

OB32 SURPLUS WATER STUDY: DPS INFILTRATION STUDY (STAGE 2)

BRISBANE | **PERTH** | SINGAPORE | BRAZIL | PNG

BHP IRON ORE PTY LTD



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EXECUTIVE SUMMARY

This report presents the results from the Orebody 32 (OB32) DPS Precipitate Study conducted by Hydrobiology on behalf of BHP Iron Ore. This study is investigating the potential for mineral precipitation from the dewatering discharge from the OB32 project to the receiving environment. The discharge options investigated in this report include dewatering discharge rates of 60 ML/d into Homestead Creek (HC) for up to 9 months of the year. Further information and background is also provided in the Stage 1 report investigating this issue (Hydrobiology 2019).

This report assesses the results of the kinetic bench-top precipitation experiment from mixing OB32 discharge water with natural receiving waters at varying ratios over 31 days. These results were then compared to geochemical equilibrium speciation modelling results to investigate the potential for the OB32 discharge water to interact geochemically with the natural receiving surface water. Hydraulic modelling software was then used to investigate the extent of the wetting front of OB32 discharge into HC.

The bench-top mixing experiment used OB32 dewatering discharge to a receiving water analogue (sourced from the Ophthalmia Dam) ratios of 100%, 90%, 50%, 10% and 0% OB32 water respectively. All mixtures had reached complete, or near complete, Calcium (Ca) precipitation equilibrium after 18 days. Mixtures with a greater percentage of OB32 discharge water had faster equilibration/precipitation rates, with the majority of precipitates forming in the first 6 days of the experiment. Under the experimental kinetic conditions total mass Ca lost as precipitate for 100%, 90%, 50%, 10% and 0% OB32 mixtures were 74.5 mg/L, 71.1 mg/L, 50.7 mg/L, 31.3 mg/L, and 26.0 mg/L respectively.

The geochemical equilibrium speciation modelling saturation indices indicated that both the OB32 and receiving waters were oversaturated with respect to the carbonate phases dolomite, calcite, and aragonite. Under kinetic conditions likely to occur in HC, calcite would preferentially precipitate, while in the receiving waters dolomite would preferentially precipitate. The modelling of the various solid phase Ca minerals mass loss as precipitates closely followed that of the bench-top precipitation experiments, indicating that the modelling is a reasonable approximation of the geochemical process likely to occur under the various discharge mixing scenarios.

Hydraulic modelling of OB32 discharge into HC including infiltration losses was conducted by BHP (2021). The modelled losses to infiltration at steady state flow are minimal, approximately 0.28% loss. For the purpose of this assessment, it has been assumed that the formation of any calcite precipitate armouring on the sediments will occur in the initial 5 km downstream from the discharge point. This is based on the bench-top measured precipitation rates and observation of regional analogues. The total modelled surface area of water-sediment interaction (wetted surface) for the reach 0 to 5 km downstream of the proposed dewatering discharge point has been estimated at 0.07 km². At the measured calcite precipitation rate of 112.4 mg/L, at total calcite precipitate rate (layer depth) of 0.85 mm/yr is estimated.

The discharge option to Homestead Creek would incur impacts dominated by precipitate formation and potential armouring of sediments. The rate of armouring and the formation of a visible crust in the receiving creek-bed sediments is dependent on multiple factors including the frequency and magnitude of scouring (high-flow) events, the mobility of the existing sediments and, the residence

time of discharge waters within any one section of the creek. It is likely that it will take on the order of several years for sufficient precipitate cohesion to occur and the filling of existing sediment interstices, for observable armouring/precipitate coatings to appear. These may be periodically broken up and mobilised/dispersed under high flow/flood events and reset this lag period within more mobile bed (sediment) reaches.

Mitigation options for the avoidance of precipitate driven sediment armouring may include retention (dam/sump) facilities, chemical additions (raising pH), blending (with waters of lower calcite saturation) and physical/mechanical disruption of formed precipitate crusts. Each of these options has limitations, which are discussed further in this report.

Contents

EXECUTIVE SUMMARY	4
1. INTRODUCTION	9
1.1 Scope	10
1.2 OB32 Study Area	10
2. METHODS	12
2.1 Bench-top Precipitation Study	12
2.2 PHREEQC Modelling	15
2.3 Hydraulic and Precipitate Thickness Modelling	15
3. RESULTS	16
3.1 Bench-top Precipitation	16
3.2 Geochemical Speciation Modelling	23
3.3 Hydraulic Modelling and Precipitate Thickness Calculations – Homestead Creek Option	24
4. DISCUSSION	27
4.1 Potential Mitigation Options	28
4.1.1 Homestead Creek Discharge	28
5. REFERENCES	30
APPENDIX A. PHREEQC GEOCHEMICAL MODELLING	31
A.1 Model inputs (15.5°C)	31
A.2 Model outputs (15.5°C)	32
A.3 Model inputs (40°C)	34
A.4 Model outputs (40°C)	35
APPENDIX B. PRECIPITATE THICKNESS CALCULATION INPUTS	37

tables

Table 2-1 Experimental OB32 and OPD water mixture ratios.	13
Table 3-1 Mass loss of Ca precipitates after 31 days from bench-top experiment (Batch-2) and PHREEQC chemical equilibrium speciation modelling run at 15.5 °C and 40.0°C.	23
Table 5-1 Ophthalmia Dam receiving water chemistry.....	31
Table 5-2 OB32 discharge water chemistry	31
Table 5-3 Saturation indices for Ophthalmia Dam receiving waters. Bolded phase minerals past saturation	32
Table 5-4 Saturation indices OPD 90:10 OB32 water mixture.	32
Table 5-5 Saturation indices OPD 50:50 OB32 water mixture.	32
Table 5-6 Saturation indices OPD 10:90 OB32 water mixture.	33
Table 5-7 Saturation indices OB32 discharge water.....	33
Table 5-8 Ophthalmia Dam receiving water chemistry.....	34
Table 5-9 OB32 discharge water chemistry	34
Table 5-10 Saturation indices for Ophthalmia Dam receiving waters. Bolded phase minerals past saturation.	35
Table 5-11 Saturation indices OPD 90:10 OB32 water mixture.	35
Table 5-12 Saturation indices OPD 50:50 OB32 water mixture.	35
Table 5-13 Saturation indices OPD 10:90 OB32 water mixture.	36
Table 5-14 Saturation indices OB32 discharge water.....	36

figures

Figure 1-1 Homestead Creek discharge option site showing the Upper Fortescue River drainage lines to Jigalong Road.	11
Figure 2-1 Bench-top experimental 2L beakers with individual magnetic stirrers.....	12
Figure 2-2 Batch 1 water samples showing heavy staining with iron oxyhydroxides. Beakers 1+2 = 100% OB32 (far left), beakers 3+4 = 90% OB32-10%OPD, beakers 5+6 = 50% OB32-50%OPD (middle), beakers 7+8 = 10%OB32-90%OPD, and beakers 9+10 = 100% OPD.....	14
Figure 2-3 Batch 2 field filtered water samples. Beakers 1+2 = 100% OB32 (far left), beakers 3+4 = 90% OB32-10%OPD, beakers 5+6 = 50% OB32-50%OPD (middle), beakers 7+8 = 10%OB32-90%OPD, and beakers 9+10 = 100% OPD.....	14
Figure 3-1 Batch 1 precipitation of Calcium under differing mixing ratios of OB32 discharge water and Ophthalmia Dam waters.	18

Figure 3-2 Batch 2 precipitation of Calcium under differing mixing ratios of OB32 discharge water and Ophthalmia Dam waters. Included (in black) is the loss of calcium from the field sample bottles that sat undisturbed in the lab over the duration of the experiment. 19

Figure 3-3 Piper Diagram of the 100% OB32 discharge waters progression over the bench top experiment (Batch 2) 20

Figure 3-4 Piper Diagram of the 100% OPD receiving waters progression over the bench top experiment (Batch 2) 21

Figure 3-5 Major ion concentration progression over the bench-top experiment (OB32 water – left; OPD water – right) 22

Figure 3-6 Mass loss of Ca precipitates after 31 days from bench-top experiment (Batch-2) and PHREEQC chemical equilibrium speciation modelling run at 15.5 °C and 40.0°C. 24

Figure 3-8 Modelled OB32 60 ML/d discharge into Homestead Creek, showing downstream wetting front extent up to the Fortescue River. 26

1. INTRODUCTION

This report assesses potential for mineral precipitates forming from the proposed OB32 dewatering discharge to the receiving environment.

BHP Iron Ore Pty Ltd (BHP) propose to dewater from BHP's planned Ore Body 32 (OB32) to the Homestead Creek. The planned OB32 pushback will form part of the Eastern Ridge mine in the Eastern Pilbara region of Western Australia. At the request of BHP, Hydrobiology has undertaken a scope of works in relation to assessing environmental impacts from the OB32 dewatering discharge. Further information and background is also provided in the Stage 1 report investigating this issue (Hydrobiology 2019).

The OB32 discharge water is predicted to precipitate calcite minerals to the receiving waterway sediments over time, based on chemical equilibrium speciation modelling (Hydrobiology 2021). Although the receiving waters were modelled as under saturated with respect to calcite, and would likely mitigate this effect, there will be periods of the annual wet/dry season where the OB32 discharge is the dominant or only water source within Homestead Creek (HC, see Figure 1-1). The modelling undertaken was preliminary and was based on chemical equilibrium, which is not always representative of complex "real-world" conditions. It was recommended from previous studies (Hydrobiology 2021) that additional investigations were warranted to understand the potential extent of the precipitate issue (mass, spatial area, environmental/ecological impacts and infiltration impacts).

River beds are naturally dynamic systems with mobile sediments, scouring events, seasonal and event based flows and bio-geochemical processes that influence the physical stability of the sediments and habitat quality for the riverine ecology. Assessing the potential build-up of mineral precipitates from mine dewatering is complicated by the interactions of these complex and variable factors over seasonal cycles and large flow events. A multiple lines of evidence approach was used to provide a

semi-quantitative risk assessment of the potential for precipitates to occur and, the impacts those precipitates may have on the receiving environment values.

