MAC and South Flank

Carbonate Precipitation from Groundwater – Source, Controls and Management

prepared for

BHP

By

Earth Systems

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1. INTRODUCTION

At BHPs Mining Area C (MAC) and South Flank operations in the Pilbara, groundwater dewatering is required to enable mining to proceed. Water from most dewatering bores is alkaline and, in most locations, appears to have the potential to generate carbonate mineral precipitates (eg. calcite, dolomite, magnesite) once pumped to the surface (Earth Systems, 2021).

The potential of water to precipitate carbonate minerals (also known as 'scale' when affecting infrastructure such as pipes or pumps) can be indicated by either mineral saturation indices (SI; via equilibrium thermochemical calculations) or a less onerous (and less accurate) Langelier Saturation Index (LSI) calculation. Mineral SI's are used to indicate whether water of a given composition is in chemical equilibrium with a mineral. The LSI is a similar but independent measure of a solutions ability to dissolve or precipitate calcium carbonate and is commonly used in industry to assess scaling potential.

BHP has requested that a study be undertaken to better understand the general quality of groundwater (eg. dissolved metal concentrations) as well as potential risks posed by the discharge of the dewatering stream in terms of carbonate precipitation in the receiving environment.

This project has other implications for BHP WAIO operations as the dewatering water is also used as process water and for dust suppression, and carbonate precipitation is reportedly causing some operational difficulties.

2. BACKGROUND

2.1 Dewatering Infrastructure

Figure 2-1 shows a schematic overview of the dewatering infrastructure at MAC and South Flank. Groundwater is pumped to the surface via production bores. The groundwater from production bores in E Deposit, F Deposit, and some of the bores from C Deposit is transferred to the E Deposit Turkey's Nest Dam. From the E Deposit Turkey's Nest Dam, different proportions of the groundwater are transferred via pipelines to:

- Juna Downs managed aquifer recharge (MAR) area.
- Runaway Valley Infiltration Ponds (eastern, central, and western pond).
- Western Sediment Pond.

Groundwater from production bores located in A Deposit as well as some of the bores in C Deposit is transferred to the A Deposit Turkey's Nest Dam. From here the groundwater is transferred to the:

- Central Sediment Basin.
- South Flank Crusher.

Whilst dewatering at South Flank has yet been undertaken at a large scale, the current plan for dewatering at South Flank is to discharge groundwater to the South Flank MAR as well as directly into the catchment of Pebble Mouse Creek.

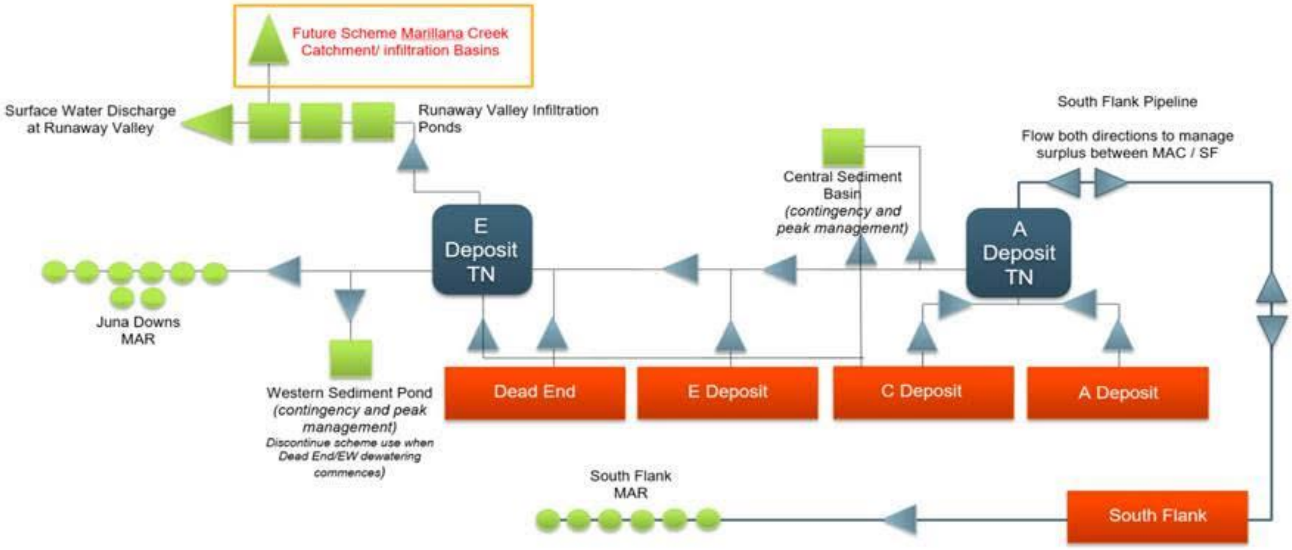

Figure 2-1: Schematic diagram of groundwater infrastructure at MAC / South Flank. Orange fields reflect groundwater derived from production bores. Blue lines / arrows indicate the flow direction of groundwater. Blue coloured fields indicate Turkey's Nest Dams. Green fields indicate discharge points to the environment.

2.2 Generic Controls on Carbonate Precipitation

The key processes that help facilitate the precipitation of carbonate minerals include:

- Increases in water temperature (note: this is the opposite behaviour to most other minerals).
- Decreases in water pressure.
- Increases in pH.

- CO_2 degassing - generally related to decreases in pressure and leading to increases in pH.
- Evaporation (ie., concentration of the components required for carbonate precipitation [eg. calcium, magnesium, alkalinity]).
- Nucleation sites (eg. seed crystals).
- Addition of soluble calcium (eg. active water softening).

It should also be noted that the inverse of the above changes may help facilitate the dissolution of carbonate minerals (or prevent their precipitation), for example, a decrease in water temperature may inhibit carbonate precipitation and/or lead to dissolution of carbonate minerals.

3. SCOPE OF WORKS

BHP requested the following scope of works:

Field Surveys

- Collection of water quality samples and *in-situ* water quality data from production bores within the aquifer to be dewatered.
  - Analysis of groundwater samples for the following parameters using NATA accredited laboratories:
    - pH, EC (µS/cm), and water temperature (°C) (*in-situ*).
    - Ionic composition: Ca, K, Mg, Na, HCO_3, Cl, SO_4, CO_3, alkalinity and hardness.
    - Nutrients: total N, total P, NO_x and NH_3.
    - Dissolved metals: Al, As, B, Ba, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, S, Se, U, V and Zn
    - Total Dissolved Solids [TDS].
- Conduct trials to determine the rate of carbonate precipitation if groundwater is discharged to the environment.
- Conduct trials to determine CO_2 degassing rates.

Data Assessment

- Report groundwater quality data against the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018) default guideline values [DGV's] for the protection of 95% and 99% of freshwater species and other guideline values as appropriate.
- Calculate Langelier Saturation Index (LSI).
- Assess the likelihood of carbonate precipitation forming in the receiving environment if groundwater is discharged.
- Assess rate and time for calcite precipitate to occur.

Reporting

- Preparation of a report outlining key finding of work undertaken.
- Prepare separate short letter report of any recommendations for further work and or mitigation options.
- Reporting has considered the requirements of:
  - EPA (2021) Statement of Environmental Principles, Factors and Objectives; and
  - EPA (2018) Environmental Factor Guideline: Inland Waters.

4. METHOD

4.1 Selection of Production Bores for Field Testwork

For the field testwork program outlined above to yield meaningful results, it is required that the groundwater sampled from the production bores were saturated with respect to carbonate minerals. Likewise, groundwater samples from production bores that are undersaturated with respect to carbonate minerals were to be avoided.

As described in Section 1, the most accurate indication of whether a water sample is saturated with respect to carbonate minerals is provided by thermochemical modelling, rather than the industry standard LSI calculation. Hence, prior to the site visit, thermochemical modelling was performed using data provided by BHP (see Attachment A). This data (BHP, 2020) included water chemistry (2019-2020) for 12 production bores at MAC (including A Deposit, C Deposit and E Deposit) as well as five (5) production bores from South Flank. The available water chemistry data includes key parameters such as pH, electrical conductivity (EC), total alkalinity, dissolved calcium, and dissolved magnesium concentrations.

Mineral saturation indices (SI) were derived from the data provided by BHP using the PhreeqC software package. The SI values are calculated by comparing the chemical activities (Ion Activity Product, IAP), of dissolved (soluble) mineral ions (eg. Ca^{2+}, CO_3^{2-}, HCO_3^{-}) with their solubility product (Ksp) using equation 1.

$$\textit{Saturation Index (SI)} = \textit{Log (IAP / Ksp)} \qquad \textit{(Eq.1)}$$

Where saturation indices are negative [<0] the water is undersaturated with respect to a particular mineral and that mineral is likely to dissolve into solution. Where saturation indices are positive [>0] the water is saturated with respect to a particular mineral and that mineral is likely to precipitate from solution. In the instance where the saturation indices are zero, the water is in chemical equilibrium with a particular mineral, and that mineral should be stable (ie. it will neither dissolve nor precipitate).

It is important to recognised that an SI value >0 indicates saturation (ie. a particular mineral has the potential to precipitate), but it does not necessarily mean that the mineral will precipitate under real world conditions. This is because non-equilibrium conditions are possible, and water may become saturated without precipitation, and for example, may require seed crystals for precipitation to begin.

Additional to the water quality data, BHP (2020) included geological and borehole construction logs, which were assessed to understand the stratigraphic layers the water is drawn from when brought to the surface.

4.2 CO_2 Degassing and Carbonate Precipitation Testwork

4.2.1 Testwork Design

As a result of previous water quality studies, BHP identified that groundwater samples from MAC had LSI values that indicate saturation with respect to calcium carbonate. Therefore, this water posed a potential risk of carbonate mineral precipitation upon discharge. In response, BHP is seeking to understand:

- The quality of groundwater, in terms of the concentrations of total and dissolved metals, nutrients, as well as physiochemical parameters (pH, EC, ORP, Temperature).
- Whether this groundwater is suitable for direct discharge to the environment, ie. is it compliant with relevant Australian freshwater quality guidelines?
- The specific source and cause of carbonate saturation in groundwater.
- The volume and spatial / temporal distribution of groundwater that constitutes a risk of carbonate precipitation.
- The potential magnitude of carbonate precipitation.

- The timeframe under which CO_2 degases from groundwater.
- The timeframe under which carbonate precipitates form, and their likely stability, eg. will they dissolve over time or are they permanent?

A better understanding of the above would assist with the development of management and/or mitigation measures, which lower or eliminate the risk of environmental impact associated with groundwater discharge.

A field testwork program utilising selected production bores was designed to address the above uncertainties leveraging the key generic controls on carbonate precipitation (see Section 2.2). Specific components of this testwork program are outlined below.

4.2.2 Analysis of Groundwater

Samples collected during the field testwork program were analysed *in-situ* for physiochemical parameters (ie. pH, EC, ORP, and Temperature; using TPS 90FL-T water quality meters) and for selected parameters (ie. Ca, Mg, Alkalinity; using Merck Millipore Sprectroquant Move 100 spectrophotometers). In addition, selected samples were collected in duplicate and dispatched to an external laboratory (SGS) for analyses of additional parameters (see below). Data collected during the fieldwork program is tabulated in Attachment B, and external laboratory reports are provided in Attachment C.

Due to progressive degassing of these water samples and associated chemical changes (described in subsequent sections of this report) comparison of the field and laboratory water chemistry provides important constraints on processes such as degassing and carbonate precipitation. In this regard, it is noteworthy that laboratory analyses occurred up to 8 days after field sampling. The parameters analysed *in-situ* in the field and in the laboratory are detailed below.

In-situ Field Analysis

- pH, Electrical Conductivity [EC] (µS/cm), Oxidation Reduction Potential [ORP] (mV), and water temperature (°C).
- Total calcium (mg/L), magnesium (mg/L), and alkalinity (mg $CaCO_3$ equiv./L) via spectrophotometric techniques.
- Dissolved (filtered) calcium (mg/L), magnesium (mg/L), and alkalinity (mg $CaCO_3$ equiv./L) via spectrophotometric techniques.

Laboratory Analysis

- pH, EC (µS/cm), and Total Dissolved Solids [TDS] (mg/L).
- Total major ions – Ca, Mg, Na, K, F, Cl, SO_4.
- Dissolved (filtered) major ions –Ca, Mg.
- Alkalinity (bicarbonate, carbonate, hydroxide, total) and hardness (all in mg/L).
- Filtered alkalinity (bicarbonate, carbonate, hydroxide, total).
- Nutrients – total P, total N, total Kjeldahl nitrogen (TKN), NO_2, NO_3 and NH_3 (all in mg/L).
- Laboratory – Filtered dissolved metals – Al, As, Ag, B, Ba, Bi, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, S, Sb, Se, Sn, Te, Tl, U, V and Zn (all in mg/L).

4.2.3 Rates of CO_2 Degassing and Carbonate Mineral Precipitation

Key field tests were designed in an attempt to determine the rates of CO_2 degassing and carbonate mineral precipitation. Conducting field tests acknowledges the key generic controls on carbonate mineral precipitation outlined in Section 2.2. The following tests (and combinations thereof) were conducted in the field.

- Passive degassing – tests were conducted to determine the natural CO_2 degassing rate when groundwater (sampled directly from production bores) is exposed to atmospheric pressure and temperature.
- Active degassing (aeration) – tests were conducted to determine the CO_2 degassing rate when the sample was subject to gentle-moderate stirring with the view to accelerate degassing (simulating aeration).
- Nucleation – tests were conducted using various seed crystal types (eg. quartz sand, precipitated calcium carbonate, crushed hematite-rich material) with the view to assessing the benefits of artificially promoting / enhancing carbonate precipitation.

4.3 Inspection of Site Water Bodies & Dewatering Infrastructure

4.3.1 Water

Several water bodies at MAC and South Flank were inspected and (where possible) sampled with the aim of elucidating the processes currently occurring within these water bodies and associated dewatering infrastructure (eg. passive degassing and carbonate precipitation). The locations inspected include:

- A Deposit Turkey's Nest (inflow and discharge).
- E Deposit Turkey's Nest (inflow and discharge).
- Runaway Valley Infiltration Ponds (inflow and discharge), receiving water from E Deposit Turkey's Nest.
- Sediment Discharge Basin from A Deposit Turkey's Nest.
- Sediment Discharge Basin from E Deposit Turkey's Nest.
- Creeks draining the Runaway Valley Infiltration Ponds.
- Discharge point into the catchment of Pebble Mouse Creek.

Field water quality parameters were analysed (pH, EC, ORP, and Temperature) and samples collected for laboratory analyses (see Section 4.2.2 for parameters) at these sites where possible.

4.3.2 Soil and Sediment

Sediment / solid samples were collected from the locations listed below:

- A Deposit Turkey's Nest subaqueous sediment.
- E Deposit Turkey's Nest subaqueous sediment.
- Eastern Runaway Valley - Pond 1, soil material from a depth of ~100 mm.

These samples were reacted with dilute acid in what is known as a 'fizz' test, a common field procedure to test for the presence of carbonate minerals.

In order to conclusively confirm that carbonate minerals were present (due to precipitation), and if so, quantify their concentrations these three samples were subject to Quantitative X-Ray Diffraction (QXRD) analysis and measurement of their Acid Neutralising Capacity (ANC). These two laboratory tests can provide independent quantification of the presence and abundance of carbonate minerals.

4.3.3 Gas

A personal oxygen monitor was used during inspection of key site infrastructure. It is inferred that any detected decrease in oxygen concentrations adjacent to water sources is likely due to dilution with elevated concentrations of CO_2 (ie. CO_2 degassing from the water).

4.4 Groundwater Chemistry

Typical groundwater chemistry (BHP and Earth Systems data) was collated. The major element concentrations and physiochemical parameters were used to assess the ultimate source of carbonate saturated groundwater, and to help constrain processes occurring between the time of initial sampling and laboratory analysis. The metal concentrations were used for comparison with relevant water quality guidelines in order to assess the suitability of groundwater for discharge (see below)

4.4.1 Comparison with Water Quality Guidelines

To assess the suitability of groundwater for discharge to the environment, water chemistry data from the current study, as well as data collected by BHP during 2021 [the most recent year of coherent data collection] were compared with the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018) default guideline values [DGV's] for the protection of 95% and 99% of freshwater species. The 99% level of species protection is applied to high ecological/conservation value systems, whereas a 95% level of species protection is applied to slightly to moderately disturbed systems. Hereafter, these guidelines values are simply referred to as "*ANZG 99% freshwater guideline values*" and "*ANZG 95% freshwater guideline values*".

4.4.2 Spatial and Temporal Variations in Groundwater Chemistry

During the fieldwork program, it became evident that additional data was required to understand the typical groundwater chemistry, how the groundwater chemistry is evolving over time, and the temporal / spatial distribution of production bores which produce groundwater saturated with respect to carbonate minerals (see Attachment D).

Additional water chemistry data from all production bores operating from 2010 to present was made available by BHP. This data included water chemistry for 112 production and re-injection bores from MAC and South Flank. The database received includes field pH and EC, as well as laboratory chemistry data (eg. pH, EC, total alkalinity, sulfate, calcium, magnesium, potassium, chloride, and dissolved metals [Al, Ba, B, Cd, Cu, Fe, Mg, Mn, Hg, Mo, Ni, Se, Si, Ag, Zn]). Although not all data was available for all production and re-injection bores.

This laboratory water chemistry data was used to calculate the LSI for all samples. The LSI is derived from the difference between the measured pH of a solution and the calculated pH of a solution determined to be saturated with respect to calcium carbonate (Equation 2). The calculated pH of the saturated solution is based on chemical equilibrium expressions for calcium carbonate solubility, bicarbonate dissociation, temperature, and ionic strength (see *Eq. 2*).

$$LSI = pH - pHs \qquad (Eq.2)$$

Where: pHs = (9.3 + A + B) - (C + D), and:

- $A = (\mathrm{Log}_{10}\,[TDS] - 1) / 10$
- $B = -13.12 \times \mathrm{Log}_{10}\,(°C + 273) + 34.55$

- C = Log_{10} [Ca^{2+} as $CaCO_3$] – 0.4
- D = Log_{10} [alkalinity as $CaCO_3$]

If LSI values are greater than 0 then the water is supersaturated with respect to calcium carbonate and scaling may occur. If LSI values are less than 0 than the water is undersaturated with respect to calcium carbonate and the solution is non-scale forming.

4.5 Source of Carbonate Saturated Water

Knowledge of the carbonate mineralogy in the South Flank and MAC area was combined with assessment of key elemental ratios (ie. Ca/Mg) in water samples in order to elucidate the ultimate source of carbonate saturated groundwater. This information was then cross checked against available bore construction logs (BHP, 2020).

4.6 Stability of Carbonate Precipitates

Knowledge of the key controls on carbonate mineral precipitation / dissolution were used to provide an assessment of the long-term stability of carbonate precipitates (ie. will they persist, or will they redissolve) at South Flank / MAC.

5. RESULTS

5.1 Selection of Production Bores for Field Testwork

The results of modelling mineral saturation indices are provided in Attachment A (Earth Systems, 2021). This modelling considered 17 boreholes (BHP, 2020) and showed that water from 16 out of 17 (94%) production bores were saturated (SI > 0) with respect to the carbonate minerals calcite ($CaCO_3$), dolomite ($Ca,Mg(CO_3)_2$), and magnesite ($MgCO_3$).

The production bores listed below were selected for sampling during the fieldwork program based on: (1) saturation with respect to carbonate minerals (see Attachment A); (2) their spatial distribution – production bores that feed into A Deposit and E Deposit Turkey's Nests; (3) Accessibility and a safe environment for conducting field-based tests; and (4) the bores being operational during the field visit (ie. not undergoing maintenance).

- HGA0062P and HGA0074P (inflow into A Deposit Turkey's Nest Dam).
- HGE0148P (inflow into E Deposit Turkey's Nest Dam).

5.2 CO_2 Degassing and Carbonate Precipitation Testwork

5.2.1 Testwork Implementation

All field-based degassing and carbonate precipitation tests were performed on ~20L samples collected directly from the tap attached to the production bore. The large sample volume allowed a sufficient volume to be subsampled for laboratory analysis, and collection in 20L buckets (with watertight lids) permitted samples to be transferred to the temporary onsite laboratory as required.

Two samples were collected from each production bore. One of these samples was subject to Passive Degassing (PDG), and the other subject to Active Degassing (ADG) (see Section 4.2.3 for further details). The physiochemical parameters (pH, EC, ORP, T°C) of both samples (ADG and PDG) were logged semi-continuously at 5-minute intervals. Total calcium, magnesium, and alkalinity concentrations were analysed in the field (see Section 4.2.2 for details) for both PDG and ADG samples every 15 to 30 minutes. Each test was run over a span of 3 to 5 hours, however, on occasion the logging of physiochemical parameters continued overnight. Note: the physiochemical parameters were logged overnight in order to understand passive degassing over an extended duration.

Water samples for laboratory analysis were collected at the beginning of all ADG and PDG tests, and again at the completion of the tests (see Section 4.2.2 for parameters).

After the pH and EC values stabilised within a given test, nucleation agents (seed crystals) were added to both ADG and PDG samples. This included the addition of quartz sand, precipitated calcium carbonate, and crushed hematite-rich material. Following the addition of seed crystals, the samples were also analysed in the field for filtered (dissolved) calcium, magnesium, and alkalinity (see Section 4.2.2 for details). The comparison of total (unfiltered) and dissolved (filtered) calcium, magnesium and alkalinity can provide an indication of the magnitude of carbonate mineral precipitation.

The testwork program commenced with production bore HGA0062P (A Deposit). However, testwork at this production bore was soon abandoned due to pump issues, which required maintenance to be performed. Therefore, ADG and PDG testwork was performed for a short period, but not nucleation testwork. Full testwork was completed on samples from production bore HGA0074P (A Deposit) and production bore HGE0148P (E Deposit; Figure 5-1).

Figure 5-1: Production bore HGE0148P at E Deposit.

5.2.2 Rates of CO_2 Degassing and Carbonate Mineral Precipitation

Rapid changes in physiochemical parameters of the groundwater were noted in the seconds to minutes following sampling from the tap of the production bores (see Figure 5-2 and Figure 5-3). This involved a rapid increase in the pH of approximately 0.15 to 0.20 log units, whereas the EC either remained relatively stable (HGA0062P) or decreased significantly (HGE0148P). These changes in water chemistry coincide with observations of initially rapid degassing (see Figure 5-4 and Figure 5-5).

It is important to note that the groundwater from production bore HGA0062P was sampled from a relatively small outlet pipe (~25 mm), which took approximately 90 seconds to fill a 20L bucket. Whereas the groundwater from production bore HGE0148P was sampled from a relatively large outlet pipe (~150 mm) which took approximately 5-10 seconds minutes to fill a 20L bucket. These differences in sampling likely account for the different initial evolution of the groundwater chemistry, as detailed below:

- The slow groundwater extraction from HGA0062P likely meant that by the time enough water was sampled to allow the water quality monitoring probes to be inserted into the sample, significant degassing had already occurred, evidenced by a higher initial pH value and slower rate of pH increase. Likewise, the lack of significant change in EC could be due to the fact that significant carbonate precipitation may have already occurred prior to monitoring (i.e., during filling of the sample bucket).
- On the other hand, rapid extraction from HGE0148P meant that more of the degassing and precipitation processes were captured during the monitoring period. Shown by a rapid increase in pH (CO_2 degassing) and a decrease in EC (carbonate precipitation).

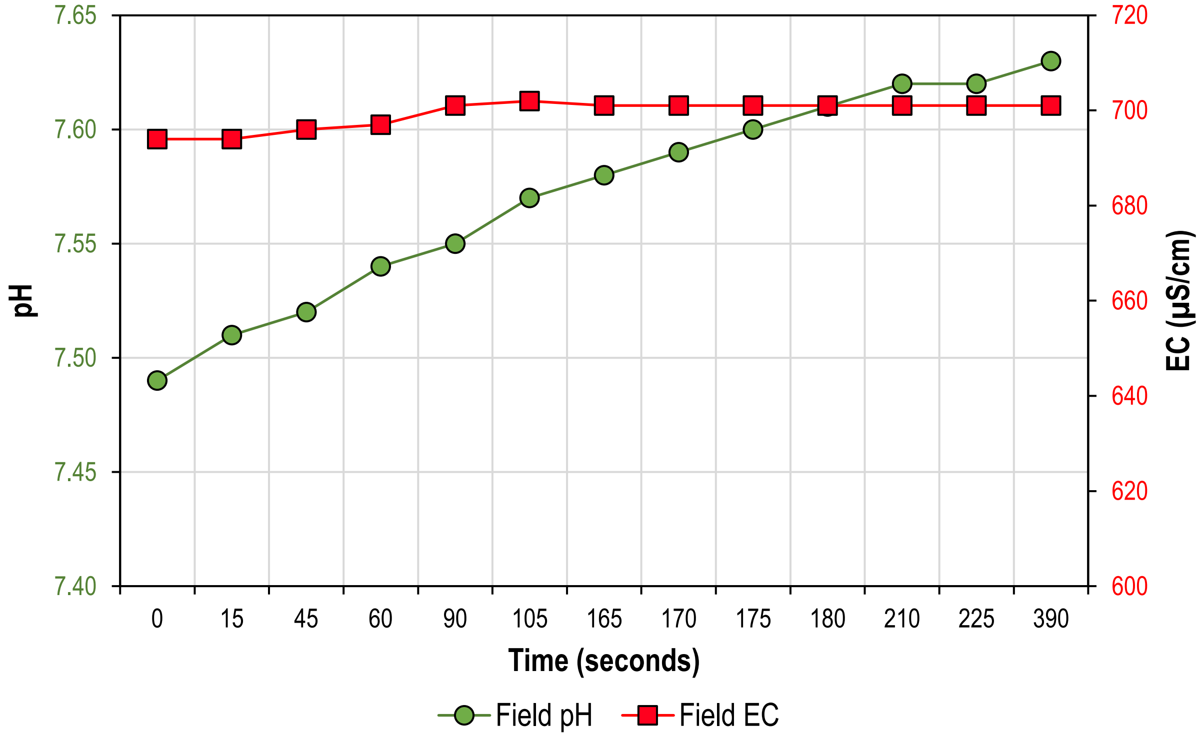

Figure 5-2: Initial changes in field pH and EC of groundwater sampled from production bore HGA0062P. Green symbols represent field pH measurements and orange symbols represent field EC measurements.

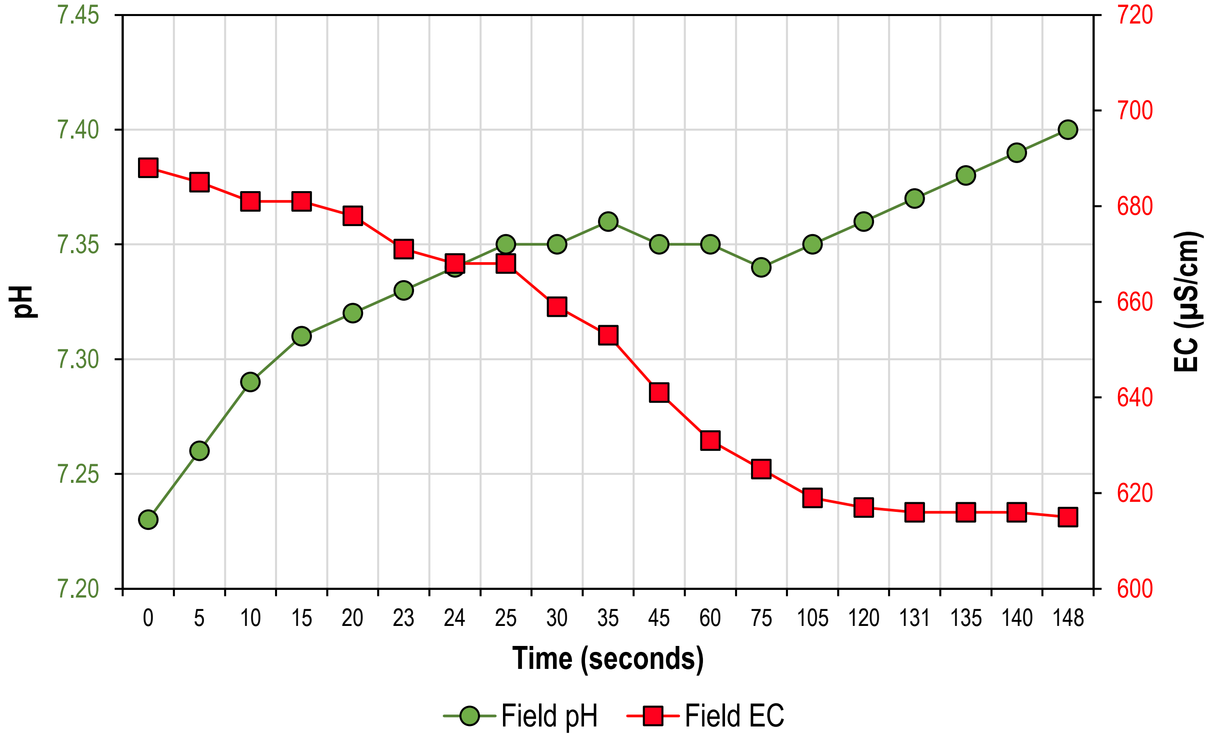

Figure 5-3: Initial changes in field pH and EC of groundwater sampled from production bore HGE0148P. Green symbols represent field pH measurements and orange symbols represent field EC measurements.

