# Sanjiv Ridge Stage 5 - Waste Rock Assessment

## Interim Report - Preliminary Geochemical Characterisation

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## Terms and acronyms commonly used in waste material characterisation

| Abbreviation | Description |
|---|---|
| ABA | Acid-base accounting |
| ABCC | Acid Buffering Characteristic Curve |
| AC | Acid consuming |
| AP | Acid production |
| Alkalinity | A measure of the buffering capacity of water and capacity to neutralise acidity (kgCaCO3/l) |
| AMD | Acid and metalliferous drainage |
| ANC | Acid neutralisation capacity (kg $H_2SO_4$/t) |
| $ANC_{Lab}$ | Acid neutralisation capacity measured in the laboratory (kg $H_2SO_4$/t) |
| $ANC_{Carb}$ | Acid neutralising capacity estimated from carbonate (total inorganic carbon) (kg $H_2SO_4$/t) |
| $ANC_{ABCC}$ | Acid neutralising capacity estimated from ABCC test (kg $H_2SO_4$/t) |
| BIF | Banded iron formation |
| Circum-neutral | pH value near neutral (~pH 7) |
| EAT | Emerson Aggregate Test |
| EC | Electrical conductivity (µS/cm) |
| $EC_{1:2}$ | EC of a sample slurry with a solid to water ratio of 1:2 (µS/cm) |
| ECEC | Effective cation exchange capacity |
| ESP | Exchangeable sodium percentage |
| GAI | Geochemical abundance index |
| ITF | Interface between Stage 4 and Stage 5 |
| MPA | Maximum potential acidity (kg $H_2SO_4$/t) |
| NAF | Non-acid forming |
| NAG | Net acid generation |
| NAG pH | Measured pH of the NAG solution |
| NAG pH 4.5 | NAG acidity to endpoint pH 4.5 (kg $H_2SO_4$/t) |
| NAG pH 7.0 | NAG acidity to endpoint pH 7.0 (kg $H_2SO_4$/t) |
| NAPP | Net acid producing potential (kg $H_2SO_4$/t) |
| PAF | Potentially acid forming |
| $pH_{1:2}$ | pH of a sample slurry with a solid to water ratio of 1:2 |
| PMLU | Post-mining land use |
| PSD | Particle Size Distribution |
| QXRD | Quantitative X-ray diffraction |
| SAQP | Sampling, analysis and quality program |
| SD | Saline drainage |
| Sulfate | Oxidised form of sulfur ($SO_4^{2-}$) |
| Sulfide | Reduced form of sulfur ($S^{2-}$) |
| Total-C | Total carbon (%). |
| TDS | Total dissolved solids |
| TIC | Total inorganic carbon |
| TOC | Total organic carbon |
| Total-S | Total sulfur (%) |
| TVD | True Vertical Depth |
| UC | Uncertain |
| WRD | Waste Rock Dump |

# Executive Summary

Mine Earth was commissioned by Atlas Iron to conduct a waste rock characterisation assessment for the Sanjiv Ridge Stage 5 project. This Stage 5 preliminary study review focused on the total sulfur data contained in the drilling database and preliminary geochemical characterisation tests run on 34 samples collected from three drillholes positioned on the edge of the Runway pit and three drillholes positioned on the edge of the Sparrow pit. These six drillholes traversed the pits from the surface to below Stage 5 and were tested for preliminary geochemical characterisation. This work follows on from the drillhole database review and the detailed geochemical characterisation work undertaken on the Stage 4 samples (Mine Earth, 2024a).

The data review and the analytical work indicate that the waste materials extracted from both pits present a low risk of AMD with only a few sulfur spikes recorded in the dataset. Over 90% of the sulfur data recorded for the Sparrow pit is below the conservative cut-off value of 0.1%S, reaching 100% for the Runway pit where all waste materials can be classed as non-acid forming (NAF). The Sparrow pit does contain some localised pockets of sulfurous material that may be sulfidic with 6.4% of the material having a sulfur content above 0.3%. This material should be classed as potentially acid-forming (PAF) until further testing has been undertaken. The higher sulfur values are mostly found in the shale and the chert, along the eastern side of the pit. The shale samples analysed from the three drillholes have low $pH_{1:2}$ and NAGpH values, indicating existing acidity, plus the potential to generate acid and metalliferous drainage (AMD).

This preliminary review provides the following recommendations:

- As for stage 4, there are discrepancies between the sulfur data presented in the block model and the sulfur data collected in the drillhole database. These should be addressed as these discrepancies may affect the waste management strategy.
- Stage 5 waste rock management will likely require the construction of PAF cells, the dimensions of these cells will depend on the volumes of PAF material extracted. A detailed characterisation including at least NAGpH, acid neutralisation capacity (ANC) and chromium reducible sulfur (CRS) should be undertaken on samples representative of the geology of the pit.
- The risk of saline and metalliferous drainage should also be investigated by incorporating leaching tests.
- Regular monitoring of the material extracted should be undertaken to validate the findings, through the development of a sampling and analysis quality plan (SAQP).

# 1. Introduction

Mine Earth was engaged by Atlas Iron (Atlas) to conduct a waste rock characterisation assessment on six geochemical drillholes targeting the Stage 4 and Stage 5 expansion areas of the Sanjiv Ridge Project. The Stage 4 and Stage 5 expansions extend the Stage 3 Sparrow and Runway pits with mining for Stage 4 expansion above the water table and mining for Stage 5 expansion below the water table.

Samples from the 6 drillholes were analysed for pH, NAGpH, EC and total sulfur. The preliminary data was reviewed to select subsamples for the detailed geochemical characterisation of Stage 4 materials and the respective findings have been provided to Atlas (Mine Earth, 2024a). Stage 5 samples were not analysed further as it was acknowledged that the drillholes were not spatially representative of the pit. It was decided that it would be preferable to wait for the 2024 drilling campaign to be finalised as it would provide samples more spatially representative of the Stage 5 pit.

The objectives of this Stage 5 interim report were to provide a summary and an interpretation of the sulfur data collected by Atlas during the drilling campaign and the review of the data ($pH_{1:2}$, $EC_{1:2}$, NAGpH and total sulfur). This guided how this data affected the material characterisation program and the mine waste management strategy.

The following documentation relates to this study:

- Mine Earth. (2022). Review of Waste Characterisation Requirements for the Runway South Pit Expansion.
- Mine Earth (2024a). Sanjiv Ridge Stage 4 – Waste rock Assessment – Detailed Geochemical Characterisation-Rev1, May 2024.
- Mine Earth (2024b). Sanjiv Ridge Stage 4 – PAF Material Management Plan – Rev0, June 2024
- Recent drilling databases for the Sparrow (formerly Split Rock) and Runway project areas, including data for iron and sulfur content, lithology, stratigraphy and rock quality designation (RQD)
- Mining surfaces for all planned pits, from Stage 3 to Stage 5:
  - spl_pit_u_dc_v5 (Sparrow Stage 3)
  - spl_pit_u_bwt1_v1 (Sparrow Stage 4)
  - spl_bwt_pit (Sparrow Stage 5)
  - run_pit_u_s1_v3 (Runway Stage 3)
  - run_pit_u_sbwt1_v1 (Runway Stage 4)
  - run_pit_u_sbwt_v1 (Runway Stage 5)
- Mining surfaces for geological units and mineralisation
- Block model including data for iron, sulfur, lithology, stratigraphy and volume: spl_202110, *runway_202107*

The drilling database and block model (as provided by Atlas) were imported into Leapfrog Works, along with the pit shell files, to assist with the interpretation of the data.

# 2. Geology

The Project is hosted by the Cleaverville Formation, part of the Gorge Creek Group located in the Coongan Greenstone Belt. The dominant lithologies at the Project are banded iron formation (BIF), chert and sediments including sandstones, siltstones and shales. The BIF rocks are associated with jaspillites and interbedded cherts. Shales can contain variable iron contents and can be sulfidic and carbonaceous below the weathering horizon (Atlas, 2024).

The iron ore mineralisation is distributed through most BIF units as goethititic or hematitic ironstone (with hypogene magnetite-martite mineralisation) and displays massive to vuggy textures. Silica leaching and supergene enrichment have further concentrated the ore mineralisation (Atlas, 2024).

### 2.1.1 Sparrow

The geology of the Sparrow deposit consists of westerly-dipping, sub-vertical beds of alternating BIF and chert, bounded on the east and west by shale. Several major shears converge at the deposit, resulting in high-strain zones and hydrothermal brecciation (Atlas, 2024).

### 2.1.2 Runway

The westerly-dipping Runway deposit consists of two BIF units separated by an unmineralised chert, bound to the west by a fault and to the east by carbonaceous shale. Zones of hydrothermal breccia have been identified in the west of the deposit (Atlas, 2024).

### 2.1.3 Lithological distribution

The drilling database for both Stage 4 and 5 pits contains regolith, iron detrital, mineralisation, veining and sedimentary rock groups. Nineteen lithologies (with 33 variations) can be observed within these groups, with the proportions of these lithologies provided in Appendix B. The major lithologies (with >5% of the total intervals logged in one of the stages) are presented in Table 1 and accounted for 87% of the Sparrow pit and 85% of the Runway pit.

**Table 1: Major lithologies logged for Stage 5**

| Lithology | Sparrow | Runway |
|---|---|---|
| Goethite (%) | 25 | 31 |
| Hematite/Goethite (%) | 15 | 12 |
| Hematite (%) | 5 | 5 |
| Chert (%) | 39 | 37 |
| Shale (%) | 12 | 3 |
| BIF (%) | 1 | 5 |

## 2.2 Pit geometry

The Stage 5 geometries for Sparrow and Runway are shown in Figure 1 and Figure 2 . The estimated volumes to be generated for each pit are presented in Table 2. These estimated volumes were derived by “tagging” the block model with the planned pit shells and interrogating the total block volumes contained within.