This scope of works is a follow-on from recommendations made in a preliminary study of the geochemical interactions for OB32 discharge water and receiving waters undertaken by Hydrobiology from March to June 2021 (Hydrobiology 2021).

1.1 SCOPE

The following tasks were undertaken to assess the potential alteration to infiltration rates due to geochemical processes as a result of introducing the OB32 dewatering discharge into a proposed site within Homestead Creek.

- **Bench-top precipitation experiment:** Measurements of the mass of precipitates forming over different time-steps (kinetics). Mixing of OB32 discharge water with receiving water (OPD) at different ratios.
 - **Field sampling:** Collection of water quality samples for additional baseline and modelling inputs as well as for bench-top experiments. OPD was sampled to provide the receiving water component for bench-top experiments.
- **Hydraulic modelling:** Hydraulic modelling conducted by Advisian using existing TUFLOW (surface water flows) and GoldSim (water balance with alluvium) models were coupled to explore the interaction between surface and subsurface flows in Homestead Creek. Hydrobiology also used HEC-RAS modelling, informed by the Advisian data, of determine the wetting area downstream of the discharge option point.
- **Chemical Equilibrium Modelling:** Comparison of bench-top experiment results with theoretical precipitate mass balance.
- **Spreadsheet modelling:** Use of spreadsheet calculations to estimate the precipitate extent and crust thickness (mm over surface area) based on wetting area modelling and precipitate mass calculations. Calculation of time periods of greater precipitate formation and settlement risk. Adjustments for mitigation options.
- **Ecological impact assessment:** EIA was undertaken by Biologic (2023) to assess the potential impacts to the downstream ecology of precipitate formation.

1.2 OB32 STUDY AREA

Orebody 32 (OB32) is part of the BHP Iron Ore – Eastern Ridge project located within the existing mining area of Newman. The project is adjacent to existing operational mining projects including the Mt Whaleback, Orebody 24 and Orebody 25 deposits. Figure 1-1 provides a map of the OB32 project showing proposed dewatering discharge option location along Homestead Creek.

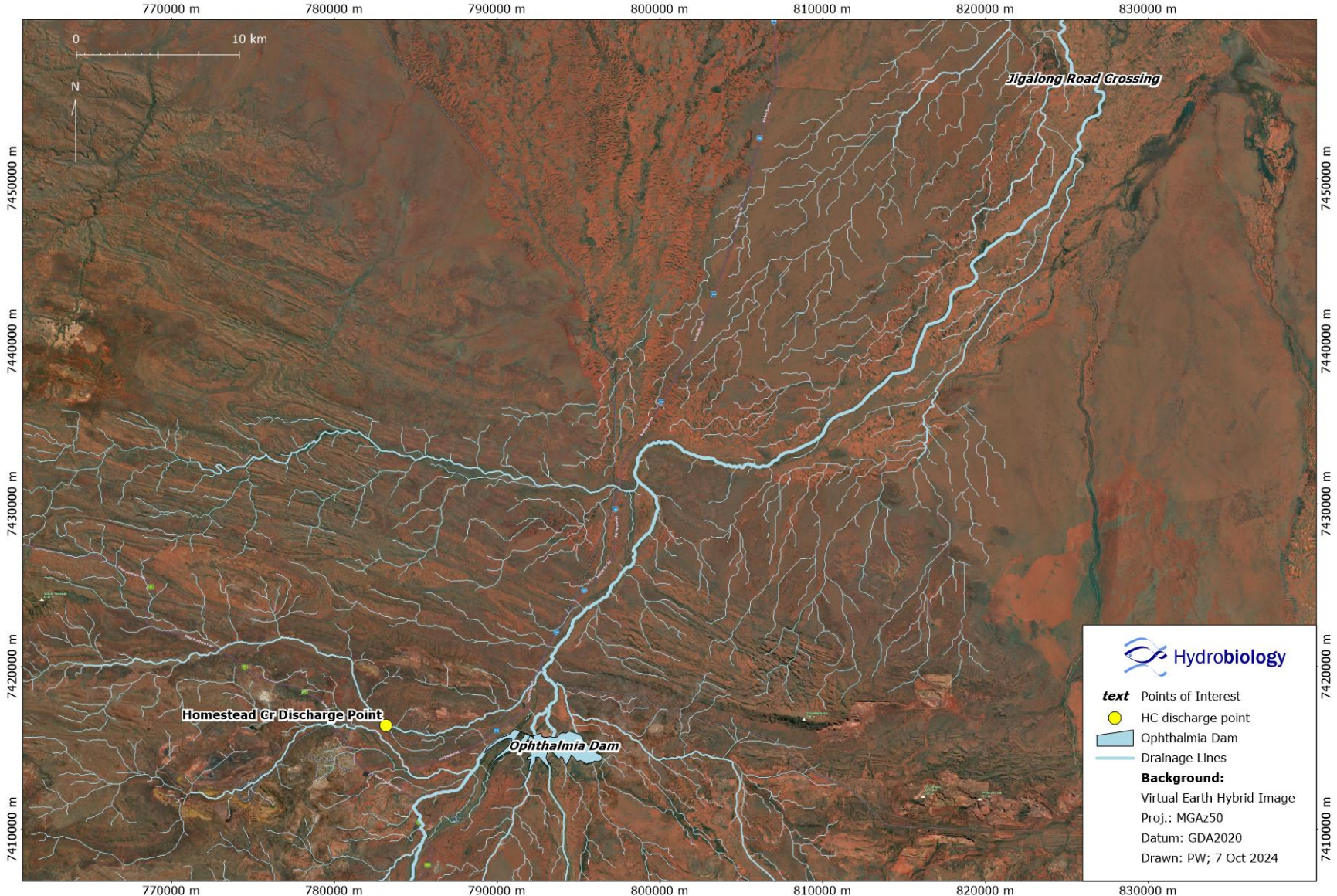


Figure 1-1 Homestead Creek discharge option site showing the Upper Fortescue River drainage lines to Jigalong Road.

2. METHODS

2.1 BENCH-TOP PRECIPITATION STUDY

A bench-top precipitation experiment was set up to mix proposed OB32 discharge water with receiving environment water drawn from OPD (as an analogue for the Fortescue River / Homestead Creek receiving waters). A total of 10 x 2 L experiment beakers were set up on magnetic stirrer apparatus to simulate the flow dynamics of the receiving OPD waters over the experimental time frame (Figure 2-1). Table 2-1 provides the mixture ratios for the bench-top experiments, with each mixture ratio replicated within the experiment.

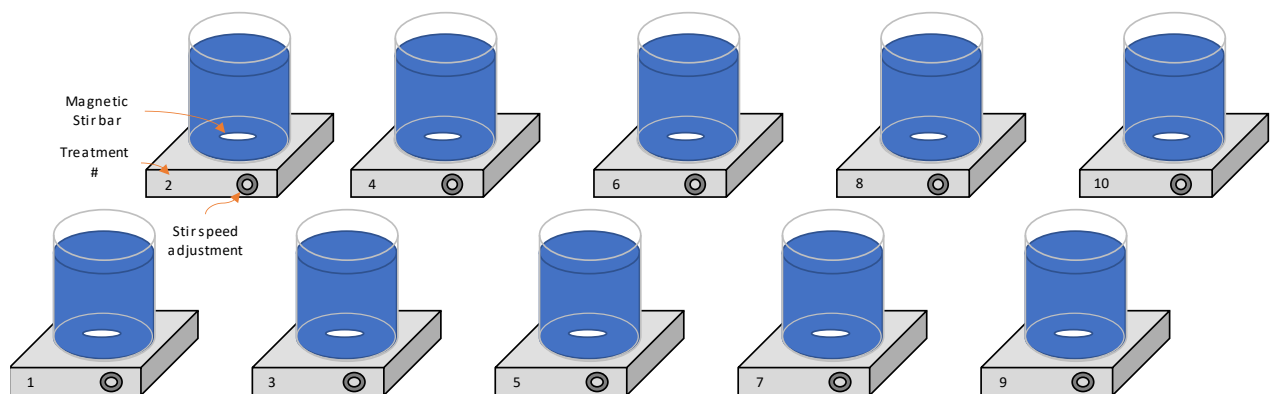


Figure 2-1 Bench-top experimental 2L beakers with individual magnetic stirrers.

Table 2-1 Experimental OB32 and OPD water mixture ratios.

Test beakers	OB32 volume (L)	OPD volume (L)
OB32 alone	2.0 (100%)	0 (0%)
High OB32	1.8 (90%)	0.2 (10%)
Equal	1.0 (50%)	1.0 (50%)
High OPD	0.2 (10%)	1.8 (90%)
OPD alone	0 (0%)	2.0 (100%)

The experiment was conducted on two different batches of sampled waters from OB32 and OPD. The mean laboratory temperatures for both batch experiments were 15.5°C over the 31 days. The Batch 1 water samples were provided by the client from bore HHS0091P in the vicinity of the OB32 deposit. The Batch 1 bore water samples were heavily stained with iron oxyhydroxides, with further investigation indicating that the bore may have been non-representative of proposed dewatering quality due to insufficient development of the bore (Figure 2-2). A second batch of water samples was collected (Batch 2) which were considered more representative of the proposed OB32 discharge. To accommodate the priority Batch 2 water samples, Batch 1 bench-top testing was taken off the stirrers after two weeks and the mixtures decanted into clean sample bottles and kept at the same experimental temperature.

The second batch (Batch 2) of water samples was collected and subjected to the same experimental protocols (Figure 2-3). The water samples for Batch 2 were collected from two OB32 dewatering (groundwater) bore sources (HNPIHS0048P and HNPIHS0013P) and mixed (50% from each bore) to be representative of the proposed OB32 dewatering discharge to mix with OPD water.

Sampling for major ions in the supernatant (0.45 µm filtered) was conducted at 0, 1, 2, 3, 5, 7, 11, 17 and 31 days from the start of the experiment for Batch 1 and at 0, 1, 2, 3, 4, 6, 11, 18 and 31 days for Batch 2. A 120 ml filtered water sample was taken on each of the sample days from each beaker and sent to ALS Environmental for analysis. It was considered that sampling of the removal of major ions from solution was likely to be a more accurate and measurable indicator of the loss to mineral precipitation than direct measurement of the precipitates. Precipitates can form highly suspended micro-crystals and be difficult to measure through gravimetric methods. Solute measurements are accurate to less than part-per million (mg/L) levels and have more uniform spatial distribution within the sample (allowing more representative and repeatable results).



