detected Tot. CN in 3 groundwater monitoring bores immediately downstream of the TSF
31/10/2001	Stage 1B commenced the downstream lift/buttressing, to crest level 141 m.		
01/03/2002	Construction of Northern Waste Rock Dump (NWRD) commences		
27/05/2002			Increased electrical conductivity and sulfate reported to MRMB12. SO4 concentration increased to 220 mg/L, which dropped to 93 mg/L one month later. EC oscillated month-to-month between 1054 and 2700 uS/cm.
31/10/2002	Stage 2A centerline lift commenced, to a crest level of RL143 m.		
20/12/2002	The Environmental Authority, which defined the sediment dam contaminant release limits and associated frequency of monitoring required at the overflow from each sediment dam, was approved.		
03/02/2003	An intense rainfall event occurred (227 mm in the first week of February and 336.75mm for whole of February).	This rainfall event resulted in leaching of the NWRD and overtopping of the impoundment into 12 Mile Creek. In addition, low pH water sample reported to Rawdon Creek.	
04/02/2003			
05/02/2003			
06/02/2003			
26/02/2003		Problems were reported downstream of one of the sediment dams below the TSF.	
28/02/2003	Equigold installed a pump in the Sediment Dam and returned water to the TSF.		
10/10/2003	Equigold were requested to implement a strategy that limited cyanide exposure in the TSF to avian fauna (to include scare guns, inspections of cyanide levels, species of birds, record bird deaths if they occur and notify EPA)		

Date	Events	Exceedences	Incidents
15/10/2003	Equigold notified the EPA of its plan to address acid rock drainage and related issues. Equigold commenced the designs of four water retention dams to impound future acid rock drainage from the NWRD. WD1 and WD2 were constructed by 15/10/03 in accordance with DME (1995) guidelines (to contain a 1:20 year rainfall event). In addition $Ca(OH)_2$ was added to catch drains at the NWRD toe. 100 tonnes of AgLime were added to the NWRD toe, with higher applications that targeted flow paths of the interception dams. WD3 and WD4 were being constructed. Equigold also commissioned geochemical consultants to develop a plan to minimise AMD risk by managing waste rock.		
31/10/2003	Stage 2B centerline lift commences, to a crest level of 146.5 m.		
11/12/2003	Completion of WD3 & WD4 (1st build), also sized to contain a 1:20 year rainfall event.		
15/02/2004	The EPA required Equigold to develop an Environmental Evaluation regarding acid generation at Mount Rawdon and explain the reasons for the release of AMD into Twelve Mile Creek and Rawdon Creek between 03/02/01 and the 26/02/01.		
23/03/2004	Completion of interim Environmental Evaluation report.		
31/03/2004			Sulfate reporting to MRMB12 started to stabilise, while EC continued to rise.
29/04/2004	The EPA required Equigold to provide additional information about the sizing of interception dams.		
19/01/2005			MRMB10 reported a sudden increase in SO_4 (247 to 1260 mg/L) and EC (1990 to 14250 uS/cm).
20/01/2005			The rate of increase in SO_4 reporting to MRMB09 suddenly near-halved, accompanied by a decrease in EC (10320 to 7660 uS/cm) that continued to decrease linearly until measurements stopped on 1/10/2014).
02/04/2005	Completion of the Environmental Evaluation, which revised the earlier EGI96 method of selective handling of waste rock, which was flawed and overlooked AMD potential, and replaced it with an updated waste rock classification and handling scheme that has worked more effectively since then.		
31/12/2005	Stage 2C Centreline Lift commenced, to an RL of 150 m, with upstream earth fill and a geomembrane liner with rock fill buttressing.		
03/05/2006	Equigold supplied the EPA with a hydrogeological impact report written by Kevin Morgan and Associates.		
31/05/2007		Exceedances reported to MRMB20, Sediment Dam 1 and South Dam	
01/01/2008	Before 2008, pumpback bores had been established in the Rawdon Creek drainage, in MRMB1, MRMB22, MRMB23		
08/01/2008			Bird death reported in TSF
31/01/2008	The Stage 3A Downstream lift to Southern Embankment commenced, to a crest height of 153 m. The lift featured upstream earth fill and geomembrane liner with rock fill buttressing. The lift to the Northern Embankment comprised upstream embankment lifts formed on the tailings beaches and tailings fill or earth fill construction. The upstream lift embankments formed over natural sequences incorporated deepened foundation sub-excavations and cut-off keys.		

Date	Events	Exceedences	Incidents
01/02/2008	In 2008 the Southern Embankment seepage collection system was installed as part of the Stage 3A construction works. This system comprised a seepage collection trench with subsurface drainage pipe, located beneath the Southern Embankment along the eastern perimeter, adjacent to the plant site. The trench extends for approximately 550m, beneath the embankment and drains to a sump (identified as "Stan's Well") located adjacent to the site office. Seepage water collected within the sump is recovered to transfer water to the Process Water Dam within the plant site.		
14/02/2008			MRMB12 reported that the increase in EC over a prolonged dry period became replaced by seasonal oscillations marking a return to more regular seasonal rainfall. Seasonal oscillations in EC stabilised in amplitude after 2011, while the maximum seasonal peaks in SO_4 progressively increased until 2017.
18/02/2008			Nine animal deaths reported in TSF (birds, marsupials and a cat)
21/02/2008		MRMB19 outside trigger value (pH)	
12/03/2008		MRMB24 exceeded trigger value (Cd, Pb)	
13/05/2008		MRMB20 (for pH and Zn) and MRMB24 (for Cd and Pb) exceeded trigger values	
15/05/2008		South Dam exceeded trigger value (Cu)	
18/05/2008		MRMB24 (for Cd and Pb) & MRMB25 (Zn, Pb) exceeded trigger value	
20/05/2008	The Toe Seepage Interception Drain was constructed in 2008 (20th - 23rd May 2008) downstream of the Northern Embankment toe and extending the length of the embankment. This drain discharges into TSF Sed Dam 1. Because the Toe Seepage Interception Drain had limited flow capacity, the system was upgraded in 2013 to include a further three sumps (TSF Well 2, TSF Well 3, TSF Well 4) on the western part of this drain and provide additional pump-out/seepage recovery capacity from the upper western abutment.		
18/06/2008			
23/06/2008		South Dam exceeded trigger value (Cu)	
01/07/2008		MRMB10 exceeded trigger value (TDS)	
22/07/2008		SD1 exceeded trigger value (Tot. CN, WAD CN)	
15/08/2008			Five animal deaths reported in TSF (marsupials and birds)
18/08/2008		MRMB24 exceeded trigger value (Cd, Pb). MRMB25 exceeded trigger value (Pb, Zn)	
15/10/2008		MRMB20 exceeded trigger value (NO3)	
17/10/2008			
21/10/2008	Equigold initiated a soil investigation into exceedances of heavy metals (e.g. cadmium) in vicinity of WD1.		
31/10/2008	Mt Rawdon Gold Mine Site Stormwater Management Plan developed.		
20/11/2008			Thirty-six animal deaths reported in TSF (birds and a marsupial)
23/12/2008			
30/06/2009			Tails line rupture in processing area
02/07/2009			Oil spill on ROM
28/02/2010	Stage 3B downstream lift to Southern Embankment commenced to 156 m crest level. Construction as for the Stage 3A lift.		
16/09/2010			<10L minor oil spill on decant wall
26/09/2010			Raw water spill in processing area
27/09/2010			150t of solid tailings spill in the processing area due to discharge pipe failure.
29/09/2010			Tailings slurry spill in processing area due to discharge pipe failure.
11/11/2010			Sudden increase in Tot. CN reported in MRMB09, which increased linearly over time and varied seasonally until measuring ceased on 1/10/2014.
15/12/2010		Overtopping of WD's.	