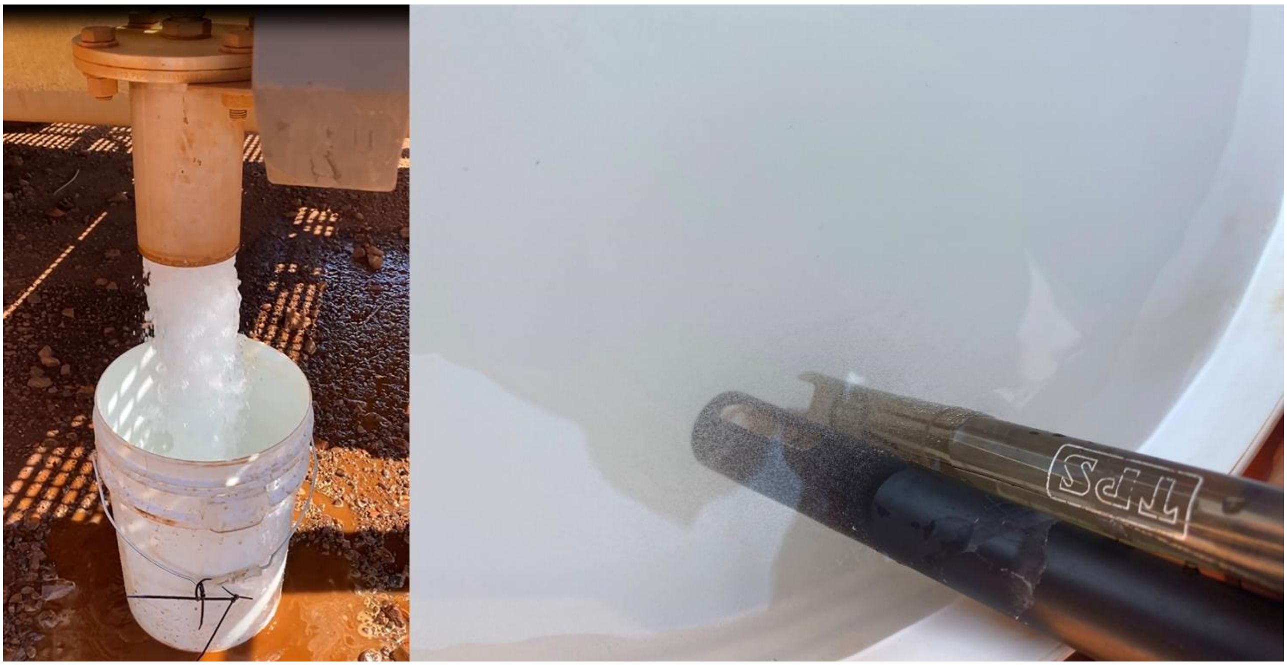

Figure 5-4: Photo showing sampling of groundwater from production bore HGE0148P (left) and bubbles (likely CO_2) forming shortly after sampling (right).

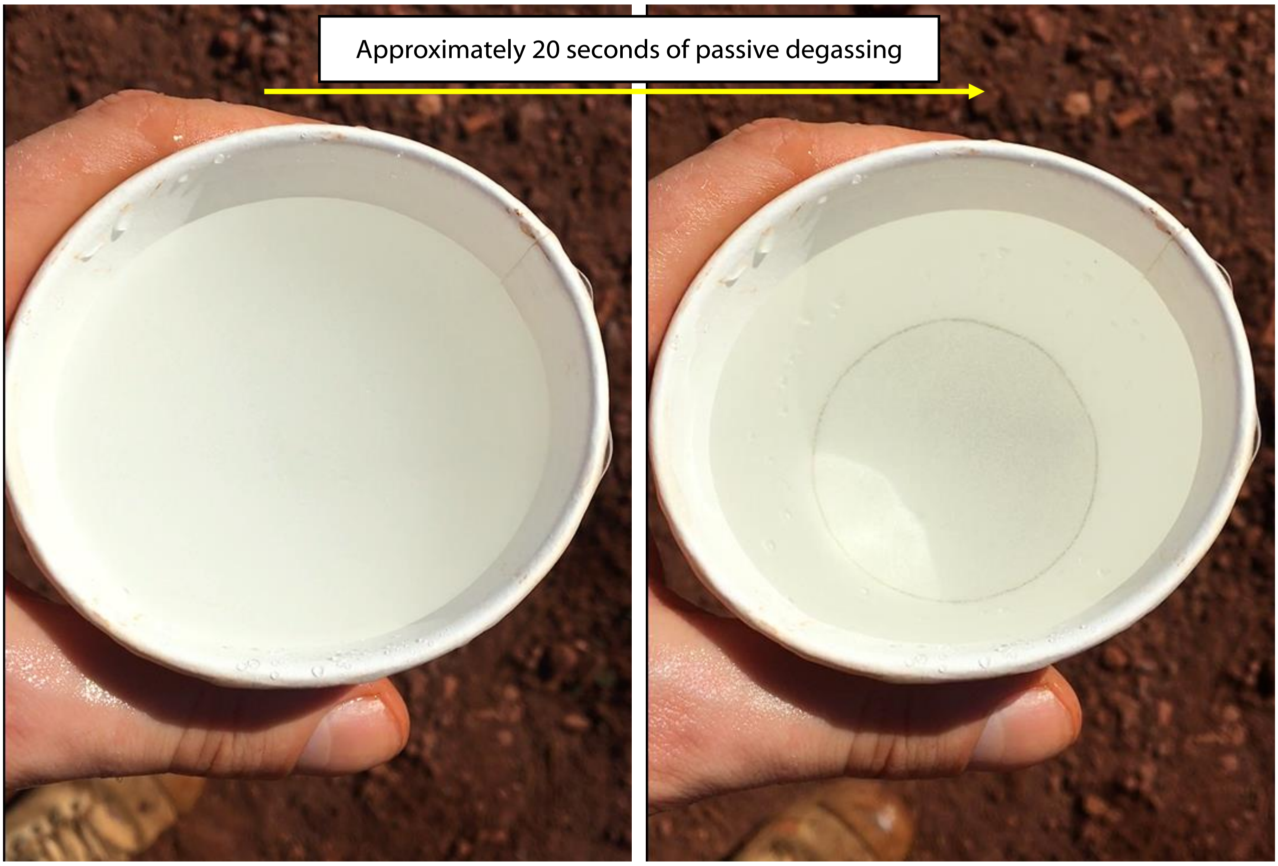

Figure 5-5: Groundwater immediately after sampling (left panel) has a cloudy appearance [bottom of the cup is not visible]due to the presence of abundant gas bubbles (likely CO_2 – as indicated by gas monitoring equipment – see Section 5-24). Groundwater sample after exposure to ambient surface pressure and temperatures for approximately 20 seconds (right panel) has degassed significantly (very few CO_2 bubbles) resulting in a transparent appearance.

Whilst the initial changes over a time frame of seconds to minutes were discussed above, the below discussion relates to changes observed over the duration of multiple hours.

Over 3 to 5 hours, passive degassing (PDG) resulted in the following changes in groundwater chemistry:

- HGA0074P: A slow and reasonably linear increase in pH from 7.20 to 7.50 (Figure 5-6a).
- HGE0148P: A slow increase in pH from 7.51 to 7.76 (Figure 5-6b).
- HGA0074P and HGE0148P: Fluctuating EC values, but no systematic trend over time.
- HGA0074P: A range in total alkalinity concentrations from 185 to 256 mg $CaCO_3$ / L, but no systematic trend over time.
- HGE0148P: A range in total alkalinity concentrations from 187 to 219 mg $CaCO_3$ / L, but no systematic trend over time.
- Neither Ca nor Mg concentrations from either PDG tests show any systematic trends over time.

Over 3 to 5 hours, active degassing (ADG) resulted in the following changes in groundwater chemistry:

- HGA0074P: An initially rapid increase in pH from 7.25 to 8.18, followed by stabilisation of pH values (Figure 5-6a).
- HGE0148P: An initially rapid increase in pH from 7.50 to 8.10, followed by stabilisation of pH values (Figure 5-6b),
- HGA0074P and HGE0148P: Fluctuating EC values, but no systematic trend over time.
- HGA0074P: A range in total alkalinity concentrations from 165 to 253 mg $CaCO_3$ / L, but no systematic trend over time.
- HGE0148P: A range in total alkalinity concentrations from 187 to 219 mg $CaCO_3$ / L, but no systematic trend over time.
- Neither Ca nor Mg concentrations from either PDG tests show any systematic trends over time.

The key observation from comparison of the ADG and PDG results (see above) is that active aeration, even though not vigorous, dramatically increased the rate of CO_2 degassing (evidenced by an increase in the pH). However, the lack of systematic change in EC values, likely means that carbonate precipitation did not occur. This is supported by no systematic decrease in the concentrations of alkalinity, Ca, or Mg. The lack of carbonate precipitation could be due to the fact that most of the carbonate precipitation occurred rapidly (i.e., within a matter of minutes to seconds – see above), leaving the sample with little capacity for further carbonate precipitation. However, whilst these rapid changes can be observed by monitoring physiochemical parameters, they are unfortunately unable to be captured by field analysis of Ca, Mg, or alkalinity as preparation of the spectrophotometric tests requires between 3 and 12 minutes.

It should also be noted that during field testwork the temperature of the water samples decreased from approximately 31 °C to 15 °C. This decrease in temperature may also contribute to the lack of carbonate precipitation during these field tests because the decrease in temperature results in carbonate minerals being more soluble (ie. less likely to precipitate).

The addition of seed crystals, irrespective of material type (precipitated calcium carbonate, quartz sand, or crushed hematitic material) had no discernible effect on water quality parameters. This is likely due to the fact that these seed crystals were added after pH had stabilised, and hence, after the water sample had cooled significantly.

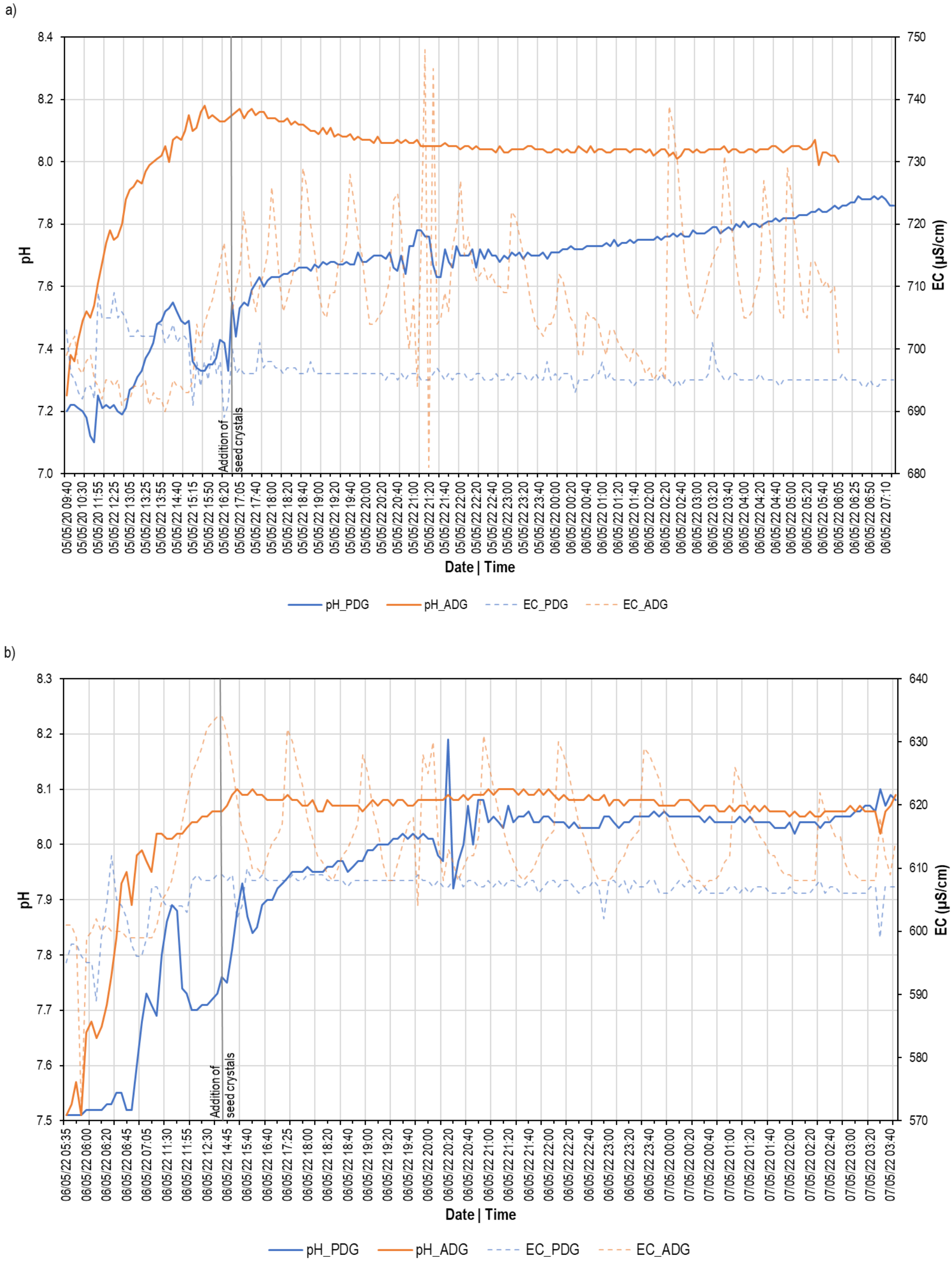

Figure 5-6: Field pH and field EC over time during testwork on groundwater from production bore a) HGA0074P and b) HGC0148P. pH is shown with continuous lines (blue for passive (PDG) and orange for active degassing (ADG)). EC is shown with dotted lines (blue for PDG and orange for ADG). Black line indicates time quartz sand was added.

5.3 Inspection of Site Water Bodies & Dewatering Infrastructure

Water bodies and associated dewatering infrastructure were inspected to elucidate degassing and carbonate precipitation processes occurring within the current dewatering configuration. This inspection involved:

- In-situ analysis of water samples for field parameters (pH, EC, Temp, ORP), and collection of water samples for laboratory analysis (see Section 4.2.2 for parameters).
- Semi-quantitative field assessments of the carbonate content of soil / sediment materials, as well as collection of samples for quantitative laboratory analysis (QXRD, ANC / Total Carbon).
- Measurement of oxygen concentrations (hand-held gas monitor) as a proxy to elucidate potential increases in CO_2 due to degassing of groundwater.

5.3.1 Water

Variations in field water quality parameters measured at the A and E Deposit Turkey's Nest Dams and surrounding dewatering infrastructure are displayed schematically in Figure 5-7. Key observations from the inspection of these site water bodies and dewatering infrastructure, as well as assessment of the field water quality parameters are provided below.

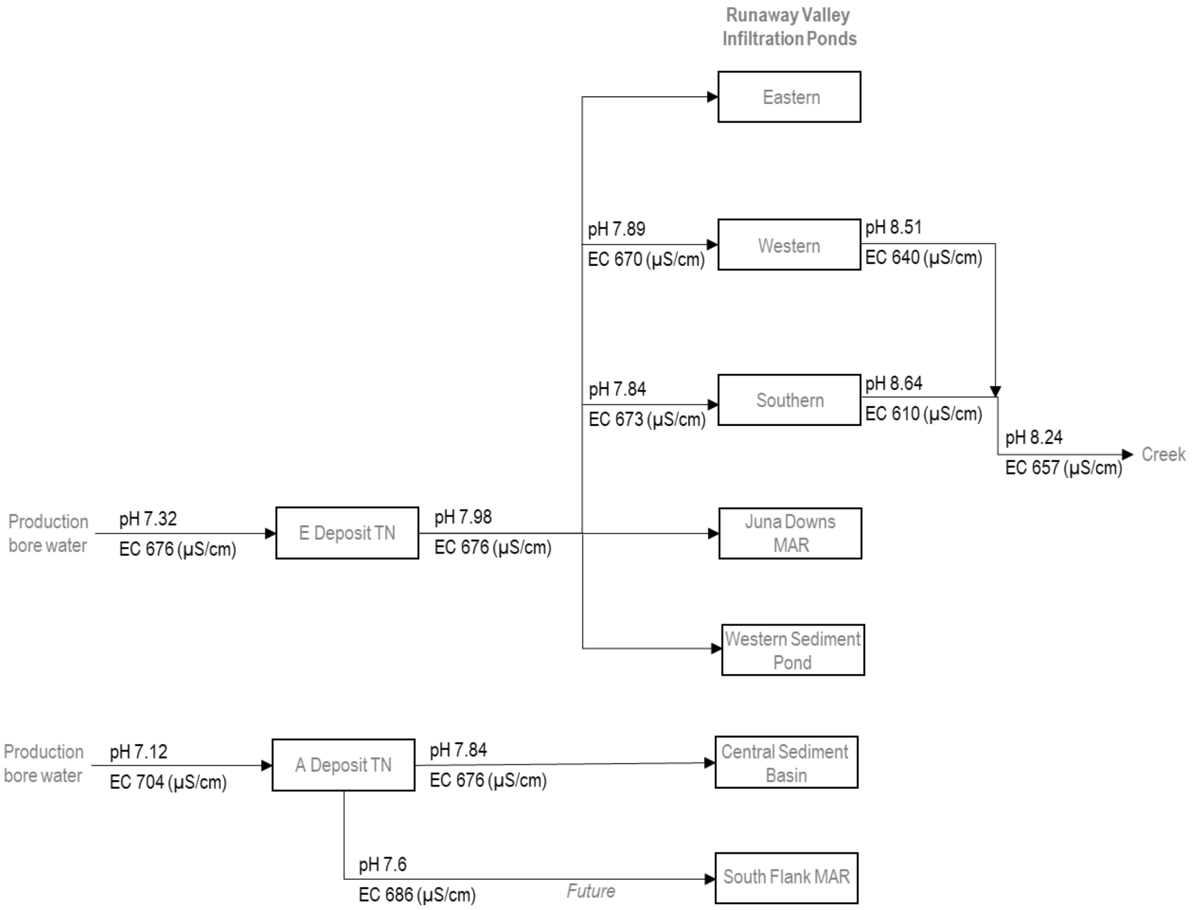

Figure 5-7: Groundwater pathways from production bores in MAC feeding the A and E Deposit Turkey's Nest Dams indicated by black arrows. The field pH and EC is provided adjacent to the locations analysed during field work.

A Deposit Turkey's Nest Dam and Surrounding Dewatering Infrastructure

- Residence time in the A Deposit Turkey's Nest Dam is roughly estimated at roughly 3-5 hours.
- Groundwater from production bores enters the A Deposit Turkey's Nest Dam at a pH of 7.12 and an EC of 704 µS/cm (measured at the inlet - Figure 5-7).
- Water discharged to the standpipe has a higher pH (7.84) and lower EC (676 µS/cm) compared to the inlet water. Whereas water discharged to the South Flank Crusher has a pH of 7.60 and an EC of 686 µS/cm.
  - The increase in pH values is likely due to CO_2 degassing (lower concentrations of carbonic acid), whereas the decrease in EC is likely due to carbonate precipitation within the Turkey's Nest Dam (see also Section 5.3.2).
- The outlet suction lines which supply water to the South Flank Crusher are located close to the inlet from production bores (Figure 5-8), whereas the outlet lines to the standpipe are located at the other end of the A Deposit Turkey's Nest Dam.
- Water sent to the standpipe therefore has a longer residence time in the Turkey's Nest Dam compared to water sent to the South Flank Crusher. The water sent to the standpipe therefore experiences a greater extent of passive CO_2 degassing, resulting in a larger pH increase, and a greater opportunity for carbonate precipitation.

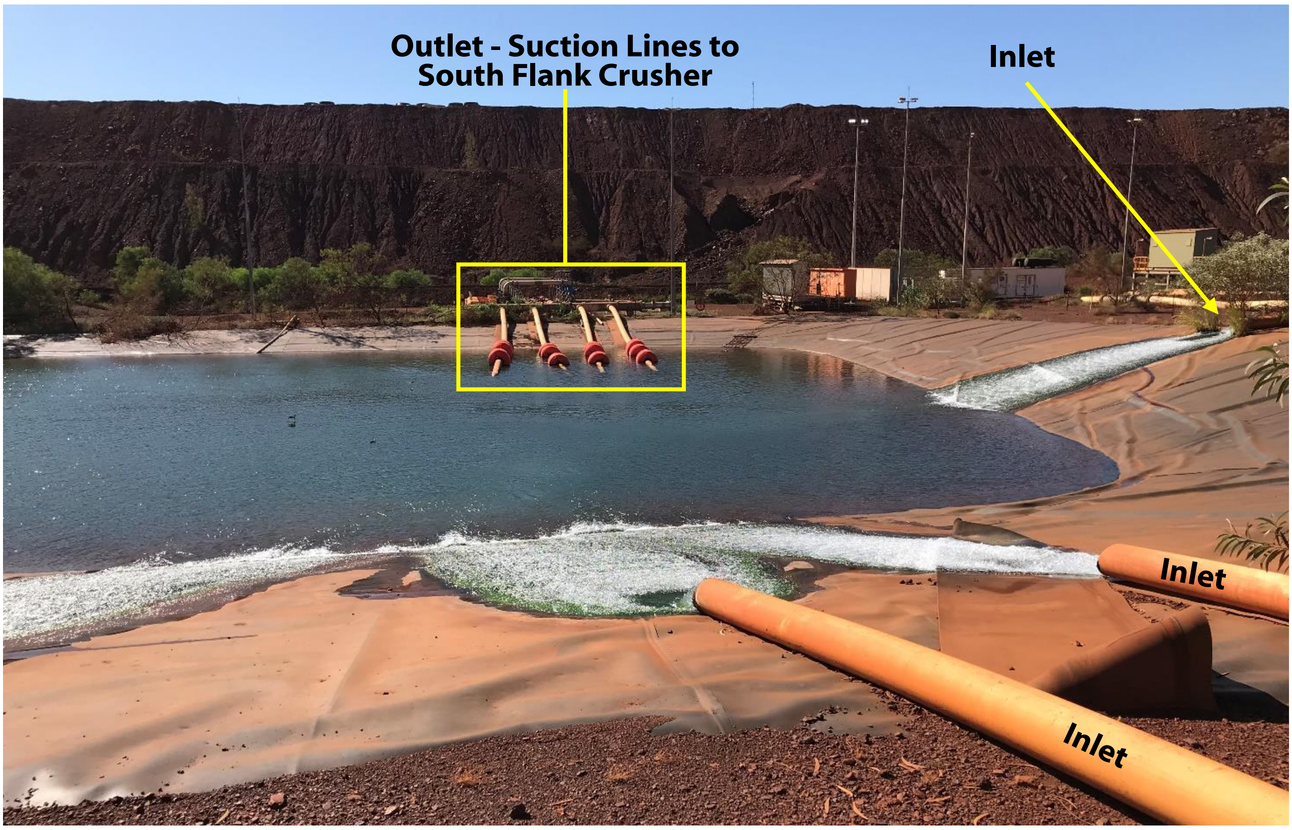

Figure 5-8: Photo showing the inlet pipe and outlet suction lines at the A Deposit Turkey's Nest Dam. Note: the short distance between the inlet and outlet compared with the E Deposit Turkey's Nest Dam (cf. Figure 5-9).

E Deposit Turkey's Nest Dam and Surrounding Dewatering Infrastructure

- Residence time in the E Deposit Turkey's Nest Dam is roughly estimated at 10-20 hours.

- Groundwater from production bores enters the E Deposit Turkey's Nest Dam at a pH of 7.32 (measured at the inlet) and increases to a pH of 7.98 at the outlet suction lines to the Runaway Valley Infiltration Ponds (Figure 5-7). This suggests that CO_2 degassing occurs within the E Deposit Turkey's Nest Dam.
- Unlike pH, the EC displays a stable value of 676 µS/cm across the Turkey's Nest Dam (both at the inlet and outlet). This indicates that either precipitation was not occurring (at least at the time of the field visit) or was offset by changes in alkalinity speciation.
- This water then enters the Western and Southern Runaway Valley Infiltration Ponds at pH values of 7.89 and 7.84, respectively; and is discharged at pH values of 8.51 and 8.64, respectively. This increase in pH across the Runaway Valley Infiltration Ponds indicates that degassing continues across Infiltration Ponds and is not complete when discharged from the Turkey's Nest Dam.
- The decrease in EC between the inlet of the E Deposit Turkey's Nest Dam (676 µS/cm) and the outlets from the Western and Central Runaway Valley Infiltration Ponds (640 and 610 µS/cm) indicates that carbonate precipitation occurs within the Infiltration Ponds.

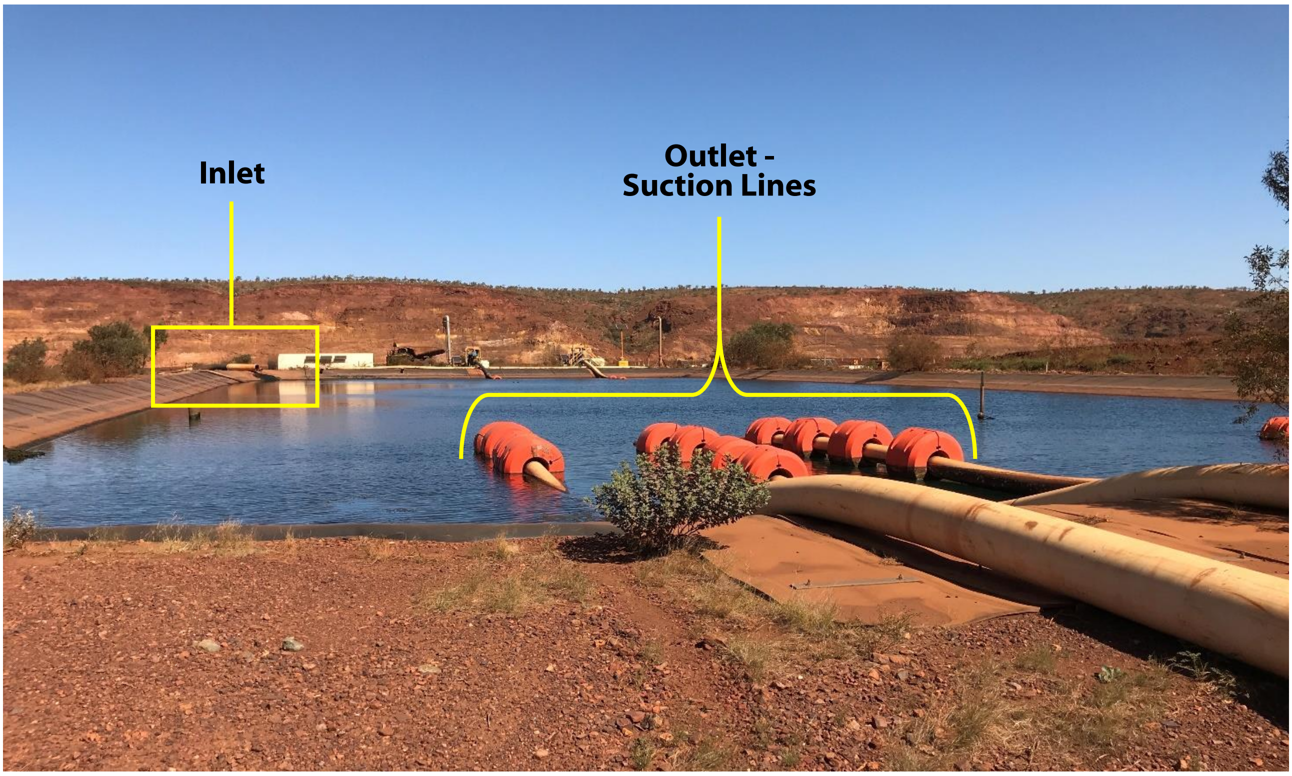

Figure 5-9: Photo showing the inlet pipe and outlet suction lines at the E Deposit Turkey's Nest Dam. Note: the relatively long distance between the inlet and outlet compared with the E Deposit Turkey's Nest Dam.