Figure 2-2 Batch 1 water samples showing heavy staining with iron oxyhydroxides. Beakers 1+2 = 100% OB32 (far left), beakers 3+4 = 90% OB32-10%OPD, beakers 5+6 = 50% OB32-50%OPD (middle), beakers 7+8 = 10%OB32-90%OPD, and beakers 9+10 = 100% OPD.



Figure 2-3 Batch 2 field filtered water samples. Beakers 1+2 = 100% OB32 (far left), beakers 3+4 = 90% OB32-10%OPD, beakers 5+6 = 50% OB32-50%OPD (middle), beakers 7+8 = 10%OB32-90%OPD, and beakers 9+10 = 100% OPD.

2.2 PHREEQC MODELLING

Geochemical equilibrium speciation modelling was undertaken using the PHREEQC (Parkhurst and Appelo, 2013) software program to investigate the potential for the OB32 discharge water to interact geochemically with the natural water of OPD to subsequently reduce infiltration rates (i.e. precipitation of solids and clogging of sediments). Water chemistry values obtained from analysis of the OB32 bore and OPD waters used in the bench-top experiments were modelled to assess the formation of precipitates. The modelling was conducted under the same mean temperature (15.5°C) as the bench-top experiments for consistency in result comparison. The modelling was also conducted at 40°C to investigate the effects on speciation and precipitation under potential maximum Pilbara summer temperature conditions. The modelling investigated the various mixture ratios (Table 2-1) to capture variation in the presence of natural and discharge water in receiving OPD waters.

2.3 HYDRAULIC AND PRECIPITATE THICKNESS MODELLING

Modelling for discharge losses to evaporation and infiltration was conducted separately to this study by Advisian following BHP (2021). The relevant results for this work are summarised in Section 3.3.

Precipitate thickness was modelled using a spreadsheet approach, based on inputs from the hydraulic modelling and bench-top testing (see Appendix B). This modelling assumed that the majority of precipitates would form within the initial 5 km downstream of the discharge point. The 5km distance downstream was chosen as the distance from the proposed discharge point taking into account the following factors:

- The bench-top precipitation experiment indicated that the majority of Ca precipitated out in the first 6 days;
- Advisian hydraulic modelling determined the wetting distance downstream from the discharge at 6 days was approximately 8.2 km;
- Site observations at an analogous site in the region where discharge has been approximately 6 times greater than the 60ML/d proposed from OB32 bores there was significant calcite armouring up to 3km from the discharge. From this point downstream there was some calcite precipitation over mostly loose sediments.

Taking these factors into consideration heavy armouring precipitation would unlikely occur over the modelled 8.2km indicated for a 6 day wetting front. In the case of the analogous site, the armouring and precipitation over a shorter distance downstream is likely due to higher particle surface area in the sediments compared to the bench-top beaker turbulent experiments enhancing Ca precipitation. This indicates that the modelled 8.2km downstream distance for significant Ca precipitation may be an over estimation, with likely hard armouring occurring less than 3km from the discharge and some precipitation onto large non-mobile substrates possibly up to 5km (given some downstream entrainment due to storm flow events). More distant reaches (i.e., further than 5 km downstream of the discharge point) would be subject to additional natural inflows, more mobile sediments and a broadening of the channel.

The modelled flow velocity within the initial 5 km reach at 60 ML/d discharge was 0.22 m/s and the wetted surface area within this reach was 0.07 km².

3. RESULTS

3.1 BENCH-TOP PRECIPITATION

The bench-top experiment aimed to provide an additional line of evidence and data for the calculation of potential precipitation rates and precipitate mass derived from the mixing of the proposed OB32 dewatering discharge and the natural receiving waters at the discharge point on Homestead Creek. Various ratios of discharge and receiving waters were mixed over a 1-month period and the change in major ion concentrations monitored. The water samples from the bench-top experiments were analysed for dissolved major ions and alkalinity. Previous geochemical speciation modelling had indicated that calcium carbonate minerals (calcite, dolomite, aragonite) would dominate the precipitate formation in the test waters. The precipitation of calcium (Ca) over the duration of the bench-top experiments for Batch 1 and Batch 2 are shown in Figure 3-1 and Figure 3-2 respectively. The progression of major ion concentrations for the 100% OB32 and 100% OPD mixtures is further illustrated in Figure 3-5 which shows that carbonate and calcium were the only major ions to trend downward. This indicates that calcium carbonate mineral precipitation is a likely cause.

The only major ions to show a clear and progressive precipitation signal over the course of the bench-top experiments were calcium and bicarbonate. A Piper Diagram showing the progression of the duplicated 100% OB32 discharge water sample results over the Batch 2 experiment shows that Ca became depleted over the 31 days of the experiment (Figure 3-3). The Ophthalmia Dam waters (as an analogue for the receiving waters of Homestead Creek) showed a similar though less pronounced signal over the experimental timeframe (Figure 3-4). Note that the sample codes in Figure 3-3 and Figure 3-4 indicate Batch-Mixture-Day (e.g., 2-9-6 indicates Batch 2, Mixture 9 (100% OPD) and Day 6 of the experiment).

The Batch 1 precipitation of Ca in all five of the treatment ratios in (Table 2-1) reached an equilibrium after approximately 7-11 days, with little change in Ca concentrations in solution between day 11 and day 31. The total mass of Ca lost as precipitates was different for each mixture ratio, with 100% OB32 dewatered discharge (bore HHS0091P) showing the greatest loss (76 mg/L), which was approximately

three times the mass loss of Ca from the OPD water (23 mg/L). The equal mixture ratio of both the OB32 and OPD waters resulted in a mass loss of 56.5 mg/L Ca, being slightly closer to the 100% OB32 value than the median Ca loss mass between the two water sources. The rate of precipitation for the 100% and 90% OB32 mixture ratios over the first three days of the experiment was significantly higher than that for either the 10% OB32 or OPD mixtures.

The Batch 2 precipitation of Ca in all five of the treatment ratios was similar that recorded in Batch 1, with the majority precipitating out in the first 6 days. The Batch 2 100%, 90%, 10% OB32, and 100% OPD mixture ratios reached equilibrium after 18 days while the 50/50% ratio mixture reached equilibrium after 31 days. The total mass Ca lost as precipitate for 100%, 90%, 50/50%, 10% OB32 and 100% OPD ratio mixtures were 74.5 mg/L, 71.15 mg/L, 50.75 mg/L, 31.35 mg/L, and 26.0 mg/L respectively. Unlike the 50/50% ratio in Batch 1, Batch 2 Ca precipitation equalled the median loss mass between the two water sources.

The Ca precipitation in the two OB32 bores (HNPIHS0048 and HNPIHS0013) and OPD sample bottles left undisturbed in the lab are shown in Figure 3-2. While the Ca loss in the bore samples vary, they both show considerably lower precipitation than the experimental 100% OB32 value. The same is also observed for the OPD sample. The OPD undisturbed sample would more closely resemble precipitation rates in the dam itself due to less turbulent mixing. The continual mixing by the magnetic stirrers therefore is unlikely to represent the hydraulic kinetics in OPD when mixing with OB32 discharges (for the direct to OPD discharge option). The 100% OB32 results with the continuous mixing as conducted with the bench-top experiment would best represent direct discharge into Homestead Creek and subsequent flow into the Fortescue River. For much of the annual cycle it can be expected that Homestead Creek will have no natural flow and therefore the OB32 discharge will represent 100% of the flow.

Precipitation rates of OB32 discharge mixing within the OPD would likely be lower than bench-top testing results (for the given dilution) due to less turbulent mixing within the dam.