**Table 2: Estimated block model volumes and tonnages for Stage 5**

| | Sparrow | Runway |
|---|---|---|
| Volume ($m^3$) | 3,943,203 | 636,563 |
| Estimated Tonnage (tn) | 9,092,376 | 1,507,227 |

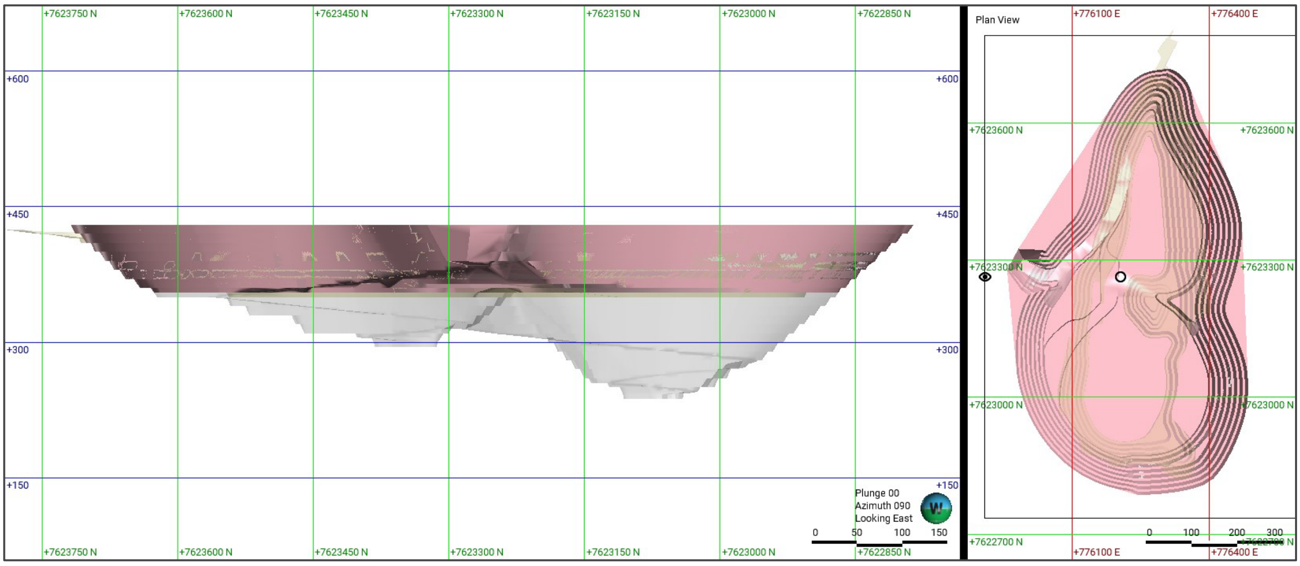


**Figure 1: Sparrow – Stage 4 pit geometry in pink, Stage 5 pit geometry in grey**

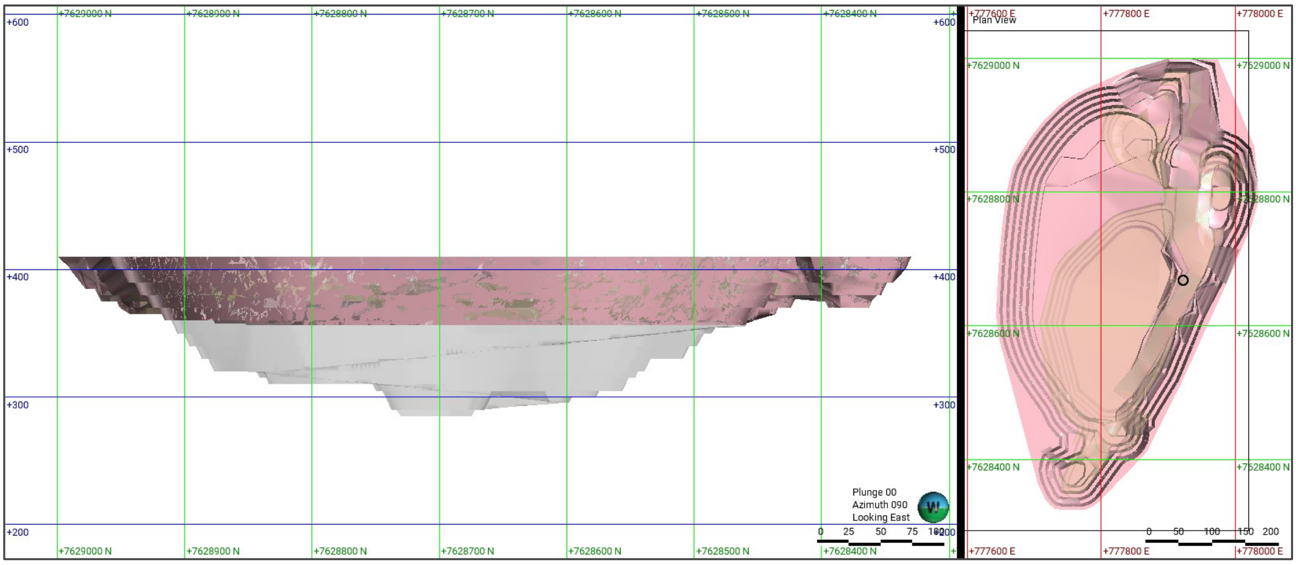


**Figure 2: Runway – Stage 4 pit geometry in pink, Stage 5 pit geometry in grey**

# 3. Methods

## 3.1 Analytical program

The samples were tested for a selection of analytes as outlined in Table 3. The testwork was undertaken by Intertek Genalysis (Intertek).

**Table 3: Geochemical testwork**

| Characteristic | Parameters and specific tests |
|---|---|
| Natural pH and salinity | pH, EC on a 1:2 solid/water slurry |
| Sulfur forms | Total sulfur (total-S) |
| Acid generation | Net acid generation pH (NAGpH) |

## 3.2 Geochemical data analysis

The data analysis was limited to estimating the potential acid generation of materials using $pH_{1:2}$, NAGpH and total sulfur (Table 4).

The saline drainage (SD) potential of materials was estimated using the $EC_{1:2}$. Risk classification for SD potential was assessed based on use and receptors such as irrigation (Table 5) for context. The uses and associated receptors should be aligned with the site's long-term strategy and the regulator's advice.

**Table 4: Preliminary screening criteria based on Total-S, NAPP and NAG test data (DFAT, 2016)**

| | | | Amira System | | Price System |
|---|---|---|---|---|---|
| | Total-S (%S) | $pH_{1:2}$ (pH Unit) | NAGpH (pH Unit) | NAPP Value (kg $H_2SO_4$/t) | NPR |
| Existing Acidity | | <5.5 | | | |
| Potentially Acid Forming (PAF) | | | < 4.5 | ≥ 10 | <2 |
| PAF-Low Capacity (PAF-LC) | | | <4.5 | <10 | |
| Non-Acid Forming (NAF) | <0.1 | | ≥ 4.5 | < 0 (negative) | ≥2 |
| Acid Consuming (ACM) | | | ≥ 4.5 | < -100 | |
| Uncertain (UC-NAF) | | | ≥ 4.5 | ≥ 0 (positive) | |
| Uncertain (UC-PAF) | | | < 4.5 | < 0 (negative) | |

**Table 5: Guidance on additional characterisation for water usage for irrigation (DMP, 2016)**

| EC (µS/cm) | Suitability for use |
|---|---|
| 0-400 | Suitable for topsoil growth medium |
| 400-1600 | Suitable for some salt-tolerant species |
| >1600 | May not be suitable for growth medium |

# 4. Geochemical Data Interpretation

## 4.1 Drilling Database Sulfur Assessment - Stage 5

The drilling database was assessed to determine the spatial coverage of drillholes across the deposit. The drilling database was "tagged" with the planned pit shells and only total sulfur content in the Waste (cut-off grade Fe 45%) was considered. The datasets for stage 5 are considered comprehensive across both pits and are presented as box and whisker plots for the major lithologies (>5%) in Figure 3 and Figure 4. Waste rock sulfur contents across lithologies for the Stage 5 pits are presented in Table 6. The spatial distribution of the sulfur across the pits is presented in Figure 5 and Figure 6

The data shows that 90.5% and 100% of the sulfur measurements for Sparrow and Runway were less than 0.1% TS which is a conservative cut-off value used in the absence of NAGpH and ANC measurements. The Sparrow pit figure (Figure 5) show that some areas of the pit are enriched in sulfur, in particular on the edges of the pit, where shale is located.