5.3.2 Soil and Sediment

Soil from the Eastern Runway Valley (Pond 1) as well as sediment samples from the A and E deposit Turkey's Nest Dams reacted (effervesces) with dilute acid. This is known as a 'fizz' test, a common field test for the presence of carbonate minerals. Based on a positive field test for the presence of carbonate minerals, these three samples were subject to QXRD analysis and measurement of their Acid Neutralising Capacity (ANC). These two laboratory tests provide independent quantification of the presence and abundance of carbonate minerals.

The results of these tests (see Table 5-1) show that calcite is present in all sediment / soil samples analysed. The concentration of calcite determined by QXRD is lower than that suggested by ANC determination. This could indicate that some of the calcite is present in the poorly crystalline / amorphous fraction detected by QXRD. Poorly crystalline / amorphous may be expected if crystallisation is rapid, for example, where crystalised from supersaturated water due to rapid CO_2 degassing.

It is noteworthy the samples from the Turkey's Nest Dams were sampled from stockpiles of materials that had been dredged previously (not directly from the base of the dam). These samples were therefore exposed to atmospheric oxygen. These samples contain pyrite, meaning that when exposed to atmospheric oxygen they will oxidise and generate sulfuric acid. This sulfuric acid will then dissolve carbonate minerals. This process means that the carbonate concentration measured by laboratory analysis represents a minimum concentration.

Table 5-1: QXRD, Acid Neutralising Capciaity [ANC], and Total Carbon analysis of sediment and soil samples from MAC.

Mineral / Parameter	A Deposit Turkey's Nest Sediment	E Deposit Turkey's Nest Sediment	Eastern Runway Valley - Pond 1 Soil
Quantitative X-Ray Diffraction (QXRD) Analysis			
Hematite (wt.%)	30.7	29.6	13.5
Goethite (wt.%)	20.9	26.3	2.1
Quartz (wt.%)	16.8	12.5	28.9
Kaolinite (wt.%)	13	14.3	27.1
Dolomite (wt.%)	1.2	0.1	-
Microcline (wt.%)	1.6	0.6	-
Calcite ($CaCO_3$) (wt.%)	**0.3**	**1.4**	**1.1**
Urea (wt.%)	1.4	0.4	-
Alum (wt.%)	0.4	0.2	-
Natroalunite-K (wt.%)	-	-	0.8
Pyrite (wt.%)	0.3	0.2	-
Römerite (?) (wt.%)	0.9	0.6	-
Maghemite (wt.%)	0.5	0.3	5.9
Siderite (wt.%)	0	0	-
Rutile (wt.%)	-	-	1.6
Illite (wt.%)	-	-	-
Amorphous (wt.%)	12	13.5	18.6
SUM	100	100	100
Acid Neutralising Capacity (ANC) / Total Carbon Analysis			
ANC as % $CaCO_3$ (Calcite)	**3.6**	**2.7**	**2.2**
ANC as kg H_2SO_4 /tonne	35.0	26.8	21.5
Total Carbon (%)	3.37	4.16	0.52

5.3.3 Gas

During inspection of the A Turkey's Nest Dam, gas monitoring equipment detected a decrease in O_2 concentrations (from 20.95% to 19.3%). It is likely this reflects an increase in CO_2 concentrations due to degassing of the groundwater either within the pipeline or immediately as it discharges from the pipeline. This is consistent with observations of vigorous degassing when samples are initially exposed to atmospheric conditions (see Figure 5-4 and Figure 5-5).

5.3.4 Carbonate Precipitation within Turkey's Nest Dams & Infiltration Ponds

The external laboratory analytical reports for all water samples are provided in Attachment C. Observations from the assessment of water chemistry data collected at key sites along the dewatering infrastructure, and their implications for carbonate precipitation are provided below.

Comparison of field and laboratory pH data for the same samples shows that the water chemistry changes during transit and storage (Figure 5-10). Specifically, the pH measured in the laboratory is almost always higher than the pH measured in the field. This indicates that CO_2 degassing continues through samples transit. The only field pH values that align with the laboratory pH values are the samples from the discharge of Central and Western Runaway Valley Infiltration Ponds. This suggests that at a pH of 8.6, CO_2 degassing is largely complete and that the potential for additional carbonate precipitation has largely been exhausted. Therefore, laboratory water quality data is not representative of groundwater samples extracted from production bores on site, and these data need to be interpreted with this in mind.

At the pressure and temperature conditions of the screened zone / pump of the production bores (eg. ~30°C at 10-20 Bar / 100-200 meters depth) the groundwater is in chemical equilibrium with carbonate bearing geological units. However, as this groundwater is pumped to the surface the pressure rapidly decreases (~0.1 bar per meter), which makes CO_2 less soluble in water and as a result some of the CO_2 degasses causing the pH to increase (ie. lower concentrations of carbonic acid). This process is most rapid as the water reaches atmospheric pressure and temperature (ie. within the first few seconds to minutes after sampling – see Section 5.2.2), although slowly continues for hours (and possibly days) during sample transit to the laboratory. These changes in water chemistry (eg. CO_2 degassing and pH increase), can lead to carbonate mineral precipitation, which would likely result in lower calcium concentrations.

Comparison of laboratory measured total alkalinity concentrations from the E Deposit Turkey's Nest Dam and the Western Runaway Valley Infiltration Pond, show the following:

- Groundwater that discharges from the E Deposit Turkey's Nest Dam to the Runaway Valley Infiltration Ponds has a total alkalinity concentration of 220 mg $CaCO_3$ / L.
- Groundwater that discharges from the Western Runaway Infiltration Pond has a total alkalinity concentration of 180 mg $CaCO_3$ / L.
- This implies the loss of 40 mg $CaCO_3$ / L between these points (through precipitation). At an estimated flow rate of 400 L / second, this suggests that 1.4 t $CaCO_3$ precipitates within the Runaway Valley Infiltration Ponds per day.
- The tonnage of precipitates might differ between seasons (eg. more precipitates in summer months – see Section 2.2).

Precipitation of carbonate minerals across the Runaway Valley Infiltration Ponds is further supported by a drop in calcium concentrations from 50 mg/L (E Deposit Turkey's Nest) to 35 mg/L (Western Runaway Valley Infiltration Pond). However, magnesium concentrations show no significant change between these two locations (32 and 33 mg/L), which supports the precipitation of calcite as opposed to dolomite (see also Section 5.3.2).

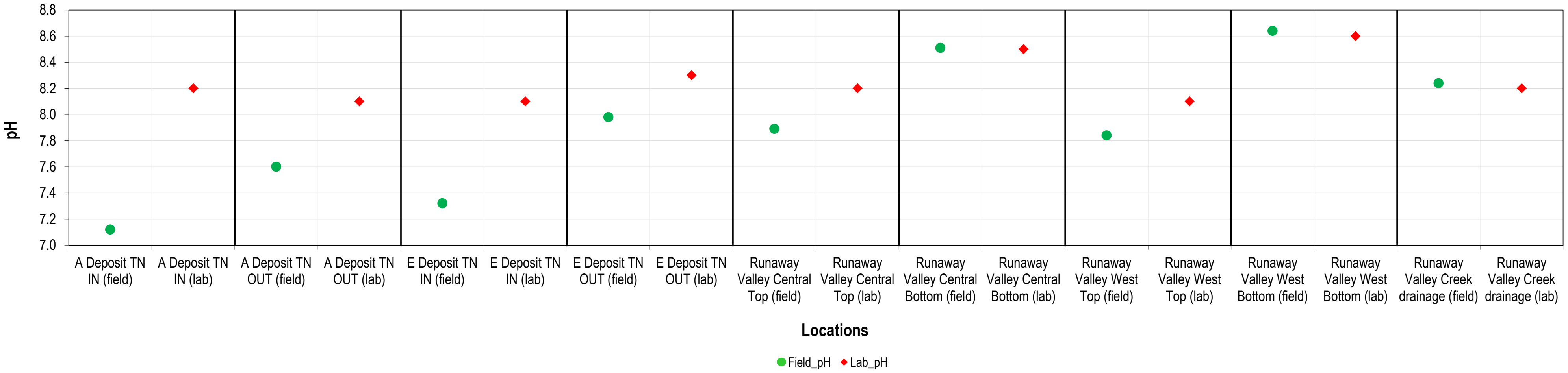

Figure 5-10: Comparison of field pH values (measured by Earth Systems) and laboratory pH values (measured by SGS).

5.4 Groundwater Chemistry

Typical groundwater chemistry (major ions and physiochemical parameters) from South Flank and MAC is presented in Table 5-2 below, where the data is presented as the range between Q1 [25th percentile] and Q3 [75th percentile]. The major element chemistry of groundwater is used to educate the ultimate source of carbonate saturated groundwater (see also Section 5.5); and comparison of field and laboratory measured physiochemical parameters help to constrain processes occurring between the time of initial sampling and laboratory analysis.

Table 5-2: Typical groundwater chemistry (Q1-Q3) for MAC and South Flank (data from BHP, 2020).

Parameter	Mining Area C	South Flank
pH	7.8 – 8.1	8.0 – 8.2
EC (µS / cm)	540 – 660	539 – 615
Calcium (mg / L)	37 – 50	44 – 49
Magnesium (mg / L)	23 – 30	23 – 29
Sodium (mg / L)	27 – 35	21 – 31
Potassium (mg / L)	6 – 9	8 – 14
Total alkalinity* (mg $CaCO_3$ / L)	187 – 220	230 – 245
Chloride (mg / L)	38 – 52	24 – 29
Sulfate (mg / L)	33 – 42	17 – 36

* Total Alkalinity in all samples is dominated by bicarbonate alkalinity.

Comparison of all available laboratory and field pH values (data from BHP and Earth Systems) is presented in (Figure 5-11). As noted above for data collected during the recent field visit, the pH values measured in the field are systematically lower than the corresponding pH measured in the laboratory (some days later). This increase in pH is attributed to CO_2 degassing from the water.

In addition, comparison of this larger data set (data from BHP and Earth Systems) shows subtle differences in the EC values, where maximum and average field EC values are often higher than those measured in the laboratory. The decrease in EC values between measurement in the field and the laboratory is likely to be due to (minor) carbonate precipitation during sample transit.

The clear differences between the field and laboratory water chemistry, means that laboratory data collected by BHP in the past, and going forward, needs to be interpreted carefully. These differences also validate the decision to analyse water samples in the field by spectrophotometric techniques.

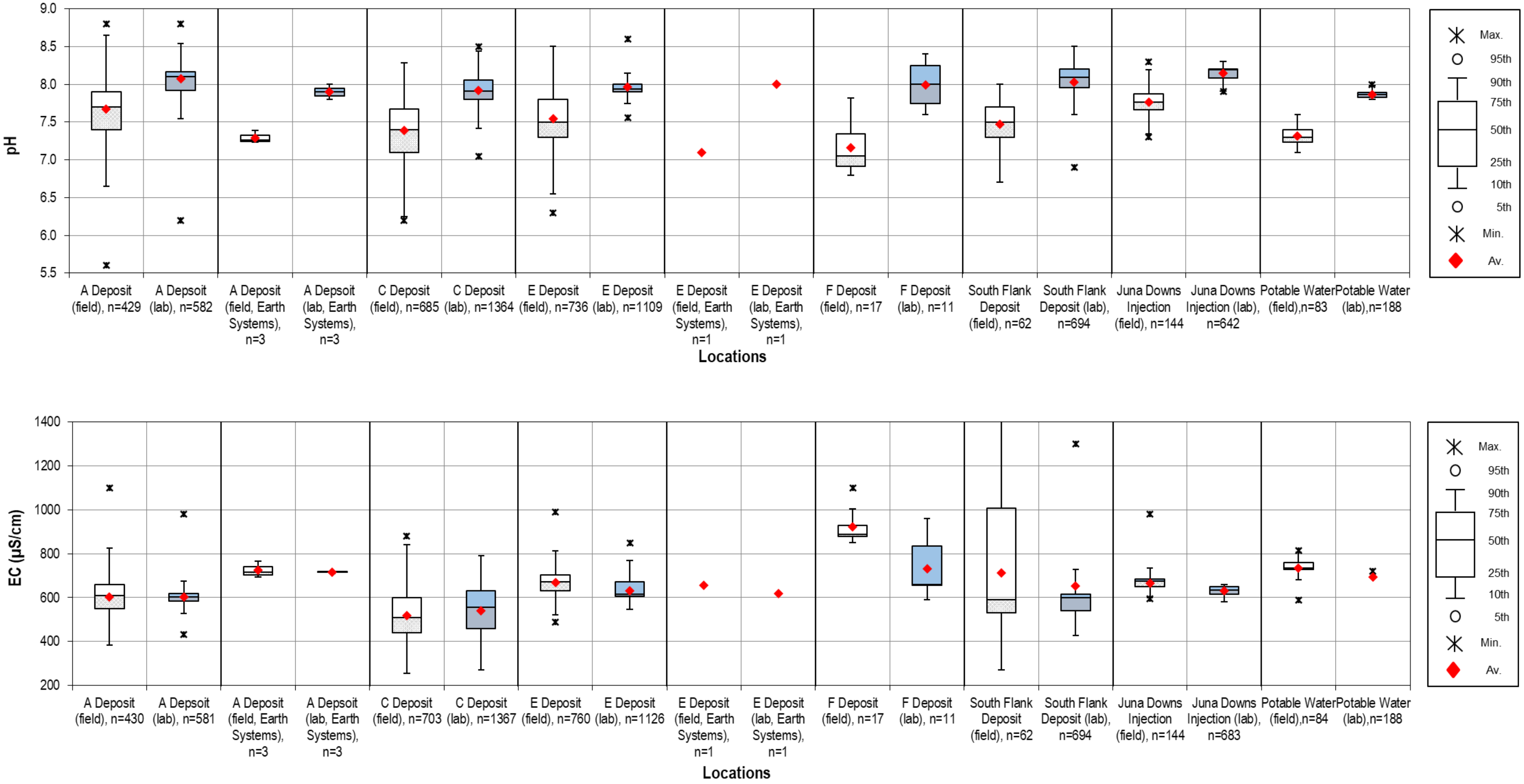

Figure 5-11: pH (top panel) and EC (bottom panel) measured in the field and laboratory as a function of deposit. The data plotted includes values for samples taken during field work by Earth Systems, as well as BHP data (112 production and reinjection bores at MAC and South Flank; and potable water between 2010 and 2022. Light coloured boxes highlight the data that has been collected in the field. Dark coloured boxes highlight the data that has been collected in the laboratory (lab). The number of analyses is indicated with *n*.

5.4.1 Comparison with Water Quality Guidelines

When comparing groundwater chemistry with the relevant water quality guideline values (ie. ANZG 99% *freshwater*, and ANZG 95% *freshwater* guideline values– see Section 4.2.2) only the most recent water chemistry data was considered (ie. 2021). This data includes 32 production bores at MAC and South Flank. From this comparison (see Table 5-3) it is evident that there are only occasional and marginal exceedances, which are limited to individual production bores (ie. exceedances are not common across all bores in an area). In general, the groundwater is of good quality, and when groundwater from multiple production bores is combined (ie. prior to discharge) it is considered unlikely that the combined water source would exceed any of the ANZG 99% *freshwater* guideline values. Details of specific exceedances are documented below.

The following production bores slightly exceed ANZG 99% *freshwater* guideline values (see also Table 5-3):

- A Deposit:
  - HGA0070P for zinc (0.005 mg / L).
- C Deposit:
  - HGC0233P for boron (0.48 mg / L) and zinc (0.006 mg / L).
  - HGC0261P for zinc (0.006 mg / L).

The following production bores exceed ANZG 95% *freshwater* guideline values:

- C Deposit:
  - HGC0261P for copper (0.002 mg / L).
- F Deposit:
  - HGF0026P for lead (0.014 mg /L) and zinc (0.010 mg / L).
- South Flank:
  - HSF5493P for copper (0.002 mg / L) and zinc (0.014 mg / L).

Table 5-3: Variations in groundwater chemistry (mg/L) sampled from production bores at MAC and South Flank during 2021. Water chemistry is compared with ANZG (2018) default guideline values for toxicants in freshwater (FW), where exceedances of 99% level of species protection are highlighted orange, and exceedances of 95% level of species protection are highlighted red.

Analyte Name	A Deposit	C Deposit	E Deposit	F Deposit	South Flank	ANZG 99% FW guideline values	ANZG 95% FW guideline values	ANZG %*
Aluminium, Al	<0.005	<0.005	<0.005	<0.005	<0.005	0.027 (pH>6.5)	0.055	NA
Antimony, Sb	NA	NA	NA	NA	NA	NA	NA	0.009
Arsenic, As	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.024	NA
Bismuth, Bi	NA	NA	NA	NA	NA	NA	NA	NA
Barium, Ba	0.004	0.002-0.011	<0.001-0.010	0.004-0.014	<0.001-0.034	NA	NA	NA
Boron, B	0.26-0.30	0.31-0.48	0.19-0.25	0.20-0.27	0.05-0.26	0.34	0.94	NA
Cadmium, Cd	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00006	0.0002	NA
Chromium, Cr	<0.001	<0.001	<0.001-0.002	<0.001	<0.001-0.002	NA	NA	0.033
Cobalt, Co	NA	NA	NA	NA	NA	NA	NA	0.0014
Copper, Cu	<0.001	<0.001-0.002	<0.001	<0.001	<0.001-0.002	0.001	0.0014	NA
Iron, Fe	<0.005	<0.005-0.062	<0.005	<0.005-0.011	<0.005-0.075	NA	NA	NA
Lead, Pb	<0.001	<0.001	<0.001	<0.001-0.014	<0.001	0.001	0.0034	NA
Manganese, Mn	<0.001 - 0.004	<0.001-0.048	<0.001-0.15	<0.001-0.037	<0.001-0.14	1.2	1.9	NA
Molybdenum, Mo	<0.001 - 0.003	<0.001	<0.001	<0.001	<0.001 - 0.003	NA	NA	0.034
Nickel, Ni	<0.001	<0.001-0.002	<0.001-0.001	<0.001	<0.001-0.001	0.008	0.011	NA
Selenium, Se	<0.001	<0.001	<0.001-0.002	<0.001-0.001	<0.001	0.005	0.011	NA
Thallium, Tl	NA	NA	NA	NA	NA	NA	NA	0.00003
Tin, Sn	NA	NA	NA	NA	NA	NA	NA	NA
Uranium, U	NA	NA	NA	NA	NA	NA	NA	0.0005
Vanadium, V	NA	NA	NA	NA	NA	NA	NA	0.006
Zinc, Zn	<0.005 - 0.005	<0.005-0.006	<0.005	<0.005-0.010	<0.005-0.014	0.0024	0.008	NA
Tellurium, Te	NA	NA	NA	NA	NA	NA	NA	NA
Silver, Ag	NA	NA	<0.001	<0.001	<0.001	0.00002	0.00005	NA
Mercury	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.00006	0.0006	NA

* The ANZG species protection percentage is unknown. The listed values represent “low reliability” trigger values for fresh water and should be considered an indicative interim working level until additional toxicology data becomes available.

5.4.2 Spatial and Temporal Variations in Groundwater Chemistry

Variations in the chemistry of groundwater as a function of time or location have the potential to indicate process responsible for carbonate mineral saturation and precipitation, as well as potentially predict any future issues related to deteriorating water quality. The below assessment is based on Earth Systems and BHP data collected between 2010 and 2022 for the 112 production and reinjection bores as well as potable water at MAC and South Flank. Key observations from assessment of these data are provided below, with additional plots provided in Attachment D.

Variations in sulfate concentrations as a function of time is shown in Figure 5-12. Key observations from the assessment of these data are as follows:

- Groundwater from production bores in A Deposit and C Deposit display an increase in sulfate concentrations since approximately 2015:
  - The average groundwater sulfate concentrations in production bores from A Deposit increase from 33 mg/L (2015) to 48 mg/L (2022).
  - The average groundwater sulfate concentrations in production bores from C Deposit increase from 29 mg/L (2015) to 37 mg/L (2022).
- Water from reinjection bores at Juna Downs shows an increase in average sulfate concentrations from 26 mg/L (2016) to 43 mg/L (2020).
- An increase in sulfate concentrations over time can also observed for individual production bores, for example:
  - Sulfate concentrations in groundwater from HGC0002P increases from 24 to 38 mg/L between 2010 and 2012.
  - Sulfate concentrations in groundwater from HGC0066P increases from 16 to 48 mg/L between 2011 and 2019.

The potential sources of sulfate in groundwater samples include the dissolution of secondary acid salts (eg. alunite –$KAl_3(SO_4)_2(OH)_6$)), or the oxidation of sulfide minerals such as pyrite / marcasite (FeS_2). If the increase in sulfate concentrations is attributed to sulfide oxidation, it could be expected that sulfate concentrations will continue to increase as the groundwater table is drawn down exposing more sulfide minerals to atmospheric oxygen (allowing them to oxidise).

An increase in total alkalinity concentrations over time is also observed in groundwater from A Deposit, C Deposit, and F Deposit (Figure 5-13). This likely reflects the fact that dolomite horizons represent high yielding aquifers, and therefore the proportion of water extracted from these lithologies will increase over time. In turn, the increase in alkalinity is likely contributing to an increase in the LSI values of groundwater from bores in C Deposit and E Deposit (Figure 5-14).

Calculation of LSI values of the groundwater from all 112 production and injection bores as well as potable water shows that 88% of the groundwater samples are saturated with respect to calcite (Figure 5-14). Whilst some individual production bores at C Deposit, F Deposit and South Flank yield carbonate undersaturated water, based on this initial assessment the small proportion of these bores means that dilution of carbonate saturated water with water from carbonate undersaturated bores is unlikely to be a viable management option.

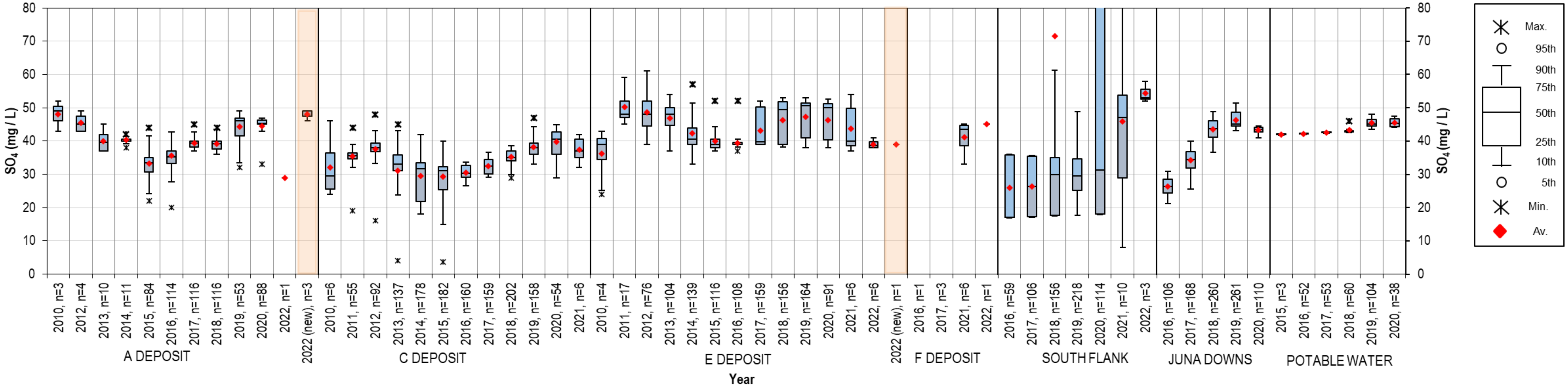

Figure 5-12: Sulfate (mg / L) analysed in the laboratory plotted as a function of time. Data plotted includes values collected during fieldwork from Earth Systems (highlighted with orange column) and all 112 production bores at MAC and South Flank as well as the Juna Downs Injection bored and potable water covering the years 2010 – 2022. The number of analyses is shown with *n*. Groundwater from production bores in F Deposit show values of up to 110 SO_4 mg / L and South Flank of up to 380 SO_4 mg / L.

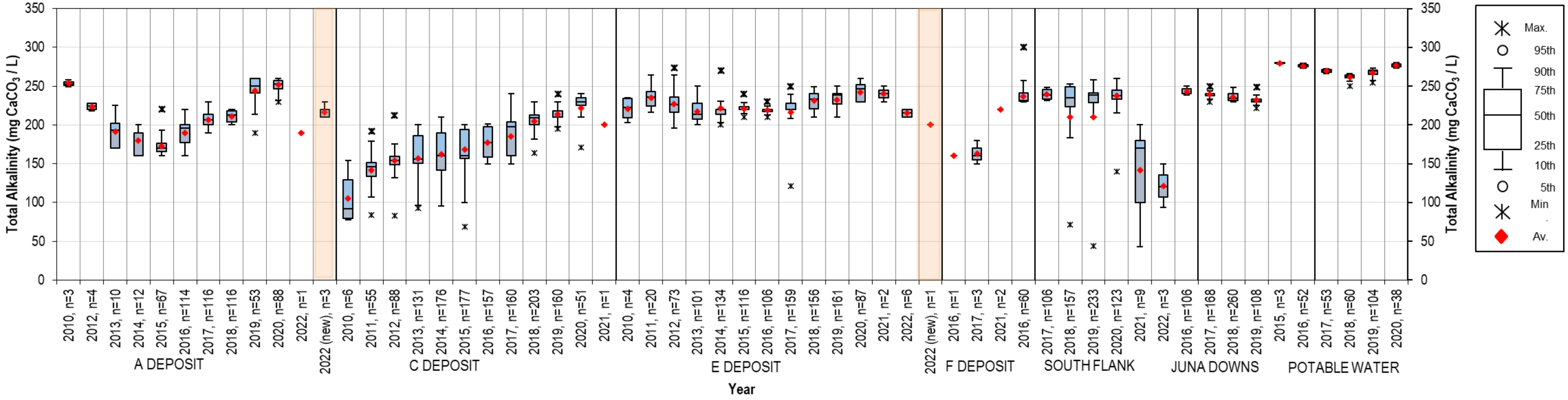

Figure 5-13: Total Alkalinity (mg $CaCO_3$ / L) analysed in the laboratory plotted as a function of time. Data plotted includes values collected during fieldwork from Earth Systems (highlighted with orange column) and all 112 production bores at MAC and South Flank as well as the Juna Downs Injection bored and potable water covering the years 2010 – 2022. The number of analyses is shown with *n*.

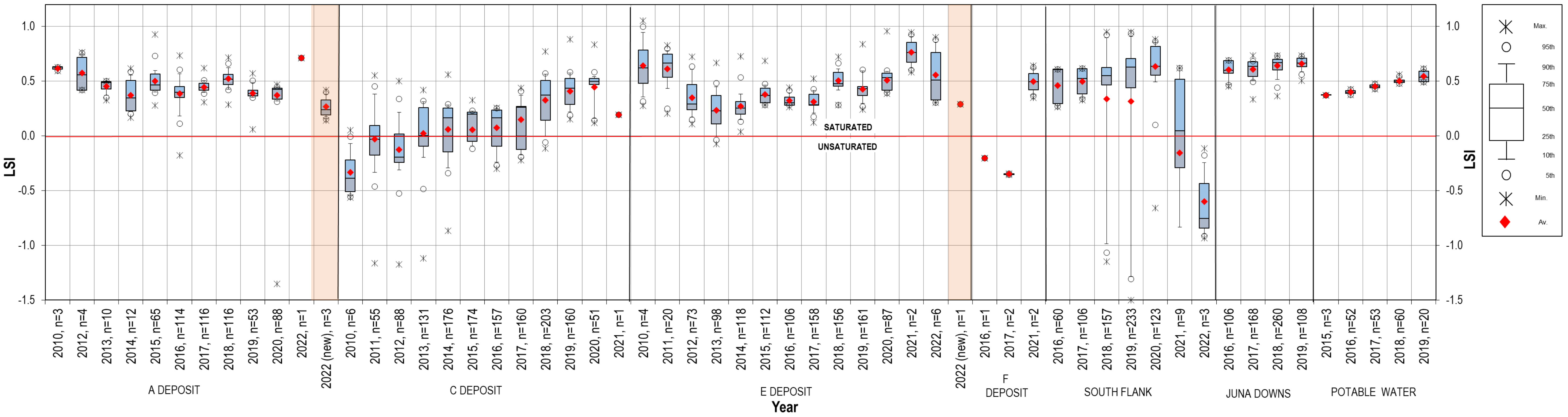

Figure 5-14: LSI as a function of time. Data plotted includes values collected during fieldwork from Earth Systems (highlighted with orange column) and all 112 production bores at MAC and South Flank as well as the Juna Downs Injection bored and potable water covering the years 2010 – 2022. The number of analyses is shown with *n*.