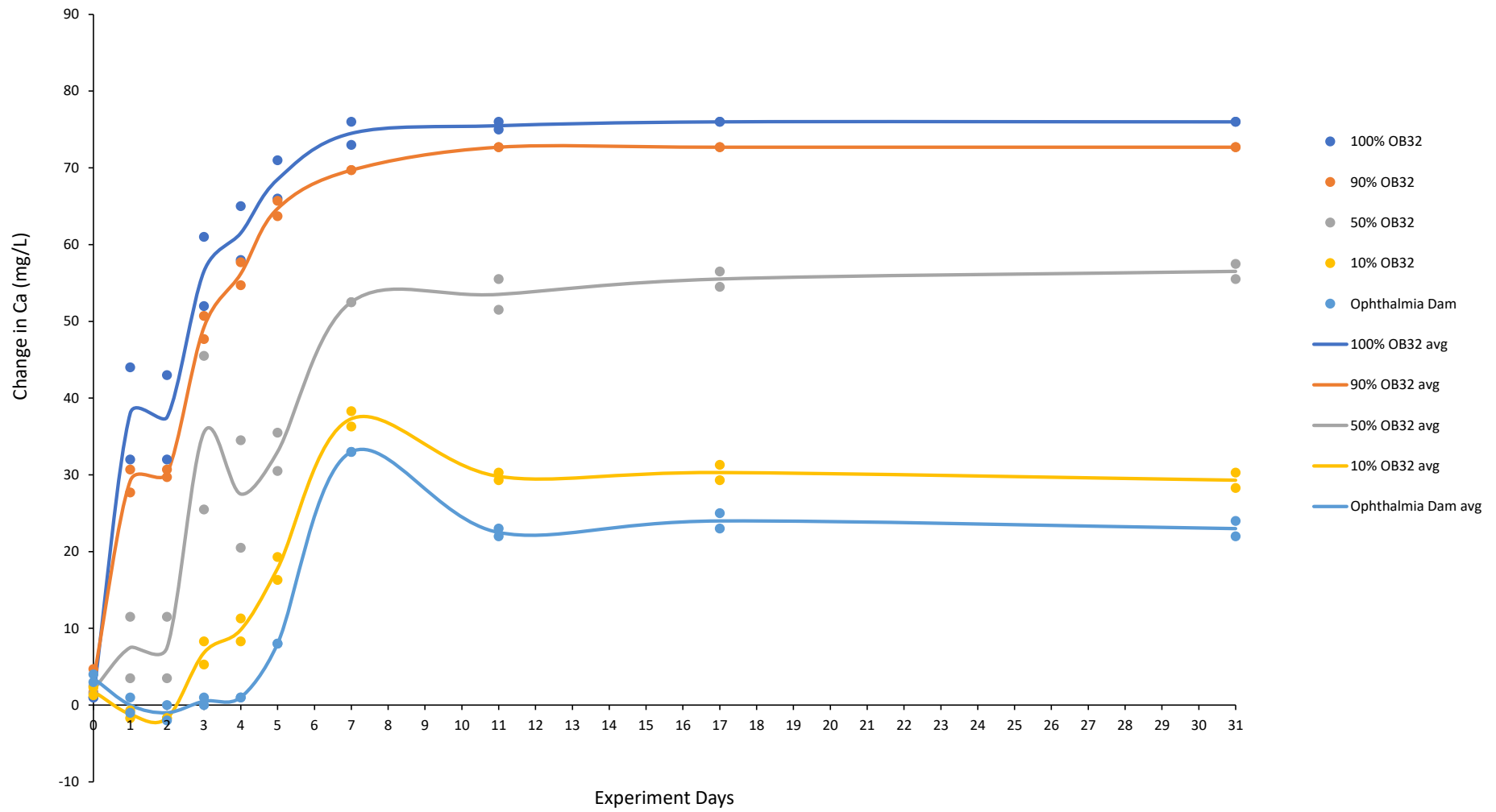


Figure 3-1 Batch 1 precipitation of Calcium under differing mixing ratios of OB32 discharge water and Ophthalmia Dam waters.

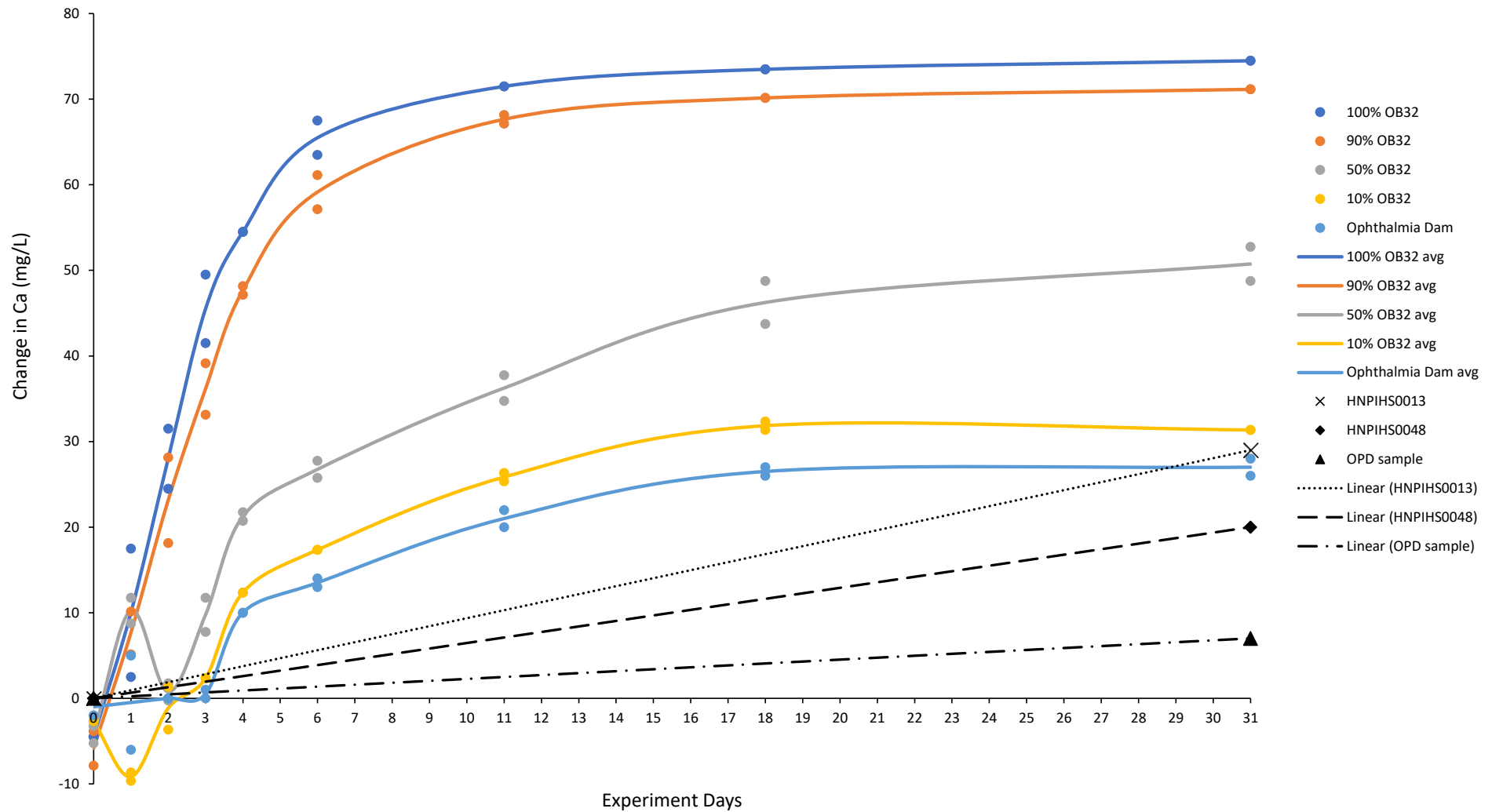


Figure 3-2 Batch 2 precipitation of Calcium under differing mixing ratios of OB32 discharge water and Ophthalmia Dam waters. Included (in black) is the loss of calcium from the field sample bottles that sat undisturbed in the lab over the duration of the experiment.

Piper Diagram

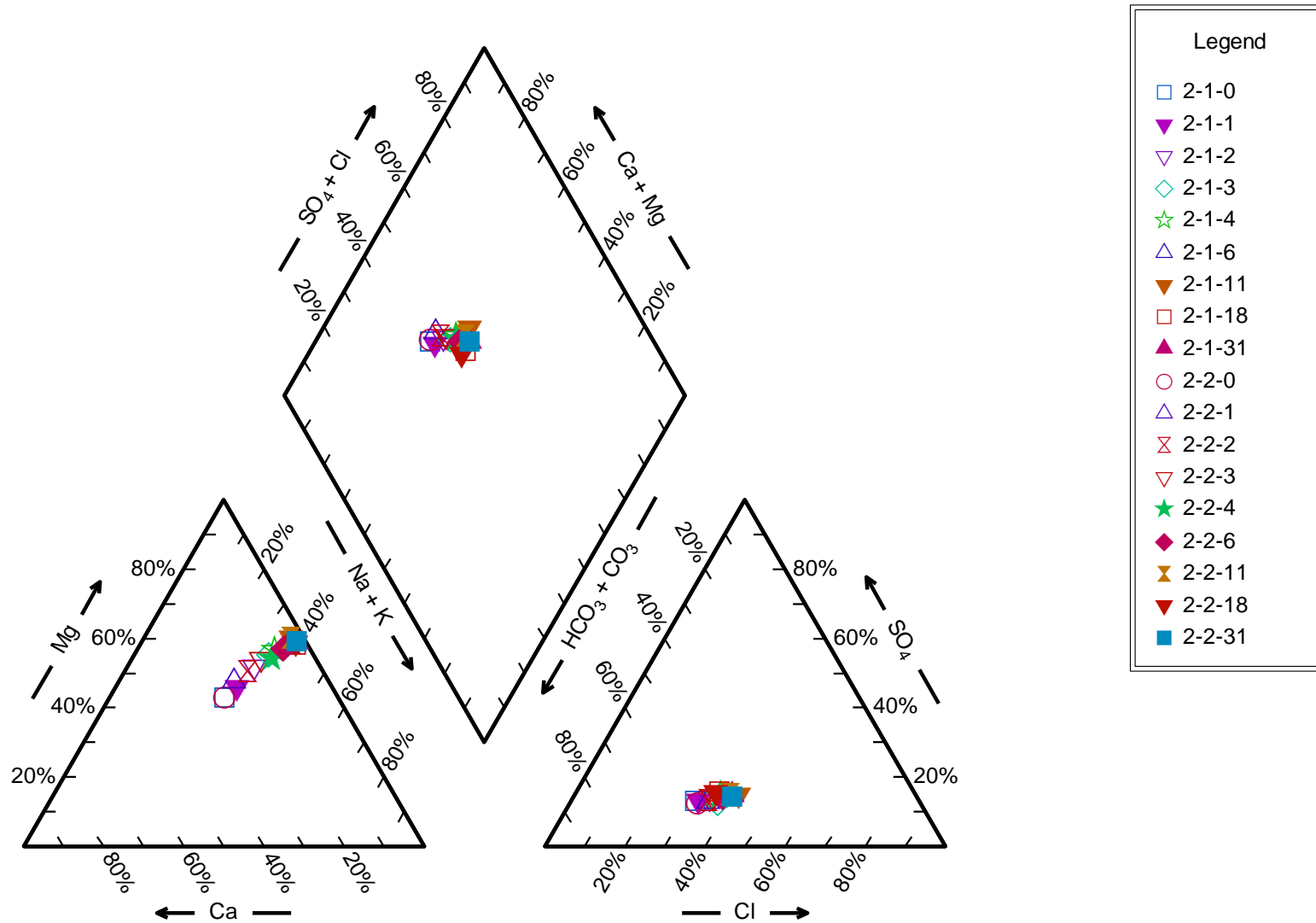


Figure 3-3 Piper Diagram of the 100% OB32 discharge waters progression over the bench top experiment (Batch 2)

