APPENDIX J
Open pit closure design and erosion assessment

Evolution MINING

EMM creating opportunities

Open Pit Continuation Project Open Pit Closure Design and Erosion Assessment

NSW Resource Regulator request for information

Cowal Gold Operations

Cowal New South Wales

Prepared by:

SLR Consulting Australia

Level 16, 175 Eagle Street, Brisbane QLD 4000, Australia

SLR Project No.: 620.04524

18 January 2024

Revision: 4.0

Making Sustainability Happen

Revision Record

Revision	Date	Prepared By	Checked By	Authorised By
4.0	11 December 2023	Greg Maddocks, Natasha Joyson	Ben Tarrant	Greg Maddocks
2.0	16 December 2023	Greg Maddocks, Natasha Joyson	Mark Heap	Greg Maddocks
3.0	9 January 2024	Greg Maddocks, Natasha Joyson	Mark Heap	Greg Maddocks
4.0_Final	18 January 2024	Greg Maddocks, Natasha Joyson	Mark Heap	Greg Maddocks

Basis of Final Report

This Final Report is provided to EMM Consulting and Cowal Gold Operations following client comments and feedback on the draft report.

This report has been prepared by SLR Consulting Australia (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Cowal Gold Operations (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

Executive Summary

SLR Consulting Australia has addressed open pit design and erosion modelling requests for information from the NSW Government's Resource Regulator, relating to the Cowal Gold Operations (CGO) Open Pit Continuation (OPC) Project's Environmental Impact Statement (EIS).

Open pit design for closure

The resource regulator requested:

- Further information is required on the proposal to remove benches in sodic soils within the E42 final void landform with replacement of rock/soil matrix on these slopes.
- Further information on what material (what depth within the final void) this surface treatment will apply to considering problematic oxides intercepted in the voids.
- Further information on the batter angle for the final voids for this treatment to be practicably applied, considering the batter angle is currently 45 degrees in oxides in E42 void.
- Clarification that the final void landform and associated footprint take this into account.

The OPC Project has been supported by feasibility level designs for the development and operation of the open pits, underground mine and integrated waste landform. There have been technical (and other) studies undertaken to support the engineering studies during the EIS approvals process. The EIS level of assessment for the open pits has documented how the open pit design will be developed to be safe, stable, non-polluting, and sustainable. Ongoing assessment and design work will be undertaken over the mine life to develop detailed designs for rehabilitation of the open pits: these designs need to enable integration of the operational and closure aspects of the pit walls. These aspects are addressed in **Section 4** and **Section 6**.

Erosion modelling

The resource regulator stated:

- It is noted that erosion modelling has not been undertaken on the final void landforms. It is recommended that erosion modelling, preferably Landform Evolution Modelling, is conducted in these areas due to the known highly dispersive soils and erodible oxides identified in the sidewalls of the final voids. This is considered necessary due to the lake protection bund being located within a relatively close distance of the crest of the final voids.

- An understanding of likely long-term post closure erosion and potential crest cutback for the final void landforms is required and will inform the need for erosion treatments of these areas.

Landform evolution modelling requires a final landform design, and while there is a feasibility study level design for the development of the open pits (that will be taken through to detail design and implementation by CGO in due course), the final void landform design for the pit walls, will be further defined. SLR sees no value in undertaking extremely detailed numerical analyses of the existing pit walls or the proposed pit walls using SIBERIA for example, when this assessment would be based on a broad series of assumptions including using one material type over the entire surface of the pit walls, when the material types in the pit walls have significantly different chemical and physical properties within the soil and regolith profile.

SLR does not discount the value of erosion measurement, erosion modelling and landform evolution modelling of the final void pit walls, however we feel that the work needs to occur in a staged approach that reflects the processes that are addressed in **Section 5** and **Section 6**.

Table of Contents

Tables in Text

Figures in Text

1.0 Project

Evolution Mining is seeking approval for continued open pit mining at Cowal Gold Operations (CGO) through the Open Pit Continuation (OPC) Project that will extend the existing E42 open pit and add one satellite pit to the south (E41) of the current pit and two satellite pits to the north (GR and E46) and lead to the expansion of the lake protection bund (LPB) that separates Lake Cowal from the open pit operations (**Figure 2-1**).

The Project primarily seeks to extend the open pit operations by approximately 10 years to 2036 and extend the total mine life by approximately two years to 2042. This will involve further development of the existing E42 Pit and the development of open pit mining in three adjacent orebodies, known as 'E46', 'GR' and 'E41'. The three new and adjacent ore bodies are within the existing mining lease (ML 1535). No change to the approved ore processing rate of 9.8 Mt per annum is proposed.

1.1 Requirement for this work

EMM has requested SLR provides advice relating to the following concerns from the NSW Resource Regulator associated with an extension to the CGO in NSW with the OPC Project.

1.1.1 Open pit design for closure

- Further information is required on the proposal to remove benches in sodic soils within E42 final void landform and placement of rock/soil matrix on these slopes.
- Further information on what material (what depth within the final void) this surface treatment will apply to considering problematic oxides intercepted in the voids.
- Further information on the batter angle for the final voids for this treatment to be practicably applied, considering the batter angle is currently 45 degrees in oxides in E42 void.
- Clarification that the final void landform and associated footprint take this into account.
- These aspects are addressed in Section 4 and Section 6.