Date	Events	Exceedences	Incidents
01/01/2011		Uncontrolled release of water from WD1, WD2, WD3, WD4, SD2 (noncompliant with licence but compliant with Draft TEP)	
28/02/2011			
06/07/2011	MRMB10: Water quality monitoring of the seepage path intercepted by this bore was recommended (watch and act).		Electrical conductivity in MRMB10 declined until 27/6/2012, then continued to decline at a slower rate until 2015. However, the SO_4/Cl ratio continued to increase, which signified that despite the total salt load being lowered (evidenced by the EC trend) the proportion of mine affected water reporting to this bore continued to increase (evidenced by the SO_4/Cl ratio).
30/09/2011	Stage 3C Centreline lift to Southern Embankment commenced. Construction as for the Stage 3A lift.		
01/10/2011			Spill of tails at TSF North Wall from tails discharge pipe (inside TSF area?)
02/10/2011	Desludging of SD1 to remove sediment accumulated in the dam.		During desludging the seal of SD1 appeared to be damaged.
18/10/2011			A small volume (<1kL) of tails was spilt from the discharge pipe within TSF North Wall area
19/10/2011			Slurry discharged to ground near carbon screen (in processing area?)
20/10/2011			Tails slurry discharged to Lime Silo Gully
27/10/2011			Spill of oil to SD1
01/12/2011			SD2 water becomes progressively like SD1 water, because of inputs from SD1 (seepage through damaged clay bund).
11/12/2011			
12/12/2011			Overtopping of SD2, which is allowed to overflow under normal operation, with monitoring of water required during overflow.
13/12/2011			
01/01/2012	TSF Well 1 installed about 2012. A significant volume of clay was removed from the borrow pit at the toe of the TSF north wall during Stage 3 Centreline lift.		
02/01/2012			MRMB30 starts to become more variable in terms of SO_4 concentrations.
06/01/2012	Dewatering of SD2 to address risk of overtopping		
10/01/2012			
24/01/2012			SD2 overtopped.
03/02/2012			
08/02/2012		Evolution contacted DERM on 09/02/2012. SD2 overtopping exceeded ANZECC 95% protection level for Cu, Zn, Cd.	
09/02/2012			
01/05/2012	Corrective action initiated to restore the damaged clay bund in SD1 after the wet season finished.		
01/06/2012	Corrective action: several companies were contacted about removing sulfate from water reporting to bores MRMB20, MRMB25, MRMB27 and MRMB49.		
27/06/2012			MRMB10: Abrupt slowing of declining trend in EC values, which continued to decline until sampling ceased on 14/5/2015.
30/06/2012		MRMB25 and MRMB27 exceeded trigger values (NO_3 and SO_4)	
24/08/2012		MRMB8 exceeded trigger value (Tot. CN.)	
04/09/2012			Significant jump in Tot. CN concentrations in many bores to the north of the TSF in Aug/Sept 2012.
10/09/2012		MRMB8 exceeded trigger value (Tot. CN.)	
14/09/2012	NRC were engaged to investigate the seepage path near MRMB8. ATC Williams indicated on 21/09/2012 that a temporary seepage interception trench was appropriate. BDN Earthmovers were commissioned on 24/09/2012 to construct "Marty's Trench". Dewatering practices were changed to avoid overloading drains.		
24/09/2012			
25/09/2012		Evolution notified DEHP of Tot. CN exceedance in MRMB8 and 9 on 10/9 and provided an update of the seepage investigation	
16/10/2012			Evolution updated DEHP re. status of seepage investigation
30/10/2012			Evolution discussed with DEHP re. status of seepage investigation

Date	Events	Exceedences	Incidents
17/11/2012			Evolution updated DEHP re. status of seepage investigation and notified that the 24/10 sample had returned to within tolerable limits
20/11/2012		Evolution notify DEHP of non-compliances in MRMB25 and MRMB27 during July 2012	
28/11/2012			Evolution sent DEHP seepage investigation report.
30/11/2012	Stage 3D Centreline lift to Southern Embankment, and upstream lift to Northern Embankment (as for 3A).		
19/12/2012		MRMB27 and MRMB49 exceeded trigger values (NO_3 and SO_4)	
20/12/2012		Evolution notified DES of non-compliances at MRMB25 and MRMB27 (for July 2012 samples)	
31/12/2012		Evolution notified DES of non-compliances at MRMB27 and MRMB49 (for Dec 2012 samples)	
02/01/2013	NRC were commissioned to investigate exceedances of MRMB27 and MRMB49		
09/01/2013		MRMB09 exceeded trigger value (Tot. CN)	
11/01/2013		Overtopping of WD's.	
19/01/2013		MRMB09 exceeded trigger value (Tot. CN)	
31/01/2013		MRMB27 and MRMB49 exceeded trigger values (NO_3 and SO_4)	
15/02/2013		Evolution notified DEHP of seepage exceedance in MRMB09 (on 9/1/13) and provided an update on the status of remediation works. Evolution also notified DEHP of January non-compliances in MRMB27 & MRMB49	
01/03/2013	Temporary removal of pumps to allow seepage recharge in the seepage collection system.		The pump removal overloaded the seepage drain and resulted in higher readings
05/03/2013		Evolution notify DEHP of no sampling of MRMB8 and MRMN9 due to wet weather	
06/03/2013		Evolution notify DEHP of exceedances in MRMB27 and MRMB49 during Feb 2013	
13/03/2013	NRC provide advice on managing exceedences in MRMB27 and MRMB49		
14/03/2013	Seepage interception wells were constructed (14-15/03/2013)		
31/03/2013	Stage 3D (Emergency Raise) temporary Centreline lift to the Northern Embankment and Centreline lift to the Southern Embankment, to 164 m. Upstream earth fill and geomembrane liner with rock fill buttressing.		
22/04/2013			MRMB09: Increasing linear trend in cyanide concentrations breaking through at MB09, which continued with some seasonal flushing until monitoring stopped (14/5/2015)
15/05/2013		MRMB09 exceeded trigger value (Tot. CN)	
14/06/2013			MRMB09 returned to compliance (Tot. CN)
27/06/2013		Evolution notified DEHP of seepage exceedance in MRMB09 (on 15/05/13) and provided an update on the status of remediation works	
09/07/2013		Evolution notified DEHP of return to compliance in MRMB09 (on 14/06/13) and provided an update on the status of remediation works	
01/08/2013			MRMB30 SO_4 concentrations start to level off and stabilise at about 600 mg/L SO_4 (not as much secular variation as was previously observed)
03/09/2013	A dewatering bore located on the Stage 2C (RL 150.0m) crest of the Northern Embankment was installed and equipped as a siphoned bore to transfer water to TSF Sed Dam1. The dewatering bore extends some 7m depth into the upstream rock fill shell of the Stage 1/Stage 2 (starter embankment). The purpose of this bore was to: (1) Remove excess water in the rock fill of the Starter Embankment which is likely to be applying head to the Northern Embankment core and cut-off key; (2) Allow greater dewatering of the		