Piper Diagram

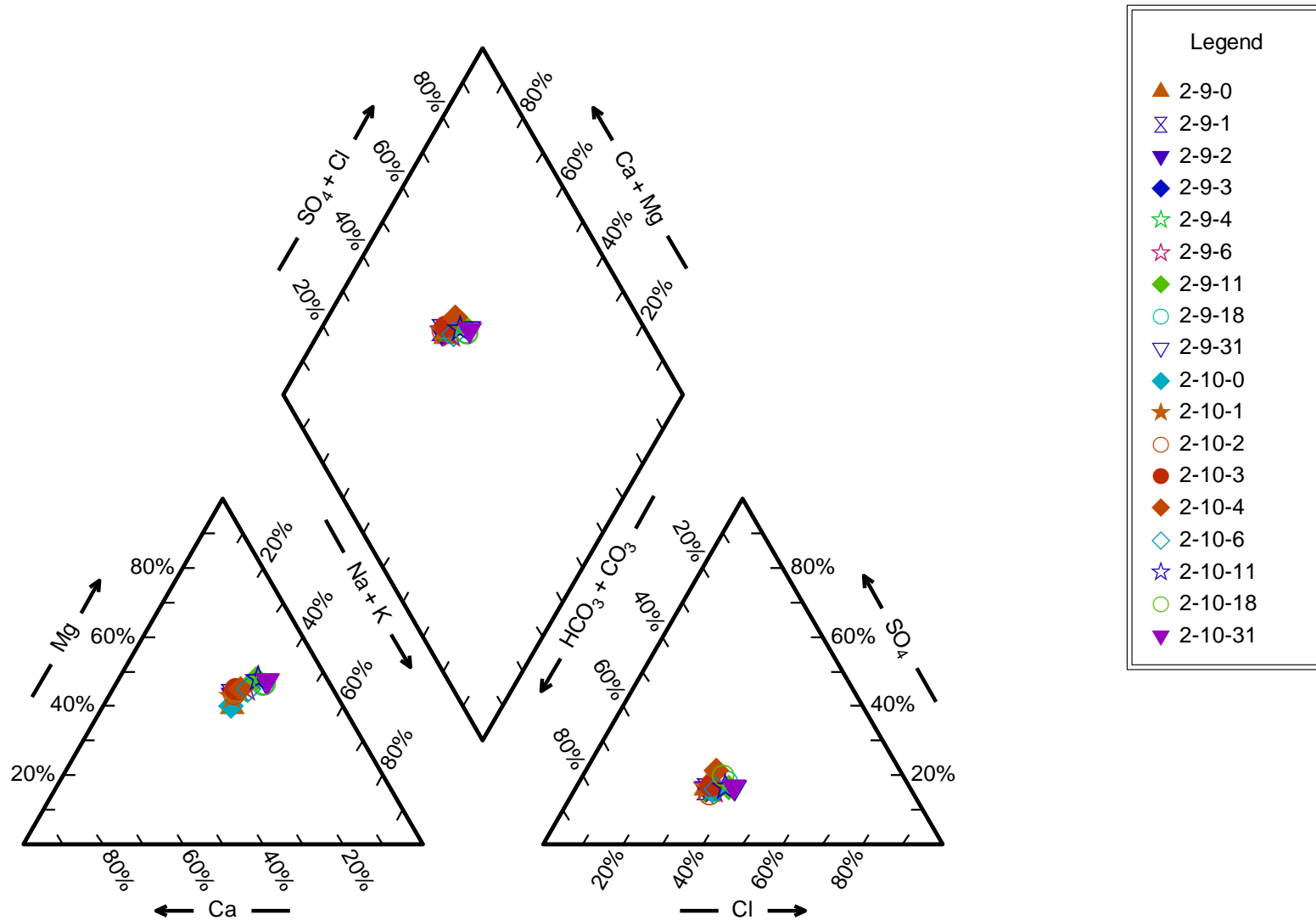


Figure 3-4 Piper Diagram of the 100% OPD receiving waters progression over the bench top experiment (Batch 2)

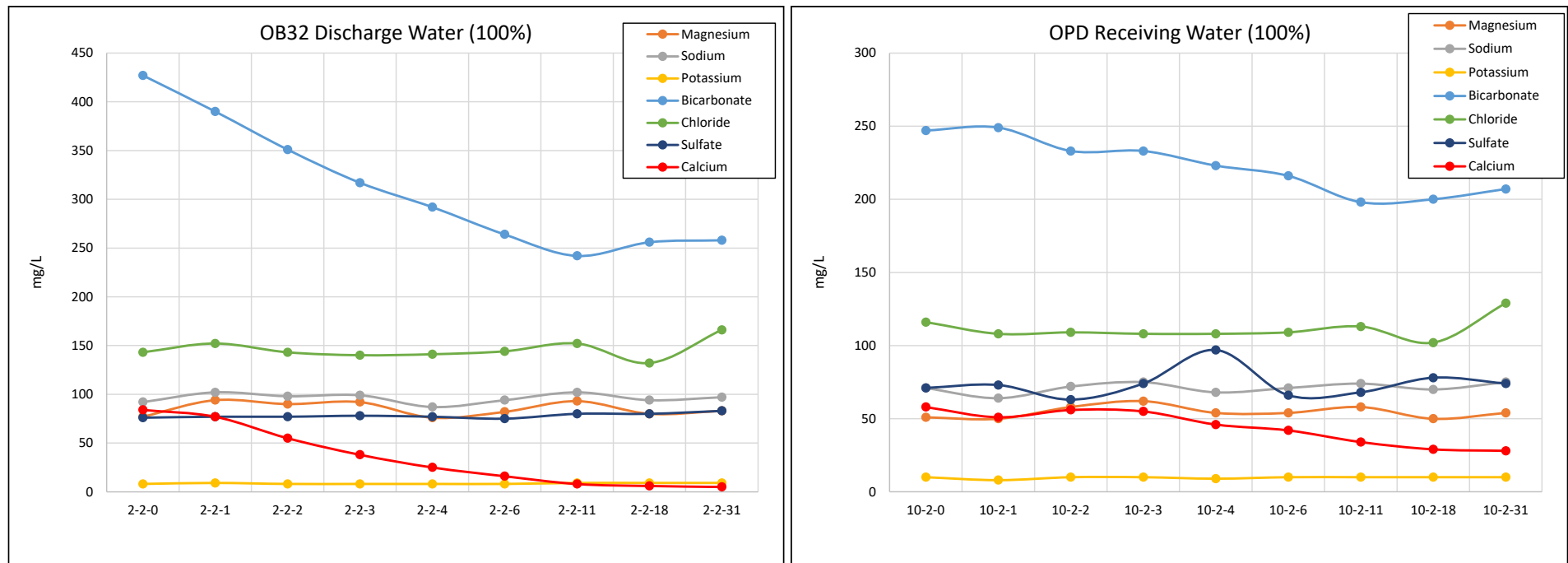


Figure 3-5 Major ion concentration progression over the bench-top experiment (OB32 water – left; OPD water – right)

3.2 GEOCHEMICAL SPECIATION MODELLING

As a further line of evidence, theoretical modelling of the potential for precipitates to form from various mixtures of OB32 and OPD waters was conducted using the geochemical speciation modelling software PHREEQC. The theoretical minerals and mass formed at equilibrium (0-saturation index value) were calculated for each test mixing ratio.

The modelling of the various solid phase Ca minerals mass loss as precipitates in the 15.5°C model closely followed that of the bench-top (Batch-2) precipitation experiments (Table 3-1 and Figure 3-6). As the results are similar (in the same order of magnitude) this indicates that the modelling is a good approximation of the geochemical process likely to occur under the various discharge mixing scenarios. The PHREEQC modelling and the bench-top experiments showed very similar losses of Ca through precipitation for 0% and 10% OB32 water. The greater mass of Ca precipitated out in the experiment in the 100%, 90% and 50% OB32 mixes may be due to magnetic stirring forming and maintaining larger precipitate crystals than would otherwise occur the field.

The phase Ca minerals mass loss as precipitates in the 40°C model resulted in increased loss from solution in comparison to the 15.5°C model (Table 3-1 and Figure 3-6). The greatest increase in Ca precipitation was modelled for the 100% OPD solution (47% increased Ca loss), with the additional Ca loss decreasing as OB32 proportional contribution increased (42%, 29%, 22% and 21% increased Ca loss respectively). This modelling indicates that Ca mineral precipitation will likely increase during the warmer months. The 40°C OPD 50:50 OB32 mixture model produced the most similar mineral Ca loss in comparison to the bench-top experiment. The higher than modelled Ca loss in the bench-top experiment in the 90% and 100% OB32 discharge mixtures is potentially due to the effect of enhanced crystallisation (seeding) on the surfaces of the greater abundance of forming solid particles in these mixtures. The modelling does not account for the presence of suspended calcite solids in suspension (formed *in-situ*) as additional surfaces for precipitate formation.

Table 3-1 Mass loss of Ca precipitates after 31 days from bench-top experiment (Batch-2) and PHREEQC chemical equilibrium speciation modelling run at 15.5 °C and 40.0°C.