5.5 Source of Carbonate Saturated Water

With the exception of siderite $FeCO_3$, which is relatively insoluble, dolomite [$Ca,Mg(CO_3)_2$] (and lesser calcite [$Ca CO_3$]) is the most abundant carbonate mineral in the stratigraphic sequence at MAC / South Flank. Dolomite is moderately soluble (particularly at depth / elevated pressure) and has a Ca/Mg ratio of ≈ 1 on a molar (mol) basis. Hence in a simple system, the dissolution of dolomite should produce water with a Ca/Mg (mol) ratio of ≈ 1. Although, slight deviations from a Ca/Mg ratio of 1 are possible (and likely) when other Ca or Mg bearing minerals are present (eg. gypsum, calcite), or the water has subsequently undergone precipitation of Ca or Mg bearing minerals (eg. calcite - $Ca(CO_3)$).

The Ca/Mg (mol) ratio of water samples from MAC and South Flank is presented in Figure 5-15, this dataset includes production bores, Juna Downs reinjection bores, and potable water covering the years 2010 to 2022. Figure 5-15 shows that most water samples have a Ca/Mg molar ratio ranging from 0.8 to 1.0, which supports the dissolution of dolomite. This observation is consistent with the fact that dolomite horizons are a high yielding aquifer, and that most bore construction logs record the presence of dolomite around the screened zone (BHP, 2020).

5.6 Stability of Carbonate Precipitates

Once formed carbonate precipitates are stable in subaerial settings, that is they are not sensitive to exposure to atmospheric oxygen.

When carbonate minerals are exposed to water, their stability depends on the saturation index of that water. Carbonate minerals will only dissolve if exposed to undersaturated water. For practical purposes (ie. considering human rather than geological timeframes), carbonate precipitates will be relatively stable under most conditions encountered on site at MAC / South Flank. The only instances where significant carbonate precipitate dissolution is likely to occur is when these precipitates are exposed to exceptionally pure (eg. RO water) or acidic water.

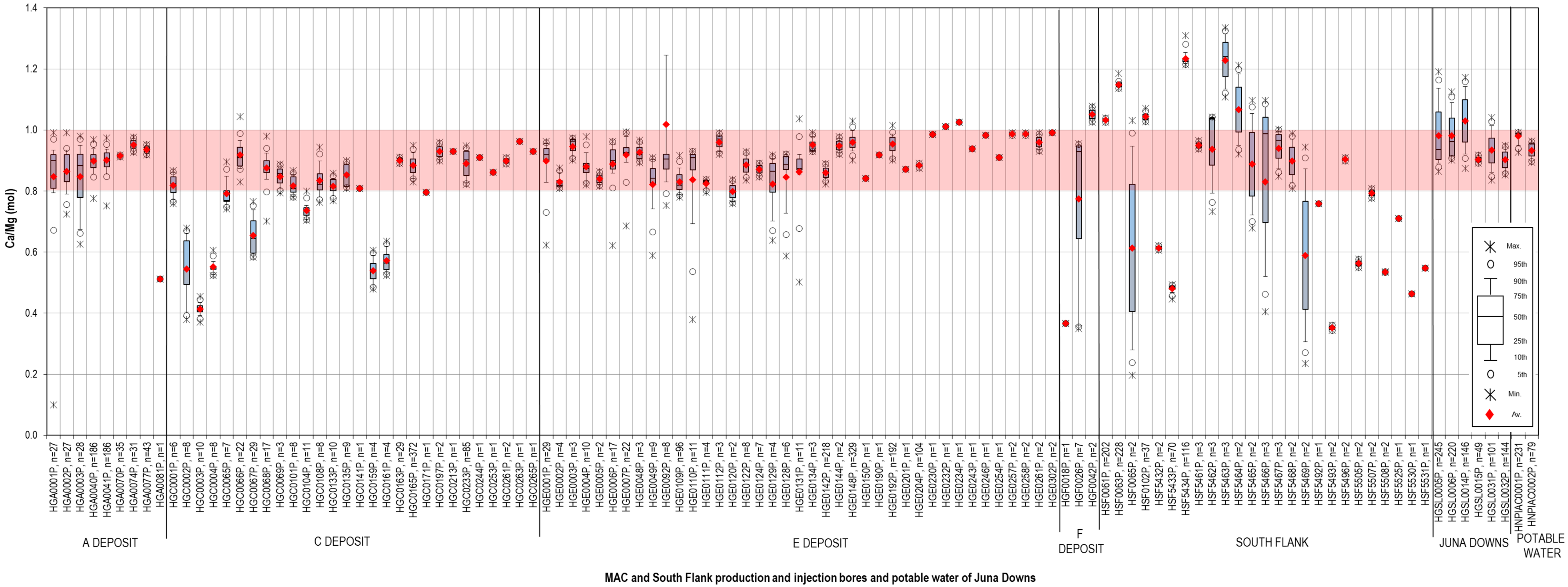

Figure 5-15: Ratio of laboratory dissolved calcium and magnesium concentrations in mol as a function of sample point. Data plotted includes values for all 112 production bores at MAC and South Flank as well as the Juna Downs Injection bored and potable water covering the years 2010 – 2022. Indicator of dolomite solution at Ca/Mg =1. During sample transit, carbonate likely precipitates, causing a small deviation from Ca/Mg of = 1 towards smaller Ca/Mg values. This error is indicated by the red shaded area.

6. CONCLUSIONS

If production bores were to be activated at South Flank and groundwater discharged directly to the environment, widespread precipitation of carbonate minerals could be expected from the current discharge point and along Pebble Mouse Creek.

Additional conclusions drawn from the assessment of existing data as well as data collected during the recent field study are listed below.

- At BHP's MAC and South Flank operations in the Pilbara, groundwater dewatering is required to enable mining to proceed.
- Groundwater quality from MAC and South Flank is generally very good. The typical water chemistry is provided below for all data from MAC and South Flank, expressed as the range in values between the 25th and 75th percentiles:
  - pH: 7.9-8.2; EC: 550-650 µS/cm; total alkalinity: 200-240 mg $CaCO_3$/L; calcium: 41-51 mg/L; magnesium: 25-30 mg/L; sodium: 26-33 mg/L; potassium: 7-9 mg/L; chloride: 37-50 mg/L; and sulfate: 32-42 mg/L.
- Based on data collected by BHP in 2021, groundwater samples from a small number of bores at A Deposit (HGA0070P) and C Deposit (HGC0233P; HGC0261P) contain concentrations of dissolved zinc which slightly exceed the ANZG 99% *freshwater* guideline values. In addition, groundwater samples from a bore at F Deposit (HGF0026P) and South Flank (HSF5493P) contain concentrations of dissolved zinc which slightly exceed ANZG 95% *freshwater* guideline values.
- Based on BHP's data from 2021, a groundwater sample from a single bore at C Deposit (HGC0261P) and South Flank (HSF5493P) contain concentrations of dissolved copper which exceed ANZG 95% *freshwater* guideline values.
- Overall, when groundwater from the small number of bores that contain elevated dissolved zinc and copper concentrations is mixed with the substantially larger number of bores where these metals are below detection limits (prior to discharge), the net effect is likely to be dissolved metal concentrations that are compliant with ANZG 99% *freshwater* guideline values.
- Groundwater from production bores at A Deposit, C Deposit, and the Juna Downs injection bores display increasing sulfate concentrations over time. These changes could be related to early-stage sulfide oxidation due to groundwater drawdown, or enhanced alunite dissolution. The marginal decrease in water quality highlighted by incipient increases in sulfate concentrations can be expected to continue as dewatering advances.
  - It is noteworthy that these trends are more pronounced at A and C Deposits, where the groundwater level has been depressed for a longer period of time. This same process could potentially occur at South Flank when extensive dewatering proceeds.
- Most of the production bores at MAC and South Flank are at least partially drawing groundwater from dolomite-bearing carbonate formations at depths of ~100-150 m. At these depths / hydrostatic pressures (ie. pressures created by the head of groundwater) the groundwater is likely saturated with respect to several carbonate minerals (eg. calcite [$CaCO_3$], dolomite [$Ca,Mg(CO_3)_2$], magnesite [$MgCO_3$]; see Earth Systems, 2021).
- Concentrations of calcium and magnesium in groundwater strongly indicate the presence of dolomite in the dewatering zone.
- According to Langelier Saturation Index (LSI) calculations performed on laboratory water chemistry data, almost 90% of the production bores at MAC and South Flank display carbonate saturated groundwater.

  - Groundwater from bores at A Deposit and E Deposit tend to have slightly higher LSI values compared with other Deposits, whereas groundwater bores from C Deposit and South Flank tend to have a greater proportion of carbonate undersaturated bores.
- Groundwater from A and C Deposits is becoming increasingly carbonate saturated over time, particularly in recent years (2016 – present) probably reflecting the fact that dolomitic lithologies are amongst the most productive and persistent groundwater horizons.
- Whilst thermodynamic modelling of groundwater chemistry suggests saturation with respect to multiple carbonate minerals, this does not necessarily mean that they will actually precipitate. Under natural conditions it is far more likely for calcite to precipitate rather than dolomite or magnesite. Hence, this groundwater is hereafter simply referred to as "*carbonate-saturated*".
- The pressure drop associated with pumping groundwater to the surface is considerable, decreasing by 1 bar for every 10 m of groundwater head overcome. The solubility of carbonate minerals in water decreases with decreasing pressure. Hence the pressure drop associated with pumping groundwater to the surface generates carbonate over saturated water in the Turkey's Nest Dams.
  - Specifically, the relationship between carbonate solubility and pressure (described above) is largely due to the loss of CO_2 gas from groundwater as the pressure is decreased during pumping to the surface. At lower hydrostatic pressures (eg. at the earth's surface), CO_2 is less soluble in the groundwater and is released to the atmosphere. This CO_2 degassing is visible in groundwater sampled directly from bores, as well in groundwater entering the Turkey's Nest Dams. As dissolved CO_2 is an acid (ie. carbonic acid: H_2CO_3), its degassing results in a pH increase.
- At the earth's surface (ie. atmospheric pressure conditions), the groundwater degasses CO_2, which causes an increase in the pH (see above). The temporary rise in alkalinity associated with the pH increase, often results in the precipitation of (calcium) carbonate minerals, in turn lowering soluble alkalinity, calcium, and possibly magnesium concentrations.
- A decrease in the electrical conductivity (EC) of water in the Turkey's Nest Dams is likely related to decreases in soluble alkalinity associated with carbonate precipitation (see above). However, decreases in EC may be somewhat offset by the conversion of single charge HCO_3^- anions to double charged CO_3^{2-} anions (ie. changes in aqueous speciation) associated with pH increases of the water due to CO_2 degassing.
- The transition from carbonate saturation to carbonate oversaturation has resulted in the precipitation of carbonate minerals within the Turkey's Nest Dams as well as Runaway Valley Infiltration Ponds and Sediment Basins.
- The progression of CO_2 degassing can clearly be traced by field measurements of groundwater pH across the system:
  - The pH increase across the Turkey's Nest Dams can be up to 0.8 of a log unit (from pH = 7.1 at the inlet, to pH =7.9 at the outlet at the E Deposit Turkey's Nest Dam). This pH increase is due to CO_2 degassing and is likely associated carbonate precipitation.
  - The maximum pH decrease measured in the field was 1.5 log units (from 7.1 to 8.6), which occurs between the inlet to the E Deposit Turkey's Nest, and the Runaway Valley creek discharge point.
  - The highest laboratory pH value from the current work program was also 8.6, associated with the same Runaway Valley creek discharge point referred to above. The fact that the field and laboratory pH values were identical in this instance suggests that full CO_2 degassing has likely occurred, and that no further (significant) carbonate precipitation is likely from water discharging from the Runaway Valley Infiltration Ponds.
- The rapid chemical response to groundwater depressurisation and degassing indicates that laboratory water chemistry data is rarely representative of field conditions. This is because reactions in the water start during initial pumping to the surface and continue through to the time of sample collection and laboratory

analyses (some days later). This is evident in the fact that the field pH is lower than the laboratory pH, and the field alkalinity is most commonly higher than laboratory alkalinity.

  - Based on field observations it is likely that a significant proportion of the degassing and associated chemical changes occur within the first few minutes after being pumped to the surface and exposed to atmospheric pressure. After this initial rapid degassing, there is likely slower progressive degassing and associated chemical changes over a matter of hours to days.

- In addition to CO_2 degassing induced by changes in pressure, it is possible that changes in temperature also play a role in carbonate precipitation. Groundwater entering the Turkey's Nest Dams from production bores has a temperature of approximately 29-30°C. The water temperature then decreases across the water body by 5-7°C, at least in the cooler months. A decrease in water temperature results in an increase in the solubility of carbonate minerals (retarding carbonate precipitation) and therefore the water remains oversaturated. Contrarily, it is possible that in the warmer months water residing within the Turkey's Nest Dams is hotter than the inlet groundwater, and that carbonate precipitation (associated with CO_2 degassing) is enhanced.
- Between groundwater entering the E Deposit Turkey's Nest Dam, and being discharged from the Runaway Valley Infiltration Ponds, it is estimated that the water resides in the system (undergoing passive [unassisted] CO_2 degassing), for 2-4 days. Based on achieving a maximum discharge pH of 8.6, this time appears to be roughly adequate for most passive CO_2 degassing and carbonate precipitation to occur.
- The residence time for groundwater in the E Deposit Turkey's Nest Dam is estimated to be roughly 10-20 hours. However, the residence time for groundwater in the A Deposit Turkey's Nest dam is much shorter, possibly as little as 3-5 hours, due to the configuration of the inflow and outflow pipes. The water from the A Deposit Turkey's Nest dam is then directed to the South Flank crusher.
- The above suggests that a realistic target pH for optimising carbonate precipitation from production groundwater prior to discharge at MAC and South Flank is probably ~8.6. This can likely be achieved by ≥ 2 days of passive degassing, or potentially significantly less for active degassing.
- The combination of the E Deposit Turkey's Nest Dam and the downstream Runaway Valley Infiltration Ponds are providing adequate conditions for optimising carbonate precipitation and deposition. It is probable that no further intervention is necessary for lowering the risk of carbonate precipitation in the environment from groundwater at this domain in MAC.
- There is insufficient residence time for groundwater in the A Deposit Turkey's Nest Dam (and no downstream Runaway Valley Infiltration Ponds) to precipitate the majority of the carbonate minerals prior to its use in the South Flank crusher. This is likely to present as calcium carbonate scale issues on infrastructure in the crusher plant.
- Based on changes in water chemistry within the Turkey's Nest Dams, if production groundwater from South Flank was discharged directly to the environment, it is possible that under optimum conditions close to 40 kg of calcium carbonate ($CaCO_3$) could be Deposited for every 1 ML of water. At a discharge volume of 50 ML per day could result in the precipitation of approximately 2 tonnes of $CaCO_3$ per day downstream of the discharge point.
- The potential for carbonate deposition from water discharging from the A Deposit Turkey's Nest Dam and from the South Flank dewatering bores remains significant due to insufficient time for passive degassing.
- It is considered likely that few carbonate precipitation issues have been encountered in the Juna Downs MAR reinjection activities. This is likely because the increase in pressure associated with groundwater injection and storage at depth increases the solubility (ie. dissolution) of carbonate in the injected water. Moreover, the water for reinjection has likely already precipitated some carbonate within the E Deposit Turkey's Nest Dam, lowering its capacity for further precipitation.

- Testwork and analysis on site with carbonate saturated groundwater demonstrated that passive degassing is inevitable, but that associated carbonate mineral precipitation may require either temperature increases and/or the addition of appropriate seed crystals to promote nucleation.
- Potential high-level management strategies could include a combination of enhanced passive degassing as well as accelerated (active) degassing of groundwater, combined with optimised carbonate precipitation (eg. temperature increase, seed crystal addition) in a controlled location (where precipitates can be captured and removed), rather than direct groundwater release to the environment.
- Any management measures that help to lower the environmental risk of groundwater discharged to the environment, could also be applied to groundwater used as process water. This should help to overcome the impact of carbonate precipitation during mineral processing.

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EPA (2018). *Environmental Factor Guidelines – Inland Waters.* Environmental Protection Authority, Western Australia.

EPA (2021). *Statement of environmental principles, factors, objectives and aims of EIA.* Environmental Protection Authority, Western Australia.

ATTACHMENT A

Earth Systems (2021): Technical Memorandum - Assessment of Carbonate Saturation In Groundwater

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Environment · Water · Sustainability

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TECHNICAL MEMORANDUM

DATE	12/05/2021	**REF**	BHP224506.0
TO	Ms Kimberley Flowerdew- BHP Minerals Australia	**REV**	Rev0
FROM	John Waters Jeff Taylor	**PROJECT**	Carbonate Precipitation at MAC and South Flank

ASSESSMENT OF CARBONATE SATURATION IN GROUNDWATER

INTRODUCTION

Geochemical modelling of groundwater from the available production bores at Mining Area C (MAC) and South Flank was conducted to identify;

- Bores that were producing water that was saturated with respect to carbonate minerals (ie. those groundwater bores contributing to the carbonate precipitation), and would therefore be the focus of fieldwork to identify carbonate precipitation mitigation measures;
- Bores that were undersaturated with respect to carbonate minerals, and therefore to be avoided during field testwork, but potentially useful in the future as a potential dilution resources for lowering carbonate saturation.

DATA ASSESSMENT

Water Quality Data – Production Bores

A preliminary assessment was conducted on water quality data from the production bores in Mining Area C (MAC) and South Flank areas to establish whether there is any similarity between the bores, and between the screened formations within the bores. The data was compiled in a separate file (Doc. BHP224503) and the following preliminary observations were made:

- Water quality for 22 production bores from MAC and 10 production bores from South Flank area were part of the preliminary assessment. Data for all of these was sourced from Mining Area C & South Flank Borefields - Annual Aquifer Review (September 2020).

- All the bores assessed were screened in either the Wittenoom Formation or the Marra Mamba Iron Formation. Preliminary examination has not identified a relationship between water quality and the formation encountered in the screened interval.
- Key water quality parameters (pH, bicarbonate alkalinity, dissolved calcium, dissolved magnesium) are provided in Figures 1 to 4. These are expected to be the key parameters controlling carbonate precipitation from the groundwater.
- The pH of all bore waters examined (including the South Flank) bores has a median value of ~8 (range: 7.3-8.2)
- MAC bicarbonate alkalinity ranges from 210-320 mg/L with the majority in the range 270-310 mg/L. Bicarbonate alkalinity is greatest in waters from A Deposit (290-320 mg/L), followed by E Deposit (260-300 mg/L), then C Deposit (210-280 mg/L). Bicarbonate alkalinity from the South Flank bores shows some variability with bore HSF5433P having significantly lower alkalinity (91-94 mg/L).
- Dissolved Ca concentrations mimic the bicarbonate alkalinity with A Deposit having slightly higher concentrations (46-58 mg/L) than E Deposit (43-52 mg/L), followed by C Deposit (38-46 mg/L).
- Dissolved Ca in waters from South Flank bores is more irregular and ranges from 11 to 130 mg/L. Low Ca concentrations also have low bicarbonate alkalinity, but the higher Ca concentrations do not necessarily display the highest bicarbonate concentrations.
- Dissolved Mg concentrations also mimic the bicarbonate alkalinity and Ca concentrations with A Deposit having slightly higher concentrations (30-36 mg/L) than E Deposit (29-35 mg/L), followed by C Deposit (25-32 mg/L).
- Dissolved Mg in waters from South Flank bores is more irregular and ranges from 14 to 60 mg/L. Magnesium concentrations appear to show a relationship to Ca concentrations, with elevated Mg being associated with elevated Ca and low Mg showing a relationship with low Ca concentrations.
- The relationships between Ca, Mg and bicarbonate concentrations suggests that the groundwater quality observed within the high alkalinity bores is likely to be largely controlled by dolomite dissolution in the aquifer.

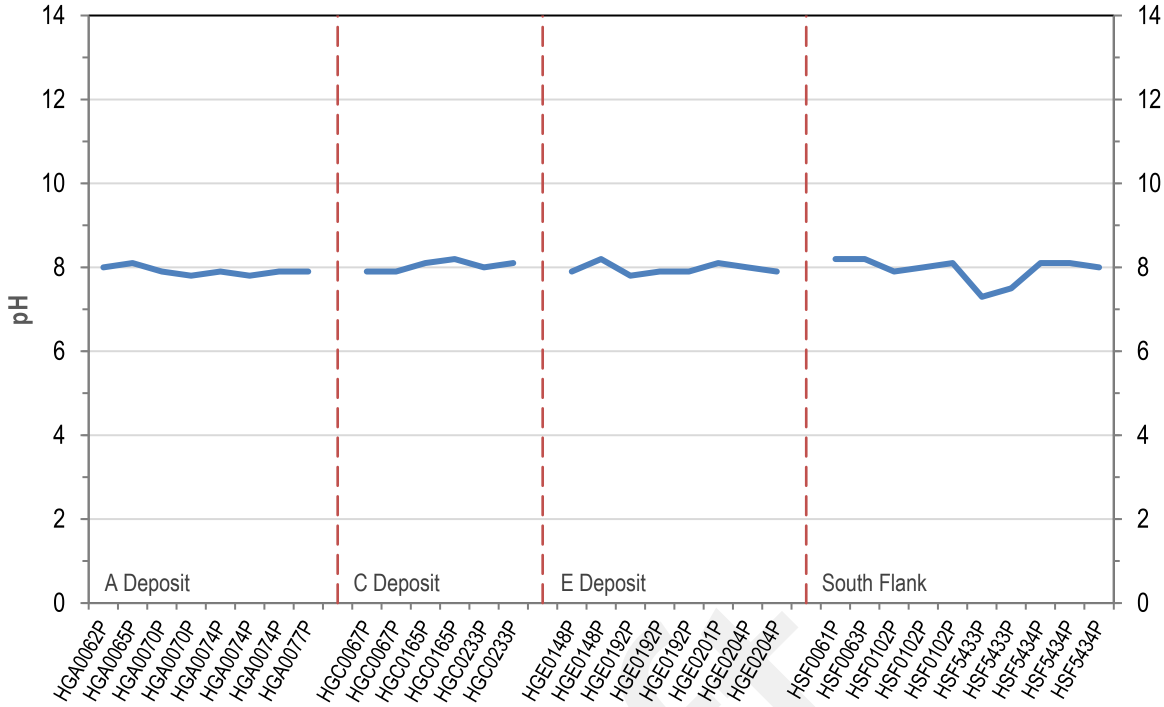

Figure 1: pH recorded from water production bores in MAC and South Flank areas. Some bores have multiple data points, representing sampling at different times throughout 2019-2020.

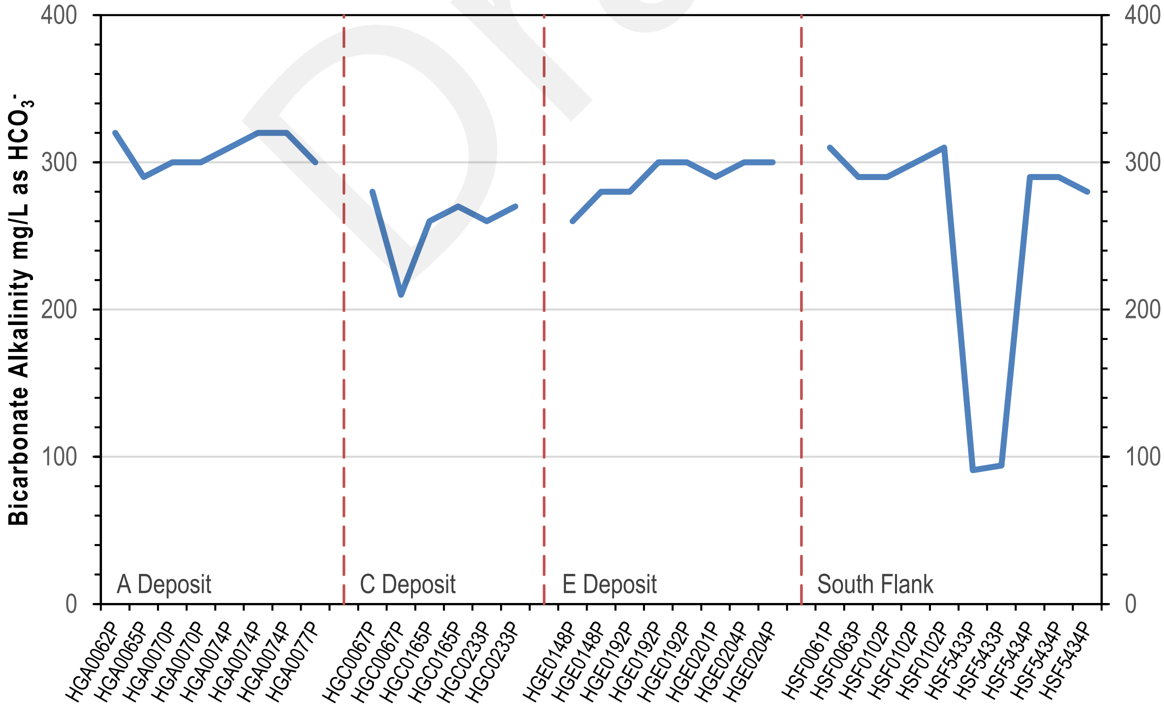

Figure 2: Bicarbonate (HCO_3^-) alkalinity recorded from water production bores in MAC and South Flank areas. Some bores have multiple data points, representing sampling at different times throughout 2019-2020.

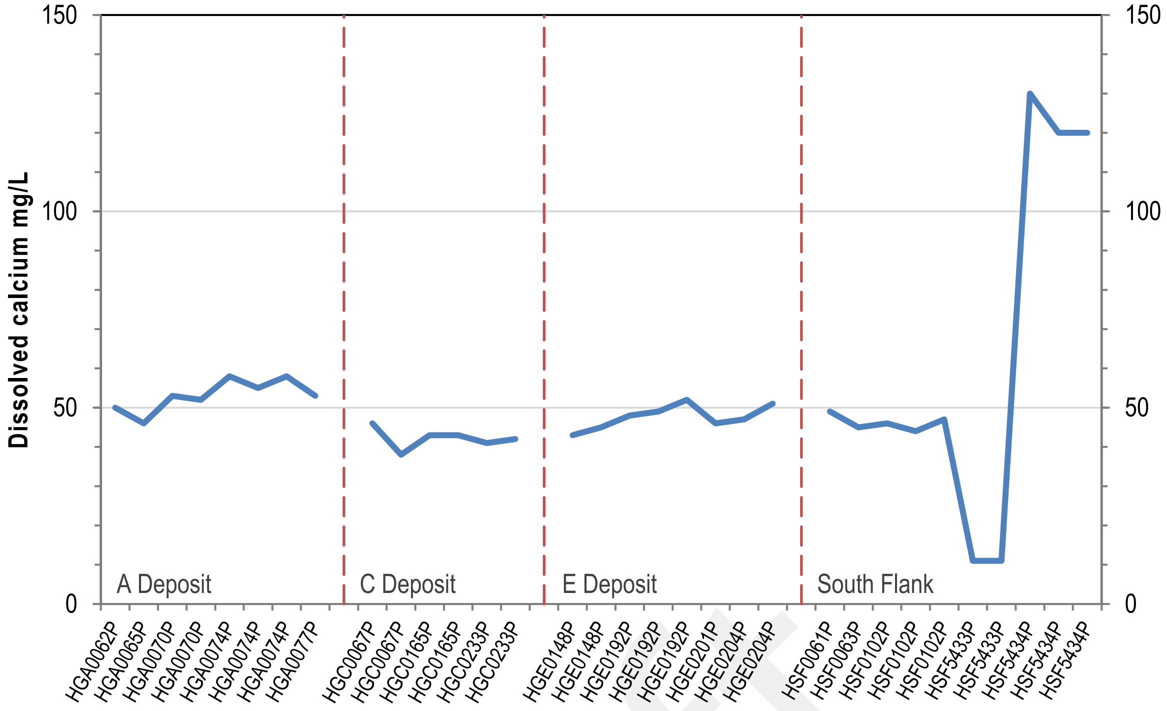

Figure 3: Dissolved calcium concentrations recorded from water production bores in MAC and South Flank areas. Some bores have multiple data points, representing sampling at different times throughout 2019-2020.