1.1.2 Erosion modelling

- It is noted that erosion modelling has not been undertaken on the final void landforms.
- It is recommended that erosion modelling, preferably Landform Evolution Modelling, is conducted in these areas due to the known highly dispersive soils and erodible oxides identified in the sidewalls of the final voids.
- This is considered necessary due to the lake protection bund being located within a relatively close distance of the crest of the final voids.
- An understanding of likely long-term post closure erosion and potential crest cutback for the final void landforms is required and will inform the need for erosion treatments of these areas.
- These aspects are addressed in **Section 5** and **Section 6**.

1.2 Scope of work

EMM requested a short letter proposal that would include the following scope.

- A kick-off meeting with EMM and the engineering team at CGO.
- A review of current information and data. EMM and CGO to provide the geotechnical reports not currently appended to the EIS.
- Research on potential options to address the issues raised in **Section 1.1.**
- Aim to provide a solution to the regulators concern that may exclude a requirement to model erosion around the voids (note the northern proposed pit will be backfilled).
- A second meeting to discuss options and agree an approach with the team.
- A letter report detailing answers to the questions.

1.3 Technical report

Completed technical reports relevant to this scope of work include the following.

- Mining One Geotechnical pre-feasibility study – Cowal Expansion Project (2020)
- Mining One rockfall review stage_i_cutback_d07_v12 (2021)
- Evolution Mining Technical Pre-feasibility Report (2021)
- Mining One Numerical modelling Stage 1 Conventional Cutback (2021)
- LPB Combined Detailed Design 221116 Rev 0 (2022)
- Soil assessment - Minesoils (May 2023)
- Geochemical assessment - GEM (April 2023) – overburden in oxide zone to base of weathering
- Geotechnical analysis – SLR (April 2023), Mining One (August 2021), AECOM (January 2023)
- AECOM Cowal IWL North Feasibility Design Report_Final (2023)
- Erosion assessment – Landloch (2023)
- Mine layout (CGO_EIS_P4000_LayoutV8R5_Complete Design.dxf (January 2023)
- Mining One Appendix G-1 - Hydrogeology_v3-Draft (2023)
- AMC122038 Cowal Open Pit Continuation FS - Independent Peer Review FINAL 230808
- Mining One Geotechnical stability of pit designs (2023) 3203_M_7885v2
- Final EIS Chapters (2023)
    - Appendix A - Design drawings
    - Appendix D - Mitigation measures
    - Appendix E - Geochemistry assessment & LPB RMS
    - Appendix F – Groundwater
    - Appendix G - Surface Water Assessment
    - Appendix T - Soil and land
    - Appendix Z - Mine Closure & Rehab Strategy

2.0 Site knowledge

Key findings and assumptions from the soil assessment and closure and rehabilitation plans for the final void include the following.

2.1 Site layout

The site layout for the OPC Project is in **Figure 2-1**.

2.2 Soil assessment

Soil surveying for the EIS was done by Minesoils (May 2023) (Appendix T of the EIS). The soil units in the OPC Project footprint include Vertosol and Dermosol to the east and Sodosol to the west beyond the footprint of the open pits (**Figure 2-2**). The Vertosol is associated with very gently undulating lower slopes leading into Lake Cowal. These soils have a high clay content of 35% or more throughout the solum except for thin surface crusty horizons 30 mm or less in depth. The Vertosols were observed to have a cracked surface conditions and contained topsoil with well-structured clay loams through to heavy clay overlying well-structured medium to heavy clay subsoil. The comments in the soil report state that topsoil were non-saline and non-sodic trending to highly saline to extreme salinity and strong sodicity at up to 1 m bgl. These descriptions are not entirely consistent with the results in the report that are summarised in **Section 2.3.**

2.3 Soil chemical analyses in the pedolith (A and B horizons 0 to 1 m bgl)

Soil analyses in the Soil and Land Impact Assessment (Minesoil 2023) have documented the soil mapping units and soil types that are present in the topsoil horizon (**Figure 2-2**).

- The observations and analyses <u>do not</u> extend below 1 m bgl.
- The pit wall is almost certainly contained in Vertosol not Sodosol <u>soil</u> units.
- The Vertosol results are quantified with test pits 16 and 17 in the north and 5b, 8a, 9 and 10 to the south.
- The test pit analyses are summarised as follows.
    - $EC^{1}_{1:5}$ in all samples from 0 to 70 cm bgl are 30 to 1,020 µS/cm
    - ESP in all samples from 0 to 70 cm bgl was 1.7% up to 21% but,
        - 11 samples < ESP 5%
        - 7 samples > 5% < 10% ESP
        - 7 samples > 10% ESP

In our opinion the Vertosol results in the immediate vicinity of the open pit are more likely to be considered to have <u>low salinity and low to moderate ESP and sodic potential</u>.