Date	Events	Exceedences	Incidents
05/09/2013	tailings beach adjacent to the Northern Embankment, thereby enhancing tailings consolidation and associated beach strength, and reducing the liquefaction potential subject to an extreme seismic event. (3) Assess the further potential to install additional bores along the Northern Embankment to further enhance the seepage recovery. Siphoning was halted in late 2016, with the system to be revaluated in light of the alternate seepage and embankment stabilisation measures.		
01/11/2013	Between November and December 2013, approved vegetation clearing for the West WRD was performed.		
30/11/2013	Stage 3E Centreline lift to Southern Embankment formed by earth and rockfill to a crest height of 166m. The lift to the Northern Embankment comprised upstream embankment lifts formed on the tailings beaches and comprising tailings fill or earth fill construction. The upstream lift embankments formed over natural sequences incorporate deepened foundation sub-excavations and cut-off keys.		
01/01/2014	In 2014, WD1 & 2 remedial works were performed. The WD1 crest and spillway was raised by 1 meter, the clay core and cut-off key was reconstructed, and the storage capacity increased by raising the embankment and spillway. WD2 remedial works involved raising the crest and spillway to increase the total storage capacity to some 221ML.		
01/03/2014	MRO Mining Department implement adjustment in explosives practices to lessen NO3_N residues		
12/03/2014	NRC are commissioned to perform isotope tracer study to indicate the provenance of sulfate and nitrate affecting well MRMB17 and MRMB49 and other bores in the mining lease	Evolution inform DEHP of status of seepage interceptions in Twelve Mile Creek and notify of intent to undertake isotope tracer study to further investigate the situation.	
03/04/2014		Evolution notified DEHP of seepage exceedance in MRMB09 (on 11/03/14)	
04/04/2014	Constructed dewatering bore on TSF wall		
05/04/2014	The trial commissioned on 01/06/2014 to investigate sulfate removal from WD water was unsuccessful		
01/05/2014			Pipe failure on the northern TSF drain, allowing 2 - 3 kL water to be released towards Swindon Creek. DEHP notified of incident.
30/06/2014	In 2014 construction of the West Dam was completed, and construction of the WWRD commenced		
12/08/2014	ATC Recommendations for seepage works to be installed at the downstream toe of WD1 and WD2, to intercept groundwater seepage through an alluvial layer and fractured rock. The option chosen was deepening the clay core key at WD1 plus installation of a seepage interception trench (to 5 meters depth) and pump back well at WD1 and WD2 before commencement of the 2014/15 wet season.		
01/01/2015	TSF Seepage Well 3 with pump back capability was installed to reduce the load on the the North Wall toe drain.		
31/08/2015		Evolution send letter report to DEHP regarding noncompliance in groundwater bores MRMB25, MRMB26, MRMB27, MRMB49 and MRMB20, noting that these values were reporting below ground and not to the surface.	
30/09/2015	Stage 4A upstream (and centreline) lift to Southern and Northern Embankment to a crest height of 169 m. This involved upstream embankment lifts 3m in height formed on the tailings beaches and comprising tailings fill or earth fill construction. The Southern Embankment has earth fill only. The upstream lift embankments formed over natural sequences incorporate deepened foundation sub-excavations and cut-off keys.		

Date	Events	Exceedences	Incidents
09/11/2015		Evolution reports exceedance of Tot. CN in MRMB31 to DEHP (October sampling round) and indicated that further monitoring of these bores is warranted	
27/11/2015		SD2 overflowed into Rawdon Creek (overtopping water contained more than 100 mg/L SO4).	
07/12/2015	An Action Plan was developed to address non-compliance of MRMB31 observed during October 2015.		
30/01/2016	In January 2016, a clay seepage cut-off wall (140m x up to 6m deep) was installed either side of TSF Well 3. The efficacy of the cut-off wall was questioned, because the abundance of seepage water made it difficult to compact the clay. At the same time leaks in TSF Well 3 were repaired.		
31/01/2016	In early 2016, waste rock started to be placed into the TSF west cell		
01/04/2016	In April 2016, a battery was installed to provide back-up power for the solar pump installed at TSF Well 3, which allowed 24hr/day pumping		
19/04/2016	Evolution identified that salts (Na, SO_4) exposed in the TSF borrow areas were reporting to SD2. The source of the salt was considered by RGS to be naturally occurring and exposed by borrow activities for TSF construction, being leached from soil by groundwater mounding below the TSF.	Evolution notified DERM of intention to (1) divert stormwater runoff from the TSF borrow pit catchment to SD1 to improve management of SD2 water, and (2) improve water management practices in the borrow area adjacent to the TSF.	
30/06/2016	In July 2016 TSF rock buttressing works commenced, as well as construction of the new decant		
31/10/2016	Stage 4B upstream lift (3m) to Southern and Northern Embankment, to a crest level of 172 m. As for the Stage 4A lift		
01/12/2016	Dec 2016 the Pump back bore between Marty's trench and MRMB30 was installed		
31/03/2017		SD1 and SD2 overflowed into Rawdon Creek	
03/04/2017			
01/07/2017	TSF Well 5 was installed		
02/07/2017	Construction of the Downstream Seepage Interception Drain commenced in mid-2017 as part of the TSF Sed Dam 3 development. This drain will border the downstream toe of the TSF Northern Embankment and has been extended into basement sequences by up to 4m (to 115m AHD) to enhance the overall seepage recovery. Seepage within the trench reports to TSF Sed Dam 1.		
06/10/2017			SD1 discharge (not clear if this is an incident)?
31/10/2017	Seep 19 (north-east TSF wall) ceased to flow		
01/11/2017		Evolution informed DES that it did not meet the Design Storage Allowance and had completed the TSF wall construction to 173.6m RL (Spillway at 173 m RL).	
31/12/2017	Stage 4C lift to crest level 175 m. This 3m lift continued the upstream lift of the Southern Embankment (earth fill and rock fill), the upstream lift of the West Saddle Embankment, and the downstream lift of the Northern Embankment. On the Northern Embankment the downstream rock fill buttress extends over all the upstream raises (Stages 3A, 3B, 3C, 3D, 3E, 4A and 4B), with the buttress extending downstream to the Stage 2 embankment outside crest.		
19/02/2018			Seepage observed in gully near Bore 10. ATC Williams provided a response on how to contain it on 21st Feb 2018
20/02/2018			
21/02/2018			
16/03/2018			ATC Williams inspected Seepage 21. This seepage was expressing downstream of the Western Saddle Embankment via the former Clean Water Diversion Drain (CWDD) outlet and was considered likely to be seeping through shallow basement sequences beneath the Stage 4C lift. ATCW provided Work Instruction Reference: 111359.46 M02-a for remedial construction works.