Mixture	Bench-top Experiment Ca Loss (mg/L)	PHREEQC Modelled Ca Loss 15.5°C (mg/L)	PHREEQC Modelled Ca Loss 40°C (mg/L)
OPD 100% - 0% OB32	26.00	24.94	36.70
OPD 90% - 10% OB32	31.35	28.02	39.77
OPD 50% - 50% OB32	50.75	40.21	51.87
OPD 10% - 90% OB32	71.15	52.35	63.88
OPD 0% - 100% OB32	74.50	55.37	66.87

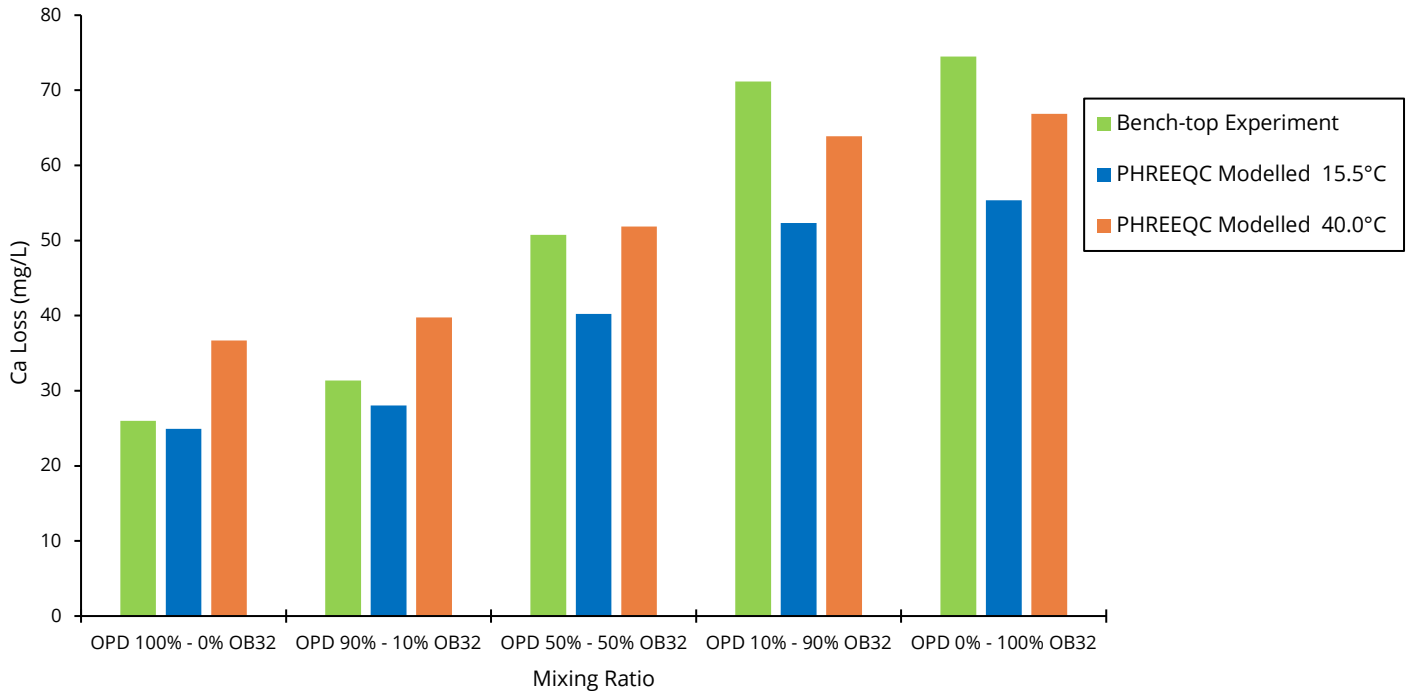


Figure 3-6 Mass loss of Ca precipitates after 31 days from bench-top experiment (Batch-2) and PHREEQC chemical equilibrium speciation modelling run at 15.5 °C and 40.0°C.

The chemical equilibrium speciation modelling for the saturation indices (S.I.) of both the 15.5°C and 40°C models indicated that both the OB32 and OPD waters were oversaturated with respect to the carbonate phases dolomite, calcite, and aragonite. As such, dolomite would preferentially precipitate first followed by calcite and aragonite under all mixing ratios (Appendix B). The saturation index data is useful for identifying mineral phases that have the potential to precipitate. However, it does not indicate the amount of precipitate that would form or the rate of formation. While dolomite was shown by the equilibrium modelling to preferentially precipitate, under natural kinetic conditions calcite may also be a dominant precipitate. If dolomite were to be the dominant carbonate mineral precipitate with calcite as the second dominant mineral precipitate this would be consistent with the available literature for the wider study area region (Upper Fortescue) in that calcrite deposits are dominated by dolomite (e.g., RPS 2015, Golder Associates 2015, Aquaterra 2010, MWH 2009, Smith 2014).

3.3 HYDRAULIC MODELLING AND PRECIPITATE THICKNESS CALCULATIONS – HOMESTEAD CREEK OPTION

Hydraulic modelling was conducted by Advisian using existing TUFLOW (surface water flows) and GoldSim (water balance with alluvium) models (see BHP 2021) were coupled to explore the interaction between surface and subsurface flows in Homestead Creek and Fortescue River. The limitations and model parameterisations are detailed further in the modelling report BHP (2021).

The modelled losses to infiltration at steady state flow are minimal, approximately 0.28% loss equating to 0.156 ML/d. The modelled discharge extent and the initial 5 km reach (the assessment area) is shown in Figure 3-8. The modelled average velocity over the initial 5 km reach was 0.22 m/s and the wetted area 0.07 km². For the initial 5 km reach, a likely value of 45 mg/L Ca loss was used for the average case modelling and a low of 18 mg/L Ca loss and a high of 74.5 mg/L Ca loss were modelled to establish range limits (based on initial and final losses from the bench-top testing).

Based on an operational scenario of 60 ML/d discharge for up to 9 months of the year and a mid-case scenario of 112.4 mg/L average rate of calcite precipitation (low scenario = 40.1 mg/L CaCO₃ and high scenario = 186.1

mg/L CaCO₃), the resulting calcium (and/or dolomite) mineral precipitation is estimated to be on the order of 0.845 mm/year (low = 0.34 mm/yr; high = 1.40 mm/yr) over the initial 5 km reach.

A total of 4074 t/yr deposition of CaCO₃ precipitates to the downstream receiving watercourse is modelled based on the equilibration of 60 ML/d of discharge for a 9-month period. The initial 5 km reach, where the formation of armouring is most likely, was modelled to receive 160 t/yr (low = 64 t/y; high = 264 t/yr), with the remainder mobilised with the flow beyond the armouring zone. This precipitation value may be attenuated by some resuspension and downstream deposition due to wet season scouring; however, we believe that this first 5 km will be where calcrete armouring is likely to occur to some degree.

There is a potential for some localised armouring to occur beyond the initial 5 km discharge reach on Homestead Creek though the potential for break-down and mobilisation of any armouring is also higher due to the increasing natural flows and mobile sediments with distance downstream. The sediments within the Fortescue River at the confluence with Homestead Creek and downstream were noted to be loosely to non-aggregated and largely sands with minor gravels.

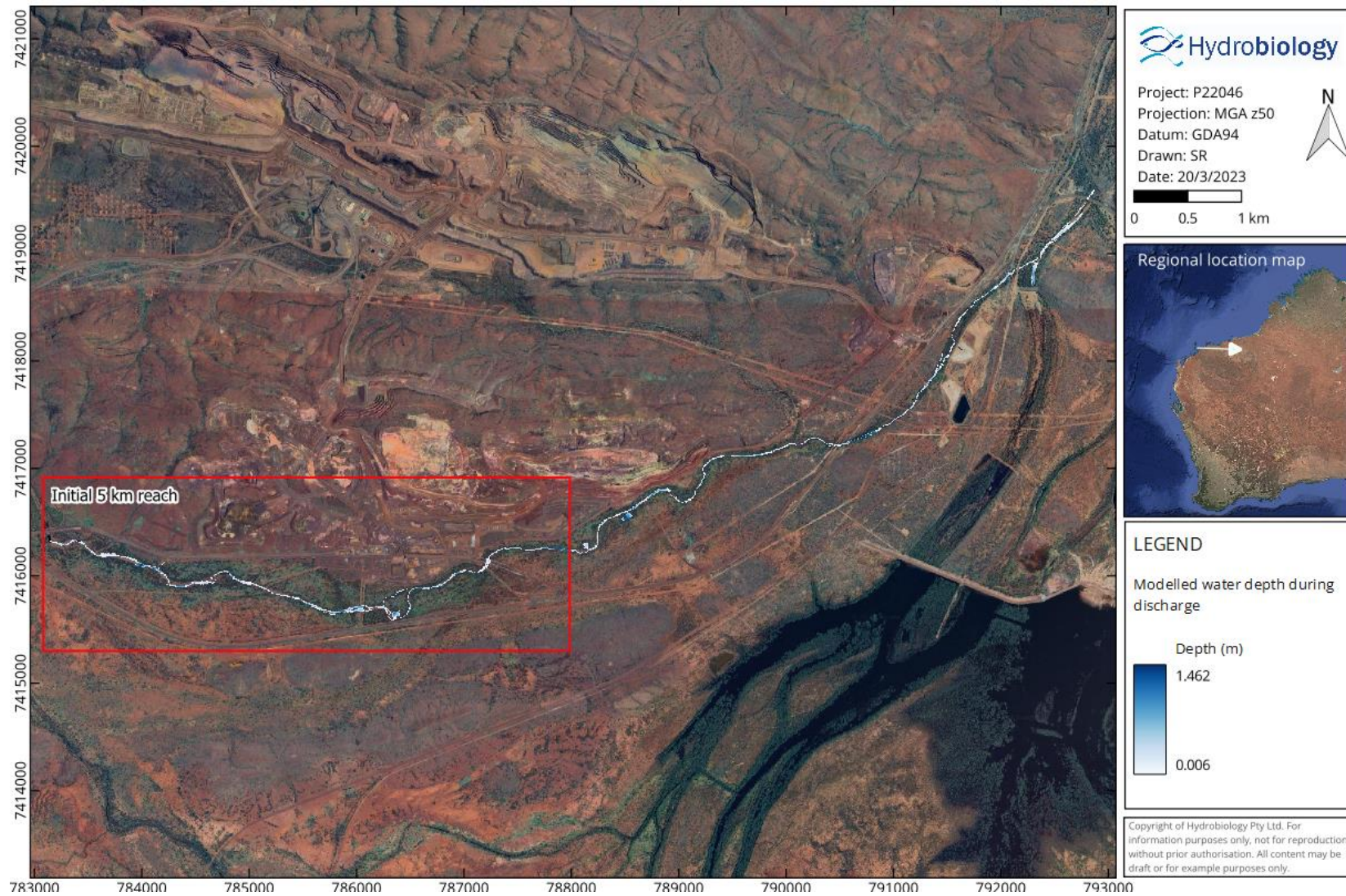


Figure 3-7 Modelled OB32 60 ML/d discharge into Homestead Creek, showing downstream wetting front extent up to the Fortescue River.