[1] Salinity levels are usually determined by measuring the electrical conductivity of soil/water suspensions. Traditionally, the electrical conductivity of saturated extracts was used (ECe) but these values are time-consuming and difficult to determine. Electrical conductivity is commonly determined more rapidly and easily on a 1:5 soil/water suspension (EC 1:5). These are converted to ECe values based on the estimated water-holding capacities of the soil based on the texture of the soil. Multiplier factors are used for converting EC 1:5 (dS/m) to an appropriate value of ECe (dS/m). In soil science the common units for electrical conductivity are deciSiemen per metre (dS/m), but a wide range of units is used in reports and discussions.

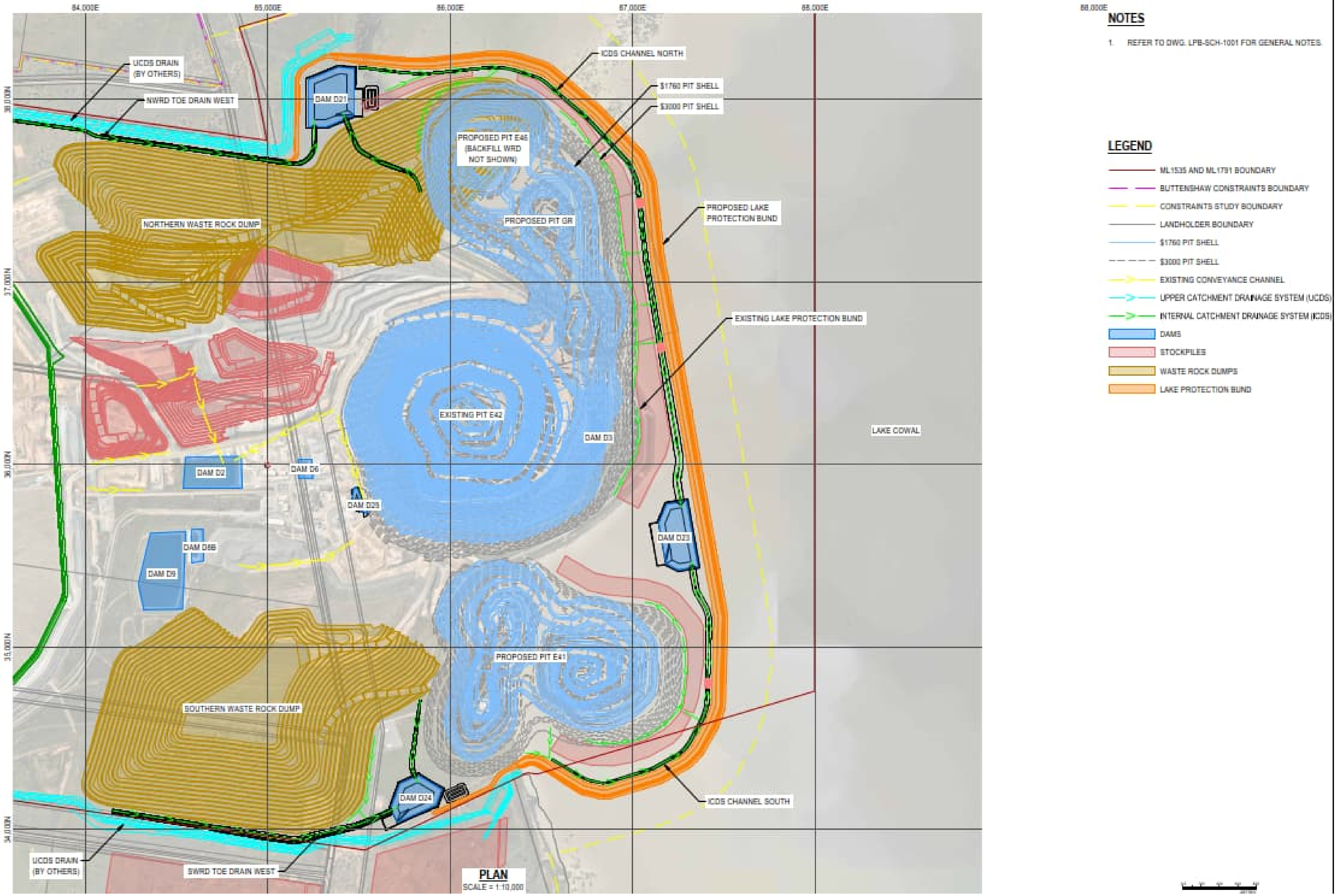

Figure 2-1: OPC Project site layout

2.4 Overburden chemical analyses from 1 m to 100 m bgl

GEM (2023) collected and analysed overburden samples for EC, CEC, and ESP in alluvium (n=5), colluvium (n=1), lacustrine (n=3), saprolite (n=6) and saprock (n=13).

The overburden samples include samples from surface to 119 m bgl include alluvium to depths of 29 m bgl, colluvium from 5 to 27 m bgl, lacustrine sediment from surface to 60 m bgl, saprolite 10 m to 77 m bgl and saprock at 7 to 129 m bgl.

The results from these samples include $pH_{1:5}$, $EC_{1:2}$ $EC_{1:5}$, and ESP values. The $EC_{1:5}$ results are 28 to 4,808 µs/cm with an average of 1,316 µs/cm (**Table 2-1**). The ESP values are very low 4.6% to 62% (extremely high).