Date	Events	Exceedences	Incidents
31/10/2018		DES notified of Seepage 26.	Seepage 26 was noticed near Well 1, which entered Swindon Creek. Follow-up actions involved an investigation of the receiving waters, the intention to install 3 pump back bores, and the intention to extend the Downstream Toe Interception Drain to capture potential seepage or stormwater bypassing Well 1.
11/01/2019		DES informed of A limit non-compliances in MRMB41 (Fe), MRMB43 (EC, SO_4), MRMB44 (EC, SO_4), MRMB49 (EC), MRMB54 (Fe), MRMB67 (Zn), MRMB71 (SO_4), MRMB74 (EC, SO_4), MRMB75 (EC, SO_4, Fe), MRPB1 (EC,SO_4); B limit non-compliances in MRMB42 (EC, SO_4), MRMB43 (EC, SO_4), MRMB44 (EC, SO_4), MRMB49 (EC), MRMB63 (EC), MRMB67 (Zn), MRMB71 (SO_4), MRMB74 (EC, SO_4), MRMB75 (EC, SO_4, Fe), MRPB1 (EC, SO_4)	
19/03/2019		DES notified of the Well 1 bypass and follow-up actions involved an investigation of the receiving waters.	Stormwater and seepage bypassed Well 1 following a high rainfall event.
26/03/2019		DES informed of the slumping failure of WD4 drain in the Northern Waste Rock Dump thought to occur on 18/3/2019.	
24/07/2019		DES informed on new non-compliance: MRMB21 (EC A), MRMB42 (EC A), MRMB44 (Cu A), MRMB68 (EC B), MRPB2 (Fe A), MRMB77 (EC, SO_4, Cu, As V B), MRMB78 (EC, SO_4, Zn B). Continuation on non-compliances reported in January (MRMB30, MRMB42, MRMB43, MRMB44, MRMB49, MRMB63, MRMB67, MRMB68, MRMB71, MRMB74, MRMB75, MRPB1). Return to compliance for MRMB42 (EC B), MRMB71 (EC A).	