4. DISCUSSION

The results, including calculated precipitation rates and flow distances/surface areas, presented in this report are theoretical and based on many assumptions. In most cases these assumptions have been chosen to be deliberately conservative. There are many factors which may mitigate the final observed deposition of precipitates and potential channel armouring. These include periodic sediment mobilisation and distribution downstream by large storm/flood events, filtering/entrapment of particulates by macrophyte vegetation and algae, bioturbation by benthic organisms and, dissolution by interaction with meteoric water and groundwater.

The bench-top experiment results showed a clear and expected precipitation signal, indicating the method provides a useful approach to confirming and extending desktop modelling.

The area in the direct vicinity of the discharge into Homestead Creek would likely see observable calcite precipitation on woody debris and rocks. Calcite precipitation in secondary channels may form a light loose surface crust on larger sediment particles and small rocks, blocking interstitial pore spaces in the surface sediments (1 to 2 cm). A biofilm and organic detritus formation may form, reducing oxygen penetration into the sediments resulting in a black anoxic subsurface layer.

The similarity in the results from the chemical equilibrium modelling using the PHREEQC program and that of the bench-top precipitation experiments (Table 3-1) indicates that the calcium phase speciation identified in the modelling is applicable to the various discharge options. The Homestead Creek discharge scenario would likely result in calcite precipitation under natural kinetic conditions associated with in-creek turbulence.

The hydraulic modelling for continual 60 ML/d discharge (over 9-months of the year) into Homestead Creek identified the 5 km reach downstream of the discharge point as most likely at risk for calcite precipitation and the formation of armouring. However, due to variability in residence time, off-channel pooling and geomorphic/sediment variability, some armouring may occur further downstream. The calculated deposition rate of 0.845 mm/yr (low 0.34; high 1.40) may not necessarily translate to the same rate of calcrete formation on creek sediments as wet season flows will act to

resuspend and transport precipitates downstream. However, this estimated 5 km precipitation zone is most likely to be impacted by decreased infiltration rates, biofilm formation and reduced interstitial pore space over time. Wetted channel wide armouring (calcrete) formation within Homestead Creek would likely occur within 3 km of the discharge point. The timescales in which total sediment armouring would occur is unclear though it is likely that visible crusts of calcite (as a white powder or crystals on rock and sediment surfaces) will occur within two to three years of discharge starting. These may be periodically removed or broken down by scouring events such as flood flows, which would re-set the timeline of calcite buildup in the sediments and subsequent armouring.

Extended discharge into Homestead Creek at the proposed 60 ML/d may result in permanent pools past the confluence with the Fortescue River (depending on the achieved infiltration losses along the discharge flow route). These may act as dry season sediment traps for fine precipitates, though this would be mitigated to some extent by the plan to cease discharge over the three peak dry season months every year.

4.1 POTENTIAL MITIGATION OPTIONS

This section outlines some options for mitigation of potential impacts of dewatering discharge at each study site.

4.1.1 HOMESTEAD CREEK DISCHARGE

The discharge of OB32 dewatering into Homestead Creek is likely to generate some sediment armouring and the formation of a wetland type habitat (riparian vegetation, macrophytes, biofilms etc.) in the initial several kilometres downstream of the discharge point. Possible mitigation options are divided into those that mitigate sediment armouring and those that mitigate wetland formation:

- **Sediment armouring mitigation:**
 - **Reduced dry season discharge** – The peak period for potential precipitation and armouring formation will be the dry season, in particular the three months immediately prior to the first wet season flows where high temperatures increase the precipitation rates. Lowering or ceasing discharge over the dry season months will result in a lower total precipitate formation over the annual cycle and, reduce the formation of armouring. This is likely to be particularly important immediately prior to the wet season when there are few to no natural flows to mobilise precipitates and dilute discharge waters (which lowers the precipitation rates).
 - **Increased retention time** – the formation of calcite precipitates occurs over a period of approximately one week after the “surfacing” of the discharge water. This equates to 420,000 m³ or 420 ML at a 60 ML/d discharge rate. As an example, a 300 m x 300 m x 5 m (average depth) retention pond would have a capacity of 450,000 m³. The precipitates could be retained within this facility to prevent formation of armouring downstream of the discharge point.
 - **CO₂ bubblers** - Calcite precipitation can be facilitated using CO₂ bubblers to increase the speed of precipitation, which may be used in conjunction with a suitably sized retention basin to remove calcium and prevent downstream precipitates forming. The addition of a CO₂ system prior to retention may be used to reduce the size of the required retention basin. The effectiveness of this method would be subject to the performance of available commercial treatment equipment, which has not been investigated within the current scope.
 - **pH adjustment** – dropping the pH to below the threshold for calcite precipitation can be used to mitigate the formation of a calcite armour in downstream sediments. The

addition of a suitable acid (e.g. sulfuric, hydrochloric or acetic acid) to adjust the pH of the discharge waters may be possible. Further modelling would be required to determine the volume of acid. This option may not be acceptable due to downstream salinity or acidity issues from the pH adjustment. In addition, it is likely that the acidification would be neutralised downstream by interaction with natural waters and sediments, causing some risk of secondary solids precipitation further downstream. However, this risk would be less than unmitigated discharge alone due to the wider distribution area.

- **Blending** – it may be possible to blend waters of lower calcite saturation index values with the OB32 discharge to avoid precipitation issues. This would increase the total flow discharged and require additional infrastructure. OPD waters may be a suitable source, although these are only slightly lower in calcite precipitation potential than the discharge waters and would require blended volumes of a similar magnitude or greater to the OB32 discharge (see Section 3.1).
- **Physical scarification**: it would be possible to physically break apart any sediment armouring and crust formation in Homestead Creek via scarification or other mechanical means. It is likely that this method would need to be employed during periods of no discharge to avoid excessive sediment remobilisation and turbidity downstream. A small centreline scarified channel (~1-2 m) could create enough sediment disturbance to undermine crust formation across the channel.

5. REFERENCES

- Aquaterra (2010). Marillana Project Groundwater Study & Management Plan. Report to Brockman Resources. March 2010.
- BHP (2021). Selection Phase Study WAIO Project Ore Body 32: Surplus Water Creek Discharge Modelling Report. Doc No.: PREP-1210-C-12057/D.
- Biologic (2023) OB32: Surplus Water DPS Infiltration Ecological Impact Assessment. Unpublished report for BHP Western Australian Iron Ore. East Perth, WA. November 2023
- EPA (2018). Evaluating the environmental condition of Weeli Wolli Creek (2018). EPA services, Department of Water and Environmental Regulation.
- Golder Associates (2015). Ecohydrological Conceptualisation of the Marillana Creek Region. Report for BHP Billiton Iron Ore. September 2015.
- Hydrobiology (2019). Ore Body 32 Surplus Water: Infiltration Geochemistry Study. Report for BHP Iron Ore. June 2021.
- MWH (2009). Pilbara Integrated Water Supply: Pre-Feasibility Study. Report to the Department of Water, Western Australia.
- RPS (2015) Ecohydrological conceptualisation of the Eastern Pilbara Region. Report prepared for BHP Billiton Iron Ore by RPS, Subiaco, Western Australia. Public Environmental Review Strategic Proposal - Appendix 7: Ecohydrological Change Assessment.
- Smith, L. (2014). Clogging Mechanisms in Managed Aquifer Recharge: a case study at Mining Area C. M.Sc. Thesis, University of Western Australia.

APPENDIX A. PHREEQC GEOCHEMICAL MODELLING

A.1 MODEL INPUTS (15.5°C)

Table 5-1 Ophthalmia Dam receiving water chemistry

temp	15.5
pH	8.5
pe	4
redox	pe
units	ppm
density	1
Alkalinity	271
Ca	56
K	8
Mg	53
Na	63
S(6)	51 as SO4
water	1 # kg

Table 5-2 OB32 discharge water chemistry

temp	15.5
pH	7.74
pe	4
redox	pe
units	ppm
density	1
Alkalinity	428.5
Ca	79.5
K	6.5
Mg	80
Na	86
S(6)	77
water	1 # kg

A.2 MODEL OUTPUTS (15.5°C)

Table 5-3 Saturation indices for Ophthalmia Dam receiving waters. Bolded phase minerals past saturation

Phase	SI**	log IAP	log K (288 K, 1 atm)	
Anhydrite	-2.46	-6.64	-4.18	CaSO4
Aragonite	0.92	-7.36	-8.28	CaCO3
Calcite	1.06	-7.36	-8.42	CaCO3
CO2(g)	-3.09	-4.44	-1.35	CO2
Dolomite	2.42	-14.52	-16.94	CaMg(CO3)2
Gypsum	-2.05	-6.64	-4.59	CaSO4:2H2O
H2(g)	-25.03	-28.11	-3.07	H2
H2O(g)	-1.76	0	1.76	H2O
O2(g)	-36.52	-39.33	-2.82	O2
Sulfur	-16.05	-10.93	5.11	S

Table 5-4 Saturation indices OPD 90:10 OB32 water mixture.

Phase	SI**	log IAP	log K (288 K, 1 atm)	
Anhydrite	-2.43	-6.61	-4.18	CaSO4
Aragonite	0.86	-7.43	-8.28	CaCO3
Calcite	1	-7.43	-8.42	CaCO3
CH4(g)	-18.77	-21.47	-2.7	CH4
CO2(g)	-2.95	-4.3	-1.35	CO2
Dolomite	2.3	-14.65	-16.94	CaMg(CO3)2
Gypsum	-2.02	-6.61	-4.59	CaSO4:2H2O
H2(g)	-10.75	-13.83	-3.07	H2
H2O(g)	-1.76	0	1.76	H2O
H2S(g)	-20.13	-28.09	-7.96	H2S
O2(g)	-65.08	-67.9	-2.82	O2
Sulfur	-15.41	-10.3	5.11	S

Table 5-5 Saturation indices OPD 50:50 OB32 water mixture.