The data and document review undertaken in this report determined that the GEM samples were obtained from diamond core exploration and resource drilling programs. Due to the instability in the oxide strata it is considered probable that sodium montmorillonite (bentonite) was used a drilling mud to assist in the recovery of the weathered units. The use of sodium montmorillonite has an effect on the chemical and physical properties of the samples recovered in these drill holes because these fluids saturate the clay, silt and sand matrix and alter the in-situ chemistry: the effect of these fluids on rock is far less significant because the core can be washed with clear water during cutting and logging.

The soil chemical analyses and results can also be affected by the sample preparation process. It is common practice to use a dry sieved < 2.4 mm fraction for soil fertility, analyses that include cation exchange capacity (CEC). Conversely it is common practice for geologists to dry, crush and pulp samples prior to analysis to obtain representative analyses.

These aspects are being evaluated by CGO geologists.

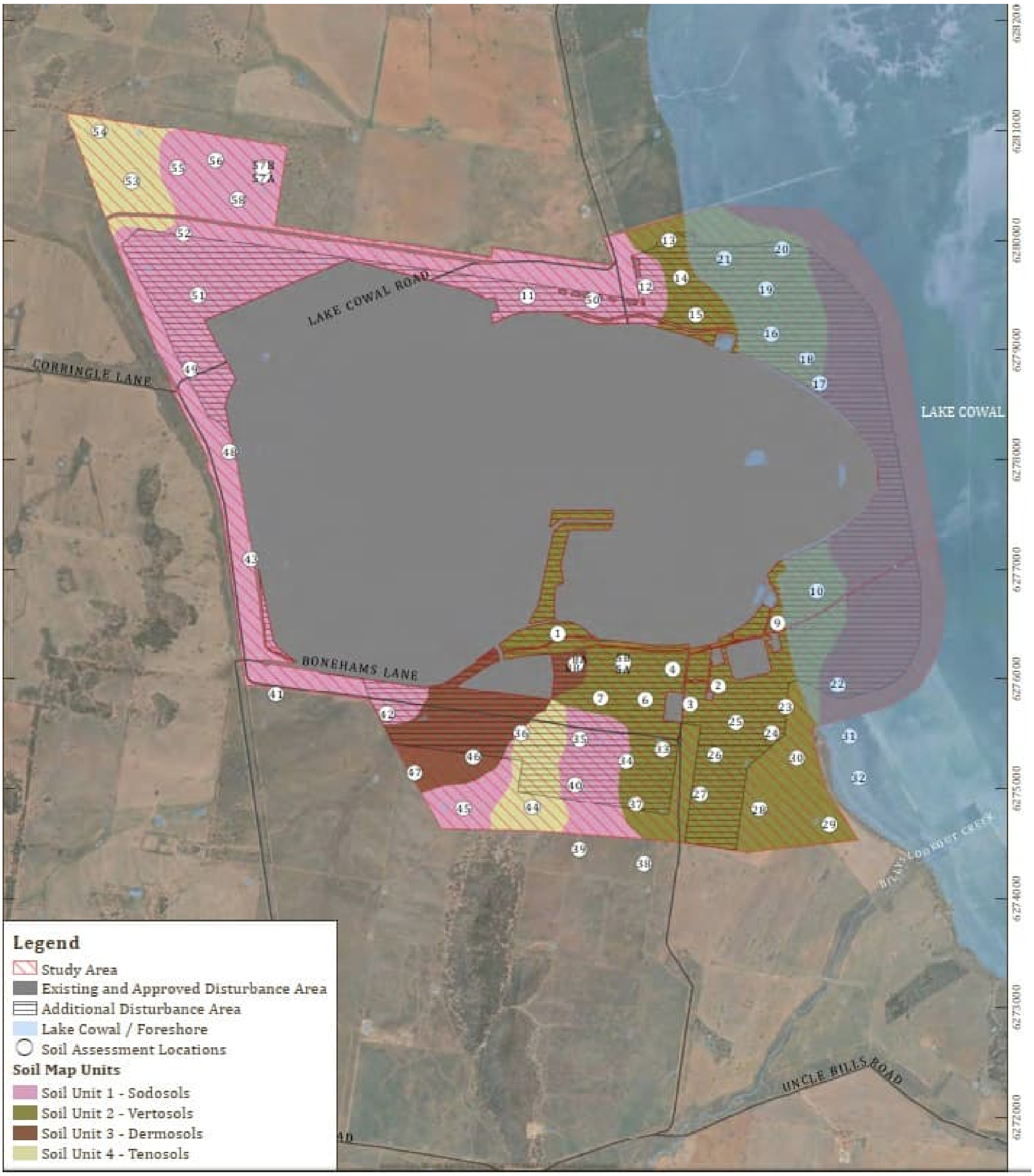

Figure 2-2: Mapped soil units

Table 2-1: Regolith mine material assessment (GEM, 2023)