Table A3: Timeline of Events, Exceedances and Incidents

8.5.2 Source Term for Tailings Fluid

Site	Sample ID	Date	Calcium Dissolved (mg/L)	K Diss (mg/L)	Magnesium Dissolved (mg/L)	Sodium Dissolved (mg/L)	Chloride Dissolved (mg/L)	Fluoride (mg/L)	Sulphate (mg/L)	Alk Bi as CaCO3 (mg/L)	EC (µS/cm)	Iron Dissolved (mg/L)	Manganese Dissolved (mg/L)	Nitrate as N (mg/L)	pH
Column Test (1 year of leaching)	Uncertain Tailings	count	7	7	7	7	7	7	7	7	7	7.00	7		7
	Uncertain Tailings	maximum	606	198	119	558	185	0.60	2840	70	4970	0.00	6.170		8.09
	Uncertain Tailings	minimum	19	13	2	74	3	0.00	183	28	507	0.00	0.043		7.00
	Uncertain Tailings	**average**	**383**	**96**	**47**	**261**	**73**	**0.29**	**1659**	**42**	**2889**	**0.00**	**1.878**		**7.53**
	Uncertain Tailings	median	479	76	56	172	45	0.30	1790	40	2790	0.00	1.610		7.55
TSF Column (2 years of leaching)	KLC sat	count	14	14	14	14	14	14	14	14	14	14	14		14
	KLC sat	maximum	534	370	73	1360	576	0.60	2970	244	8160	0.34	5.440		7.72
	KLC sat	minimum	142	19	3	17	6	0.20	345	74	814	0.00	0.231		5.99
	KLC sat	**average**	**355**	**89**	**19**	**249**	**99**	**0.26**	**1246**	**125**	**2697**	**0.04**	**1.663**		**7.17**
	KLC sat	median	355	39	9.5	59.5	16.5	0.20	1116	110	2034	0.00	1.570		7.25
	KLC unsat	count	14	14	14	14	14	14	14	14	14	14	14		14
	KLC unsat	maximum	519	411	74	1580	701	0.60	3590	68	7560	0.00	0.053		7.79
	KLC unsat	minimum	249	35	8	8	4	0.20	663	28	1253	0.00	0.026		7.09
	KLC unsat	**average**	**369**	**139**	**27**	**396**	**157**	**0.39**	**1669**	**39**	**3212**	**0.00**	**0.036**		**7.53**
	KLC unsat	median	346	84.5	20	140	25.5	0.35	1225	35.5	2230	0.00	0.032		7.60
Monitoring data representing tailings discarge and decant water	Tailings Discharge	count	74	74	74	74	74	74	74	74	74	74	74	74	74
	Tailings Discharge	maximum	334	185	11	1120	754	2.40	2170	441	5460	9.83	0.048	5.23	11.56
	Tailings Discharge	minimum	26	109	0	556	342	0.60	72	70	2615	0.00	0.000	0.00	9.07
	Tailings Discharge	**average**	**93**	**143**	**1**	**777**	**455**	**0.94**	**1365**	**265**	**4010**	**2.33**	**0.003**	**0.37**	**10.22**
	Tailings Discharge	median	90	140.5	0	757.5	429	0.90	1355	267	3985	2.06	0.002	0.02	10.17
	Tailings_Decant	count	75	75	75	75	75	75	75	75	75	75	75	75	75
	Tailings_Decant	maximum	166	141	47	898	394	1.10	1790	189	5010	1.20	4.480	4.64	8.68
	Tailings_Decant	minimum	39	56	7	421	130	0.50	886	76	2127	0.00	0.106	0.00	7.19
	Tailings_Decant	**average**	**76**	**98**	**17**	**630**	**223**	**0.78**	**1340**	**136**	**3535**	**0.02**	**0.738**	**0.43**	**8.12**
	Tailings_Decant	median	68	99	16	645	210	0.80	1370	138	3548	0.00	0.511	0.06	8.16
Monitoring data representing Sediment Dam water	Sediment Dam 1	count	88	88	88	88	88	88	88	88	88	88	88	88	88
	Sediment Dam 1	maximum	316	72	183	845	926	1.10	2090	464	4926	3.50	18.300	21.80	7.69
	Sediment Dam 1	minimum	41	2	25	53	0	0.20	322	0	735	0.00	1.350	0.01	4.21
	Sediment Dam 1	**average**	**145**	**32**	**80**	**506**	**267**	**0.76**	**1370**	**111**	**3315**	**0.09**	**11.429**	**5.08**	**6.73**
	Sediment Dam 1	median	147.5	34	83	555.5	253.5	0.80	1510	101	3725	0.00	10.900	3.12	6.90
	Sediment Dam 2	count	141	141	141	141	141	141	141	141	140	141	141	141	140
	Sediment Dam 2	maximum	174	11	171	674	1270	0.70	800	374	5050	75.80	10.900	14.00	9.61
	Sediment Dam 2	minimum	0	0	1	11	8	0.00	0	0	62.9	0.00	0.000	0.00	4.68
	Sediment Dam 2	**average**	**20**	**3**	**18**	**101**	**129**	**0.16**	**98**	**66**	**722**	**0.79**	**0.765**	**0.34**	**6.75**
	Sediment Dam 2	median	11	3	10	65	66	0.10	65	43	505.5	0.09	0.122	0.06	6.64
	Sediment Dam 3	count	3	3	3	3	3	3	3	3	3	3	3	3	3
	Sediment Dam 3	maximum	126	9	67	342	382	0.60	604	250	2453	0.00	6.600	7.36	7.51
	Sediment Dam 3	minimum	53	2	38	140	39	0.30	258	1	1319	0.00	0.170	0.15	4.82
	Sediment Dam 3	**average**	**87**	**6**	**50**	**249**	**262**	**0.47**	**465**	**135**	**1844**	**0.00**	**3.083**	**3.72**	**6.53**
	Sediment Dam 3	median	81	6	45	264	365	0.50	534	154	1760	0.00	2.480	3.66	7.27
Monitoring data representing South Dam and Stan's	South Dam	count	108	108	108	108	108	107	108	107	108	10	108	108	108
	South Dam	maximum	391	43	161	678	776	0.80	1660	154	4140	2.90	15.400	24.60	8.12
	South Dam	minimum	44	4	13	31	12	0.00	187	24	620	0.05	0.007	0.05	6.15
	South Dam	**average**	**182**	**11**	**52**	**170**	**118**	**0.34**	**744**	**84**	**1833**	**0.37**	**0.781**	**7.81**	**7.17**
	South Dam	median	186	9	44	127	59	0.30	741	87	1782.5	0.11	0.265	7.32	7.17

Site	Sample ID	Date	Calcium Dissolved (mg/L)	K Diss (mg/L)	Magnesium Dissolved (mg/L)	Sodium Dissolved (mg/L)	Chloride Dissolved (mg/L)	Fluoride (mg/L)	Sulphate (mg/L)	Alk Bi as CaCO3 (mg/L)	EC (µS/cm)	Iron Dissolved (mg/L)	Manganese Dissolved (mg/L)	Nitrate as N (mg/L)	pH
Well water	Stan's Well	count	0	0	0	79	79	79	79	0	79	79	79	79	79
	Stan's Well	maximum				869	353	1.4	1770		4780	0.48	3.070	1.32	8.64
	Stan's Well	minimum				302	0.2	0.5	736		1905	0.00	0.952	0.00	7.63
	Stan's Well	**average**				**636**	**214**	**0.9**	**1312**		**3481**	**0.09**	**1.821**	**0.11**	**8.02**
	Stan's Well	median				637	214	0.8	1320		3460	0.09	1.780	0.02	7.99

Table A4: Tailings Source Term (major ions)