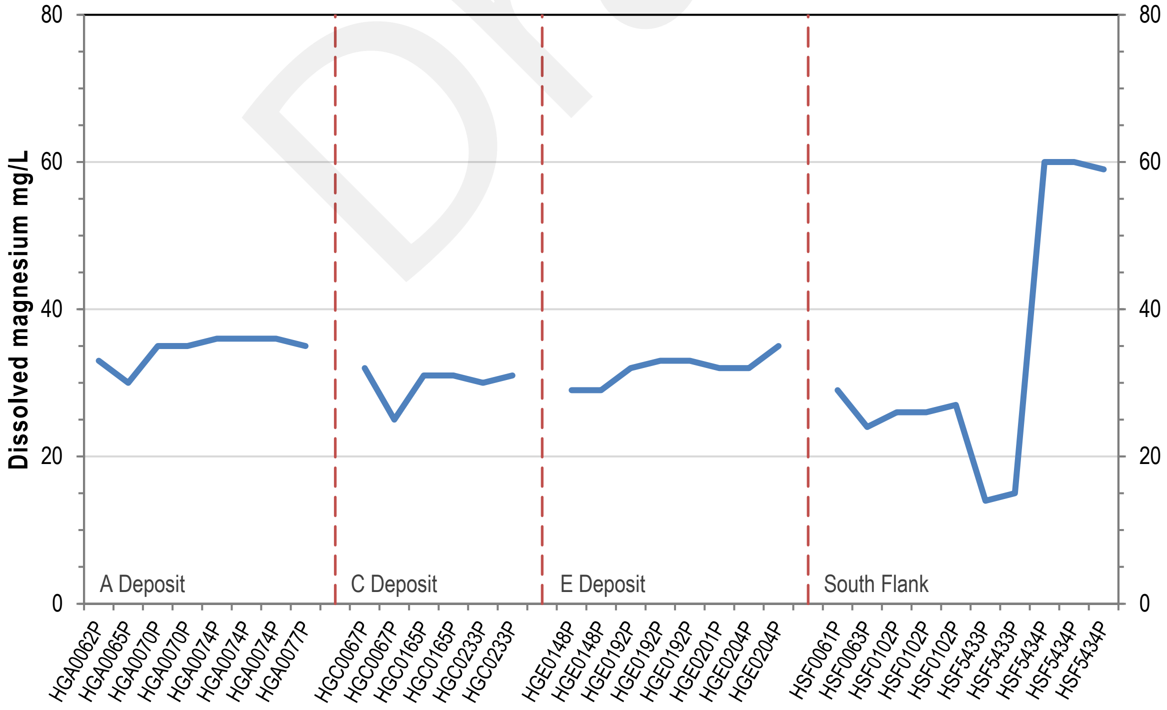

Figure 4: Dissolved magnesium concentrations recorded from water production bores in MAC and South Flank areas. Some bores have multiple data points, representing sampling at different times throughout 2019-2020.

Geochemical Modelling

Water quality data was modelled using PhreeqC to obtain mineral saturation indices. Mineral saturation indices (SI) provided an indication on whether the chemical composition of a water is likely to dissolve (SI <0, mineral undersaturated solution) or precipitate (SI>0, mineral saturated solution) a particular mineral. The primary issue of concern for the MAC and South Flank areas is the potential for groundwater to precipitate calcium carbonate phases in local waterways.

The outcomes of the modelling runs are provided in a separate file (Doc. BHP224503) and plots of key saturation indices (SI) are provided in Figures 5 to 8. The following high-level observations have been made:

- Modelling of water quality data from all the bores, except for HSF5433P (South Flank, sampled on two separate dates), indicates that the samples are saturated with respect to the carbonate minerals such as calcite, dolomite, aragonite and magnesite.
- While most of the groundwater samples were saturated with respect to these carbonate minerals, it is likely that one or perhaps two key phases will actually precipitate. However, the precipitation process with necessarily result in the other carbonate phases becoming undersaturated.
- A preliminary assessment from the modelling, allowing some carbonates to precipitate, suggests that thermodynamically dolomite may be the primary carbonate mineral to precipitate. Dolomite precipitation appears to result in the other carbonate minerals becoming unsaturated (SI < 0). However, while dolomite should theoretically precipitate, in natural systems calcite or possibly weakly magnesian calcite is commonly observed to be the primary precipitate. Calcite precipitate can be enhanced by pressure decreases, decreases in the partial pressure of carbon dioxide (CO_2 degassing), evaporation and water temperature increases, as well as enhanced nucleation processes or soluble calcium increases.
- Saturation indices for quartz, chalcedony and cristobalite also suggest that when the groundwaters are pumped to the surface, that they are silica saturated. This suggests that one or more of these silica phases may precipitate as a crystalline or amorphous phase. Such phases could include quartz or microcrystalline silica. Silica precipitation can be enhanced by pressure decreases and temperature decreases.
- Both carbonate and silica saturation may result in scaling of pumping and piping infrastructure with the bore fields, but more importantly may be contributing to precipitation in the local waterways.

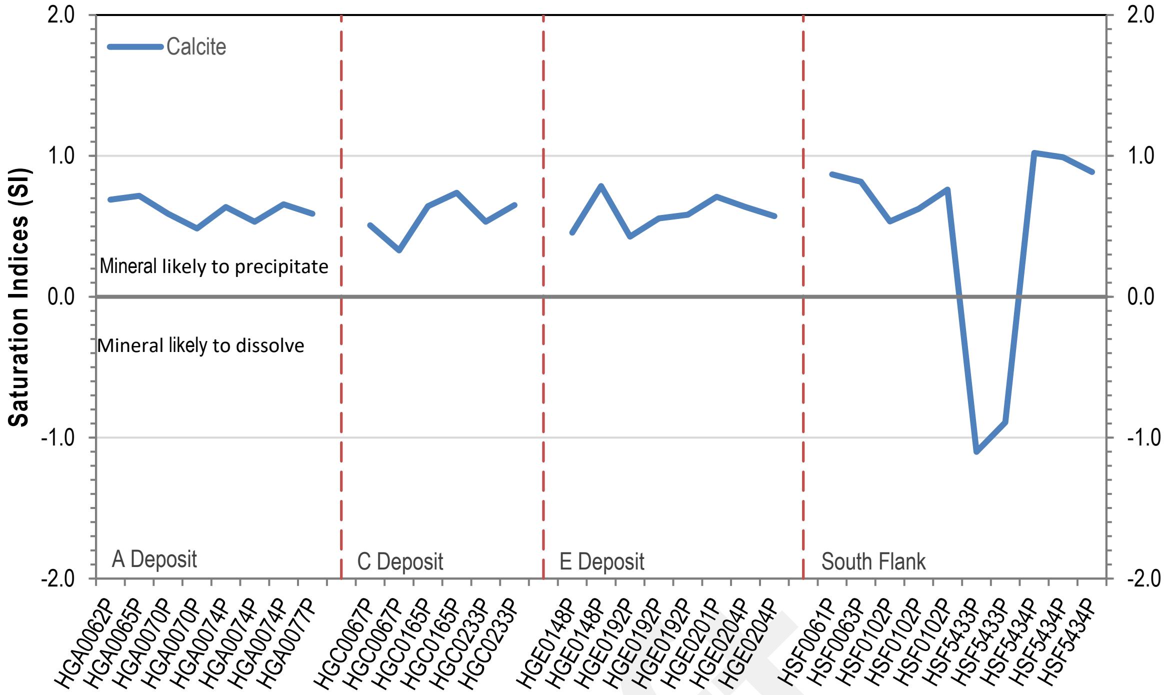

Figure 5: Saturation indices (SI), for calcite recorded from water production bores in MAC and South Flank areas. Saturation indices greater than zero indicate the waters are saturated with respect to that mineral phase, and precipitation is likely to occur. Some bores have multiple data points, representing sampling at different times throughout 2019-2020.

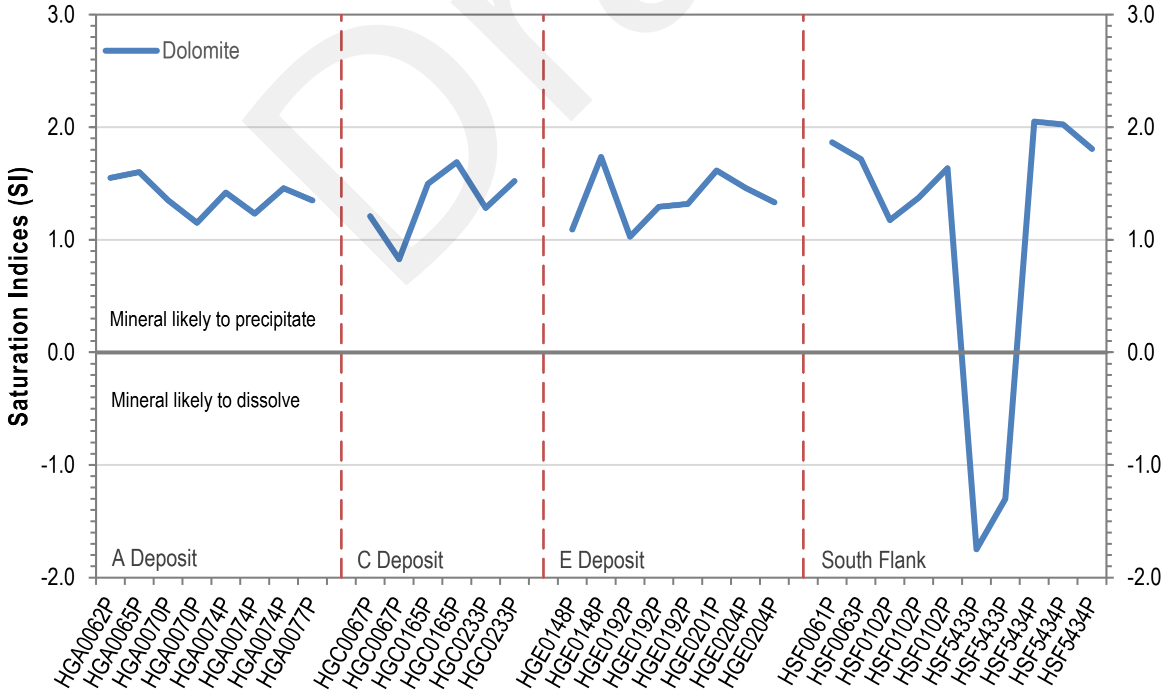

Figure 6: Saturation indices (SI), for dolomite recorded from water production bores in MAC and South Flank areas. Saturation indices greater than zero indicate the waters are saturated with respect to that mineral phase, and precipitation is likely to occur. Some bores have multiple data points, representing sampling at different times throughout 2019-2020.

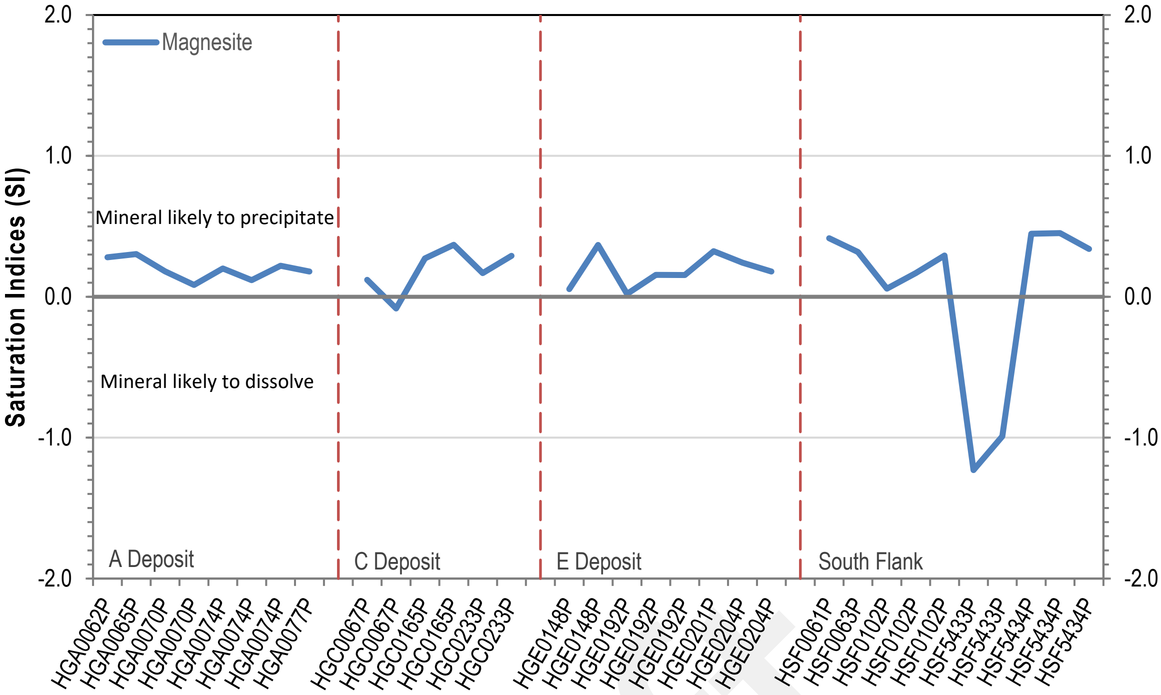

Figure 7: Saturation indices (SI), for magnesite recorded from water production bores in MAC and South Flank areas. Saturation indices greater than zero indicate the waters are saturated with respect to that mineral phase, and precipitation is likely to occur. Some bores have multiple data points, representing sampling at different times throughout 2019-2020.

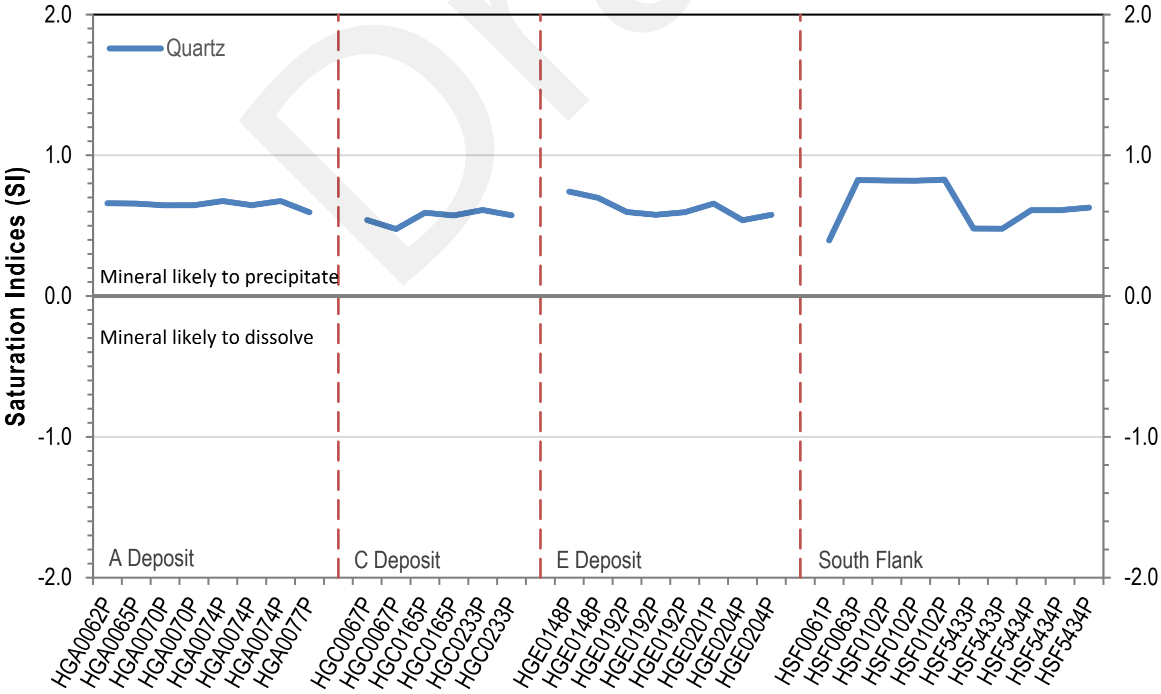

Figure 8: Saturation indices (SI), for quartz recorded from water production bores in MAC and South Flank areas. Saturation indices greater than zero indicate the waters are saturated with respect to that mineral phase, and precipitation is likely to occur. Some bores have multiple data points, representing sampling at different times throughout 2019-2020.

CONCLUSIONS

Key conclusions from this preliminary geochemical study include:

- The following groundwater bore could be used during upcoming fieldwork to assess the controls on carbonate precipitation and assist in developing carbonate precipitation mitigation measures.
    - A Deposit – HGA0062P, HGA0065P, HGA0070P, HGA0074P, HGA0077P
    - C Deposit – HGC0067P, HGC0165P, HGC0233P
    - E Deposit - HGE0148P, HGE0192P, HGE0201P, HGE0204P
    - South Flank – HSF0061P, HSF0063P, HSF0102P, HSF5434P
- The following groundwater bore cannot be used to assess carbonate precipitation due to the groundwater sampled from this bore being carbonate undersaturated.
    - South Flank – HSF5433P
- Degassing of CO_2 from the groundwater resulting from depressurisation as it reaches the surface needs to be investigated. Degassing of CO_2 results in increased pH and carbonate mineral precipitation. Degassing is expected to occur within transfer pipelines, but because CO_2 is still in contact with water it may not be effective at promoting $CaCO_3$ precipitation until the CO_2 is separated from the water.
- The following testwork methods are proposed to assess the rate and magnitude of carbonate precipitation and to assist with development of carbonate precipitation mitigation options.
    - Passive degassing.
    - Active degassing (mixing / aeration).
    - Precipitation via nucleation using (1) precipitated calcium carbonate; and (2) quartz sand.
    - Precipitation via water softening (increasing pH via calcium hydroxide addition).
- Additional information on whether scaling has been reported from pumping and piping infrastructure should be collected. This would help support whether the groundwater is carbonate saturated, but also indicate a change in water chemistry from when the water exited to bores to when the water exited the piping.
- Additional information on whether there are precipitates (and their composition) within the sediment basins / infiltration ponds should also be collected. This will assist in assessing carbonate saturation and the location and controls on carbonate precipitation.
- Monitoring water temperature changes between the bores and the final discharge to local waterways will also be important to conduct. Carbonates are one of the rare minerals / compounds that display decreases in solubility with increasing temperature. Hence, carbonate precipitation could be at least partially facilitated by progressive warming of the groundwater.

ATTACHMENT B

Data collected during fieldwork

Table B-1: Field data taken during fieldwork from ES.

Borehole ID	ES Sample ID	date / time	pH	EC (µS/cm)	Temperature (degrees °C)	ORP (+mV)	Total Alkalinity 1 (mg $CaCO_3$/L)	Total Alkalinity 2 (mg $CaCO_3$/L)	Average Total Alkalinity	Filtered Alkalinity (mg $CaCO_3$/L)	Ca (mg/L)	filtered Ca (mg/L)	Mg (mg/L)	filtered Mg (mg/L)	Laboratory sample	Comments
HGA0062P	HGA0062P/4/5/22/10:35/PDG	04/05/22 10:35:00	7.39	694	30	157	NA	NA	NA	NA	NA	NA	NA	NA	NA	Baseline field sample
HGA0062P	HGA0062P/4/5/22/11:13	04/05/22 11:13:00	7.45	711	29.8	111	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0062P	HGA0062P/4/5/22/11:13	04/05/22 11:13,30	7.45	709	29.9	100	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0062P	HGA0062P/4/5/22/11:14	04/05/22 11:14:00	7.45	705	29.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0062P	HGA0062P/4/5/22/11:14	04/05/22 11:14,30	7.45	702	29.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0062P	HGA0062P/4/5/22/11:15	04/05/22 11:15:00	7.44	693	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0062P	HGA0062P/4/5/22/11:19	04/05/22 11:19:00	7.46	690	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0062P	HGA0062P/4/5/22/11:19	04/05/22 11:19,30	7.49	694	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0062P	HGA0062P/4/5/22/11:19	04/05/22 11:19,45	7.51	694	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0062P	HGA0062P/4/5/22/11:20	04/05/22 11:20,15	7.52	696	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0062P	HGA0062P/4/5/22/11:20	04/05/22 11:20,30	7.54	697	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0062P	HGA0062P/4/5/22/11:21	04/05/22 11:21:00	7.55	701	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0062P	HGA0062P/4/5/22/11:21	04/05/22 11:21,15	7.57	702	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0062P	HGA0062P/4/5/22/11:22	04/05/22 11:22:15	7.58	701	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0062P	HGA0062P/4/5/22/11:22	04/05/22 11:22,20	7.59	701	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0062P	HGA0062P/4/5/22/11:22	04/05/22 11:22,25	7.6	701	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0062P	HGA0062P/4/5/22/11:22	04/05/22 11:22,30	7.61	701	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0062P	HGA0062P/4/5/22/11:23	04/05/22 11:23:00	7.62	701	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0062P	HGA0062P/4/5/22/11:23	04/05/22 11:23,15	7.62	701	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0062P	HGA0062P/4/5/22/11:26	04/05/22 11:26:00	7.63	701	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0074P	HGA0074P/4-5-22/13:30/PDG	04/05/22 13:30:00	7.26	715	29.3	224	231	NA	231	NA	71	NA	NA	NA	Y	Sample vigorously degassing for initial 20-40 seconds
HGA0074P	HGA0074P/4-5-22/13:55/ADG	04/05/22 13:55:00	7.01	704	30.4	189	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
HGA0074P	HGA0074P/4-5-22/14:00/PDG	04/05/22 14:00:00	7.3	714	28.2	205	217	NA	217	NA	NA	NA	NA	NA	NA	NA
HGA0074P	HGA0074P/4-5-22/14:25/ADG	04/05/22 14:25:00	7.56	711	28	112	211	NA	211	NA	NA	NA	NA	NA	NA	NA
HGA0074P	HGA0074P/4-5-22/14:30/PDG	04/05/22 14:30:00	7.31	705	27.4	195	256	NA	256	NA	NA	NA	NA	NA	NA	NA
HGA0074P	HGA0074P/4-5-22/14:55/ADG	04/05/22 14:55:00	7.84	716	27.6	90	205	NA	205	NA	NA	NA	NA	NA	NA	NA
HGA0074P	HGA0074P/4-5-22/15:00/PDG	04/05/22 15:00:00	7.33	697	27.2	187	236	NA	236	NA	NA	NA	NA	NA	NA	NA
HGA0074P	HGA0074P/4-5-22/15:25/ADG	04/05/22 15:25:00	7.86	724	26.6	80	184	NA	184	NA	NA	NA	NA	NA	NA	NA
HGA0074P	HGA0074P/4-5-22/15:30/PDG	04/05/22 15:30:00	6.06	699	26.2	179	185	NA	185	NA	NA	NA	NA	NA	NA	NA
HGA0074P	HGA0074P/4-5-22/15:55/ADG	04/05/22 15:55:00	7.89	721	25.8	79	219	218	218.5	NA	NA	NA	NA	NA	NA	NA
HGA0074P	HGA0074P/4-5-22/16:00/PDG	04/05/22 16:00:00	-	705	25.5	175	198	189	193.5	NA	NA	NA	NA	NA	NA	pH probe faulty
HGA0074P	HGA0074P/4-5-22/16:25/ADG	04/05/22 16:25:00	7.99	726	25	74	164	166	165	NA	72	NA	NA	NA	NA	NA
HGA0074P	HGA0074P/4-5-22/16:30/PDG	04/05/22 16:30:00	-	712	24.6	168	189	186	187.5	NA	76	NA	NA	NA	Y	pH probe faulty

Borehole ID	ES Sample ID	date / time	pH	EC (µS/cm)	Temperature (degrees °C)	ORP (+mV)	Total Alkalinity 1 (mg $CaCO_3$/L)	Total Alkalinity 2 (mg $CaCO_3$/L)	Average Total Alkalinity	Filtered Alkalinity (mg $CaCO_3$/L)	Ca (mg/L)	filtered Ca (mg/L)	Mg (mg/L)	filtered Mg (mg/L)	Laboratory sample	Comments
HGA0074P	HGA0074P/4-5-22/17:00/ADG	04/05/22 17:00:00	8.05	728	24.6	82	NA	NA	NA	NA	NA	NA	NA	NA	Y	NA
HGA0074P	HGA0074P/5-5-22/9:25/PDG	05/05/22 09:25:00	7.23	765	28.2	NA	215	NA	215	NA	30	NA	33.6	NA	Y	NA
HGA0074P	HGA0074P/5-5-22/9:25	05/05/22 09:25:00	7.23	765	28.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0074P	HGA0074P/5-5-22/9:26	05/05/22 09:26:00	7.23	750	29.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0074P	HGA0074P/5-5-22/9:26	05/05/22 09:26:15	7.2	701	30.8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0074P	HGA0074P/5-5-22/9:26	05/05/22 09:26:30	7.19	696	30.8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0074P	HGA0074P/5-5-22/9:26	05/05/22 09:26:45	7.19	703	30.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0074P	HGA0074P/5-5-22/9:27	05/05/22 09:27:00	7.19	693	30.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0074P	HGA0074P/5-5-22/9:27	05/05/22 09:27:15	7.19	693	30.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0074P	HGA0074P/5-5-22/9:30	05/05/22 09:30:00	7.18	701	30.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGA0074P	HGA0074P/5-5-22/9:40/PDG	05/05/22 09:40:00	7.22	700	NA	NA	207	NA	207	NA	37	NA	36.8	NA	NA	NA
HGA0074P	HGA0074P/5-5-22/9:55/PDG	05/05/22 09:55:00	7.22	694	NA	90	196	NA	196	NA	34	NA	34.3	NA	NA	NA
HGA0074P	HGA0074P/5-5-22/10:10/PDG	05/05/22 10:10:00	7.23	694	NA	84	200	NA	200	NA	35	NA	35.7	NA	NA	NA
HGA0074P	HGA0074P/5-5-22/10:25/PDG	05/05/22 10:25:00	7.2	692	NA	80	188	NA	188	NA	68	NA	38.7	NA	NA	NA
HGA0074P	HGA0074P/5-5-22/12:30/PDG	05/05/22 12:30:00	7.2	705	27.6	219	223	NA	223	NA	78	NA	33.9	NA	NA	NA
HGA0074P	HGA0074P/5-5-22/12:30/ADG	05/05/22 12:30:00	7.31	700	27.7	115	201	NA	201	NA	70	NA	33.5	NA	NA	NA
HGA0074P	HGA0074P/5-5-22/13:00/PDG	05/05/22 13:00:00	7.22	702	27.2	216	205	NA	205	NA	72	NA	32.8	NA	NA	NA
HGA0074P	HGA0074P/5-5-22/13:00/ADG	05/05/22 13:00:00	7.52	696	27.3	106	228	230	229	NA	70	NA	33.8	NA	NA	NA
HGA0074P	HGA0074P/5-5-22/13:30/PDG	05/05/22 13:30:00	7.36	701	26.5	213	230	NA	230	NA	80	NA	36	NA	NA	NA
HGA0074P	HGA0074P/5-5-22/13:30/ADG	05/05/22 13:30:00	7.71	693	26.4	91	241	233	237	NA	74	NA	33.7	NA	NA	NA
HGA0074P	HGA0074P/5-5-22/14:00/PDG	05/05/22 14:00:00	7.48	704	25.5	208	243	NA	243	NA	71	NA	36.5	NA	NA	NA
HGA0074P	HGA0074P/5-5-22/14:00/ADG	05/05/22 14:00:00	7.85	694	25.5	80	250	NA	250	NA	81	NA	37.5	NA	NA	NA
HGA0074P	HGA0074P/5-5-22/14:30/PDG	05/05/22 14:30:00	7.56	703	24.9	207	239	NA	239	NA	91	NA	36.8	NA	NA	Calcium solution analysed was turbid, calcium concentration is potentially unreliable
HGA0074P	HGA0074P/5-5-22/14:30/ADG	05/05/22 14:30:00	8.03	692	24.8	71	241	NA	241	NA	112	NA	40.2	NA	NA	Calcium solution analysed was turbid, calcium concentration is potentially unreliable
HGA0074P	HGA0074P/5-5-22/15:00/PDG	05/05/22 15:00:00	7.42	690	25.4	205	256	NA	256	NA	113	NA	34.1	NA	NA	Calcium solution analysed was turbid, calcium concentration is potentially unreliable
HGA0074P	HGA0074P/5-5-22/15:00/ADG	05/05/22 15:00:00	8.11	692	24.2	71	245	NA	245	NA	114	NA	35.6	NA	NA	Calcium solution analysed was turbid, calcium concentration is potentially unreliable
HGA0074P	HGA0074P/5-5-22/15:30/PDG	05/05/22 15:30:00	7.33	698	24.7	203	252	NA	252	NA	106	NA	38.4	NA	NA	NA
HGA0074P	HGA0074P/5-5-22/15:30/ADG	05/05/22 15:30:00	8.18	692	23.5	71	244	NA	244	NA	103	NA	36.7	NA	NA	NA
HGA0074P	HGA0074P/5-5-22/16:00/PDG	05/05/22 16:00:00	7.33	696	24.4	203	250	NA	250	198	71	64	32.3	NA	NA	NA