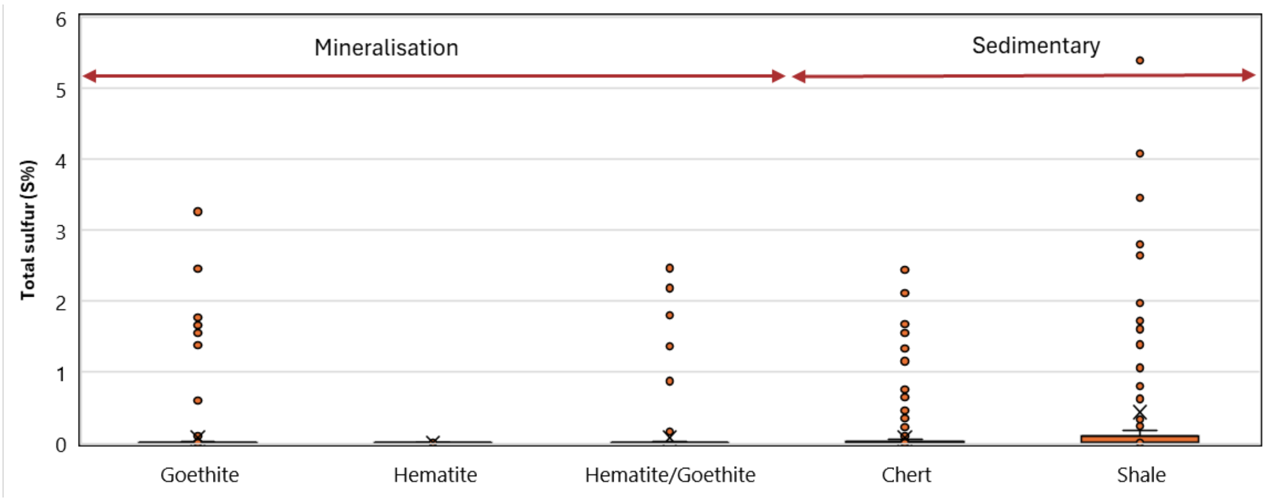


**Figure 3: Box and Whiskers plot for Sparrow, stage 5 data major lithologies**

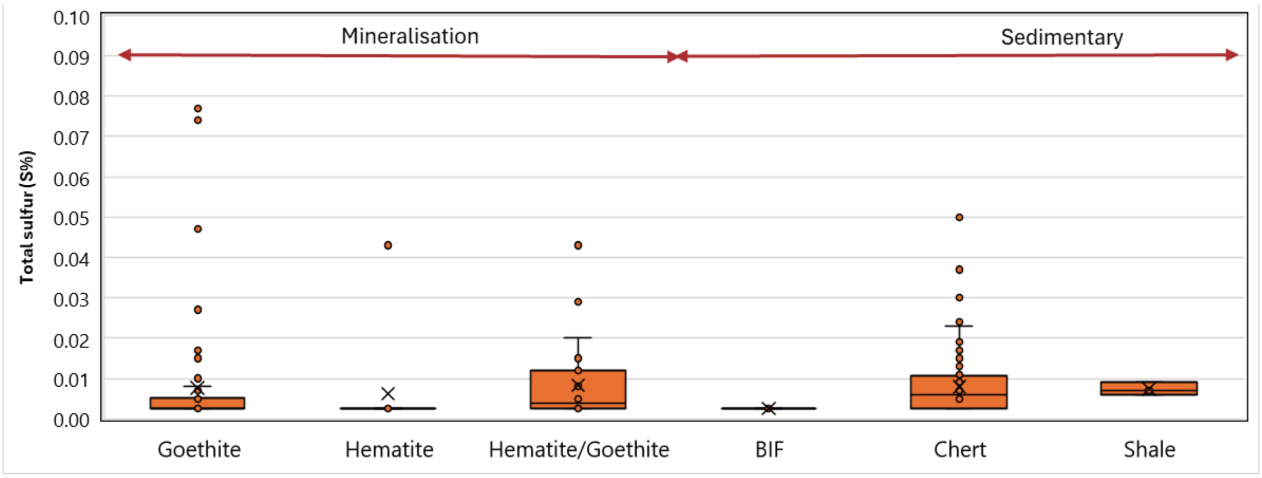


**Figure 4: Box and Whiskers plot for Runway, stage 5 data major lithologies**

**Table 6: Waste rock sulfur content across lithologies for the Sparrow and Runway Stage 5 pits (major lithologies in bold)**

| | | Sparrow | | | Runway South | | |
|---|---|---|---|---|---|---|---|
| | | **Total samples** | **Median S%** | **Maximum S%** | **Total samples** | **Median S%** | **Maximum S%** |
| Regolith | Saprolite | 11 | 0.003 | 0.021 | 9 | 0.003 | 0.007 |
| | Laterite | 1 | 0.012 | 0.012 | | | |
| Mineralisation | **Goethite** | **224** | **0.007** | **3.3** | **58** | **0.003** | **0.077** |
| | **Hematite/Goethite** | **129** | **0.006** | **2.5** | **30** | **0.004** | **0.043** |
| | **Hematite** | **48** | **0.003** | **0.038** | **11** | **0.003** | **0.043** |
| | Limonite | | | | 1 | 0.006 | 0.006 |
| Sedimentary | **Chert** | **346** | **0.007** | **2.4** | **84** | **0.006** | **0.050** |
| | **Shale** | **103** | **0.011** | **5.4** | 3 | 0.007 | 0.009 |
| | **BIF** | 8 | 0.003 | 0.008 | **9** | **0.003** | **0.003** |
| | Sandstone | | | | 4 | 0.004 | 0.005 |
| | Goethite | 1 | 0.011 | 0.011 | | | |
| Igneous | Basalt | 1 | 2 | 2 | | | |
| Veining | Quartz | 6 | 0.063 | 0.100 | 2 | 0.004 | 0.005 |