Phase	SI**	log IAP	log K (288 K, 1 atm)	
Anhydrite	-2.32	-6.5	-4.18	CaSO4
Aragonite	0.63	-7.65	-8.28	CaCO3
Calcite	0.77	-7.65	-8.42	CaCO3
CH4(g)	-124.94	-127.64	-2.7	CH4
CO2(g)	-2.48	-3.82	-1.35	CO2
Dolomite	1.85	-15.1	-16.94	CaMg(CO3)2
Gypsum	-1.91	-6.5	-4.59	CaSO4:2H2O
H2(g)	-37.41	-40.49	-3.07	H2
H2O(g)	-1.76	0	1.76	H2O

H2S(g)	-125.97	-133.93	-7.96	H2S
O2(g)	-11.75	-14.57	-2.82	O2
Sulfur	-94.58	-89.47	5.11	S

Table 5-6 Saturation indices OPD 10:90 OB32 water mixture.

Phase	SI**	log IAP	log K (288 K, 1 atm)	
Anhydrite	-2.24	-6.41	-4.18	CaSO4
Aragonite	0.51	-7.77	-8.28	CaCO3
Calcite	0.66	-7.77	-8.42	CaCO3
CH4(g)	-26.92	-29.63	-2.7	CH4
CO2(g)	-2.18	-3.52	-1.35	CO2
Dolomite	1.63	-15.32	-16.94	CaMg(CO3)2
Gypsum	-1.82	-6.41	-4.59	CaSO4:2H2O
H2(g)	-12.99	-16.06	-3.07	H2
H2O(g)	-1.76	0	1.76	H2O
H2S(g)	-27.75	-35.71	-7.96	H2S
O2(g)	-60.61	-63.43	-2.82	O2
Sulfur	-20.79	-15.68	5.11	S

Table 5-7 Saturation indices OB32 discharge water.

Phase	SI**	log IAP	log K (288 K, 1 atm)	
Anhydrite	-2.22	-6.39	-4.18	CaSO4
Aragonite	0.5	-7.78	-8.28	CaCO3
Calcite	0.64	-7.78	-8.42	CaCO3
CO2(g)	-2.12	-3.47	-1.35	CO2
Dolomite	1.6	-15.34	-16.94	CaMg(CO3)2
Gypsum	-1.8	-6.39	-4.59	CaSO4:2H2O
H2(g)	-23.51	-26.59	-3.07	H2
H2O(g)	-1.76	0	1.76	H2O
O2(g)	-39.56	-42.37	-2.82	O2
Sulfur	-96.81	-91.7	5.11	S

A.3 MODEL INPUTS (40°C)

Table 5-8 Ophthalmia Dam receiving water chemistry

temp	40
pH	8.5
pe	4
redox	pe
units	ppm
density	1
Alkalinity	271
Ca	56
K	8
Mg	53
Na	63
S(6)	51 as SO ₄
water	1 # kg

Table 5-9 OB32 discharge water chemistry

temp	40
pH	7.74
pe	4
redox	pe
units	ppm
density	1
Alkalinity	428.5
Ca	79.5
K	6.5
Mg	80
Na	86
S(6)	77
water	1 # kg

A.4 MODEL OUTPUTS (40°C)

Table 5-10 Saturation indices for Ophthalmia Dam receiving waters. Bolded phase minerals past saturation.

Phase	SI**	log IAP	log K (313 K, 1 atm)	
Anhydrite	-2.27	-6.72	-4.45	CaSO ₄
Aragonite	1.21	-7.23	-8.45	CaCO₃
Calcite	1.38	-7.23	-8.62	CaCO₃
CH ₄ (g)	-116.69	-119.6	-2.91	CH ₄
CO ₂ (g)	-2.97	-4.59	-1.63	CO ₂
Dolomite	3.14	-14.25	-17.4	CaMg(CO₃)₂
Gypsum	-2.12	-6.72	-4.6	CaSO ₄ ·2H ₂ O
H ₂ (g)	-34.44	-37.56	-3.13	H ₂
H ₂ O(g)	-1.14	0	1.14	H ₂ O
H ₂ S(g)	-118.56	-126.48	-7.92	H ₂ S
O ₂ (g)	-9.66	-12.64	-2.98	O ₂
Sulfur	-89.9	-85.35	4.55	S

Table 5-11 Saturation indices OPD 90:10 OB32 water mixture.

Phase	SI**	log IAP	log K (313 K, 1 atm)	
Anhydrite	-2.24	-6.69	-4.45	CaSO ₄
Aragonite	1.18	-7.27	-8.45	CaCO₃
Calcite	1.35	-7.27	-8.62	CaCO₃
CH ₄ (g)	-117.47	-120.38	-2.91	CH ₄
CO ₂ (g)	-2.85	-4.47	-1.63	CO ₂
Dolomite	3.07	-14.33	-17.4	CaMg(CO₃)₂
Gypsum	-2.09	-6.69	-4.6	CaSO ₄ ·2H ₂ O
H ₂ (g)	-34.66	-37.79	-3.13	H ₂
H ₂ O(g)	-1.14	0	1.14	H ₂ O
H ₂ S(g)	-119.27	-127.19	-7.92	H ₂ S
O ₂ (g)	-9.2	-12.19	-2.98	O ₂
Sulfur	-90.38	-85.84	4.55	S

Table 5-12 Saturation indices OPD 50:50 OB32 water mixture.

Phase	SI**	log IAP	log K (313 K, 1 atm)	
Anhydrite	-2.13	-6.58	-4.45	CaSO ₄
Aragonite	1	-7.44	-8.45	CaCO₃
Calcite	1.17	-7.44	-8.62	CaCO₃
CH ₄ (g)	-115.58	-118.49	-2.91	CH ₄
CO ₂ (g)	-2.39	-4.02	-1.63	CO ₂
Dolomite	2.73	-14.67	-17.4	CaMg(CO₃)₂
Gypsum	-1.98	-6.58	-4.6	CaSO ₄ ·2H ₂ O
H ₂ (g)	-34.3	-37.43	-3.13	H ₂

H2O(g)	-1.14	0	1.14	H2O
H2S(g)	-117.09	-125.01	-7.92	H2S
O2(g)	-9.92	-12.91	-2.98	O2
Sulfur	-88.57	-84.02	4.55	S

Table 5-13 Saturation indices OPD 10:90 OB32 water mixture.

Phase	SI**	log IAP	log K (313 K, 1 atm)	
Anhydrite	-2.04	-6.49	-4.45	CaSO4
Aragonite	0.86	-7.59	-8.45	CaCO3
Calcite	1.03	-7.59	-8.62	CaCO3
CH4(g)	-23.01	-25.92	-2.91	CH4
CO2(g)	-2.04	-3.67	-1.63	CO2
Dolomite	2.44	-14.96	-17.4	CaMg(CO3)2
Gypsum	-1.89	-6.49	-4.6	CaSO4:2H2O
H2(g)	-11.25	-14.38	-3.13	H2
H2O(g)	-1.14	0	1.14	H2O
H2S(g)	-24.29	-32.21	-7.92	H2S
O2(g)	-56.03	-59.02	-2.98	O2
Sulfur	-18.82	-14.27	4.55	S

Table 5-14 Saturation indices OB32 discharge water.

Phase	SI**	log IAP	log K (313 K, 1 atm)	
Anhydrite	-2.02	-6.47	-4.45	CaSO4
Aragonite	0.83	-7.62	-8.45	CaCO3
Calcite	1	-7.62	-8.62	CaCO3
CH4(g)	-29.82	-32.73	-2.91	CH4
CO2(g)	-1.97	-3.6	-1.63	CO2
Dolomite	2.39	-15.01	-17.4	CaMg(CO3)2
Gypsum	-1.88	-6.47	-4.6	CaSO4:2H2O
H2(g)	-12.97	-16.1	-3.13	H2
H2O(g)	-1.14	0	1.14	H2O
H2S(g)	-31.06	-38.98	-7.92	H2S
O2(g)	-52.59	-55.58	-2.98	O2
Sulfur	-23.87	-19.32	4.55	S

APPENDIX B. PRECIPITATE THICKNESS CALCULATION INPUTS

9 months per year discharge scenario					
Parameter	Likely Value	Low	High	Unit	Comments
Ca precipitation per L	45	18	74.5	mg/L	Taken from day 3 of benchtop testing results.
CaCO ₃ precipitation	112.38	44.95	186.05	mg/L	Calc.
Ca mol. Wt.	40.08	40.08	40.08	g	
C mol. Wt.	12.01	12.01	12.01	g	
O mol. Wt.	16.00	16.00	16.00	g	
CaCO ₃ mol. Wt.	100.09	100.09	100.09	g	Calc.
Ca precip rate per L per Hr	1.56	0.62	2.58	mg/L/hr	Calc.
SW Model avg. velocity	0.22	0.22	0.22	m/s	
Assessment reach length	5	5	5	km	Downstream reach where precip armouring most likely.
Travel time	6.3	6.3	6.3	hrs	Calc.
Discharge rate	60	60	60	ML/d	
Sp. Gravity CaCO ₃	2.7	2.7	2.7	kg/L	
CaCO ₃ thickness rate	2.7	2.7	2.7	kg/mm/m ²	General rate for kg of CaCO ₃ per mm per m ²
CaCO ₃ precip wght. Total	6743	2697	11163	kg/d	Calc.
CaCO ₃ precip wght. 5km	1774	709	2936	kg/d	Calc. based on velocity and time
Creek avg. wet width	14	14	14	m	From Worley modelling
Creek surface area	70000	70000	70000	m ²	Calc. For precip.
Days of Discharge per year	270	270	270	d/yr	9 months per year discharge scenario
Volume discharged per year	16200	16200	16200	ML/y	Calc.
Discharge ML/hr	2500000	2500000	2500000	L/hr	Calc.
CaCO ₃ precip wgh per hr	281	112	465	kg/hr	Calc.

9 months per year discharge scenario

Parameter	Likely Value	Low	High	Unit	Comments
CaCO ₃ precip wgh per day	6743	2697	11163	kg/d	Calc.
CaCO ₃ precip per 5km per L	9.9	3.9	16.3	mg	Calc.. Per L precip over the 6.3 hours (5km)
CaCO ₃ precip per 5km per year	159629	63851	264274	kg/yr	Calc.
CaCO ₃ volume 9 month scenario	59122	23649	97879	L	Calc.
CaCO ₂ precip thickness 9 mth scenario	0.845	0.338	1.398	mm/yr	For 5km reach based on velocity and time

*Grey filled cells indicate calculations based on other cell inputs



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