Borehole ID	ES Sample ID	date / time	pH	EC (µS/cm)	Temperature (degrees °C)	ORP (+mV)	Total Alkalinity 1 (mg $CaCO_3$/L)	Total Alkalinity 2 (mg $CaCO_3$/L)	Average Total Alkalinity	Filtered Alkalinity (mg $CaCO_3$/L)	Ca (mg/L)	filtered Ca (mg/L)	Mg (mg/L)	filtered Mg (mg/L)	Laboratory sample	Comments
HGA0074P	HGA0074P/5-5-22/16:00/ADG	05/05/22 16:00:00	8.21	692	24.4	71	241	NA	241	198	83	77	34	NA	NA	NA
HGA0074P	HGA0074P/5-5-22/16:30/PDG	05/05/22 16:30:00	7.45	697	24	201	212	NA	212	NA	67	NA	35.9	NA	NA	NA
HGA0074P	HGA0074P/5-5-22/16:30/ADG	05/05/22 16:30:00	8.22	694	22.7	72	253	NA	253	NA	105	NA	37	NA	NA	NA
HGA0074P	HGA0074P/5-5-22/17:00/PDG	05/05/22 17:00:00	7.45	694	23.6	199	196	NA	196	NA	78	NA	37.5	NA	NA	Quartz seed crystals added
HGA0074P	HGA0074P/5-5-22/17:00/ADG	05/05/22 17:00:00	8.26	698	22.3	66	197	NA	197	199	84	NA	36.8	NA	NA	Quartz seed crystals added
HGA0074P	HGA0074P/5-5-22/17:30/PDG	05/05/22 17:30:00	7.6	696	23.2	200	213	NA	213	NA	75	NA	37.4	NA	Y	NA
HGA0074P	HGA0074P/5-5-22/17:30/ADG	05/05/22 17:30:00	8.3	708	21.9	60	215	NA	215	NA	73	NA	37.3	NA	Y	NA
HGA0074P	HGA0074P/6-5-22/6:40/PDG	06/05/22 06:40:00	7.89	694	17	190	219	NA	219	218	20	65	41.9	38.2	NA	NA
HGA0074P	HGA0074P/6-5-22/6:40/ADG	06/05/22 06:40:00	8.18	712	16.4	80	212	220	216	219	18	59	41.2	38.9	NA	NA
HGA0074P	HGA0074P/6-5-22/7:10/ADG	06/05/22 07:10:00	8.28	711	16.3	67	200	NA	200	215	NA	NA	NA	NA	NA	PCC seed crystals added
HGE0148P	HGE0148P/6-5-22/11:20/PDG	06/05/22 11:20:00	7.1	655	28.9	210	219	NA	219	209	NA	74	NA	26	Y	NA
HGE0148P	HGE0148P/6-5-22/11:35/PDG	06/05/22 11:35:00	7.51	598	30	NA	208	NA	208	209	NA	68	NA	25.5	NA	NA
HGE0148P	HGE0148P/6-5-22/11:50/PDG	06/05/22 11:50:00	7.52	595	29.6	137	192	NA	192	200	NA	66	NA	26.7	NA	NA
HGE0148P	HGE0148P/6-5-22/12:05/PDG	06/05/22 12:05:00	7.52	594	29.6	127	209	NA	209	192	NA	64	NA	25	NA	NA
HGE0148P	HGE0148P/6-5-22/12:20/PDG	06/05/22 12:20:00	7.53	605	29	122	187	NA	NA	196	NA	70	NA	25.2	NA	NA
HGE0148P	HGE0148P/6-5-22/12:44	06/05/22 12:44:00	7.23	688	23	137	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGE0148P	HGE0148P/6-5-22/12:44	06/05/22 12:44:05	7.26	685	23	137	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGE0148P	HGE0148P/6-5-22/12:44	06/05/22 12:44:10	7.29	681	24	135	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGE0148P	HGE0148P/6-5-22/12:44	06/05/22 12:44:15	7.31	681	24	133	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGE0148P	HGE0148P/6-5-22/12:44	06/05/22 12:44:20	7.32	678	24	131	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGE0148P	HGE0148P/6-5-22/12:44	06/05/22 12:44:23	7.33	671	24	126	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGE0148P	HGE0148P/6-5-22/12:44	06/05/22 12:44:43	7.34	668	25	124	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGE0148P	HGE0148P/6-5-22/12:44	06/05/22 12:44:25	7.35	668	25	124	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGE0148P	HGE0148P/6-5-22/12:44	06/05/22 12:44:30	7.35	659	25	119	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGE0148P	HGE0148P/6-5-22/12:44	06/05/22 12:44:35	7.36	653	26	117	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGE0148P	HGE0148P/6-5-22/12:44	06/05/22 12:44:45	7.35	641	27	108	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGE0148P	HGE0148P/6-5-22/12:45	06/05/22 12:45:00	7.35	631	28	98	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGE0148P	HGE0148P/6-5-22/12:45	06/05/22 12:45:15	7.34	625	28	92	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGE0148P	HGE0148P/6-5-22/12:45	06/05/22 12:45:45	7.35	619	29	85	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGE0148P	HGE0148P/6-5-22/12:46	06/05/22 12:46:00	7.36	617	29	82	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGE0148P	HGE0148P/6-5-22/12:46	06/05/22 12:46:11	7.37	616	29	80	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGE0148P	HGE0148P/6-5-22/12:46	06/05/22 12:46:15	7.38	616	29	79	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGE0148P	HGE0148P/6-5-22/12:46	06/05/22 12:46:20	7.39	616	29	79	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGE0148P	HGE0148P/6-5-22/12:46	06/05/22 12:46:28	7.4	615	29	79	NA	NA	NA	NA	NA	NA	NA	NA	NA	During filling of sample vessel
HGE0148P	HGE0148P/6-5-22/14:25/ADG	06/05/22 14:25:00	7.61	605	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Borehole ID	ES Sample ID	date / time	pH	EC (µS/cm)	Temperature (degrees °C)	ORP (+mV)	Total Alkalinity 1 (mg $CaCO_3$/L)	Total Alkalinity 2 (mg $CaCO_3$/L)	Average Total Alkalinity	Filtered Alkalinity (mg $CaCO_3$/L)	Ca (mg/L)	filtered Ca (mg/L)	Mg (mg/L)	filtered Mg (mg/L)	Laboratory sample	Comments
HGE0148P	HGE0148P/6-5-22/14:25/PDG	06/05/22 14:25:00	7.54	609	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
HGE0148P	HGE0148P/6-5-22/14:30/ADG	06/05/22 14:30:00	7.6	602	28.2	159	NA	NA	NA	205	NA	60	NA	29.6	NA	NA
HGE0148P	HGE0148P/6-5-22/14:30/PDG	06/05/22 14:30:00	7.55	605	28.1	167	NA	NA	NA	200	NA	69	NA	28.3	NA	Quartz seed crystals added
HGE0148P	HGE0148P/6-5-22/15:00/ADG	06/05/22 15:00:00	7.67	602	27.4	116	NA	NA	NA	189	NA	65	NA	32.9	NA	NA
HGE0148P	HGE0148P/6-5-22/15:00/PDG	06/05/22 15:00:00	7.54	598	27.3	163	NA	NA	NA	187	NA	62	NA	31.9	NA	NA
HGE0148P	HGE0148P/6-5-22/15:30/ADG	06/05/22 15:30:00	7.8	602	26.8	94	NA	NA	NA	217	NA	66	NA	33.1	NA	NA
HGE0148P	HGE0148P/6-5-22/15:30/PDG	06/05/22 15:30:00	7.69	597	26.8	164	NA	NA	NA	211	NA	68	NA	34	NA	NA
HGE0148P	HGE0148P/6-5-22/16:00/ADG	06/05/22 16:00:00	7.81	600	26	83	NA	NA	NA	210	NA	73	NA	34.1	NA	NA
HGE0148P	HGE0148P/6-5-22/16:00/PDG	06/05/22 16:00:00	7.75	605	26.2	162	NA	NA	NA	228	NA	61	NA	34.2	NA	NA
HGE0148P	HGE0148P/6-5-22/16:30/ADG	06/05/22 16:30:00	7.92	600	25.5	82	NA	NA	NA	206	NA	57	NA	32.8	NA	NA
HGE0148P	HGE0148P/6-5-22/16:30/PDG	06/05/22 16:30:00	7.84	605	25.7	163	NA	NA	NA	221	NA	67	NA	32.6	NA	NA
HGE0148P	HGE0148P/6-5-22/17:00/ADG	06/05/22 17:00:00	8.01	594	24.8	70	NA	NA	NA	213	NA	63	NA	35.8	NA	NA
HGE0148P	HGE0148P/6-5-22/17:00/PDG	06/05/22 17:00:00	7.78	602	25.1	162	NA	NA	NA	228	NA	61	NA	34.5	NA	NA
HGE0148P	HGE0148P/6-5-22/17:30/ADG	06/05/22 17:30:00	8.1	599	24.5	61	NA	NA	NA	186	NA	57	NA	39.7	NA	NA
HGE0148P	HGE0148P/6-5-22/17:30/PDG	06/05/22 17:30:00	7.72	608	24.8	161	NA	NA	NA	191	NA	70	NA	39.6	NA	NA
HGE0148P	HGE0148P/6-5-22/17:50/ADG	06/05/22 17:50:00	8.2	612	17.5	73	NA	NA	NA	194	NA	NA	NA	NA	NA	NA
HGE0148P	HGE0148P/6-5-22/17:50/PDG	06/05/22 17:50:00	8.36	608	17.8	153	NA	NA	NA	209	NA	NA	NA	NA	NA	NA
HGE0148P	HGE0148P/7-5-22/8:45/ADG	07/05/22 08:45:00	7.97	668	49.5	97	NA	NA	NA	208	NA	68	37.7	NA	NA	NA
NA	A Deposit Turkey's Nest Dam IN	05/05/22 12:30:00	7.12	704	30.7	117	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NA	A Deposit Turkey's Nest Dam OUT	06/05/22 14:15:00	7.84	676	31.6	121	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NA	E Deposit Turkey's Nest Dam IN	06/05/22 14:00:00	7.32	676	30.3	183	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NA	E Deposit Turkey's Nest Dam OUT	05/05/22 12:45:00	7.98	676	27.3	142	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NA	Runaway Valley Central Top	04/05/22 17:00:00	7.89	670	27.8	180	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NA	Runaway Valley Central Bottom	04/05/22 17:30:00	8.51	640	23.4	205	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NA	Runaway Valley West Top	04/05/22 13:30:00	7.84	673	29.4	167	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NA	Runaway Valley West Bottom	04/05/22 14:30:00	8.64	610	23.7	151	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NA	Runaway Valley Creek Drainage	05/05/22 16:15:00	8.24	657	18.9	83	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

ATTACHMENT C
External Laboratory Reports

ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS		LABORATORY DETAILS	
Contact	Jeff Taylor	Manager	Kieran Hopkins
Client	EARTH SYSTEMS CONSULTING PTY LTD	Laboratory	SGS Perth Environmental
Address	14 CHURCH STREET HAWTHORN VIC 3122	Address	28 Reid Rd Perth Airport WA 6105
Telephone	61 3 98107500	Telephone	(08) 9373 3500
Facsimile	61 3 98535030	Facsimile	(08) 9373 3556
Email	jeff.taylor@earthsystems.com.au	Email	au.environmental.perth@sgs.com
Project	**BHP2245**	SGS Reference	**PE160331 R1**
Order Number	**18052022**	Date Received	09 May 2022
Samples	21	Date Reported	25 May 2022

COMMENTS

Accredited for compliance with ISO/IEC 17025 - Testing. NATA accredited laboratory 2562(898/20210).

Metals: Dissolved B: Spike recovery failed acceptance criteria due to the presence of significant concentration of analyte (i.e. the concentration of analyte exceeds the spike level).

This report cancels and supersedes the report No. PE160331 dated 19.05.2022 issued by SGS Environment, Health and Safety due to the inclusion of filtered Alkalinity results.

SIGNATORIES

Hue Thanh LY
Metals Team Leader

Louise Hope

Louise HOPE
Laboratory Technician

Mary Ann OLA-A
Inorganics Team Leader

Murray O'NEILL
Lab Technician-Nutrients Signatory

Parameter	Units	LOR	Sample Number Sample Matrix Sample Date Sample Name			
			PE160331.001 Water 06 May 2022 E Deposit_IN	PE160331.002 Water 06 May 2022 A Deposit_OUT	PE160331.003 Water PRB-EAST-TOP	PE160331.004 Water PRB-WEST-TOP

pH in water Method: AN101 Tested: 9/5/2022

Parameter	Units	LOR	PE160331.001	PE160331.002	PE160331.003	PE160331.004
pH**	pH Units	0.1	8.1	8.1	8.2	8.1

Conductivity and TDS by Calculation - Water Method: AN106 Tested: 9/5/2022

Parameter	Units	LOR	PE160331.001	PE160331.002	PE160331.003	PE160331.004
Conductivity @ 25 C	µS/cm	2	680	720	700	670

Metals in Water (Total) by ICPOES Method: AN022/AN320 Tested: 12/5/2022

Parameter	Units	LOR	PE160331.001	PE160331.002	PE160331.003	PE160331.004
Total Calcium	mg/L	0.2	49	47	50	48
Total Magnesium	mg/L	0.1	32	31	32	31
Total Potassium	mg/L	0.1	8.1	7.6	8.3	8.1
Total Sodium	mg/L	0.5	33	34	33	32

Metals in Water (Dissolved) by ICPOES Method: AN320 Tested: 11/5/2022

Parameter	Units	LOR	PE160331.001	PE160331.002	PE160331.003	PE160331.004
Calcium, Ca	mg/L	0.2	48	48	49	49
Magnesium, Mg	mg/L	0.1	32	32	32	32
Total Hardness by Calculation	mg CaCO3/L	1	250	250	250	250

Chloride by Discrete Analyser in Water Method: AN274 Tested: 11/5/2022

Parameter	Units	LOR	PE160331.001	PE160331.002	PE160331.003	PE160331.004
Chloride, Cl	mg/L	1	52	55	48	50

Fluoride by Ion Selective Electrode in Water Method: AN141 Tested: 12/5/2022

Parameter	Units	LOR	PE160331.001	PE160331.002	PE160331.003	PE160331.004
Fluoride by ISE	mg/L	0.1	0.3	0.3	0.3	0.3

Parameter	Units	LOR				
		Sample Number	PE160331.001	PE160331.002	PE160331.003	PE160331.004
		Sample Matrix	Water	Water	Water	Water
		Sample Date	06 May 2022	06 May 2022	PRB-EAST-TOP	PRB-WEST-TOP
		Sample Name	E Deposit_IN	A Deposit_OUT		

Sulfate in water Method: AN275 Tested: 11/5/2022

Parameter	Units	LOR	PE160331.001	PE160331.002	PE160331.003	PE160331.004
Sulfate, SO4	mg/L	1	44	45	45	44

Total Dissolved Solids (TDS) in water Method: AN113 Tested: 11/5/2022

Parameter	Units	LOR	PE160331.001	PE160331.002	PE160331.003	PE160331.004
Total Dissolved Solids Dried at 175-185°C	mg/L	10	380	390	390	380

Low Level Ammonia Nitrogen by FIA Method: AN261 Tested: 12/5/2022

Parameter	Units	LOR	PE160331.001	PE160331.002	PE160331.003	PE160331.004
Ammonia, NH_3	mg/L	0.02	<0.02	<0.02	<0.02	<0.02

TKN Kjeldahl Digestion by Discrete Analyser Method: AN281 Tested: 11/5/2022

Parameter	Units	LOR	PE160331.001	PE160331.002	PE160331.003	PE160331.004
Total Kjeldahl Nitrogen	mg/L	0.05	<0.05	<0.05	0.06	<0.05

Low Level Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA Method: AN258 Tested: 12/5/2022

Parameter	Units	LOR	PE160331.001	PE160331.002	PE160331.003	PE160331.004
Nitrate/Nitrite Nitrogen, NOx as N	mg/L	0.005	0.73	0.38	0.89	0.93
Nitrite, NO_2 as NO_2	mg/L	0.05	<0.05	<0.05	<0.05	<0.05
Nitrate, NO_3 as NO_3	mg/L	0.05	3.2	1.7	3.9	4.1

Total Phosphorus by Kjeldahl Digestion DA in Water Method: AN279/AN293(Sydney only) Tested: 11/5/2022

Parameter	Units	LOR	PE160331.001	PE160331.002	PE160331.003	PE160331.004
Total Phosphorus (Kjeldahl Digestion) as P	mg/L	0.02	0.03	0.44	0.05	0.04

		Sample Number	PE160331.001	PE160331.002	PE160331.003	PE160331.004
		Sample Matrix	Water	Water	Water	Water
		Sample Date	06 May 2022	06 May 2022	PRB-EAST-TOP	PRB-WEST-TOP
		Sample Name	E Deposit_IN	A Deposit_OUT		
Parameter	Units	LOR				

Trace Metals (Dissolved) in Water by ICPMS in mg/L Method: AN318 Tested: 11/5/2022

Aluminium, Al	mg/L	0.005	<0.005	<0.005	<0.005	<0.005
Antimony, Sb	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Arsenic, As	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Barium, Ba	mg/L	0.001	**0.007**	**0.007**	**0.006**	**0.006**
Bismuth, Bi	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Boron, B	mg/L	0.005	**0.25**	**0.26**	**0.24**	**0.24**
Cadmium, Cd	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium, Cr	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Cobalt, Co	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Copper, Cu	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Iron, Fe	mg/L	0.005	<0.005	<0.005	<0.005	<0.005
Lead, Pb	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Manganese, Mn	mg/L	0.001	<0.001	**0.002**	<0.001	<0.001
Molybdenum, Mo	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Nickel, Ni	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Selenium, Se	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Silver, Ag	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Tellurium, Te	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Thallium, Tl	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Tin, Sn	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Uranium, U	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Vanadium, V	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Zinc, Zn	mg/L	0.005	**0.007**	<0.005	<0.005	<0.005

Mercury (dissolved) in Water Method: AN311(Perth)/AN312 Tested: 11/5/2022

Mercury	mg/L	0.00005	<0.00005	<0.00005	<0.00005	<0.00005

Alkalinity Method: AN135 Tested: 9/5/2022

Bicarbonate Alkalinity as HCO3	mg/L	5	**260**	**260**	**260**	**260**
Carbonate Alkalinity as CO3	mg/L	5	<5	<5	<5	<5
Hydroxide Alkalinity as OH	mg/L	5	<5	<5	<5	<5
Total Alkalinity as CaCO3	mg/L	5	**210**	**210**	**210**	**210**

Alkalinity of sample filtered to pass 0.45µm membrane filter Method: AN135 Tested: 20/5/2022

Bicarbonate Alkalinity as HCO3	mg/L	5	**290**	**290**	**290**	**290**
Carbonate Alkalinity as CO3	mg/L	5	<5	<5	<5	<5
Hydroxide Alkalinity as OH	mg/L	5	<5	<5	<5	<5
Total Alkalinity as CaCO3	mg/L	5	**230**	**240**	**240**	**240**

		Sample Number Sample Matrix Sample Name	PE160331.005 Water A Deposit TN	PE160331.006 Water PRB-CREEK DRAINAGE	PE160331.007 Water PRB-WEST-BOTTOM	PE160331.008 Water PRB-EAST-BOTTOM
Parameter	Units	LOR				

pH in water Method: AN101 Tested: 9/5/2022

Parameter	Units	LOR	PE160331.005	PE160331.006	PE160331.007	PE160331.008
pH**	pH Units	0.1	8.2	8.2	8.6	8.5

Conductivity and TDS by Calculation - Water Method: AN106 Tested: 9/5/2022

Parameter	Units	LOR	PE160331.005	PE160331.006	PE160331.007	PE160331.008
Conductivity @ 25 C	µS/cm	2	690	650	610	640

Metals in Water (Total) by ICPOES Method: AN022/AN320 Tested: 12/5/2022

Parameter	Units	LOR	PE160331.005	PE160331.006	PE160331.007	PE160331.008
Total Calcium	mg/L	0.2	48	41	35	42
Total Magnesium	mg/L	0.1	31	33	33	33
Total Potassium	mg/L	0.1	8.3	8.1	8.5	8.4
Total Sodium	mg/L	0.5	35	34	34	34

Metals in Water (Dissolved) by ICPOES Method: AN320 Tested: 11/5/2022

Parameter	Units	LOR	PE160331.005	PE160331.006	PE160331.007	PE160331.008
Calcium, Ca	mg/L	0.2	48	51	34	42
Magnesium, Mg	mg/L	0.1	32	44	32	32
Total Hardness by Calculation	mg CaCO3/L	1	250	310	220	240

Chloride by Discrete Analyser in Water Method: AN274 Tested: 11/5/2022

Parameter	Units	LOR	PE160331.005	PE160331.006	PE160331.007	PE160331.008
Chloride, Cl	mg/L	1	56	52	52	52

Fluoride by Ion Selective Electrode in Water Method: AN141 Tested: 12/5/2022

Parameter	Units	LOR	PE160331.005	PE160331.006	PE160331.007	PE160331.008
Fluoride by ISE	mg/L	0.1	0.3	0.3	0.3	0.3

		Sample Number Sample Matrix Sample Name	PE160331.005 Water A Deposit TN	PE160331.006 Water PRB-CREEK DRAINAGE	PE160331.007 Water PRB-WEST-BOTTOM	PE160331.008 Water PRB-EAST-BOTTOM
Parameter	Units	LOR				

Sulfate in water Method: AN275 Tested: 11/5/2022

Sulfate, SO4	mg/L	1	44	44	46	46

Total Dissolved Solids (TDS) in water Method: AN113 Tested: 11/5/2022

Total Dissolved Solids Dried at 175-185°C	mg/L	10	400	360	350	370

Low Level Ammonia Nitrogen by FIA Method: AN261 Tested: 12/5/2022

Ammonia, NH_3	mg/L	0.02	0.03	<0.02	<0.02	<0.02

TKN Kjeldahl Digestion by Discrete Analyser Method: AN281 Tested: 11/5/2022

Total Kjeldahl Nitrogen	mg/L	0.05	0.69	0.12	0.25	0.18

Low Level Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA Method: AN258 Tested: 12/5/2022

Nitrate/Nitrite Nitrogen, NOx as N	mg/L	0.005	0.37	0.31	0.29	0.52
Nitrite, NO_2 as NO_2	mg/L	0.05	<0.05	<0.05	<0.05	<0.05
Nitrate, NO_3 as NO_3	mg/L	0.05	1.6	1.4	1.3	2.3

Total Phosphorus by Kjeldahl Digestion DA in Water Method: AN279/AN293(Sydney only) Tested: 11/5/2022

Total Phosphorus (Kjeldahl Digestion) as P	mg/L	0.02	0.27	0.03	0.04	0.04

Parameter	Units	LOR	PE160331.005	PE160331.006	PE160331.007	PE160331.008
Sample Number			PE160331.005	PE160331.006	PE160331.007	PE160331.008
Sample Matrix			Water	Water	Water	Water
Sample Name			A Deposit TN	PRB-CREEK DRAINAGE	PRB-WEST-BOTTOM	PRB-EAST-BOTTOM

Trace Metals (Dissolved) in Water by ICPMS in mg/L Method: AN318 Tested: 11/5/2022

Parameter	Units	LOR	PE160331.005	PE160331.006	PE160331.007	PE160331.008
Aluminium, Al	mg/L	0.005	<0.005	<0.005	<0.005	<0.005
Antimony, Sb	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Arsenic, As	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Barium, Ba	mg/L	0.001	**0.010**	**0.013**	**0.004**	**0.005**
Bismuth, Bi	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Boron, B	mg/L	0.005	**0.28**	**0.32**	**0.24**	**0.24**
Cadmium, Cd	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium, Cr	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Cobalt, Co	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Copper, Cu	mg/L	0.001	**0.004**	<0.001	<0.001	<0.001
Iron, Fe	mg/L	0.005	<0.005	<0.005	<0.005	<0.005
Lead, Pb	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Manganese, Mn	mg/L	0.001	**0.004**	<0.001	<0.001	<0.001
Molybdenum, Mo	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Nickel, Ni	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Selenium, Se	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Silver, Ag	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Tellurium, Te	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Thallium, Tl	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Tin, Sn	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Uranium, U	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Vanadium, V	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Zinc, Zn	mg/L	0.005	**0.034**	<0.005	<0.005	<0.005

Mercury (dissolved) in Water Method: AN311(Perth)/AN312 Tested: 11/5/2022

Parameter	Units	LOR	PE160331.005	PE160331.006	PE160331.007	PE160331.008
Mercury	mg/L	0.00005	<0.00005	<0.00005	<0.00005	<0.00005

Alkalinity Method: AN135 Tested: 9/5/2022

Parameter	Units	LOR	PE160331.005	PE160331.006	PE160331.007	PE160331.008
Bicarbonate Alkalinity as HCO3	mg/L	5	**260**	**240**	**190**	**220**
Carbonate Alkalinity as CO3	mg/L	5	<5	<5	**12**	**11**
Hydroxide Alkalinity as OH	mg/L	5	<5	<5	<5	<5
Total Alkalinity as CaCO3	mg/L	5	**220**	**190**	**180**	**200**

Alkalinity of sample filtered to pass 0.45µm membrane filter Method: AN135 Tested: 20/5/2022

Parameter	Units	LOR	PE160331.005	PE160331.006	PE160331.007	PE160331.008
Bicarbonate Alkalinity as HCO3	mg/L	5	**290**	**270**	**220**	**250**
Carbonate Alkalinity as CO3	mg/L	5	<5	<5	**11**	**9**
Hydroxide Alkalinity as OH	mg/L	5	<5	<5	<5	<5
Total Alkalinity as CaCO3	mg/L	5	**240**	**220**	**200**	**220**

		Sample Number	PE160331.009	PE160331.010	PE160331.011	PE160331.012
		Sample Matrix	Water	Water	Water	Water
		Sample Name	E Deposit TN	4/5/22 10:49 HGA0062P/4-5-22 /10:49/PDG	4/5/22 13:30 HGA0074P/4-5-22 /13:30/PDG	5/5/22 17:30 HGA0074P/5-5-22 /17:30/PDG
Parameter	Units	LOR				

pH in water Method: AN101 Tested: 9/5/2022

pH**	pH Units	0.1	8.3	8.0	7.8	8.0

Conductivity and TDS by Calculation - Water Method: AN106 Tested: 9/5/2022

Conductivity @ 25 C	µS/cm	2	690	720	720	720

Metals in Water (Total) by ICPOES Method: AN022/AN320 Tested: 12/5/2022

Total Calcium	mg/L	0.2	50	56	49	50
Total Magnesium	mg/L	0.1	32	34	33	33
Total Potassium	mg/L	0.1	8.4	8.1	8.5	9.1
Total Sodium	mg/L	0.5	34	33	35	36