Program	Deposit	Drill-Hole ID	Sample ID	Depth (m) from	Depth (m) to	Depth (m) interval	Material Type	Lith. Group	Lithology	Area	Sample ID	Lithology	pH1:2	EC1:2	EC1:5INF>1:2	ESP (%)
				from	to	inter.										
O/C PFS	E41 West	E41D2178	E41D2178-1	0.0	6.0	6.0	Waste Rock	Alluvial	Lacustrine	E41-W	E41D2178/1	Alluvial	7.9	2.55	1.02	24.7
O/C PFS	E46	E46D3053	E46D3053-2	3.0	7.0	4.0	Waste Rock	Alluvial	Lacustrine	E46	E41D3053/2	Alluvial	7.9	0.68	0.27	36.2
O/C Expansion	E46	E46D3249	E46D3249-1	4.9	9.6	4.7	Waste Rock	Alluvial	Alluvium	E46	E46D3249-1	Alluvial	7.8	1.60	0.64	28.9
O/C Expansion	E41 East	E41D2886	E41D2886-1	2.0	10.0	8.0	Waste Rock	Alluvial	Alluvium	E41-E	E41D2886-1	Alluvial 2 - 10 m	5.8	0.48	0.19	19.3
O/C PFS	E41 East	E41D2063	E41D2063-3	8.0	11.0	3.0	Waste Rock	Alluvial	Lacustrine	E41-E	E41D2063/3	Alluvial	5.6	5.56	2.22	44.7
O/C Expansion	E41 East	E41D2893	E41D2893-1	5.1	11.6	6.5	Waste Rock	Alluvial	Transported	E41-E	E41D2893-1	Alluvial	7.4	0.42	0.17	20
O/C Expansion	E41 West	E41D2810	E41D2810-2	10.2	13.4	3.2	Waste Rock	Saprolite	Saprolite	E41-W	E41D2810-2	Saprolite	7.1	0.04	0.02	16.7
O/C Expansion	E41 East	E41D2893	E41D2893-2	11.6	13.8	2.2	Waste Rock	Saprolite	Saprolite	E41-E	E41D2893-2	Saprolite	6.6	1.09	0.44	24.6
O/C PFS	E41 East	E41D2063	E41D2063-5	16.0	17.0	1.0	Waste Rock	Alluvial	Alluvium	E41-E E	41D2063/5	Alluvial	5.7	10.36	4.14	60.9
O/C PFS	E41 East	E41D2063	E41D2063-6	18.0	19.0	1.0	Waste Rock	Saprolite	Saprolite	E41-E	E41D2063/6	Saprolite	5.6	12.02	4.81	61.6
O/C Expansion	E41 East	E41D2893	E41D2893-3	18.2	21.0	2.8	Waste Rock	Saprock	Saprock	E41-E	E41D2893-3	Saprock	6.5	1.45	0.58	22.2
O/C PFS	Galway Regal	E46D3173	E46D3173-1	23.0	25.0	2.0	Waste Rock	Alluvial	Alluvium	GR	E41D3173/1	Alluvial	6.7	2.87	1.15	45.8
O/C PFS	E46	E46D3026	E46D3026-5	25.0	27.0	2.0	Waste Rock	Alluvial	Colluvium	E46	E41D3026/5	Alluvial	6.2	2.71	1.08	49.9
O/C PFS	E46	E46D3026	E46D3026-6	28.0	32.0	4.0	Waste Rock	Saprolite	Saprolite	E46	E41D3026/6	Saprolite	6.5	1.68	0.67	35.2
O/C Expansion	E46	E46D3249	E46D3249-3	25.0	35.0	10.0	Waste Rock	Saprolite	Saprolite	E46	E46D3249-3	Saprolite	6.4	1.00	0.40	25.9
O/C PFS	E41 East	E41D2219	E41D2219-5	34.0	41.0	7.0	Waste Rock	Saprock	Saprock	E41-E	E41D2219/5	Saprock	6.1	8.86	3.54	54.2
O/C Expansion	Galway Regal	UG-BH-05	UG-BH-05-5	36.0	42.0	6.0	Waste Rock	Saprock	Saprock	GR	UG-BH-05-5	Saprock	7.4	0.09	0.04	<0.02
O/C PFS	Galway Regal	E46D3173	E46D3173-3	43.0	52.0	9.0	Waste Rock	Saprock	Saprock	GR	E41D3173/3	Saprock	6.2	3.46	1.38	49.3
O/C PFS	E46	E46D3026	E46D3026-7	33.0	53.0	20.0	Waste Rock	Saprolite	Saprolite	E46	E41D3026/7	Saprolite	6.1	6.22	2.49	55.6
O/C PFS	E41 East	E41D2063	E41D2063-10	47.0	53.0	6.0	Waste Rock	Saprock	Saprock	E41-E	E41D2063/10	Saprock	6.5	11.83	4.73	58.5
O/C PFS	Galway Regal	E46D3134	E46D3134-5	55.0	68.0	13.0	Waste Rock	Saprock	Saprock	GR	E41D3134/5	Saprock	6.2	5.50	2.20	52.6
O/C PFS	Galway Regal	E46D3173	E46D3173-4	67.0	71.0	4.0	Waste Rock	Saprock	Saprock	GR	E41D3173/4	Saprock	6.5	1.68	0.67	34.8
O/C PFS	E42 Stage I	1535DD051	1535DD051-4	64.0	80.0	16.0	Waste	Saprock	Saprock	E42-SI	1535DD051/4	Saprock	7.2	5.30	2.12	49.3
O/C Expansion	E41 West	E41D2834	E41D2834-6	78.0	88.0	10.0	Waste Rock	Saprock	Saprock	E41-W	E41D2834-6	Saprock	7.1	1.38	0.55	59.6
O/C PFS	E42 Stage I	1535DD051	1535DD051-7	96.0	99.0	3.0	Waste	Saprock	Saprock	E42-SI	1535DD051/7	Saprock	9.2	0.70	0.28	20
O/C PFS	E46	E46D3026	E46D3026-10	105.0	109.0	4.0	Waste Rock	Saprock	Saprock	E46	E41D3026/10	Saprock	8.5	0.38	0.15	4.6
O/C PFS	Galway Regal	E46D3173	E46D3173-7	110.0	114.0	4.0	Waste Rock	Saprock	Saprock	GR	E41D3173/7	Saprock	6.6	1.03	0.41	31.7
O/C PFS	Galway Regal	E46D3173	E46D3173-8	115.0	119.0	4.0	Waste Rock	Saprock	Saprock	GR	E41D3173/8	Saprock	6.6	1.21	0.49	29.4