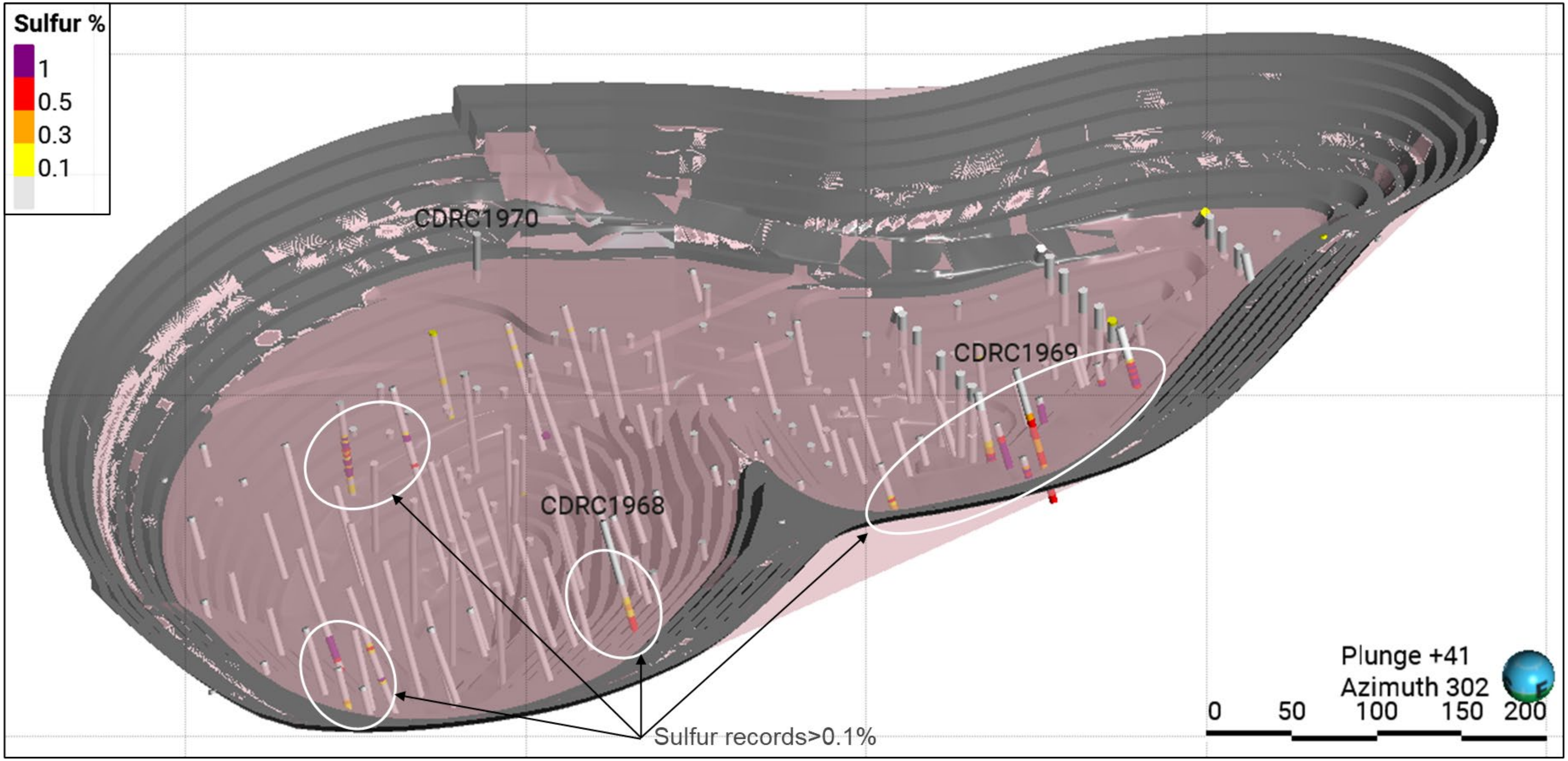


**Figure 5: Sulfur distribution within the Sparrow Pit (looking NW) - Stage 4 (pink) and Stage 5 (grey)**

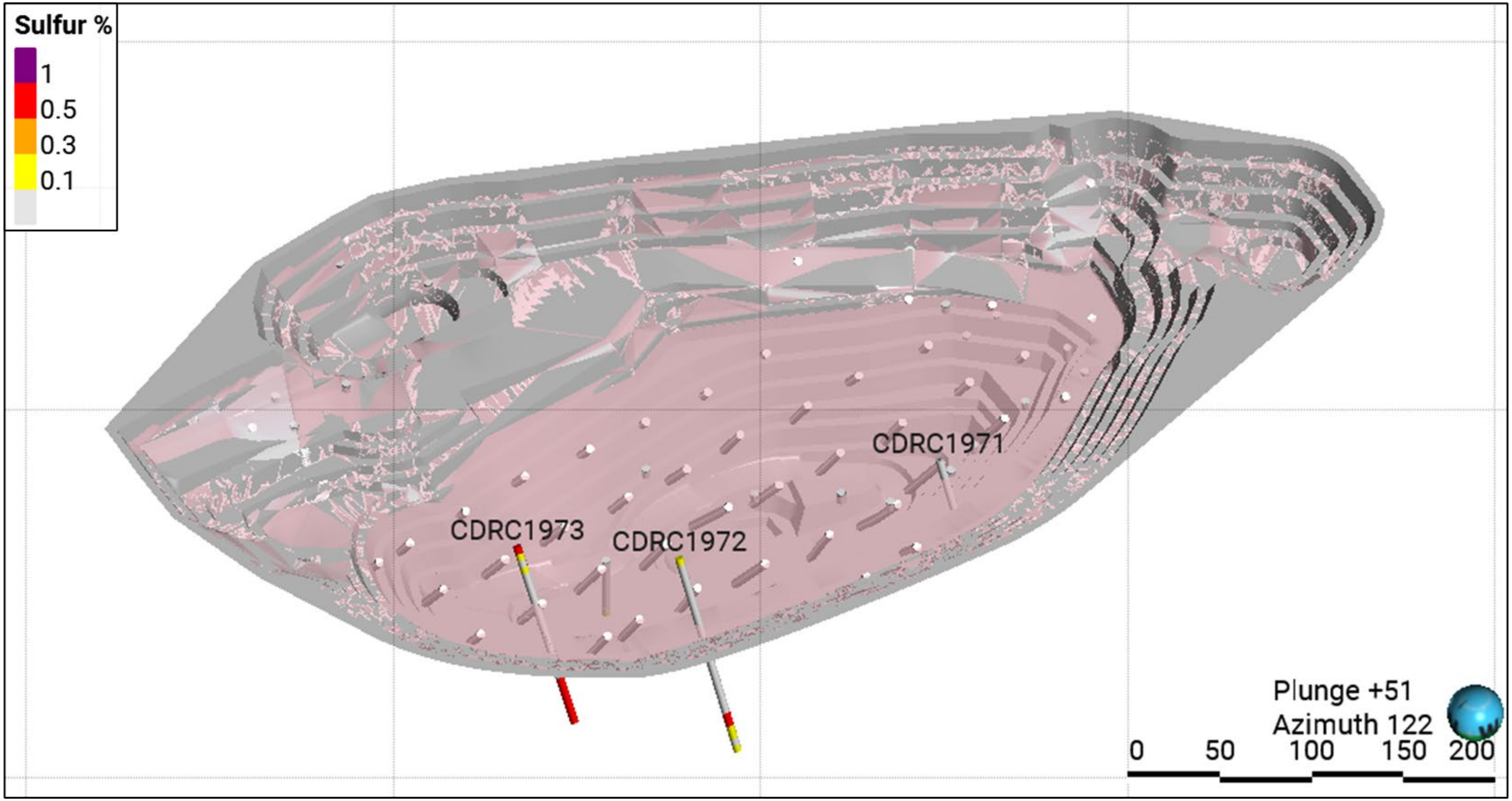


**Figure 6:** **Sulfur distribution within the Runway Pit (looking East) - Stage 4 (pink) and Stage 5 (grey)**

## 4.2 Sulfur Block Model Assessment-Stage 5

The sulfur block model was reviewed for comparison with the sulfur data from the drilling database; the data has been summarised in Table 7. The comparison shows that there are discrepancies between the datasets, this may be due to how the data is extrapolated in the block model with higher sulfur grades being extended into specific areas of the pit where drilling intercepts may be lacking. The same observations were made for Stage 4 (Mine Earth, 2024a).

**Table 7: Sulfur data comparison between block model and drilling database-Stage 5**

| Total Sulfur | Sparrow (%) | | Runway (%) | |
|---|---|---|---|---|
| | Drilling Database | Block Model | Drilling Database | Block Model |
| <0.1% | 90.5% | 83.5% | 100% | 95% |
| 0.1-0.3% | 3.2% | 9.9% | | 1% |
| 0.3-0.5% | 0.8% | 3.1% | | 0% |
| >0.5% | 5.6% | 3.6% | | 4% |

## 4.3 Stage 5 – Preliminary Geochemical Analysis

### 4.3.1 Drillholes

Six reverse circulation holes (three per deposit) were drilled to collect samples for geochemical testwork. The locations of these drillholes (with geology) are presented in Figure 7 and Figure 8 and the downhole logs of the geology and intersections with the pit stages are presented in Figure 9.