Metals in Water (Dissolved) by ICPOES Method: AN320 Tested: 11/5/2022

Calcium, Ca	mg/L	0.2	49	55	50	50
Magnesium, Mg	mg/L	0.1	32	34	33	33
Total Hardness by Calculation	mg CaCO3/L	1	260	280	260	260

Chloride by Discrete Analyser in Water Method: AN274 Tested: 11/5/2022

Chloride, Cl	mg/L	1	52	51	61	62

Fluoride by Ion Selective Electrode in Water Method: AN141 Tested: 12/5/2022

Fluoride by ISE	mg/L	0.1	0.3	0.3	0.3	0.3

		Sample Number	PE160331.009	PE160331.010	PE160331.011	PE160331.012
		Sample Matrix	Water	Water	Water	Water
		Sample Name	E Deposit TN	4/5/22 10:49 HGA0062P/4-5-22 /10:49/PDG	4/5/22 13:30 HGA0074P/4-5-22 /13:30/PDG	5/5/22 17:30 HGA0074P/5-5-22 /17:30/PDG
Parameter	Units	LOR				
Sulfate in water Method: AN275 Tested: 11/5/2022						
Sulfate, SO4	mg/L	1	45	46	49	49
Total Dissolved Solids (TDS) in water Method: AN113 Tested: 11/5/2022						
Total Dissolved Solids Dried at 175-185°C	mg/L	10	400	420	410	410
Low Level Ammonia Nitrogen by FIA Method: AN261 Tested: 12/5/2022						
Ammonia, NH_3	mg/L	0.02	<0.02	<0.02	<0.02	0.03
TKN Kjeldahl Digestion by Discrete Analyser Method: AN281 Tested: 11/5/2022						
Total Kjeldahl Nitrogen	mg/L	0.05	0.40	<0.05	<0.05	0.33
Low Level Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA Method: AN258 Tested: 12/5/2022						
Nitrate/Nitrite Nitrogen, NOx as N	mg/L	0.005	0.61	0.76	0.068	0.070
Nitrite, NO_2 as NO_2	mg/L	0.05	<0.05	<0.05	<0.05	<0.05
Nitrate, NO_3 as NO_3	mg/L	0.05	2.7	3.4	0.30	0.31
Total Phosphorus by Kjeldahl Digestion DA in Water Method: AN279/AN293(Sydney only) Tested: 11/5/2022						
Total Phosphorus (Kjeldahl Digestion) as P	mg/L	0.02	0.03	0.04	0.03	0.05

		Sample Number	PE160331.009	PE160331.010	PE160331.011	PE160331.012
		Sample Matrix	Water	Water	Water	Water
		Sample Name	E Deposit TN	4/5/22 10:49 HGA0062P/4-5-22 /10:49/PDG	4/5/22 13:30 HGA0074P/4-5-22 /13:30/PDG	5/5/22 17:30 HGA0074P/5-5-22 /17:30/PDG
Parameter	Units	LOR				

Trace Metals (Dissolved) in Water by ICPMS in mg/L Method: AN318 Tested: 11/5/2022

Parameter	Units	LOR	PE160331.009	PE160331.010	PE160331.011	PE160331.012
Aluminium, Al	mg/L	0.005	<0.005	<0.005	<0.005	<0.005
Antimony, Sb	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Arsenic, As	mg/L	0.001	<0.001	<0.001	<0.001	**0.003**
Barium, Ba	mg/L	0.001	**0.006**	<0.001	**0.004**	**0.005**
Bismuth, Bi	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Boron, B	mg/L	0.005	**0.24**	**0.21**	**0.26**	**0.25**
Cadmium, Cd	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium, Cr	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Cobalt, Co	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Copper, Cu	mg/L	0.001	**0.002**	<0.001	<0.001	<0.001
Iron, Fe	mg/L	0.005	**0.008**	<0.005	<0.005	<0.005
Lead, Pb	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Manganese, Mn	mg/L	0.001	**0.006**	**0.001**	**0.017**	**0.017**
Molybdenum, Mo	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Nickel, Ni	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Selenium, Se	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Silver, Ag	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Tellurium, Te	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Thallium, Tl	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Tin, Sn	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Uranium, U	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Vanadium, V	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Zinc, Zn	mg/L	0.005	**0.040**	**0.007**	**0.005**	**0.008**

Mercury (dissolved) in Water Method: AN311(Perth)/AN312 Tested: 11/5/2022

Parameter	Units	LOR	PE160331.009	PE160331.010	PE160331.011	PE160331.012
Mercury	mg/L	0.00005	<0.00005	<0.00005	<0.00005	<0.00005

Alkalinity Method: AN135 Tested: 9/5/2022

Parameter	Units	LOR	PE160331.009	PE160331.010	PE160331.011	PE160331.012
Bicarbonate Alkalinity as HCO3	mg/L	5	**260**	**280**	**260**	**260**
Carbonate Alkalinity as CO3	mg/L	5	<5	<5	<5	<5
Hydroxide Alkalinity as OH	mg/L	5	<5	<5	<5	<5
Total Alkalinity as CaCO3	mg/L	5	**220**	**230**	**210**	**210**

Alkalinity of sample filtered to pass 0.45µm membrane filter Method: AN135 Tested: 20/5/2022

Parameter	Units	LOR	PE160331.009	PE160331.010	PE160331.011	PE160331.012
Bicarbonate Alkalinity as HCO3	mg/L	5	**290**	**320**	**290**	**290**
Carbonate Alkalinity as CO3	mg/L	5	<5	<5	<5	<5
Hydroxide Alkalinity as OH	mg/L	5	<5	<5	<5	<5
Total Alkalinity as CaCO3	mg/L	5	**240**	**260**	**240**	**240**

		Sample Number	PE160331.013	PE160331.014	PE160331.015	PE160331.016
		Sample Matrix	Water	Water	Water	Water
		Sample Date	4/5/22 16:35	4/5/22 17:00	5/5/22 17:30	5/5/22 10:25
		Sample Name	HGA0074P/4-5-22 /16:35/PDG	HGA0074P/4-5-22 /17:00/ADG	HGA0074P/5-5-22 /17:30/ADG	HGA0074P/5-5-22 /10:25/PDG
Parameter	Units	LOR				

pH in water Method: AN101 Tested: 9/5/2022

pH**	pH Units	0.1	8.0	8.2	8.3	8.0

Conductivity and TDS by Calculation - Water Method: AN106 Tested: 9/5/2022

Conductivity @ 25 C	µS/cm	2	720	710	710	720

Metals in Water (Total) by ICPOES Method: AN022/AN320 Tested: 12/5/2022

Total Calcium	mg/L	0.2	51	51	49	50
Total Magnesium	mg/L	0.1	33	34	33	33
Total Potassium	mg/L	0.1	8.9	9.4	9.0	9.1
Total Sodium	mg/L	0.5	36	38	36	36

Metals in Water (Dissolved) by ICPOES Method: AN320 Tested: 11/5/2022

Calcium, Ca	mg/L	0.2	50	49	50	50
Magnesium, Mg	mg/L	0.1	34	33	33	33
Total Hardness by Calculation	mg CaCO3/L	1	260	260	260	260

Chloride by Discrete Analyser in Water Method: AN274 Tested: 11/5/2022

Chloride, Cl	mg/L	1	62	63	62	62

Fluoride by Ion Selective Electrode in Water Method: AN141 Tested: 12/5/2022

Fluoride by ISE	mg/L	0.1	0.3	0.3	0.3	0.3

		Sample Number Sample Matrix Sample Date Sample Name	PE160331.013 Water 4/5/22 16:35 HGA0074P/4-5-22 /16:35/PDG	PE160331.014 Water 4/5/22 17:00 HGA0074P/4-5-22 /17:00/ADG	PE160331.015 Water 5/5/22 17:30 HGA0074P/5-5-22 /17:30/ADG	PE160331.016 Water 5/5/22 10:25 HGA0074P/5-5-22 /10:25/PDG
Parameter	**Units**	**LOR**				
Sulfate in water Method: AN275 Tested: 11/5/2022						
Sulfate, SO4	mg/L	1	48	49	48	49
Total Dissolved Solids (TDS) in water Method: AN113 Tested: 11/5/2022						
Total Dissolved Solids Dried at 175-185°C	mg/L	10	400	400	400	390
Low Level Ammonia Nitrogen by FIA Method: AN261 Tested: 12/5/2022						
Ammonia, NH_3	mg/L	0.02	<0.02	0.05	0.03	<0.02
TKN Kjeldahl Digestion by Discrete Analyser Method: AN281 Tested: 11/5/2022						
Total Kjeldahl Nitrogen	mg/L	0.05	<0.05	0.32	0.37	0.22
Low Level Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA Method: AN258 Tested: 12/5/2022						
Nitrate/Nitrite Nitrogen, NOx as N	mg/L	0.005	0.070	0.071	0.070	0.069
Nitrite, NO_2 as NO_2	mg/L	0.05	<0.05	<0.05	<0.05	<0.05
Nitrate, NO_3 as NO_3	mg/L	0.05	0.31	0.30	0.30	0.30
Total Phosphorus by Kjeldahl Digestion DA in Water Method: AN279/AN293(Sydney only) Tested: 11/5/2022						
Total Phosphorus (Kjeldahl Digestion) as P	mg/L	0.02	<0.02	0.03	0.05	0.21

		Sample Number	PE160331.013	PE160331.014	PE160331.015	PE160331.016
		Sample Matrix	Water	Water	Water	Water
		Sample Date	4/5/22 16:35	4/5/22 17:00	5/5/22 17:30	5/5/22 10:25
		Sample Name	HGA0074P/4-5-22/16:35/PDG	HGA0074P/4-5-22/17:00/ADG	HGA0074P/5-5-22/17:30/ADG	HGA0074P/5-5-22/10:25/PDG
Parameter	Units	LOR				
Trace Metals (Dissolved) in Water by ICPMS in mg/L Method: AN318 Tested: 11/5/2022						
Aluminium, Al	mg/L	0.005	<0.005	<0.005	**0.006**	<0.005
Antimony, Sb	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Arsenic, As	mg/L	0.001	<0.001	**0.003**	<0.001	<0.001
Barium, Ba	mg/L	0.001	**0.004**	**0.013**	**0.012**	**0.073**
Bismuth, Bi	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Boron, B	mg/L	0.005	**0.26**	**0.26**	**0.25**	**0.27**
Cadmium, Cd	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium, Cr	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Cobalt, Co	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Copper, Cu	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Iron, Fe	mg/L	0.005	<0.005	<0.005	<0.005	<0.005
Lead, Pb	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Manganese, Mn	mg/L	0.001	**0.017**	**0.10**	**0.066**	**0.016**
Molybdenum, Mo	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Nickel, Ni	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Selenium, Se	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Silver, Ag	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Tellurium, Te	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Thallium, Tl	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Tin, Sn	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Uranium, U	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Vanadium, V	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Zinc, Zn	mg/L	0.005	**0.006**	**0.006**	**0.007**	**0.025**
Mercury (dissolved) in Water Method: AN311(Perth)/AN312 Tested: 11/5/2022						
Mercury	mg/L	0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Alkalinity Method: AN135 Tested: 9/5/2022						
Bicarbonate Alkalinity as HCO3	mg/L	5	**260**	**260**	**250**	**260**
Carbonate Alkalinity as CO3	mg/L	5	<5	<5	<5	<5
Hydroxide Alkalinity as OH	mg/L	5	<5	<5	<5	<5
Total Alkalinity as CaCO3	mg/L	5	**210**	**210**	**210**	**210**
Alkalinity of sample filtered to pass 0.45µm membrane filter Method: AN135 Tested: 20/5/2022						
Bicarbonate Alkalinity as HCO3	mg/L	5	**290**	**290**	**290**	**290**
Carbonate Alkalinity as CO3	mg/L	5	<5	<5	<5	<5
Hydroxide Alkalinity as OH	mg/L	5	<5	<5	<5	<5
Total Alkalinity as CaCO3	mg/L	5	**240**	**240**	**240**	**240**

		Sample Number	PE160331.017	PE160331.018	PE160331.019	PE160331.020
		Sample Matrix	Water	Water	Water	Water
		Sample Date	5/5/22 9:25	7/5/22 5:50	7/5/22 5:50	6/5/22 11:20
		Sample Name	HGA0074P/5-5-22 /9:25/PDG	HGE0148P/7-5-22 /5:50/ADG	HGE0148P/5-5-22 /5:50/PDG	HGE0148P/6-5-22 /11:20/PDG
Parameter	Units	LOR				

pH in water Method: AN101 Tested: 9/5/2022

pH**	pH Units	0.1	7.9	8.2	8.1	8.0

Conductivity and TDS by Calculation - Water Method: AN106 Tested: 9/5/2022

Conductivity @ 25 C	µS/cm	2	710	630	630	620

Metals in Water (Total) by ICPOES Method: AN022/AN320 Tested: 12/5/2022

Total Calcium	mg/L	0.2	50	46	47	46
Total Magnesium	mg/L	0.1	33	29	29	28
Total Potassium	mg/L	0.1	8.7	9.0	8.9	8.4
Total Sodium	mg/L	0.5	36	30	29	29

Metals in Water (Dissolved) by ICPOES Method: AN320 Tested: 11/5/2022

Calcium, Ca	mg/L	0.2	50	46	47	47
Magnesium, Mg	mg/L	0.1	33	29	29	29
Total Hardness by Calculation	mg CaCO3/L	1	260	240	240	240

Chloride by Discrete Analyser in Water Method: AN274 Tested: 11/5/2022

Chloride, Cl	mg/L	1	61	39	39	39

Fluoride by Ion Selective Electrode in Water Method: AN141 Tested: 12/5/2022

Fluoride by ISE	mg/L	0.1	0.3	0.3	0.3	0.3

		Sample Number	PE160331.017	PE160331.018	PE160331.019	PE160331.020
		Sample Matrix	Water	Water	Water	Water
		Sample Date	5/5/22 9:25	7/5/22 5:50	7/5/22 5:50	6/5/22 11:20
		Sample Name	HGA0074P/5-5-22 /9:25/PDG	HGE0148P/7-5-22 /5:50/ADG	HGE0148P/5-5-22 /5:50/PDG	HGE0148P/6-5-22 /11:20/PDG
Parameter	**Units**	**LOR**				
Sulfate in water Method: AN275 Tested: 11/5/2022						
Sulfate, SO4	mg/L	1	**49**	**39**	**39**	**39**
Total Dissolved Solids (TDS) in water Method: AN113 Tested: 11/5/2022						
Total Dissolved Solids Dried at 175-185°C	mg/L	10	**390**	**360**	**370**	**370**
Low Level Ammonia Nitrogen by FIA Method: AN261 Tested: 12/5/2022						
Ammonia, NH_3	mg/L	0.02	<0.02	**0.10**	**0.03**	<0.02
TKN Kjeldahl Digestion by Discrete Analyser Method: AN281 Tested: 11/5/2022						
Total Kjeldahl Nitrogen	mg/L	0.05	<0.05	**0.43**	**0.33**	<0.05
Low Level Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA Method: AN258 Tested: 12/5/2022						
Nitrate/Nitrite Nitrogen, NOx as N	mg/L	0.005	**0.067**	**2.1**	**2.0**	**2.0**
Nitrite, NO_2 as NO_2	mg/L	0.05	<0.05	<0.05	<0.05	<0.05
Nitrate, NO_3 as NO_3	mg/L	0.05	**0.29**	**9.1**	**8.9**	**8.8**
Total Phosphorus by Kjeldahl Digestion DA in Water Method: AN279/AN293(Sydney only) Tested: 11/5/2022						
Total Phosphorus (Kjeldahl Digestion) as P	mg/L	0.02	**0.04**	**0.19**	**0.34**	**0.25**

Parameter	Units	LOR	PE160331.017	PE160331.018	PE160331.019	PE160331.020
Sample Number			PE160331.017	PE160331.018	PE160331.019	PE160331.020
Sample Matrix			Water	Water	Water	Water
Sample Date			5/5/22 9:25	7/5/22 5:50	7/5/22 5:50	6/5/22 11:20
Sample Name			HGA0074P/5-5-22 /9:25/PDG	HGE0148P/7-5-22 /5:50/ADG	HGE0148P/5-5-22 /5:50/PDG	HGE0148P/6-5-22 /11:20/PDG

Trace Metals (Dissolved) in Water by ICPMS in mg/L Method: AN318 Tested: 11/5/2022

Parameter	Units	LOR	PE160331.017	PE160331.018	PE160331.019	PE160331.020
Aluminium, Al	mg/L	0.005	<0.005	<0.005	<0.005	<0.005
Antimony, Sb	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Arsenic, As	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Barium, Ba	mg/L	0.001	0.080	0.016	0.012	0.011
Bismuth, Bi	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Boron, B	mg/L	0.005	0.27	0.21	0.21	0.20
Cadmium, Cd	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium, Cr	mg/L	0.001	<0.001	0.002	0.002	<0.001
Cobalt, Co	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Copper, Cu	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Iron, Fe	mg/L	0.005	<0.005	<0.005	<0.005	0.027
Lead, Pb	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Manganese, Mn	mg/L	0.001	0.016	0.036	0.002	0.008
Molybdenum, Mo	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Nickel, Ni	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Selenium, Se	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Silver, Ag	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Tellurium, Te	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Thallium, Tl	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Tin, Sn	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Uranium, U	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Vanadium, V	mg/L	0.001	<0.001	<0.001	<0.001	<0.001
Zinc, Zn	mg/L	0.005	0.027	0.006	0.009	0.31

Mercury (dissolved) in Water Method: AN311(Perth)/AN312 Tested: 11/5/2022

Parameter	Units	LOR	PE160331.017	PE160331.018	PE160331.019	PE160331.020
Mercury	mg/L	0.00005	<0.00005	<0.00005	<0.00005	<0.00005

Alkalinity Method: AN135 Tested: 9/5/2022

Parameter	Units	LOR	PE160331.017	PE160331.018	PE160331.019	PE160331.020
Bicarbonate Alkalinity as HCO3	mg/L	5	260	250	250	250
Carbonate Alkalinity as CO3	mg/L	5	<5	<5	<5	<5
Hydroxide Alkalinity as OH	mg/L	5	<5	<5	<5	<5
Total Alkalinity as CaCO3	mg/L	5	210	200	210	200

Alkalinity of sample filtered to pass 0.45µm membrane filter Method: AN135 Tested: 20/5/2022

Parameter	Units	LOR	PE160331.017	PE160331.018	PE160331.019	PE160331.020
Bicarbonate Alkalinity as HCO3	mg/L	5	290	280	290	280
Carbonate Alkalinity as CO3	mg/L	5	<5	7	<5	<5
Hydroxide Alkalinity as OH	mg/L	5	<5	<5	<5	<5
Total Alkalinity as CaCO3	mg/L	5	240	240	230	230

		Sample Number	PE160331.021
		Sample Matrix	Water
		Sample Date	6/5/22 12:20
		Sample Name	HGE0148P/6-5-22 /12:20/PDG
Parameter	Units	LOR	

pH in water Method: AN101 Tested: 9/5/2022

pH**	pH Units	0.1	8.1

Conductivity and TDS by Calculation - Water Method: AN106 Tested: 9/5/2022

Conductivity @ 25 C	µS/cm	2	630

Metals in Water (Total) by ICPOES Method: AN022/AN320 Tested: 12/5/2022

Total Calcium	mg/L	0.2	47
Total Magnesium	mg/L	0.1	29
Total Potassium	mg/L	0.1	9.1
Total Sodium	mg/L	0.5	29

Metals in Water (Dissolved) by ICPOES Method: AN320 Tested: 11/5/2022

Calcium, Ca	mg/L	0.2	47
Magnesium, Mg	mg/L	0.1	29
Total Hardness by Calculation	mg CaCO3/L	1	240

Chloride by Discrete Analyser in Water Method: AN274 Tested: 11/5/2022

Chloride, Cl	mg/L	1	40

Fluoride by Ion Selective Electrode in Water Method: AN141 Tested: 12/5/2022

Fluoride by ISE	mg/L	0.1	0.3

		Sample Number	PE160331.021
		Sample Matrix	Water
		Sample Date	6/5/22 12:20
		Sample Name	HGE0148P/6-5-22 /12:20/PDG
Parameter	Units	LOR	

Sulfate in water Method: AN275 Tested: 11/5/2022

Sulfate, SO4	mg/L	1	**39**

Total Dissolved Solids (TDS) in water Method: AN113 Tested: 11/5/2022

Total Dissolved Solids Dried at 175-185°C	mg/L	10	**370**

Low Level Ammonia Nitrogen by FIA Method: AN261 Tested: 12/5/2022

Ammonia, NH_3	mg/L	0.02	**0.04**

TKN Kjeldahl Digestion by Discrete Analyser Method: AN281 Tested: 11/5/2022

Total Kjeldahl Nitrogen	mg/L	0.05	**0.37**

Low Level Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA Method: AN258 Tested: 12/5/2022

Nitrate/Nitrite Nitrogen, NOx as N	mg/L	0.005	**2.0**
Nitrite, NO_2 as NO_2	mg/L	0.05	<0.05
Nitrate, NO_3 as NO_3	mg/L	0.05	**8.8**

Total Phosphorus by Kjeldahl Digestion DA in Water Method: AN279/AN293(Sydney only) Tested: 11/5/2022

Total Phosphorus (Kjeldahl Digestion) as P	mg/L	0.02	**0.06**

		Sample Number	PE160331.021
		Sample Matrix	Water
		Sample Date	6/5/22 12:20
		Sample Name	HGE0148P/6-5-22 /12:20/PDG
Parameter	Units	LOR	

Trace Metals (Dissolved) in Water by ICPMS in mg/L Method: AN318 Tested: 11/5/2022

Parameter	Units	LOR	PE160331.021
Aluminium, Al	mg/L	0.005	<0.005
Antimony, Sb	mg/L	0.001	<0.001
Arsenic, As	mg/L	0.001	**0.001**
Barium, Ba	mg/L	0.001	**0.011**
Bismuth, Bi	mg/L	0.001	<0.001
Boron, B	mg/L	0.005	**0.21**
Cadmium, Cd	mg/L	0.0001	<0.0001
Chromium, Cr	mg/L	0.001	**0.002**
Cobalt, Co	mg/L	0.001	<0.001
Copper, Cu	mg/L	0.001	<0.001
Iron, Fe	mg/L	0.005	<0.005
Lead, Pb	mg/L	0.001	<0.001
Manganese, Mn	mg/L	0.001	<0.001
Molybdenum, Mo	mg/L	0.001	<0.001
Nickel, Ni	mg/L	0.001	<0.001
Selenium, Se	mg/L	0.001	<0.001
Silver, Ag	mg/L	0.001	<0.001
Tellurium, Te	mg/L	0.001	<0.001
Thallium, Tl	mg/L	0.001	<0.001
Tin, Sn	mg/L	0.001	<0.001
Uranium, U	mg/L	0.001	<0.001
Vanadium, V	mg/L	0.001	<0.001
Zinc, Zn	mg/L	0.005	**0.007**

Mercury (dissolved) in Water Method: AN311(Perth)/AN312 Tested: 11/5/2022

Parameter	Units	LOR	PE160331.021
Mercury	mg/L	0.00005	<0.00005

Alkalinity Method: AN135 Tested: 9/5/2022

Parameter	Units	LOR	PE160331.021
Bicarbonate Alkalinity as HCO3	mg/L	5	**250**
Carbonate Alkalinity as CO3	mg/L	5	<5
Hydroxide Alkalinity as OH	mg/L	5	<5
Total Alkalinity as CaCO3	mg/L	5	**210**

		Sample Number	**PE160331.021**
		Sample Matrix	**Water**
		Sample Date	**6/5/22 12:20**
		Sample Name	**HGE0148P/6-5-22 /12:20/PDG**
Parameter	**Units**	**LOR**	
Alkalinity of sample filtered to pass 0.45µm membrane filter	**Method: AN135**	**Tested: 20/5/2022**	
Bicarbonate Alkalinity as HCO3	mg/L	5	**280**
Carbonate Alkalinity as CO3	mg/L	5	<5
Hydroxide Alkalinity as OH	mg/L	5	<5
Total Alkalinity as CaCO3	mg/L	5	**230**

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Alkalinity Method: ME-(AU)-[ENV]AN135

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Bicarbonate Alkalinity as HCO3	LB195343	mg/L	5	<5		
Carbonate Alkalinity as CO3	LB195343	mg/L	5	<5		
Hydroxide Alkalinity as OH	LB195343	mg/L	5	<5		
Total Alkalinity as CaCO3	LB195343	mg/L	5	<5	0%	93%

Alkalinity of sample filtered to pass 0.45µm membrane filter Method: ME-(AU)-[ENV]AN135

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Bicarbonate Alkalinity as HCO3	LB195833	mg/L	5	<5		
Carbonate Alkalinity as CO3	LB195833	mg/L	5	<5		
Hydroxide Alkalinity as OH	LB195833	mg/L	5	<5		
Total Alkalinity as CaCO3	LB195833	mg/L	5	<5	0 - 2%	NA

Chloride by Discrete Analyser in Water Method: ME-(AU)-[ENV]AN274

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Chloride, Cl	LB195379	mg/L	1	<1	0%	104 - 106%	97 - 98%

Conductivity and TDS by Calculation - Water Method: ME-(AU)-[ENV]AN106

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Conductivity @ 25 C	LB195342	µS/cm	2	<2	0 - 3%	103 - 105%

Fluoride by Ion Selective Electrode in Water Method: ME-(AU)-[ENV]AN141

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Fluoride by ISE	LB195423	mg/L	0.1	<0.1	0 - 10%	98 - 99%	92 - 102%

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Low Level Ammonia Nitrogen by FIA   Method: ME-(AU)-[ENV]AN261

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Ammonia, NH_3	LB195409	mg/L	0.02	<0.02	0%	NA

Low Level Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA   Method: ME-(AU)-[ENV]AN258

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Nitrate/Nitrite Nitrogen, NOx as N	LB195409	mg/L	0.005	<0.005	0 - 19%	101 - 105%
Nitrite, NO_2 as NO_2	LB195409	mg/L	0.05	<0.05		
Nitrate, NO_3 as NO_3	LB195409	mg/L	0.05	<0.05		

Mercury (dissolved) in Water   Method: ME-(AU)-[ENV]AN311(Perth)/AN312

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Mercury	LB195386	mg/L	0.00005	<0.00005	0%	97 - 102%	98 - 110%

Metals in Water (Total) by ICPOES   Method: ME-(AU)-[ENV]AN022/AN320

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Total Calcium	LB195393	mg/L	0.2	<0.2	6%	98%	
Total Magnesium	LB195393	mg/L	0.1	<0.1		94%	
Total Potassium	LB195393	mg/L	0.1	<0.1		98%	
Total Sodium	LB195393	mg/L	0.5	<0.5	4%	95%	94%

Metals in Water (Dissolved) by ICPOES   Method: ME-(AU)-[ENV]AN320

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Calcium, Ca	LB195356	mg/L	0.2	<0.2	0 - 1%	96%	91%
Magnesium, Mg	LB195356	mg/L	0.1	<0.1	0%	96%	92%
Total Hardness by Calculation	LB195356	mg CaCO3/L	1	<1			

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

pH in water Method: ME-(AU)-[ENV]AN101

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
pH**	LB195342	pH Units	0.1	5.7 - 6.0	0%	99%

Sulfate in water Method: ME-(AU)-[ENV]AN275

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Sulfate, SO4	LB195379	mg/L	1	<1	0 - 1%	98 - 103%	93 - 95%

TKN Kjeldahl Digestion by Discrete Analyser Method: ME-(AU)-[ENV]AN281

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Kjeldahl Nitrogen	LB195348	mg/L	0.05	<0.05	0%	99%
	LB195377	mg/L	0.05	<0.05	0 - 8%	102 - 107%

Total Dissolved Solids (TDS) in water Method: ME-(AU)-[ENV]AN113

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery	MSD %RPD
Total Dissolved Solids Dried at 175-185°C	LB195368	mg/L	10	<10	0 - 2%	100%	103%	1%
	LB195369	mg/L	10	<10	0 - 1%	100%	100%	0%

Total Phosphorus by Kjeldahl Digestion DA in Water Method: ME-(AU)-[ENV]AN279/AN293(Sydney only)