2.5 Geology

The Cowal resources occur within a sequence of sedimentary, volcaniclastic and volcanic rocks, which have subsequently been intruded by a diorite sill. These rocks are unconformably overlain by a horizontal to sub-horizontal cover sequence comprising three main geological units:

- Transported Cover (the Quaternary sequence);
- Soft Oxide (SOX): the completely weathered upper part of the Tertiary laterite; and
- Hard Oxide (HOX): caprock comprising highly altered and weathered volcaniclastics.

At the existing E42 pit, the cover sequence is approximately 100m thick as shown in the SW-NE trending geological section in **Figure 2-3** (after Mining One, June 2021).

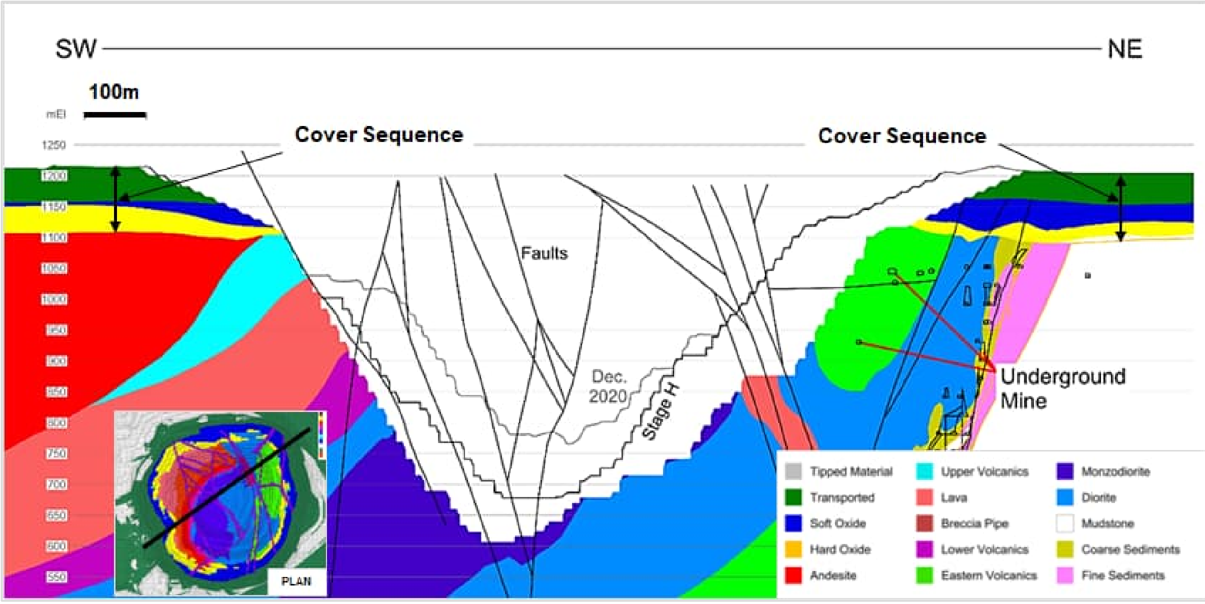

Figure 2-3: Geological Section through Pit E42 (Mining One, June 2021)

Based on pit survey data provided by CGO, the current E42 pit profiles range from 40° to 60° in the hard rock sections of the pit and approximately 25° in the overlying cover sequence. It is noted from the most recent Google Earth imagery, the presence of persistent erosion of the cover sequence layers exposed on the pit slopes (Refer **Figure 2-4**).

A site visit to CGO was undertaken by SLR in July 2022 as part of the design project for the proposed LPB. During a visit of pit E42 it was noted that the southeastern side of the pit was observed to have rill erosion in the cover sequence layer and there were some localised slumps originating in the eroded areas: this area of the open pit has since been remediated. Two examples of these slumps have been marked on **Figure 2-4** and the site photo inset.