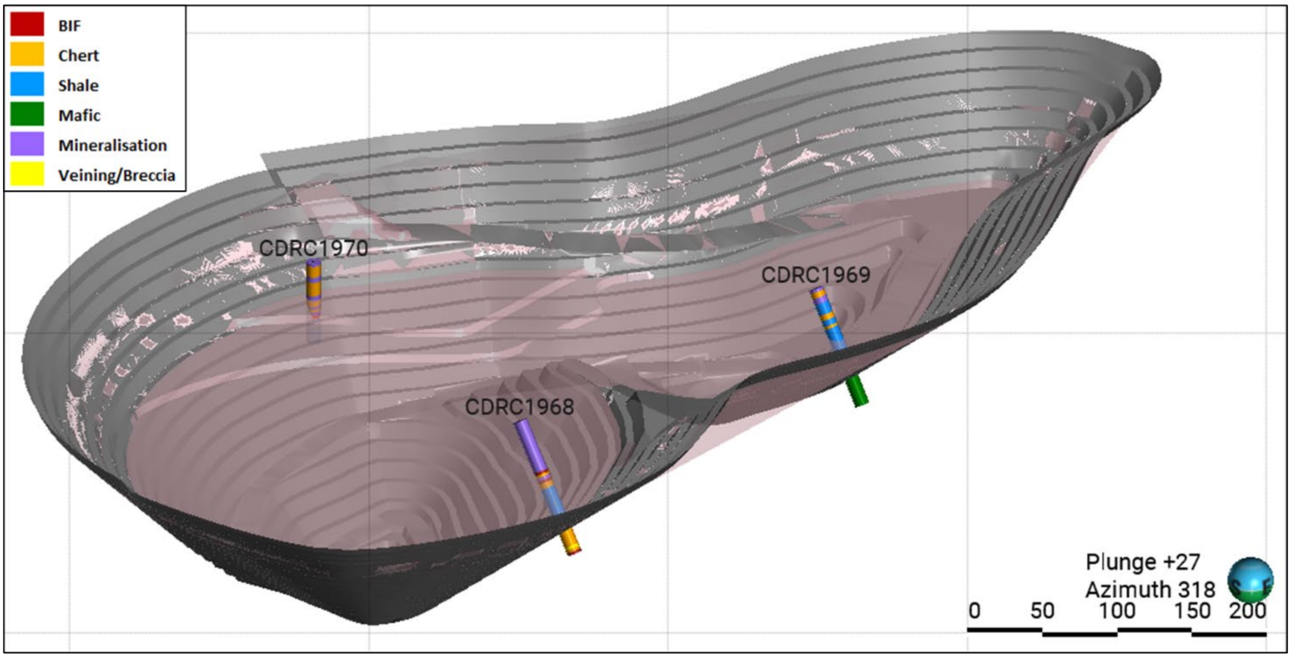


**Figure 7: Geochemical drillholes within Sparrow Pit (looking NW) - Stage 4 (pink), and Stage 5 (grey)**

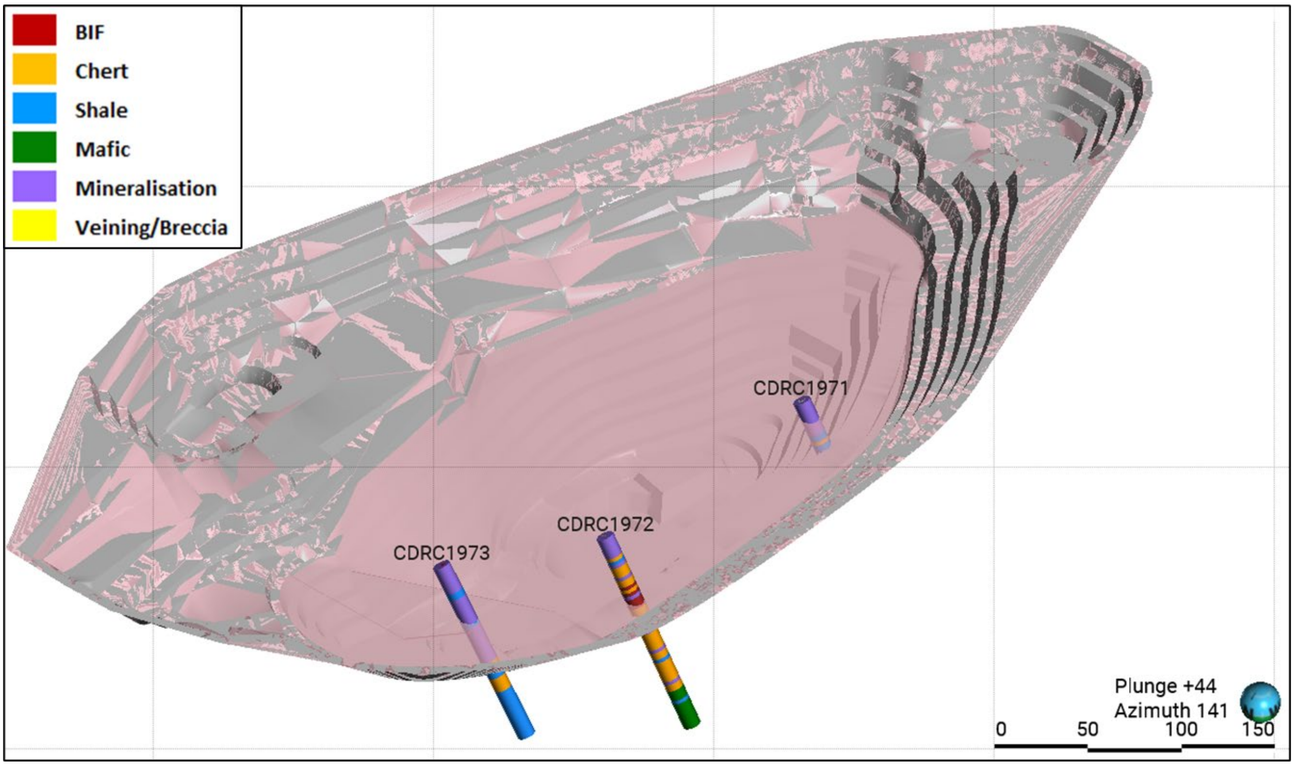


**Figure 8: Geochemical drillholes within Runway Pit (looking SE) - Stage 4 (pink) and Stage 5 (grey)**

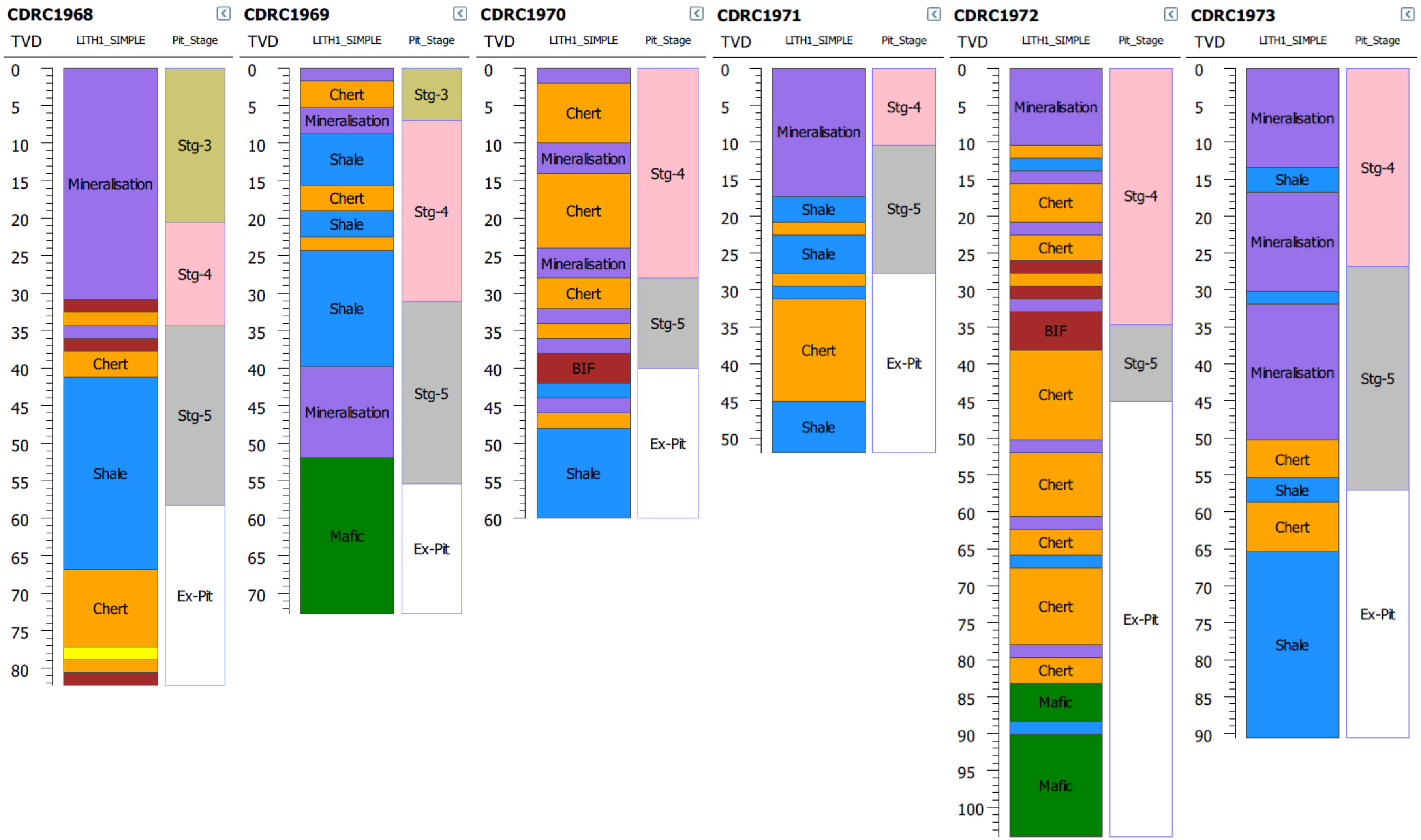


**Figure 9: Downhole logs of Sparrow (CDRC-1968, -69, -70) and Runway (CDRC-1971, -72, -73) drillholes**

Notes: TVD: True Vertical Depth
CDRC1970 was collared from surface, whilst CDRC1968 and CDRC1969 were collared from within the established pit
Mineralisation regroups hematite and goethite

### 4.3.2 Data Analysis - Existing and potential acidity ($pH_{1:2}$ and NAGpH), total sulfur and $EC_{1:2}$

Depth profiles for $pH_{1:2}$, NAGpH, total sulfur, and $EC_{1:2}$, for the Sparrow and Runway drillholes are presented by depth in Figure 10 and Figure 11. with tabulated data provided in Appendix C. These four parameters in combination provide guidance on the material's potential to release acid or generate saline leachates, using the following threshold values (Table 4, section 3.2):

- $pH_{1:2}$ <5.5: material contains existing acidity.
- NAGpH <4.5: material is likely PAF.
- Total S > 0.1% conservative sulfur cut-off.
- $EC_{1:2}$ > 400 µS/cm salt tolerant species only.

The analysis of the results indicates:

- Sparrow:
  - All shale samples except one had pH values less than pH 5.5, NAGpH values less than 4.5 and TS above 0.2%, indicating that shale and some mineralisation in this area of the pit contain existing acidity and sulfidic materials which could potentially generate AMD.
  - $EC_{1:2}$ for the low pH samples ranged from 173 to 1027 µS/cm, indicating that some salts/metals are likely to be released.
  - Samples from CDRC-1970 (opposite to CDRC1968 and CDRC-1969) can all be classed as NAF.
- Runway
  - The tests results for all Runway samples indicate that the Stage 5 material will be NAF and are unlikely to generate saline drainage.

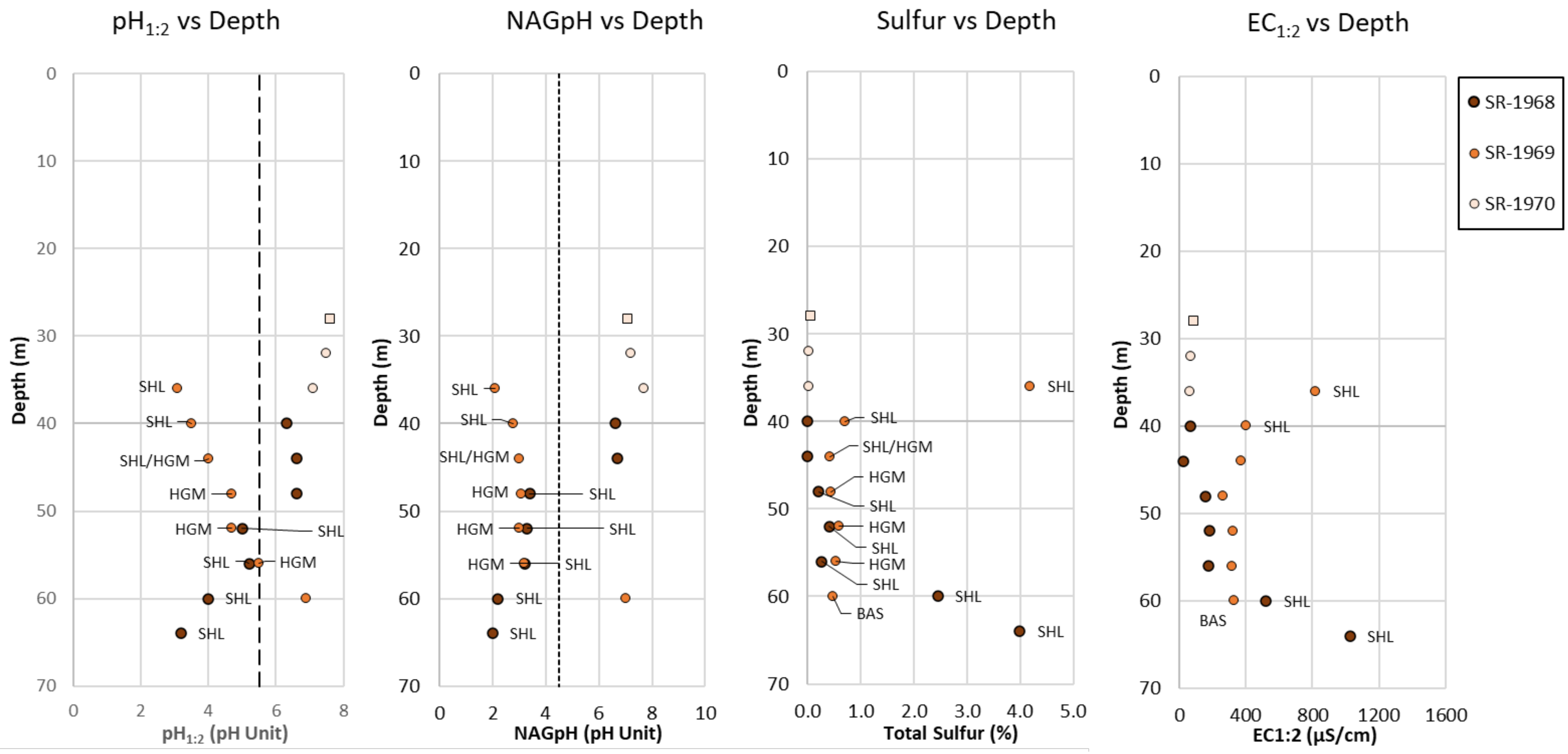


**Figure 10: pH1:2, NAGpH, total sulfur and EC1:2 plots by depth across the Sparrow Stage 5 pit. Squares represent ore samples**