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Phosphorus (Kjeldahl Digestion) as P	LB195348	mg/L	0.02	<0.02	0 - 5%	114%
	LB195377	mg/L	0.02	<0.02	0 - 42%	88 - 103%

Trace Metals (Dissolved) in Water by ICPMS in mg/L Method: ME-(AU)-[ENV]AN318

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Aluminium, Al	LB195360	mg/L	0.005	<0.005	10 - 62%	88%	91%
Antimony, Sb	LB195360	mg/L	0.001	<0.001	0%	106%	97%
Arsenic, As	LB195360	mg/L	0.001	<0.001	15 - 16%	113%	112%
Barium, Ba	LB195360	mg/L	0.001	<0.001	1%	110%	108%
Bismuth, Bi	LB195360	mg/L	0.001	<0.001	0 - 103%	89%	83%
Boron, B	LB195360	mg/L	0.005	<0.005	0 - 1%	105%	183%
Cadmium, Cd	LB195360	mg/L	0.0001	<0.0001	8 - 86%	103%	102%
Chromium, Cr	LB195360	mg/L	0.001	<0.001	2%	103%	104%
Cobalt, Co	LB195360	mg/L	0.001	<0.001	15 - 40%	104%	105%
Copper, Cu	LB195360	mg/L	0.001	<0.001	6 - 16%	115%	107%
Iron, Fe	LB195360	mg/L	0.005	<0.005	1 - 2%	110%	112%
Lead, Pb	LB195360	mg/L	0.001	<0.001	0 - 154%	114%	118%
Manganese, Mn	LB195360	mg/L	0.001	<0.001	0 - 4%	102%	101%
Molybdenum, Mo	LB195360	mg/L	0.001	<0.001	16 - 21%	108%	104%
Nickel, Ni	LB195360	mg/L	0.001	<0.001	28 - 38%	108%	102%
Selenium, Se	LB195360	mg/L	0.001	<0.001	13 - 40%	104%	98%
Silver, Ag	LB195360	mg/L	0.001	<0.001	0%	91%	119%
Tellurium, Te	LB195360	mg/L	0.001	<0.001	0%	NA	NA
Thallium, Tl	LB195360	mg/L	0.001	<0.001	0 - 15%	116%	116%
Tin, Sn	LB195360	mg/L	0.001	<0.001	0%	91%	94%
Uranium, U	LB195360	mg/L	0.001	<0.001	1 - 2%	105%	108%
Vanadium, V	LB195360	mg/L	0.001	<0.001	2 - 21%	95%	99%
Zinc, Zn	LB195360	mg/L	0.005	<0.005	1 - 2%	110%	113%

METHOD	METHODOLOGY SUMMARY
AN022/AN320	Total (acid soluble) Metals by ICP-OES: Samples are digested in nitric or nitric and hydrochloric acids prior to analysis for a wide range of metals and some non-metals. This solution is measured by Inductively Coupled Plasma. Solutions are aspirated into an argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components.
AN101	pH in Soil Sludge Sediment and Water: pH is measured electrometrically using a combination electrode (glass plus reference electrode) and is calibrated against 3 buffers purchased commercially. For soils, an extract with water is made at a ratio of 1:5 and the pH determined and reported on the extract. Reference APHA 4500-H+.
AN106	Conductivity and TDS by Calculation: Conductivity is measured by meter with temperature compensation and is calibrated against a standard solution of potassium chloride. Conductivity is generally reported as µmhos/cm or µS/cm @ 25°C. For soils, an extract with water is made at a ratio of 1:5 and the EC determined and reported on the extract, or calculated back to the as-received sample. Total Dissolved Salts can be estimated from conductivity using a conversion factor, which for natural waters, is in the range 0.55 to 0.75. SGS use 0.6. Reference APHA 2510 B.
AN106	Salinity may be calculated in terms of NaCl from the sample conductivity. This assumes all soluble salts present, measured by the conductivity, are present as NaCl.
AN113	Total Dissolved Solids: A well-mixed filtered sample of known volume is evaporated to dryness at 180°C and the residue weighed. Approximate methods for correlating chemical analysis with dissolved solids are available. Reference APHA 2540 C.
AN113	The Total Dissolved Solids residue may also be ignited at 550 C and volatile TDS (Organic TDS) and non-volatile TDS (Inorganic) can be determined.
AN135	Alkalinity (and forms of) by Titration: The sample is titrated with standard acid to pH 8.3 (P titre) and pH 4.5 (T titre) and permanent and/or total alkalinity calculated. The results are expressed as equivalents of calcium carbonate or recalculated as bicarbonate, carbonate and hydroxide. Reference APHA 2320. Internal Reference AN135
AN141	Determination of Fluoride by ISE: A fluoride ion selective electrode and reference electrode combination, in the presence of a pH/complexation buffer, is used to determine the fluoride concentration. The electrode millivolt response is measured logarithmically against fluoride concentration. Reference APHA F- C.
AN258	Nitrate and Nitrite by FIA: In an acidic medium, nitrate is reduced quantitatively to nitrite by cadmium metal. This nitrite plus any original nitrite is determined as an intense red-pink azo dye at 540 nm following diazotisation with sulphanilamide and subsequent coupling with N-(1-naphthyl) ethylenediamine dihydrochloride. Without the cadmium reduction only the original nitrite is determined. Reference APHA 4500-NO3- F.
AN261	Ammonia by Continuous Flow Analyser: Ammonium in a basic medium forms ammonia gas, which is separated from the sample matrix by diffusion through a polypropylene membrane. The ammonia is reacted with phenol and hypochlorite to form indophenol blue at an intensity proportional to the ammonia concentration. The blue colour is intensified with sodium nitroprusside and the absorbance measured at 630 nm. The sensitivity of the automated method is 10-20 times that of the macro method. Reference APHA 4500-NH3 H.
AN274	Chloride by Discrete Analyse: Chloride reacts with mercuric thiocyanate forming a mercuric chloride complex. In the presence of ferric iron, highly coloured ferric thiocyanate is formed which is proportional to the chloride concentration. Reference APHA 4500Cl-

METHOD	METHODOLOGY SUMMARY
AN275	Sulfate by Discrete Analyse: sulfate is precipitated in an acidic medium with barium chloride. The resulting turbidity is measured photometrically at 405nm and compared with standard calibration solutions to determine the sulfate concentration in the sample. Reference APHA 4500-SO42-. Internal reference AN275.
AN279/AN293(Sydney)	The sample is digested with Sulphuric acid, K2SO4 and CuSO4. All forms of phosphorus are converted into orthophosphate. The digest is cooled and placed on the discrete analyser for colorimetric analysis.
AN281	An unfiltered water or soil sample is first digested in a block digestor with sulfuric acid, K2SO4 and CuSO4. The ammonia produced following digestion is then measured colourimetrically using the Discrete Analyser . A portion of the digested sample is buffered to an alkaline pH , and interfering cations are complexed. The ammonia then reacts with salicylate and hypochlorite to give a blue colour whose absorbance is measured at 660nm and compared with calibration standards. This is proportional to the concentration of Total Kjeldahl Nitrogen in the original sample.
AN311(Perth)/AN312	Mercury by Cold Vapour AAS in Waters: Mercury ions are reduced by stannous chloride reagent in acidic solution to elemental mercury. This mercury vapour is purged by nitrogen into a cold cell in an atomic absorption spectrometer or mercury analyser. Quantification is made by comparing absorbances to those of the calibration standards. Reference APHA 3112/3500.
AN318	Determination of elements at trace level in waters by ICP-MS technique, referenced to USEPA 6020B and USEPA 200.8 (5.4).
AN320	Metals by ICP-OES: Samples are preserved with 10% nitric acid for a wide range of metals and some non-metals. This solution is measured by Inductively Coupled Plasma. Solutions are aspirated into an argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components .
AN320	Photomultipliers or CCDs are used to measure the light intensity at specific wavelengths. This intensity is directly proportional to concentration. Corrections are required to compensate for spectral overlap between elements. Reference APHA 3120 B.
Calculation	Free and Total Carbon Dioxide may be calculated using alkalinity forms only when the samples TDS is <500mg/L. If TDS is >500mg/L free or total carbon dioxide cannot be reported . APHA4500CO2 D.

FOOTNOTES

IS	Insufficient sample for analysis.	LOR	Limit of Reporting
LNR	Sample listed, but not received.	↑↓	Raised or Lowered Limit of Reporting
*	NATA accreditation does not cover the performance of this service.	QFH	QC result is above the upper tolerance
		QFL	QC result is below the lower tolerance
**	Indicative data, theoretical holding time exceeded.	-	The sample was not analysed for this analyte
***	Indicates that both * and ** apply.	NVL	Not Validated

Unless it is reported that sampling has been performed by SGS, the samples have been analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calcuated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC and MU criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here: www.sgs.com.au/en-gb/environment-health-and-safety.

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ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order : **EM2214667**
Client : **EARTH SYSTEMS PTY LTD**
Contact : SASKIA RUTTOR
Address : Unit 4/ 290 Salmon Street
Port Melbourne 3207
Telephone : ----
Project : ES2245
Order number : ----
C-O-C number : ----
Sampler : Saskia Ruttor
Site : Melbourne
Quote number : ME/016/19 V2
No. of samples received : 3
No. of samples analysed : 3

Page : 1 of 2
Laboratory : Environmental Division Melbourne
Contact : Customer Services EM
Address : 4 Westall Rd Springvale VIC Australia 3171
Telephone : +61 3 8549 9600
Date Samples Received : 01-Aug-2022 16:28
Date Analysis Commenced : 08-Aug-2022
Issue Date : 11-Aug-2022 17:41

ilac-MRA NATA
Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Sample ID*	**A Deposit TN**	**E Deposit TN**	**Eastern Runway V.**	**----**	**----**
			Sampling date / time	29-Jul-2022 00:00	29-Jul-2022 00:00	29-Jul-2022 00:00	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EM2214667-001**	**EM2214667-002**	**EM2214667-003**	**--------**	**--------**
				Result	Result	Result	----	----
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**35.0**	**26.8**	**21.5**	**----**	**----**
ANC as CaCO3	----	0.1	% CaCO3	**3.6**	**2.7**	**2.2**	**----**	**----**
Fizz Rating	----	0	Fizz Unit	**1**	**1**	**1**	**----**	**----**
EP003TC: Total Carbon (TC) in Soil								
Total Carbon	TC	0.02	%	**3.37**	**4.16**	**0.52**	**----**	**----**

Inter-Laboratory Testing

Analysis conducted by ALS Brisbane, NATA accreditation no. 825, site no. 818 (Chemistry) 18958 (Biology).

(SOIL) EP003TC: Total Carbon (TC) in Soil

(SOIL) EA013: Acid Neutralising Capacity

BHP

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Email: enviro@earthsystems.com.au
Web: www.acidmetalliferousdrainage.com
Web: www.earthsystems.com.au

Client	BHP WAIO
Project	BHP2245
Site	MAC
Reporting Units	weight %

Mineral Group	**Sample ID**	A Deposit TN	E Deposit TN	Eastern Runaway Valley - Pond 1
Sulfide	*Pyrite*	0.3	0.2	-
Sulfate	*Alum*	0.4	0.2	-
	Römerite	0.9	0.6	-
	Natroalunite-K	-	-	0.8
Carbonate	*Calcite*	0.3	1.4	1.1
	Dolomite	1.2	0.1	-
	Siderite	0	0	-
Silicate	*Microcline*	1.6	0.6	-
	Illite	-	-	0.4
	Kaolinite	13	14.3	27.1
Oxide	*Goethite*	20.9	26.3	2.1
	Hematite	30.7	29.6	13.5
	Maghemite	0.5	0.3	5.9
	Quartz	16.8	12.5	28.9
Other	*Urea*	1.4	0.4	-
	Amorphous	12	13.5	18.6
	Calculated using ImpactScan v1.02			
	MPA (kg H_2SO_4/tonne)	10.6	6.8	3.0
	ANC (kg H_2SO_4/tonne)	15.7	14.8	10.8
	NAPP (kg H_2SO_4/tonne)	-5.2	-8.0	-7.8
	ANC/MPA ratio	1.49	2.16	3.64
	Total Sulfur (wt.%)	0.36	0.23	0.13
	Total Carbon (wt.%)	0.19	0.18	0.13
	Classification	NAF	NAF	NAF

Note:

The amorphous (non-diffracting) fraction, likely composed of poorly crystalline iron (hydroxy)oxide, has been determined by standard spike addition using alumina (corundum).

ATTACHMENT D
Temporal and Spatial Water Chemistry Variation

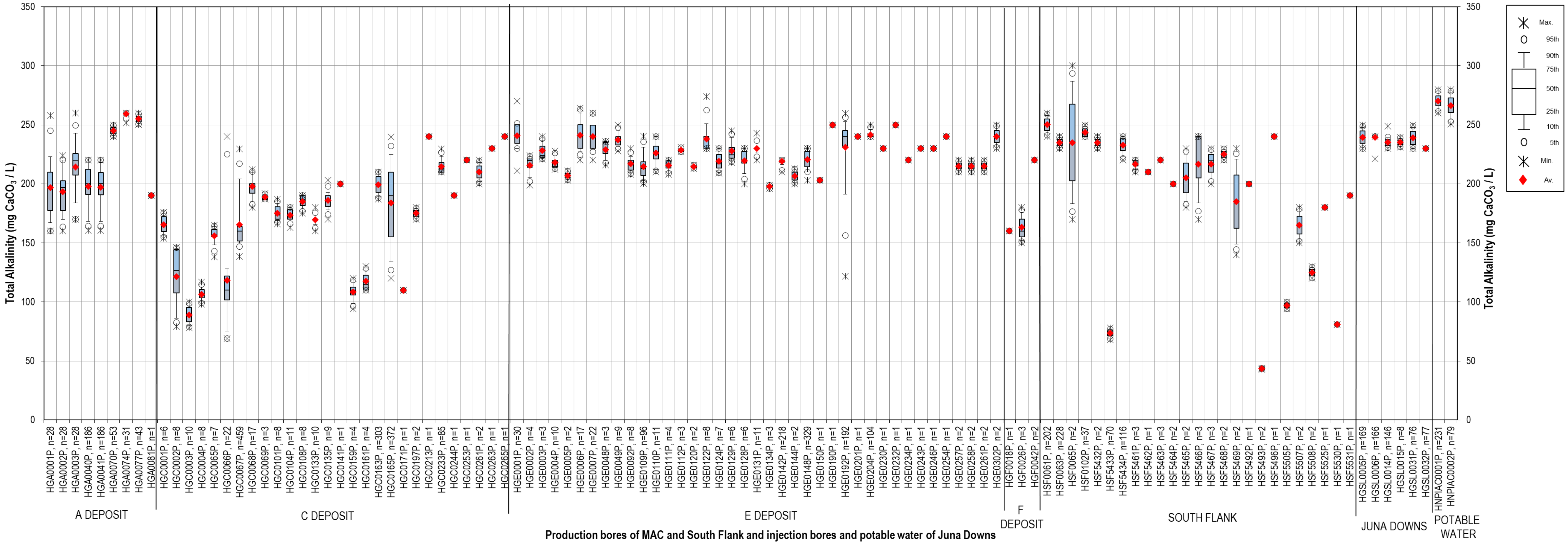

Figure D-1: Total Alkalinity (mg CaCO₃ / L) analysed in the laboratory as a function of bore / deposit. Data plotted includes values for all 112 production bores at MAC and South Flank as well as the Juna Downs re-injection bores and potable water covering the years 2010 – 2022. The number of analyses is shown with *n*.

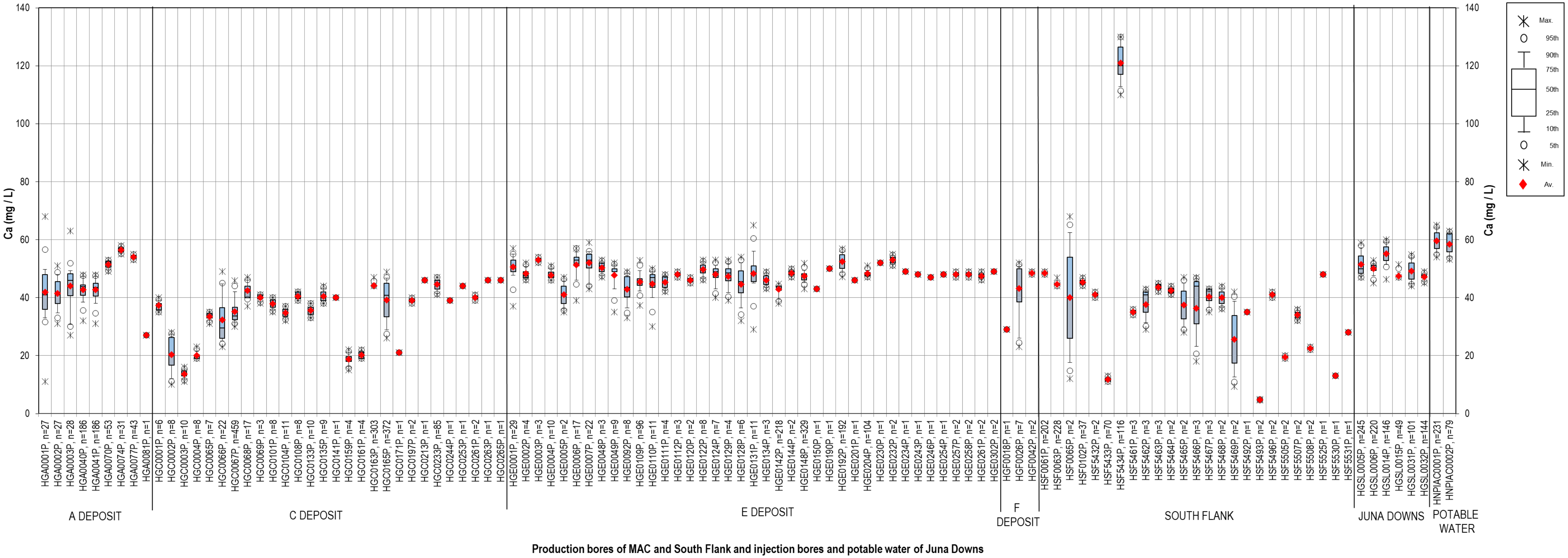

Figure D-2: Dissolved calcium concentrations (mg/L) analysed in the laboratory as a function of bore / deposit. Data plotted includes values for all 112 production bores at MAC and South Flank as well as the Juna Downs re-injection bores and potable water covering the years 2010 – 2022. The number of analyses is shown with *n*.

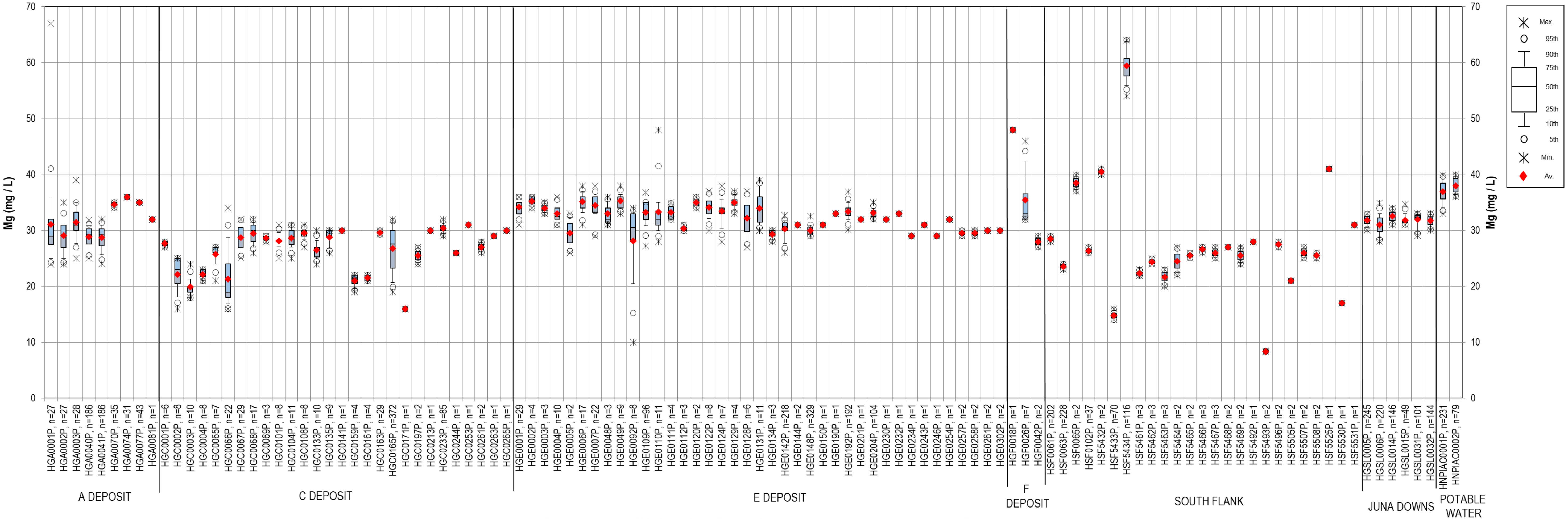

Figure D-3: Dissolved magnesium concentrations (mg/L) analysed in the laboratory as a function of bore / deposit. Data plotted includes values for all 112 production bores at MAC and South Flank as well as the Juna Downs re-injection bores and potable water covering the years 2010 – 2022. The number of analyses is shown with *n*.

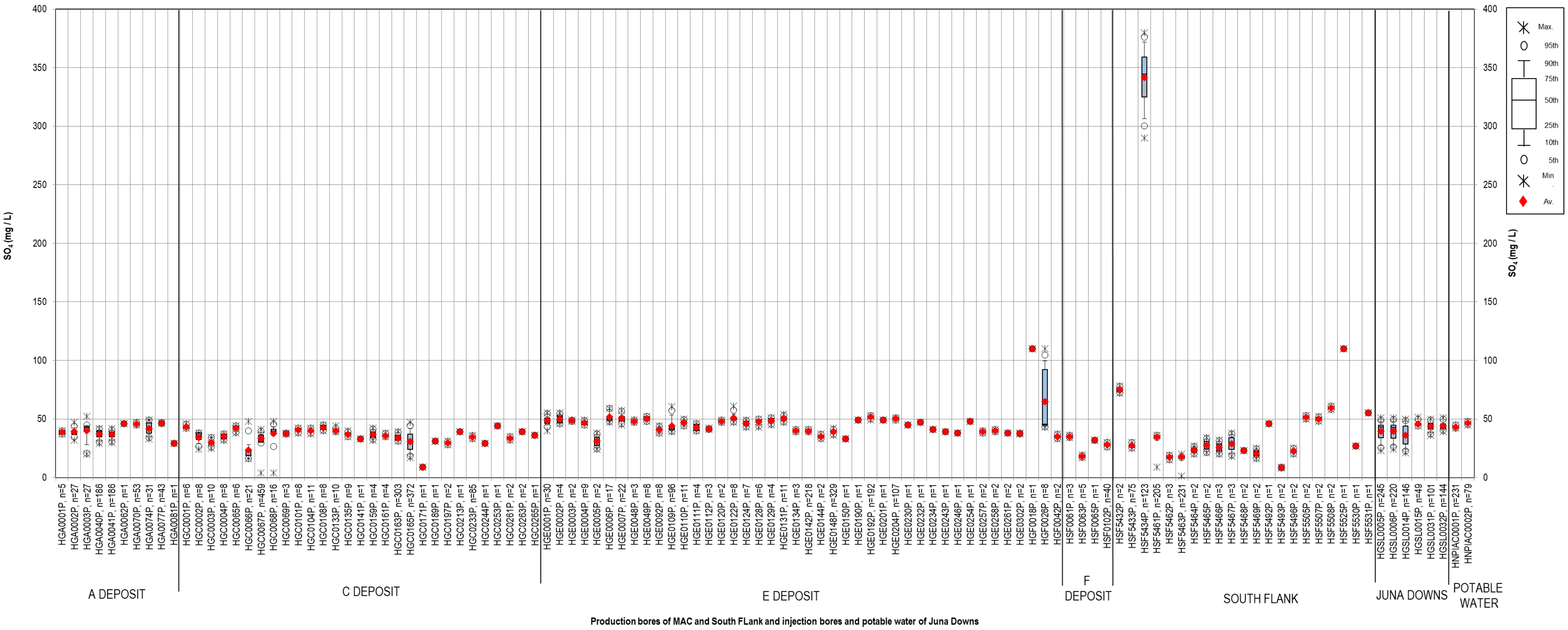

Figure D-4: Sulfate concentrations (mg/L) analysed in the laboratory as a function of bore / deposit. Data plotted includes values for all 112 production bores at MAC and South Flank as well as the Juna Downs re-injection bores and potable water covering the years 2010 – 2022. The number of analyses is shown with *n*.

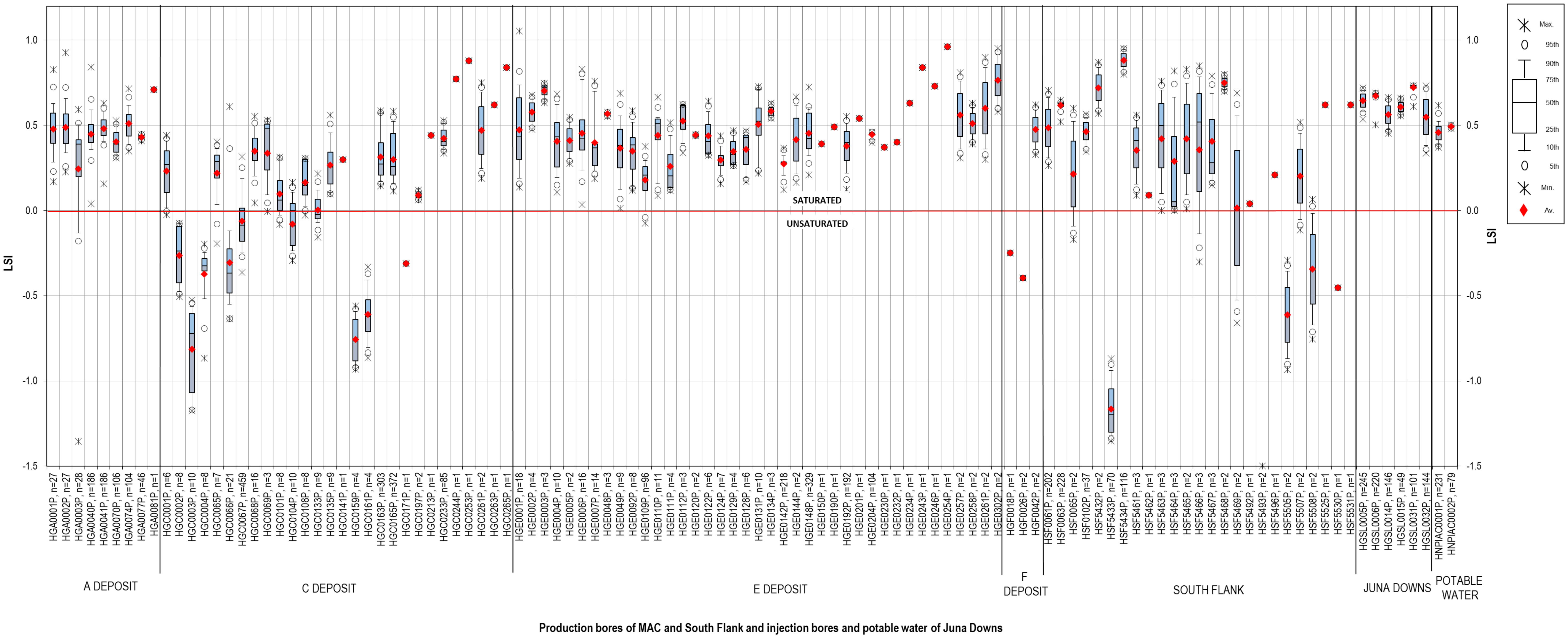

Figure D-5: The Langelier Saturation Index (LSI) calculated as a function of bore / deposit. Data plotted includes all 112 production bores at MAC and South Flank as well as the Juna Downs re-injection bores and potable water covering the years 2010 – 2022. The number of analyses is shown with *n*. Data above the red line (LSI > 0) indicates the saturation of the water with respect to calcium carbonate and the potential of scaling. Data below the red line (LSI < 0) indicates that water is undersaturated with respect to calcium carbonate.

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