Site	Sample ID	Date	Aluminium Dissolved (mg/L)	Arsenic Dissolved (mg/L)	Boron Dissolved (mg/L)	Cadmium Dissolved (mg/L)	Chromium Dissolved (mg/L)	Copper Dissolved (mg/L)	Cyanide Total (mg/L)	Lead Dissolved (mg/L)	Molybdenum Dissolved (mg/L)	Zinc Dissolved (mg/L)	Selenium (Se)	NH3 as N (mg/L)
Column Test (1 year of leaching)	Uncertain Tailings	count	8	8	8	8	8	8	0	8	8	8	8	0
	Uncertain Tailings	maximum	0.120	0.022	0.560	0.104	0.000	0.014		0.001	0.105	1.320	0.000	
	Uncertain Tailings	minimum	0.000	0.005	0.070	0.000	0.000	0.000		0.000	0.002	0.000	0.000	
	Uncertain Tailings	**average**	**0.024**	**0.010**	**0.290**	**0.023**	**0.000**	**0.007**		**0.000**	**0.058**	**0.415**	**0.000**	
	Uncertain Tailings	median	0.000	0.008	0.250	0.012	0.000	0.007		0.000	0.064	0.352	0.000	
TSF Column (2 years of leaching)	KLC sat	count	14.000	14.000	14.000	14.000	14.000	14.000	0.000	14.000	14.000	14.000	14.000	
	KLC sat	maximum	0.020	0.004	0.150	0.073	0.000	0.036		0.010	0.143	4.760	0.000	
	KLC sat	minimum	0.000	0.000	0.000	0.003	0.000	0.003		0.000	0.016	0.537	0.000	
	KLC sat	**average**	**0.001**	**0.002**	**0.084**	**0.025**	**0.000**	**0.013**		**0.001**	**0.050**	**2.257**	**0.000**	
	KLC sat	median	0.000	0.002	0.095	0.019	0.000	0.010		0.000	0.033	2.080	0.000	
	KLC unsat	count	14	14	14	14	14	14	0	14	14	14	14	
	KLC unsat	maximum	0.000	0.004	0.110	0.010	0.005	0.022		0.000	0.180	0.307	0.000	
	KLC unsat	minimum	0.000	0.001	0.000	0.005	0.000	0.010		0.000	0.027	0.066	0.000	
	KLC unsat	**average**	**0.000**	**0.002**	**0.066**	**0.008**	**0.002**	**0.016**		**0.000**	**0.070**	**0.214**	**0.000**	
	KLC unsat	median	0.000	0.002	0.075	0.008	0.002	0.016		0.000	0.043	0.218	0.000	
Monitoring data representing tailings discarge and decant water	Tailings Discharge	count	72	72	72	72	72	72	72	72	72	72	22	8
	Tailings Discharge	maximum	2.000	8.810	4.690	0.024	0.005	64.000	142.000	0.004	0.677	8.950	0.000	56.500
	Tailings Discharge	minimum	0.230	0.117	0.130	0.000	0.000	8.210	41.900	0.000	0.215	0.600	0.000	0.120
	Tailings Discharge	**average**	**0.828**	**1.979**	**0.329**	**0.003**	**0.000**	**25.152**	**90.425**	**0.000**	**0.457**	**3.505**	**0.000**	**37.764**
	Tailings Discharge	median	0.755	1.290	0.230	0.002	0.000	22.950	89.900	0.000	0.442	2.915	0.000	47.550
	Tailings_Decant	count	75	75	75	75	75	75	75	75	75	75	28	14
	Tailings_Decant	maximum	0.100	2.140	0.350	0.094	0.005	19.700	14.800	0.004	0.483	4.990	0.000	37.600
	Tailings_Decant	minimum	0.000	0.014	0.070	0.001	0.000	0.647	0.042	0.000	0.122	0.012	0.000	0.960
	Tailings_Decant	**average**	**0.007**	**0.458**	**0.189**	**0.009**	**0.000**	**5.670**	**3.448**	**0.001**	**0.318**	**0.374**	**0.000**	**19.526**
	Tailings_Decant	median	0.000	0.227	0.190	0.004	0.000	4.430	2.430	0.000	0.329	0.131	0.000	19.800
Monitoring data representing Sediment Dam water	Sediment Dam 1	count	86	86	86	86	85	86	85	86	85	86	26	10
	Sediment Dam 1	maximum	4.980	0.260	0.250	0.408	0.005	1.720	1.250	0.011	0.198	28.900	0.000	28.400
	Sediment Dam 1	minimum	0.000	0.001	0.000	0.001	0.000	0.000	0.004	0.000	0.000	0.194	0.000	1.380
	Sediment Dam 1	**average**	**0.215**	**0.044**	**0.046**	**0.178**	**0.000**	**0.452**	**0.189**	**0.001**	**0.068**	**11.668**	**0.000**	**8.820**
	Sediment Dam 1	median	0.035	0.006	0.060	0.181	0.000	0.381	0.066	0.000	0.059	11.100	0.000	8.260
	Sediment Dam 2	count	256	254	146	256	152	256	256	256	219	255	0	0
	Sediment Dam 2	maximum	133.000	0.016	0.160	1.070	0.039	4.470	0.175	0.037	0.049	28.100		
	Sediment Dam 2	minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
	Sediment Dam 2	**average**	**0.822**	**0.001**	**0.002**	**0.045**	**0.000**	**0.089**	**0.011**	**0.000**	**0.002**	**2.693**		
	Sediment Dam 2	median	0.030	0.001	0.000	0.001	0.000	0.005	0.000	0.000	0.001	0.045		
	Sediment Dam 3	count	3	3	3	3	3	2	2	3	3	3	3	3
	Sediment Dam 3	maximum	0.790	0.002		0.135		0.022	0.011		0.005	10.400		0.850
	Sediment Dam 3	minimum	0.000	0.000		0.001		0.005	0.007		0.000	0.034		0.080
	Sediment Dam 3	**average**	**0.263**	**0.001**		**0.055**		**0.014**	**0.009**		**0.003**	**3.885**		**0.347**
	Sediment Dam 3	median	0.000	0.001		0.031		0.014	0.009		0.004	1.220		0.110
Monitoring data representing South Dam and Stan's Well water	South Dam	count	9	9		9	1	9	9	9	9	9	3	
	South Dam	maximum	1.740	0.058		1.240		18.600	14.900	0.059	0.082	19.100	0.008	
	South Dam	minimum	0.000	0.000		0.006		0.010	0.000	0.000	0.002	0.503	0.000	
	South Dam	**average**	**0.224**	**0.011**		**0.287**		**3.943**	**1.668**	**0.009**	**0.024**	**6.153**	**0.003**	
	South Dam	median	0.030	0.002		0.175		0.892	0.010	0.003	0.005	4.570	0.000	
	Stan's Well	count	79	79	79	79	78	79	79	79	0	79	0	0
	Stan's Well	maximum	0.030	0.788	0.280	0.003	0.006	0.645	1.280	0.003		0.121		
	Stan's Well	minimum	0.000	0.292	0.100	0.000	0.000	0.000	0.000	0.000		0.000		

Site	Sample ID	Date	Aluminium Dissolved (mg/L)	Arsenic Dissolved (mg/L)	Boron Dissolved (mg/L)	Cadmium Dissolved (mg/L)	Chromium Dissolved (mg/L)	Copper Dissolved (mg/L)	Cyanide Total (mg/L)	Lead Dissolved (mg/L)	Molybdenum Dissolved (mg/L)	Zinc Dissolved (mg/L)	Selenium (Se)	NH3 as N (mg/L)
	Stan's Well	**average**	**0.002**	**0.546**	**0.177**	**0.000**	**0.000**	**0.016**	**0.142**	**0.000**		**0.019**		
	Stan's Well	median	0.000	0.569	0.180	0.000	0.000	0.002	0.086	0.000		0.012		

Table A4: Tailings Source Term (dissolved metals)