Note: HGM: hematite/goethite medium, SHL: shale, CHT: chert. BAS; Basalt

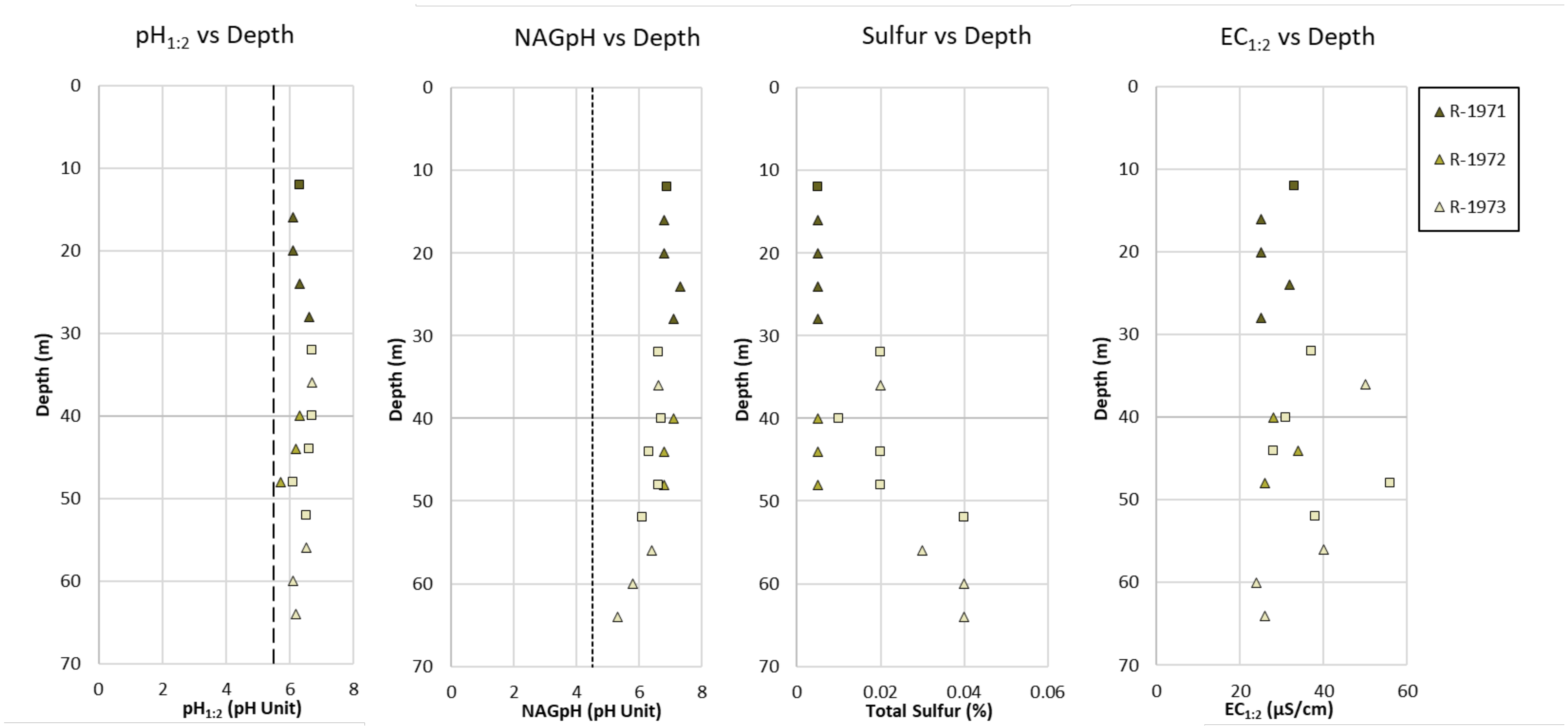


**Figure 11:** pH$_{1:2}$, NAGpH, total sulfur and EC$_{1:2}$ plots by depth across the Runway Stage 5 pit. Circles represent ore samples

# 5. Conclusions

## 5.1 Findings

This Stage 5 study review focused on the total sulfur data contained in the drilling database and preliminary geochemical characterisation tests run on 34 samples collected from six drillholes positioned on the edge of the pits. These six drillholes traverse the pit from the surface to below Stage 5 and were tested for preliminary geochemical characterisation.

The data review and the analytical work show that:

- The waste material presents a low risk of AMD:
  - 90% of the sulfur data recorded for Sparrow is below the conservative cut-off value of 0.1%S, and
  - 100% of the sulfur data recorded for Runway is below 0.1%; all waste materials at the Runway pit can be classed as NAF.
- The Sparrow pit contains some pockets of sulfurous material that may be sulfidic:
  - 6.4% of the material has a sulfur content above 0.3% and should be classed as PAF
  - the highest sulfur content are found in the shale and the chert, along the eastern side of the pit.
  - the low NAGpH values recorded in the shale drillhole samples indicate the potential for AMD and the low $pH_{1:2}$ values indicate existing acidity.
- The waste material that will be extracted from the Runway pit is non-acid forming.
- There are discrepancies between the sulfur data presented in the block model and the sulfur data collected in the drillhole database. This may affect the design of PAF cells.

## 5.2 Recommendations for material management

Future work should aim at confirming the findings of this study and addressing spatial gaps in the geochemical characterisation. The following recommendations are made:

- Sample and analyse Stage 5 material from the 2023 and 2024 drilling campaigns.
- Consider developing a sampling, analysis and quality program (SAQP) to support the Stage 5 validation program during operation (also recommended for Stage 4). The program should consider:
  - Standard sampling frequency of one sample per ~400 $m^3$.
  - Standard analysis to include TS, $pH_{1:2}$, $EC_{1:2}$ and NAGpH.
  - Detailed geochemical characterisation to be undertaken on 1 in 10 samples to increase the characterisation of the different lithologies.
- Increase the monitoring of the material at the interface between Stages 4 and 5, to delineate and segregate between above-water table and below-water table material.
- Determine the source of discrepancies between the block model and the drilling database.
- Estimate the AMD release by undertaking tests to understand how the material will oxidise:
  - Oxygen Consumption Rate at 30ºC ($OCR_{30^oC}$) / Carbon-Dioxide Release Rate at 30ºC ($CDRR_{30^oC}$) to provide an estimation of sulfide oxidation rates in a short timeframe (1 to 4 weeks).
  - Kinetic geochemical testing of these materials to provide a better understanding of long-term sulfide reactivity, neutralisation potential, salt and metal(loid) release rate, and leaching behaviour of the material. This test may run for over a year

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# Appendix A

## Stage 3 and Stage 4 Waste Characterisation Studies Summary

## A.1 Previous Waste Rock Characterisation

A number of waste rock characterisation assessments have been conducted at the Project over the course of its development. MWH (2016) describes the initial characterisation work, selecting discrete samples from existing drillholes across Sparrow (Split Rock), Shark Gully, Razorback and Runway, both within and outside of the planned pits.

The aim of Mine Earth (2018) was to resolve knowledge gaps from the MWH (2016) assessment. No sample material remained from the existing drillholes, so this assessment was required to analyse chip-tray samples.

The aim of Mine Earth (2020) was to characterise the geochemical and physical properties of mine waste expected to be produced from the Sparrow, Razorback, Shark Gully and Runway deposits. Due to the sample limitations of Mine Earth (2018), eighteen additional drillhole samples were analysed from across the four pits, to add to the current geochemical knowledge.

### A.1.1 Stage 3

The geochemical outcomes of Mine Earth (2020) for the Stage 3 pits shells showed:

- All waste rocks within the planned pit shells, including within a 10 m buffer zone outside of the pit shells, were classified as NAF.
- Mercury (Hg) enrichment greater than 1 ppm was identified in a small number of Phase 1 and Phase 2 samples. Water extraction testwork identified that enriched Hg occurs as geochemically stable forms with restricted solubility (typically below detection limit) at circum-neutral pH, consistent with the hydrogeochemistry of Hg. There was a general association between Hg enrichment and the occurrence of carbonaceous shale.

**Table A.1: Distribution of detailed geochemical samples across the historic studies**

| Study | Sparrow | Razorback | Shark Gully | Runway |
|---|---|---|---|---|
| MWH 2018 | 3 | 0 | 4 | 9 |
| Mine Earth 2016 | 4 | 9 | 2 | 7 |
| Mine Earth 2020 | 9 | 2 | 1 | 6 |
| **Total Samples** | **16** | **11** | **7** | **22** |

The recommendations from Mine Earth (2020) for the Stage 3 pits shells included:

- All waste rock types (BIF, chert, shale and clastic siltstone) from the pit shells of all deposits have been classified as NAF and do not require management from an acid-formation perspective.
- BIF and chert will make up the bulk (65-100%) of the waste rock volume to be mined from all deposits. BIF and chert will likely demonstrate high erosional stability on final WRD slopes and should provide a useful source of durable rock armour.
- BIF and chert should be managed during mining so that final WRD slopes are comprised of these rock types.
- Siltstone should be managed so that it is not placed on final WRD slopes, given it is likely to display moderate erosional stability.

Shale is not suitable for placement on final WRD surfaces given its low erosional stability. Furthermore, given its limited volume and potential to contain geochemically stable Hg enrichment, shale should be conservatively buried 10 m from final WRD surfaces to minimise the potential for plant and animal uptake of Hg.

### A.1.2 Stage 4

The Stage 4 drilling database was analysed for total sulfur and 17 samples from six drillholes (3 per pit) were analysed for detailed geochemistry (Mine Earth, 2024a).

The study identified that the material from both pits could be classed as NAF due to low percentage of sulfur values above 0.1% recorded. The detailed geochemical analysis also showed low risk of saline drainage; however this was undertaken on samples that were not spatially representative of the pit.

The findings were summarised as follows:

- Material from the Stage 4 Runway pit was classed as NAF with 99.9 % of the samples from the drillhole database below 0.1%S.
- Material from the Stage 4 Sparrow pit was classed as NAF with 94 % of the samples from the drillhole database below 0.1%TS, and 99.7% below 0.3%S.
- Sulfur content was highest at surface and depth, and one sample collected at the interface between the Stage 4 and Stage 5 Sparrow pits was classed as PAF This highlights the need for a clear distinction between two domains: above water table and below water table.
- Rock:water (1:2) extraction showed that saline drainage is unlikely, with only one leachate sample having an electrical conductivity (EC) value above 1,600 µS/cm. Metal(loid) concentrations were below the drinking water quality criteria for livestock but above the ANZG criteria for 95% species protection.
- Discrepancies between the sulfur block model and the drilling database were observed due to the extrapolation of sulfur data into areas where drilling information was limited.

The recommendations were as follows:

- Stage 4 waste rock management will not require the construction of PAF cells. However, it was recommended to allow for a buffer at the interface of Stage 4 and Stage 5 where sulfur content rises.
- The inclusion of domains that define above-water table and below-water table zones within the block model would also limit the extrapolation of high sulfur into the BWT zone.
- Regular monitoring of the material extracted should be undertaken to validate the findings, through the development of a SAQP.