The root cause of the slumps may have been caused by seepage permeating through the cover sequence from Lake Cowal, with the resulting increased pore pressure and soil saturation causing the localised slope failures: localised slope failure could also be due to weathering and residual structure in the oxidised material. The raised pore pressure conditions are considered to be a temporary case which develop during times of intense rainfall which recharges nearby catchments such as Lake Cowal.

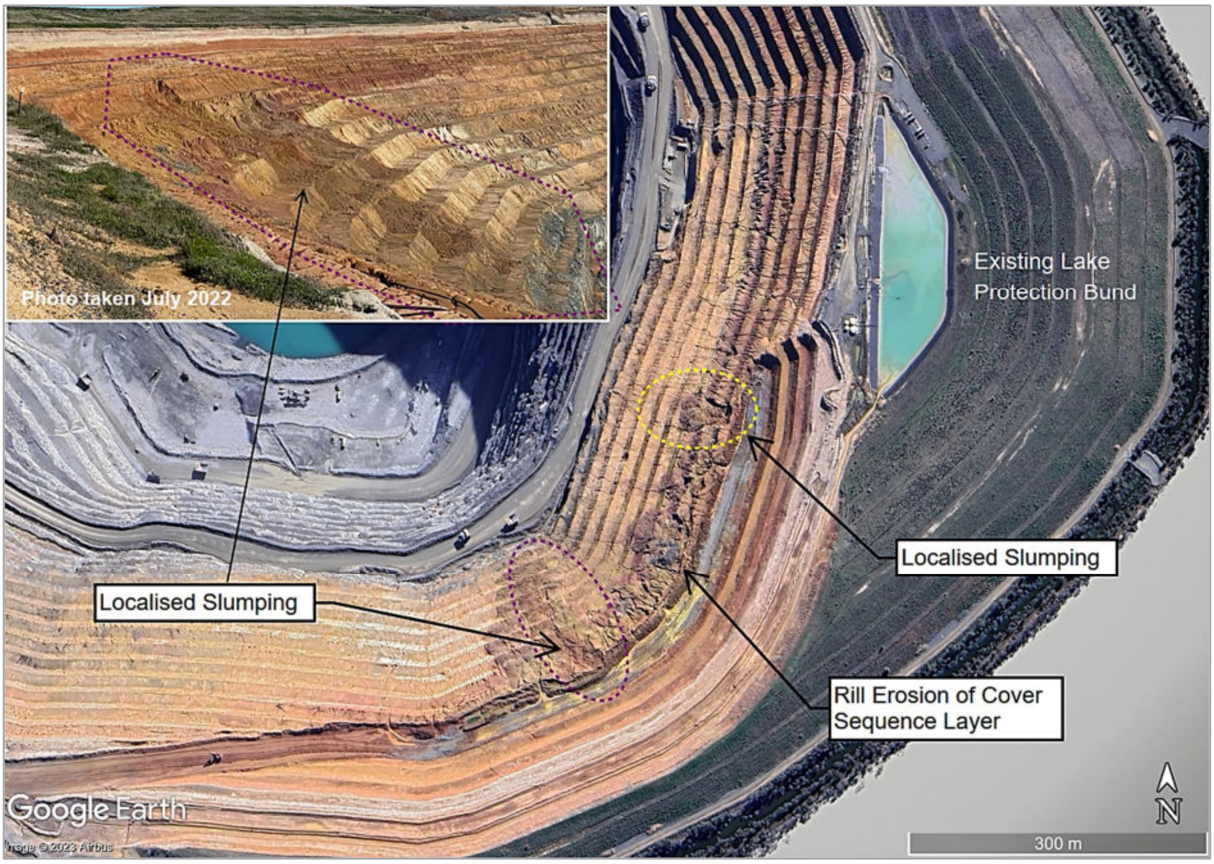

Figure 2-4: Rill Erosion on South-east Slope of Pit E42

2.6 Geotechnical overburden properties

It is unclear what physical analyses have been undertaken on the alluvium, colluvium, saprolite and saprock (Mining One, 2023). Subsequent stages of work would collate this data with other pit wall soil fertility and geochemical data.

- Dry grading of these materials to quantify the < 75 mm to < 2 mm PSD fractions.
- Hydrometer analysis to quantify the sand, silt, and clay size fractions.
- Textural analysis
- Emmerson aggregate stability
- Pin hole dispersion

Within the E42 pit there is over 23 km of RQD data and logging to define the transported sediment, soft and hard oxide zones (Mining One 2023) and this data provides a valuable source of information for the proposed pit wall mapping (**Section 3.6**) that can build on the concepts in **Figure 2-5.**

At CGO, surficial materials are distinguished into Transported Sediments (Alluvium, Colluvium Lacustrine sediment), Soft Oxides (SoX), and Hard Oxides (HoX). Geotechnical domains are defined in terms of these materials. The Hard Oxides (HoX) form the base of all the surficial materials. When compared to the surficial overlying units, the HoX is essentially a weathered and oxidised rock mass. As in previous stability assessments, the HoX is treated as surficial material, even though it is most likely composed of a mix of weathered rock units (i.e. oxidised mudstones, diorites, etc.).