8.5.3 Source Term for Waste Rock

Site	Sample Point	Date	Calcium Dissolved (mg/L)	K Diss (mg/L)	Magnesium Dissolved (mg/L)	Sodium Dissolved (mg/L)	Chloride Dissolved (mg/L)	Fluoride (mg/L)	Sulphate (mg/L)	Alk Bi as CaCO3 (mg/L)	EC (µS/cm)	Iron Dissolved (mg/L)	Manganese Dissolved (mg/L)	Nitrate as N (mg/L)	pH
Column Test (1 year of leaching)	NAF	count	7	7	7	7	7	7	7	7	7	7	7		7
	NAF	maximum	36	6	15	40	7	0.60	167	65	421	0.00	0.040		8.50
	NAF	minimum	14	1	4	1	0	0.30	74	26	282	0.00	0.005		7.84
	NAF	**average**	**26**	**3**	**8**	**27**	**2**	**0.44**	**124**	**40**	**354**	**0.00**	**0.021**		**8.17**
	NAF	median	24	3	8	32	2	0.40	140	34	375	0.00	0.020		8.13
	MedPAF	count	7	7	7	7	7	7	7	7	7	7	7		7
	MedPAF	maximum	196	19	18	28	8	0.60	832	45	1410	0.00	0.487		7.86
	MedPAF	minimum	92	6	11	4	0	0.30	316	21	660	0.00	0.002		7.44
	MedPAF	**average**	**149**	**9**	**15**	**19**	**2**	**0.37**	**484**	**30**	**905**	**0.00**	**0.143**		**7.71**
	MedPAF	median	136	8	15	19	2	0.30	419	28	778	0.00	0.069		7.76
	HighPAF	count	7	7	7	7	7	7	7	7	7	7	7		7
	HighPAF	maximum	82	16	14	25	9	0.40	338	46	703	0.00	0.396		8.10
	HighPAF	minimum	38	2	5	2	0	0.10	116	15	281	0.00	0.024		7.54
	HighPAF	**average**	**61**	**5**	**10**	**12**	**2**	**0.29**	**212**	**29**	**474**	**0.00**	**0.163**		**7.72**
	HighPAF	median	62	4	11	12	1	0.30	220	27	486	0.00	0.143		7.64
Freshly blasted rock	Pit Sump	count	52	52	52	52	52	52	52	52	52	52	52	52	52
	Pit Sump	maximum	329	31	99	402	267	0.40	1430	338	3510	3.50	0.804	45.90	8.10
	Pit Sump	minimum	74	5	14	36	7	0.10	252	49	539	0.00	0.042	4.39	6.45
	Pit Sump	**average**	**200**	**11**	**42**	**132**	**58**	**0.29**	**726**	**120**	**1686**	**0.08**	**0.269**	**13.46**	**7.06**
	Pit Sump	median	228	9	39.5	102	28.5	0.30	730	102	1626.5	0.00	0.213	10.60	7.07
Waste Rock Dams receiving leachate from rock classified using the EGI96 procedure	Waste Rock Dam 1	count	116	116	116	116	116	116	116	116	116	116	116	116	116
	Waste Rock Dam 1	maximum	546	16	322	714	868	1.80	2840	265	5888	3.50	14.000	40.00	8.24
	Waste Rock Dam 1	minimum	83	4	29	64	0	0.05	371	33	934	0.00	0.102	1.48	6.27
	Waste Rock Dam 1	**average**	**295**	**9**	**132**	**271**	**182**	**0.62**	**1433**	**99**	**2948**	**0.04**	**3.242**	**18.91**	**7.21**
	Waste Rock Dam 1	med	309	8	125	239	120.5	0.60	1485	94	2859	0.00	2.555	18.15	7.14
	Waste Rock Dam 2	count	46	46	46	46	46	46	46	46	46	46	46	46	46
	Waste Rock Dam 2	maximum	427	13	256	761	793	1.70	2100	347	5692	0.16	1.230	43.50	8.34
	Waste Rock Dam 2	minimum	104	4	35	80	15	0.30	460	45	1105	0.00	0.002	0.00	6.62
	Waste Rock Dam 2	**average**	**312**	**9**	**95**	**206**	**95**	**0.53**	**1260**	**89**	**2536**	**0.02**	**0.328**	**24.64**	**7.26**
	Waste Rock Dam 2	median	325	9.5	79	140.5	29	0.50	1230	79	2278.5	0.00	0.227	26.75	7.19
Waste Rock Dams receiving leachate from rock classified using the	Waste Rock Dam 3	count	42	42	42	42	42	42	42	42	42	42	42	42	42
	Waste Rock Dam 3	maximum	522	14	216	464	161	0.40	2710	121	4420	0.11	0.772	63.40	8.49
	Waste Rock Dam 3	minimum	66	2	20	42	8	0.20	263	30	829	0.00	0.000	0.11	6.58
	Waste Rock Dam 3	**average**	**278**	**8**	**82**	**160**	**34**	**0.34**	**1166**	**67**	**2157**	**0.02**	**0.029**	**19.16**	**7.44**
	Waste Rock Dam 3	median	261	7	74	144.5	27	0.30	1130	65	2105	0.00	0.006	16.45	7.31
	Waste Rock Dam 4	count	49	49	49	49	49	49	49	49	49	49	49	49	49

Site	Sample Point	Date	Calcium Dissolved (mg/L)	K Diss (mg/L)	Magnesium Dissolved (mg/L)	Sodium Dissolved (mg/L)	Chloride Dissolved (mg/L)	Fluoride (mg/L)	Sulphate (mg/L)	Alk Bi as CaCO3 (mg/L)	EC (µS/cm)	Iron Dissolved (mg/L)	Manganese Dissolved (mg/L)	Nitrate as N (mg/L)	pH
revised procedure	Waste Rock Dam 4	maximum	449	14	200	396	152	0.50	2280	159	4000	0.28	1.040	29.90	8.40
	Waste Rock Dam 4	minimum	35	3	11	33	10	0.10	202	28	399	0.00	0.001	0.52	6.61
	Waste Rock Dam 4	**average**	**223**	**8**	**70**	**153**	**33**	**0.37**	**988**	**80**	**1896**	**0.04**	**0.076**	**10.05**	**7.37**
	Waste Rock Dam 4	median	222	8	61	136	23	0.40	944	79	1815	0.00	0.026	9.19	7.36
	WWRD Dam	count	58	58	58	58	58	58	58	58	58	58	58	58	58
	WWRD Dam	maximum	441	11	191	421	330	1.30	1870	264	4160	0.23	0.093	24.60	8.94
	WWRD Dam	minimum	11	1	6	33	16	0.40	30	45	291	0.00	0.000	0.00	7.16
	WWRD Dam	**average**	**153**	**5**	**57**	**153**	**97**	**0.70**	**670**	**85**	**1612**	**0.01**	**0.012**	**9.01**	**7.92**
	WWRD Dam	median	108	4	46.5	144	79.5	0.70	534	79	1509.5	0.00	0.004	7.66	7.82

Table A5: Waste Rock Source Term (major ions)