# Appendix B

## Stage 5 lithological distribution within the drilling database

**Table B.1: Stage 5 lithological distibution**

| Group | Subgroup | Lithology | Code | Sparrow %distribution | Runway %distribution |
|---|---|---|---|---|---|
| Mineralisation | Goethite | Goethite Friable | GOF | 0.12 | |
| | | Goethite Moderate | GOM | 4.91 | 16.6 |
| | | Goethite Hard | GOH | 20.8 | 10.4 |
| | | Goethite Powdery | GOP | | 0.5 |
| | Hematite | Hematite Friable | HEF | 0.4 | |
| | | Hematite Moderate | HEM | 3.6 | 0.9 |
| | | Hematite Hard | HEH | 1.5 | 4.3 |
| | | Hematite Powdery | HEP | 0.1 | |
| | Hematite/Goethite | Hematite/Goethite Hard | HGH | 5.1 | 5.7 |
| | | Hematite/Goethite Moderate | HGM | 9.9 | 8.5 |
| | | Hematite/Goethite Friable | HGF | 0.1 | |
| | Limonite | Limonite – Friable | LMF | | 0.5 |
| Regolith | Saprolite | Clay | CLY | 0.9 | 1.4 |
| | Saprolite Clay | Saprolite Clay | SAP | | 2.8 |
| | Laterite | Laterite | LAT | 0.1 | |
| Sedimentary | BIF | Banded Iron Formation | BIF | 0.9 | 2.8 |
| | | Banded iron with Goethite | BIG | | 0.9 |
| | | Banded Iron with Hematite | BIH | | 0.5 |
| | Chert | Chert | CHT | 31.6 | 26.5 |
| | | Chert-Goethite | CHG | 8 | 13.3 |
| | Shale | Shale | SHL/SHLE | 5.2 | |
| | | Goethite Hard | GOH | 0.1 | |
| | | Shale Ferrugineous | SHF | 2.0 | |
| | | Shale Carbonaceous | CBS | 3.6 | |
| Igneous | Basalt | Basalt | BLT | 0.1 | |
| Veining | Quartz | Quartz | QTZ | 0.7 | 0.9 |

# Appendix C

## $pH_{1:2}$, $EC_{1:2}$, NAGpH and Total Sulfur Results

**Table C.1: Sparrow pit - $pH_{1:2}$, $EC_{1:2}$, NAGpH and Total Sulfur Results**

| HoleID | sampno | From (m) | To (m) | Pit Stage | Lithology | pH | EC (µS/cm) | S(%) | NAGpH | Grade |
|---|---|---|---|---|---|---|---|---|---|---|
| CDRC1968 | SJR001 | 0 | 4 | Stg-4 | GOM | 5.9 | 57 | <0.01 | 7.1 | Ore |
| | SJR002 | 4 | 8 | Stg-4 | GOM | 5.2 | 36 | <0.01 | 6.8 | Ore |
| | SJR003 | 8 | 12 | Stg-4 | GOM | 6.2 | 46 | <0.01 | 6.8 | Ore |
| | SJR004 | 12 | 16 | Stg-4 | GOM | 5.8 | 55 | <0.01 | 6.8 | Ore |
| | SJR005 | 16 | 20 | Stg-4 | GOM | 5.2 | 39 | <0.01 | 6.4 | Ore |
| | SJR006 | 20 | 24 | Stg-4 | GOM | 5.1 | 28 | <0.01 | 6.6 | Ore |
| | SJR007 | 24 | 28 | Stg-4 | GOM | 5.6 | 83 | <0.01 | 6.7 | Ore |
| | SJR008 | 28 | 32 | Stg-4 | HGM/GOM | 6.6 | 54 | <0.01 | 6.8 | Ore |
| | SJR009 | 32 | 36 | Stg-4 | GOM/HGM | 5.8 | 24 | <0.01 | 6.9 | Ore |
| | SJR010 | 36 | 40 | Stg-4 | BIF/CHT | 6.3 | 49 | <0.01 | 6.8 | Ore |
| | SJR011 | 40 | 44 | Stg-5 | GOM/BIF | 6.3 | 63 | <0.01 | 6.6 | Ore |
| | SJR012 | 44 | 48 | Stg-5 | CHT | 6.6 | 25 | <0.01 | 6.7 | Waste |
| | SJR013 | 48 | 52 | Stg-5 | SHL | 6.6 | 159 | 0.21 | 3.4 | Waste |
| | SJR014 | 52 | 56 | Stg-5 | SHL | 5.0 | 183 | 0.41 | 3.3 | Waste |
| | SJR015 | 56 | 60 | Stg-5 | SHL | 5.2 | 173 | 0.27 | 3.2 | Waste |
| | SJR016 | 60 | 64 | Stg-5 | SHL | 4.0 | 522 | 2.45 | 2.2 | Waste |
| | SJR017 | 64 | 68 | Stg-5 | SHL | 3.2 | 1027 | 3.99 | 2.0 | Waste |
| | SJR018 | 68 | 72 | Out | SHL | 3.8 | 507 | 0.91 | 2.8 | Waste |
| | SJR019 | 72 | 76 | Out | SHL | 4.1 | 519 | 1.50 | 2.4 | Waste |
| | SJR020 | 76 | 80 | Out | SHL/CHT | 5.4 | 143 | 0.13 | 3.8 | Waste |
| | SJR021 | 80 | 84 | Out | CHT | 6.1 | 46 | 0.03 | 5.0 | Waste |
| | SJR022 | 84 | 88 | Out | CHT | 5.7 | 143 | 0.27 | 3.2 | Waste |
| | SJR023 | 88 | 92 | Out | CHT/QTZ | 6.1 | 125 | 0.07 | 4.5 | Waste |
| | SJR024 | 92 | 96 | Out | CHT/BIF | 2.1 | 133 | 0.05 | 5.6 | Waste |
| CDRC1969 | SJR025 | 0 | 4 | Stg-4 | HGM/CHT | 6.2 | 32 | <0.01 | 7.2 | Ore |
| | SJR026 | 4 | 8 | Stg-4 | CHT/GOM | 5.7 | 24 | <0.01 | 6.7 | Ore |
| | SJR027 | 8 | 12 | Stg-4 | GOM/SHL | 6.6 | 28 | 0.03 | 6.6 | Waste |
| | SJR028 | 12 | 16 | Stg-4 | SHL | 7.6 | 93 | 0.02 | 7.4 | Waste |

| HoleID | sampno | From (m) | To (m) | Pit Stage | Lithology | pH | EC (µS/cm) | S(%) | NAGpH | Grade |
|---|---|---|---|---|---|---|---|---|---|---|
| | SJR029 | 16 | 20 | Stg-4 | SHL/CHT | 8.8 | 119 | 0.03 | 8.0 | Waste |
| | SJR030 | 20 | 24 | Stg-4 | CHT/SHL | 8.3 | 44 | 0.04 | 7.1 | Waste |
| | SJR031 | 24 | 28 | Stg-4 | SHL/CHT | 9.3 | 130 | 0.02 | 7.6 | Waste |
| | SJR032 | 28 | 32 | Stg-4 | SHL | 7.3 | 429 | 0.42 | 7.2 | Waste |
| | SJR033 | 32 | 36 | Stg-4 | SHL | 3.5 | 625 | 2.15 | 2.3 | Waste |
| | SJR034 | 36 | 40 | Stg-5 | SHL | 3.1 | 816 | 4.18 | 2.1 | Waste |
| | SJR035 | 40 | 44 | Stg-5 | SHL | 3.5 | 404 | 0.70 | 2.8 | Waste |
| | SJR036 | 44 | 48 | Stg-5 | SHL/HGM | 4.0 | 373 | 0.42 | 3.0 | Waste |
| | SJR037 | 48 | 52 | Stg-5 | HGM | 4.7 | 265 | 0.44 | 3.1 | Waste |
| | SJR038 | 52 | 56 | Stg-5 | HGM | 4.7 | 322 | 0.60 | 3.0 | Waste |
| | SJR039 | 56 | 60 | Stg-5 | HGM | 5.5 | 319 | 0.53 | 3.2 | Waste |
| | SJR040 | 60 | 64 | Stg-5 | BAS | 6.9 | 332 | 0.48 | 7.0 | Waste |
| | SJR041 | 64 | 68 | Out | BAS | 7.1 | 267 | 0.44 | 7.1 | Waste |
| | SJR042 | 68 | 72 | Out | BAS | 6.4 | 549 | 2.91 | 4.5 | Waste |
| | SJR043 | 72 | 76 | Out | BAS | 5.5 | 515 | 3.97 | 4.3 | Waste |
| | SJR044 | 76 | 80 | Out | BAS | 6.9 | 291 | 0.85 | 6.7 | Waste |
| | SJR045 | 80 | 84 | Out | BAS | 7.4 | 243 | 0.55 | 8.2 | Waste |
| CDRC1970 | SJR046 | 0 | 4 | Stg-4 | GOM/CHT | 7.9 | 511 | 0.04 | 9.5 | Waste |
| | SJR047 | 4 | 8 | Stg-4 | CHT | 8.7 | 1089 | 0.06 | 8.8 | Waste |
| | SJR048 | 8 | 12 | Stg-4 | CHT/GOM | 8.5 | 963 | 0.04 | 8.2 | Waste |
| | SJR049 | 12 | 16 | Stg-4 | GOM/CHT | 8.3 | 836 | 0.03 | 8.0 | Waste |
| | SJR050 | 16 | 20 | Stg-4 | CHT | 8.1 | 333 | 0.04 | 7.4 | Waste |
| | SJR051 | 20 | 24 | Stg-4 | CHT | 7.8 | 125 | 0.04 | 7.3 | Waste |
| | SJR052 | 24 | 28 | Stg-4 | HGM/GOM | 7.6 | 56 | 0.03 | 6.9 | Waste |
| | SJR053 | 28 | 32 | Stg-5 | CHT | 7.6 | 90 | 0.07 | 7.1 | Waste |
| | SJR054 | 32 | 36 | Stg-5 | GOM/CHT | 7.5 | 68 | 0.02 | 7.2 | Waste |
| | SJR055 | 36 | 40 | Stg-5 | GOM/BIF | 7.1 | 62 | 0.02 | 7.7 | Waste |
| | SJR056 | 40 | 44 | Out | BIF/SHL | 6.9 | 54 | 0.04 | 7.0 | Waste |
| | SJR057 | 44 | 48 | Out | HGF/CHT | 6.5 | 83 | 0.16 | 3.7 | Waste |
| | SJR058 | 48 | 52 | Out | SHL | 7.0 | 196 | 0.40 | 3.4 | Waste |

| HoleID | sampno | From (m) | To (m) | Pit Stage | Lithology | pH | EC (µS/cm) | S(%) | NAGpH | Grade |
|---|---|---|---|---|---|---|---|---|---|---|
| | SJR059 | 52 | 56 | Out | SHL | 7.3 | 217 | 0.45 | 3.1 | Waste |
| | SJR060 | 56 | 60 | Out | SHL | 6.8 | 411 | 1.35 | 2.5 | Waste |
| CDRC1971 | SJR061 | 0 | 4 | Stg-4 | HGM | 7.0 | 79 | 0.02 | 6.7 | Ore |
| | SJR062 | 4 | 8 | Stg-4 | HGM/HGF | 6.8 | 66 | 0.01 | 6.7 | Ore |
| | SJR063 | 8 | 12 | Stg-4 | HGM/GOM | 6.7 | 39 | <0.01 | 7.2 | Ore |
| | SJR064 | 12 | 16 | Stg-5 | GOM | 6.3 | 33 | <0.01 | 6.9 | Ore |
| | SJR065 | 16 | 20 | Stg-5 | GOM | 6.1 | 25 | <0.01 | 6.8 | Waste |
| | SJR066 | 20 | 24 | Stg-5 | SHL | 6.1 | 25 | <0.01 | 6.8 | Waste |
| | SJR067 | 24 | 28 | Stg-5 | CHT/SHL | 6.3 | 32 | <0.01 | 7.3 | Waste |
| | SJR068 | 28 | 32 | Stg-5 | SHL | 6.6 | 25 | <0.01 | 7.1 | Waste |
| | SJR069 | 32 | 36 | Out | CHT/SHL | 6.2 | 24 | <0.01 | 7.2 | Waste |
| | SJR070 | 36 | 40 | Out | CHT | 7.3 | 19 | <0.01 | 6.8 | Waste |
| | SJR071 | 40 | 44 | Out | CHT | 6.6 | 31 | <0.01 | 7.2 | Waste |
| | SJR072 | 44 | 48 | Out | CHT | 6.5 | 36 | <0.01 | 7.1 | Waste |
| | SJR073 | 48 | 52 | Out | CHT | 6.4 | 18 | <0.01 | 6.7 | Waste |
| | SJR074 | 52 | 56 | Out | SHL | 2.9 | 1643 | 14.02 | 2.3 | Waste |
| | SJR075 | 56 | 60 | Out | SHL | 3.8 | 272 | 9.85 | 2.1 | Waste |
| CDRC1972 | SJR076 | 0 | 4 | Stg-4 | HGM | 7.0 | 91 | 0.26 | 4.2 | Waste |
| | SJR077 | 4 | 8 | Stg-4 | GOF/GOM | 7.6 | 97 | 0.03 | 6.8 | Waste |
| | SJR078 | 8 | 12 | Stg-4 | GOM | 7.4 | 44 | <0.01 | 7.0 | Waste |
| | SJR079 | 12 | 16 | Stg-4 | CHT/SHL | 7.2 | 27 | <0.01 | 6.7 | Waste |
| | SJR080 | 16 | 20 | Stg-4 | HGM/CHT | 6.9 | 23 | 0.01 | 6.5 | Waste |
| | SJR081 | 20 | 24 | Stg-4 | CHT | 6.8 | 50 | 0.02 | 7.0 | Waste |
| | SJR082 | 24 | 28 | Stg-4 | GOM/CHT | 6.8 | 87 | 0.01 | 6.5 | Waste |
| | SJR083 | 28 | 32 | Stg-4 | CHT/BIF | 7.0 | 68 | <0.01 | 6.8 | Waste |
| | SJR084 | 32 | 36 | Stg-4 | CHT/BIF | 6.8 | 58 | <0.01 | 6.7 | Waste |
| | SJR085 | 36 | 40 | Stg-4 | HGM/BIF | 6.4 | 69 | <0.01 | 6.9 | Waste |
| | SJR086 | 40 | 44 | Stg-5 | BIF | 6.3 | 28 | <0.01 | 7.1 | Waste |
| | SJR087 | 44 | 48 | Stg-5 | CHT | 6.2 | 34 | <0.01 | 6.8 | Waste |
| | SJR088 | 48 | 52 | Stg-5 | CHT | 5.7 | 26 | <0.01 | 6.8 | Waste |

| HoleID | sampno | From (m) | To (m) | Pit Stage | Lithology | pH | EC (µS/cm) | S(%) | NAGpH | Grade |
|---|---|---|---|---|---|---|---|---|---|---|
| | SJR089 | 52 | 56 | Out | CHT | 6.2 | 23 | <0.01 | 6.7 | Waste |
| | SJR090 | 56 | 60 | Out | CHT/HGM | 6.4 | 19 | <0.01 | 6.8 | Waste |
| | SJR091 | 60 | 64 | Out | CHT | 6.1 | 14 | <0.01 | 6.4 | Waste |
| | SJR092 | 64 | 68 | Out | CHT | 6.4 | 24 | <0.01 | 6.6 | Waste |
| | SJR093 | 68 | 72 | Out | CHT/GOM | 6.3 | 33 | <0.01 | 6.3 | Waste |
| | SJR094 | 72 | 76 | Out | CHT | 6.6 | 27 | <0.01 | 6.3 | Waste |
| | SJR095 | 76 | 80 | Out | SHL/CHT | 6.4 | 24 | <0.01 | 6.2 | Waste |
| | SJR096 | 80 | 84 | Out | CHT | 6.3 | 30 | <0.01 | 6.4 | Waste |
| | SJR097 | 84 | 88 | Out | CHT | 6.4 | 24 | <0.01 | 6.2 | Waste |
| | SJR098 | 88 | 92 | Out | CHT/GOM | 6.3 | 35 | 0.04 | 4.7 | Waste |
| | SJR099 | 92 | 96 | Out | CHT | 7.4 | 32 | 0.02 | 5.3 | Waste |
| | SJR100 | 96 | 100 | Out | BAS | 3.7 | 697 | 2.95 | 2.3 | Waste |
| | SJR101 | 100 | 104 | Out | BAS/SHL | 5.9 | 117 | 0.54 | 3.8 | Waste |
| | SJR102 | 104 | 108 | Out | BAS | 6.4 | 74 | 0.29 | 4.2 | Waste |
| | SJR103 | 108 | 112 | Out | BAS | 6.7 | 57 | 0.15 | 6.8 | Waste |
| | SJR104 | 112 | 116 | Out | BAS | 6.8 | 59 | 0.07 | 7.0 | Waste |
| | SJR105 | 116 | 120 | Out | BAS | 6.8 | 72 | 0.28 | 7.1 | Waste |
| CDRC1973 | SJR106 | 0 | 4 | Stg-4 | HGM | 6.6 | 1517 | 0.73 | 3.2 | Waste |
| | SJR107 | 4 | 8 | Stg-4 | HEF | 6.7 | 567 | 0.19 | 4.9 | Waste |
| | SJR108 | 8 | 12 | Stg-4 | HGM | 7.2 | 51 | 0.03 | 7.0 | Waste |
| | SJR109 | 12 | 16 | Stg-4 | GOM | 6.8 | 81 | 0.11 | 6.8 | Waste |
| | SJR110 | 16 | 20 | Stg-4 | SHL | 6.8 | 43 | 0.05 | 6.6 | Waste |
| | SJR111 | 20 | 24 | Stg-4 | GOM | 6.8 | 36 | 0.04 | 6.7 | Waste |
| | SJR112 | 24 | 28 | Stg-4 | GOM | 6.7 | 33 | 0.04 | 6.6 | Ore |
| | SJR113 | 28 | 32 | Stg-4 | GOM | 6.8 | 35 | 0.02 | 6.6 | Ore |
| | SJR114 | 32 | 36 | Stg-5 | GOM | 6.7 | 37 | 0.02 | 6.6 | Ore |
| | SJR115 | 36 | 40 | Stg-5 | SHL/GOM | 6.7 | 50 | 0.02 | 6.6 | Waste |
| | SJR116 | 40 | 44 | Stg-5 | GOM | 6.7 | 31 | 0.01 | 6.7 | Ore |
| | SJR117 | 44 | 48 | Stg-5 | GOM | 6.6 | 28 | 0.02 | 6.3 | Ore |
| | SJR118 | 48 | 52 | Stg-5 | GOM | 6.1 | 56 | 0.02 | 6.6 | Ore |

| HoleID | sampno | From (m) | To (m) | Pit Stage | Lithology | pH | EC (µS/cm) | S(%) | NAGpH | Grade |
|---|---|---|---|---|---|---|---|---|---|---|
| | SJR119 | 52 | 56 | Stg-5 | GOM/GOF | 6.5 | 38 | 0.04 | 6.1 | Ore |
| | SJR120 | 56 | 60 | Stg-5 | GOF | 6.5 | 40 | 0.03 | 6.4 | Waste |
| | SJR121 | 60 | 64 | Stg-5 | CHT | 6.1 | 24 | 0.04 | 5.8 | Waste |
| | SJR122 | 64 | 68 | Stg-5 | CHT/SHL | 6.2 | 26 | 0.04 | 5.3 | Waste |
| | SJR123 | 68 | 72 | Out | SHL/CHT | 6.1 | 30 | 0.03 | 4.6 | Waste |
| | SJR124 | 72 | 76 | Out | CHT | 6.2 | 39 | 0.06 | 4.0 | Waste |
| | SJR125 | 76 | 80 | Out | CHT/SHL | 5.9 | 58 | 0.10 | 3.6 | Waste |
| | SJR126 | 80 | 84 | Out | SHL | 3.5 | 729 | 3.24 | 2.2 | Waste |
| | SJR127 | 84 | 88 | Out | SHL | 3.8 | 290 | 2.53 | 2.7 | Waste |
| | SJR128 | 88 | 92 | Out | SHL | 4.1 | 285 | 3.69 | 2.4 | Waste |
| | SJR129 | 92 | 96 | Out | SHL | 3.5 | 540 | 4.92 | 2.5 | Waste |
| | SJR130 | 96 | 100 | Out | SHL | 3.5 | 788 | 10.32 | 2.2 | Waste |
| | SJR131 | 100 | 104 | Out | SHL | 3.6 | 834 | 7.72 | 2.3 | Waste |
| | SJR132 | 104 | 108 | Out | SHL | 3.5 | 269 | 7.15 | 2.2 | Waste |