Site	Sample ID	Date	Aluminium Dissolved (mg/L)	Arsenic Dissolved (mg/L)	Boron Dissolved (mg/L)	Cadmium Dissolved (mg/L)	Chromium Dissolved (mg/L)	Copper Dissolved (mg/L)	Cyanide Total (mg/L)	Lead Dissolved (mg/L)	Molybdenum Dissolved (mg/L)	Zinc Dissolved (mg/L)	Selenium (mg/L)	Ammonia as N (mg/L)
Column Test (1 year of leaching)	NAF	count	7	7	7	7	7	7	0	7	7	7	7	0
	NAF	maximum	0.060	0.003	0.440	0.000	0.000	0.009		0.000	0.012	0.000	0.000	
	NAF	minimum	0.000	0.000	0.070	0.000	0.000	0.000		0.000	0.003	0.000	0.000	
	NAF	**average**	**0.027**	**0.002**	**0.241**	**0.000**	**0.000**	**0.003**		**0.000**	**0.009**	**0.000**	**0.000**	
	NAF	median	0.020	0.002	0.210	0.000	0.000	0.001		0.000	0.010	0.000	0.000	
	MedPAF	count	7	7	7	7	7	7	0	7	7	7	7	0
	MedPAF	maximum	0.020	0.021	0.810	0.000	0.000	0.006		0.000	0.053	0.034	0.000	
	MedPAF	minimum	0.000	0.004	0.000	0.000	0.000	0.000		0.000	0.013	0.000	0.000	
	MedPAF	**average**	**0.007**	**0.012**	**0.294**	**0.000**	**0.000**	**0.002**		**0.000**	**0.032**	**0.013**	**0.000**	
	MedPAF	median	0.000	0.010	0.180	0.000	0.000	0.001		0.000	0.029	0.010	0.000	
	HighPAF	count	7	7	7	7	7	7	0	7	7	7	7	0
	HighPAF	maximum	0.050	0.000	0.270	0.001	0.000	0.025		0.005	0.011	0.041	0.000	
	HighPAF	minimum	0.000	0.000	0.000	0.000	0.000	0.002		0.000	0.001	0.000	0.000	
	HighPAF	**average**	**0.013**	**0.000**	**0.146**	**0.001**	**0.000**	**0.006**		**0.002**	**0.004**	**0.022**	**0.000**	
	HighPAF	median	0.010	0.000	0.160	0.001	0.000	0.004		0.002	0.004	0.024	0.000	
Freshly blasted rock	Pit Sump	count	112	112	49	112	53	112	101	112	95	112	1	0
	Pit Sump	maximum	0.160	0.030	0.090	0.754	0.003	0.691	0.104	0.053	0.090	30.200	0.000	
	Pit Sump	minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.025	0.012	0.000	
	Pit Sump	**average**	**0.006**	**0.009**	**0.004**	**0.013**	**0.000**	**0.028**	**0.008**	**0.003**	**0.045**	**0.777**	**0.000**	
	Pit Sump	median	0.000	0.007	0.000	0.004	0.000	0.004	0.000	0.000	0.044	0.291	0.000	
Waste Rock Dams receiving leachate from rock classified using the EGI96 procedure	Waste Rock Dam 1	count	108	108	108	108	108	108	108	108	108	108	24	10
	Waste Rock Dam 1	maximum	0.380	0.013	0.090	0.360	0.006	0.189	0.017	0.058	0.024	17.000	0.000	52.200
	Waste Rock Dam 1	minimum	0.000	0.000	0.000	0.020	0.000	0.008	0.000	0.000	0.004	0.369	0.000	0.020
	Waste Rock Dam 1	**average**	**0.010**	**0.002**	**0.003**	**0.091**	**0.000**	**0.036**	**0.001**	**0.002**	**0.012**	**4.537**	**0.000**	**5.276**
	Waste Rock Dam 1	med	0.000	0.002	0.000	0.076	0.000	0.028	0.000	0.000	0.011	4.115	0.000	0.065
	Waste Rock Dam 2	count	46	46	46	46	46	46	46	46	46	46	5	1
	Waste Rock Dam 2	maximum	0.050	0.009	0.000	0.052	0.000	0.042	0.009	0.091	0.028	3.170	0.000	0.040
	Waste Rock Dam 2	minimum	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.006	0.067	0.000	0.040
	Waste Rock Dam 2	**average**	**0.003**	**0.002**	**0.000**	**0.015**	**0.000**	**0.004**	**0.001**	**0.006**	**0.016**	**1.183**	**0.000**	**0.040**
	Waste Rock Dam 2	median	0.000	0.002	0.000	0.012	0.000	0.003	0.000	0.000	0.017	1.120	0.000	0.040
Waste Rock Dams receiving leachate from rock classified using the revised procedure	Waste Rock Dam 3	count	41	41	41	41	41	41	41	41	41	41	5	1
	Waste Rock Dam 3	maximum	0.060	0.009	0.000	0.001	0.000	0.031	0.030	0.227	0.020	0.082	0.000	0.040
	Waste Rock Dam 3	minimum	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.000	0.000	0.040
	Waste Rock Dam 3	**average**	**0.005**	**0.002**	**0.000**	**0.000**	**0.000**	**0.003**	**0.001**	**0.014**	**0.015**	**0.030**	**0.000**	**0.040**
	Waste Rock Dam 3	median	0.000	0.002	0.000	0.000	0.000	0.002	0.000	0.000	0.016	0.030	0.000	0.040
	Waste Rock Dam 4	count	49	49	49	49	49	49	49	49	49	49	5	1
	Waste Rock Dam 4	maximum	0.270	0.006	0.000	0.001	0.006	0.027	0.078	0.117	0.021	0.142	0.000	0.180
	Waste Rock Dam 4	minimum	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.180
	Waste Rock Dam 4	**average**	**0.011**	**0.003**	**0.000**	**0.000**	**0.000**	**0.002**	**0.002**	**0.007**	**0.014**	**0.034**	**0.000**	**0.180**

Site	Sample ID	Date	Aluminium Dissolved (mg/L)	Arsenic Dissolved (mg/L)	Boron Dissolved (mg/L)	Cadmium Dissolved (mg/L)	Chromium Dissolved (mg/L)	Copper Dissolved (mg/L)	Cyanide Total (mg/L)	Lead Dissolved (mg/L)	Molybdenum Dissolved (mg/L)	Zinc Dissolved (mg/L)	Selenium (mg/L)	Ammonia as N (mg/L)
	Waste Rock Dam 4	median	0.000	0.003	0.000	0.000	0.000	0.002	0.000	0.000	0.015	0.029	0.000	0.180
	WWRD Dam	count	53	53	53	53	52	53	53	53	53	53	25	9
	WWRD Dam	maximum	0.140	0.022	0.050	0.002	0.000	0.006	0.000	0.000	0.072	0.115	0.000	0.870
	WWRD Dam	minimum	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000
	WWRD Dam	**average**	**0.011**	**0.005**	**0.001**	**0.000**	**0.000**	**0.002**	**0.000**	**0.000**	**0.026**	**0.016**	**0.000**	**0.198**
	WWRD Dam	median	0.000	0.004	0.000	0.000	0.000	0.002	0.000	0.000	0.027	0.000	0.000	0.040

Table A5: Waste Rock Source Term (dissolved metals)