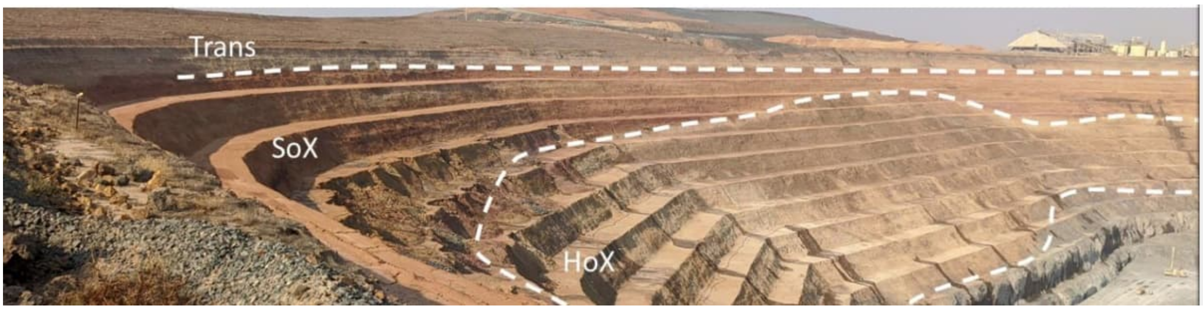

Figure 2-5: Mapped conceptual level pit wall

2.7 Surface water management

There is a drainage system around the crest of E42 on the edge of the perimeter road. However, during heavy rainfall, the drainage system is not adequately controlling water from the crest. This is leading to some erosion from the crest of the open pit down the full length of the exposed berms and benches on the pit walls which is increasing surface erosion and facilitating small, localised slumps.

As the E41 Pit is developed, as part of the OPC Project, to the south of E42, the shoulder between the pits will be removed; this will include the upper section of the eroded areas of berms and benches in the E42 pit, allowing CGO to re-design the operational draining system in this area to reduce this current problem.

At the end of mining, all surface runoff within the mine site is to be directed into the E42 open pit. Surface water will be directed around the pit crest (stopping surface flow down the oxide zone of the pit walls) and down the main haul road that will be developed to include a suitable sized and engineered drainage system. The drainage system constructed within the oxide zone must be able to contain the flow and be built in such a way that the base of the surface drains does not develop cracks in the oxide material that would enable water in the drains to flow back into the oxide material.

2.8 Revegetation of the pit walls

Aerial imagery verifies that the pedolith and regolith strata on the oxide zones of the E42 pit walls can support successional development of opportunistic vegetation even in what is assumed to be an absence of intended rehabilitation (**Figure 2-6**).

2.9 Ground water management

The operation of the open pit and underground mine has led to dewatering around the E42 pit shell. Mining One (Appendix G1 or the EIS) concluded that in the oxide zones the following aspects need to be considered.

- The slope stability is sensitive to groundwater conditions.
- Some previous studies and operating experience demonstrate that horizontal drains have proven effective in controlling pore pressures within the Transported, Saprolite, and Saprock horizons.
- The use of horizontal drains has had a beneficial effect on bench-level stability and overall pit-wall stability.
- Groundwater sensitivity to slope stability in the primary zone is still uncertain except for the zones associated with the structure.
- Nominated horizontal drill hole depth is 150 meters and may need to be tailored (longer or shorter) in other areas.
    - The setup is perpendicular to the pit slope with a sub-horizontal inclination.
    - A slightly inclined downwards (i.e. -5 degrees) drill hole is recommended as this will ultimately fill with water and may preserve the integrity of the surficial drill hole better than the upwards inclined case which will expose the surficial drill hole to the atmosphere.

- Drill hole inclinations of this magnitude will have little bearing either way on the resultant depressurization.
- All horizontal drain holes should be lined (with perforations/slotting) to preserve the hole bore and ensure that the drain continues to depressurise the materials it penetrates these liners should be fixed/bushed to the collar pipe at the time of drilling and reticulated to collection sumps.

Conversely the horizontal dewatering piezometers can become point sources for seeps that could cause erosion (**Figure 2-7**). CGO has connected the horizontal piezometers to pipes to collect the seepage and reduce erosion (**Figure 2-8**).

Mining One (2023) state that the horizontal dewatering bore have been effective in dewatering the oxide zone.

- SLR would be asking how the effectiveness of the bores has been determined?
- Is the structural orientation of the oxide zone clearly defined and presented in a 3D structural model to optimise sub horizontal borehole design?
- Intercepting interconnecting permeable structures will give the best chance of depressurising these slopes. Otherwise, dewatering slopes with a high clay content is likely to require an uneconomic number of closely spaced bore holes to be effective. Again, it would be useful to see the evidence for the effectiveness of the currently existing boreholes.
- It is unclear how the existing bore holes in the oxide zone of the pit wall will be decommissioned and then reinstated during the pit wall cut back in E42.
- It is unclear if the dewatering bores will need to be maintained post closure to maximise pit wall stability, and if they are required to be maintained, how this will be done.

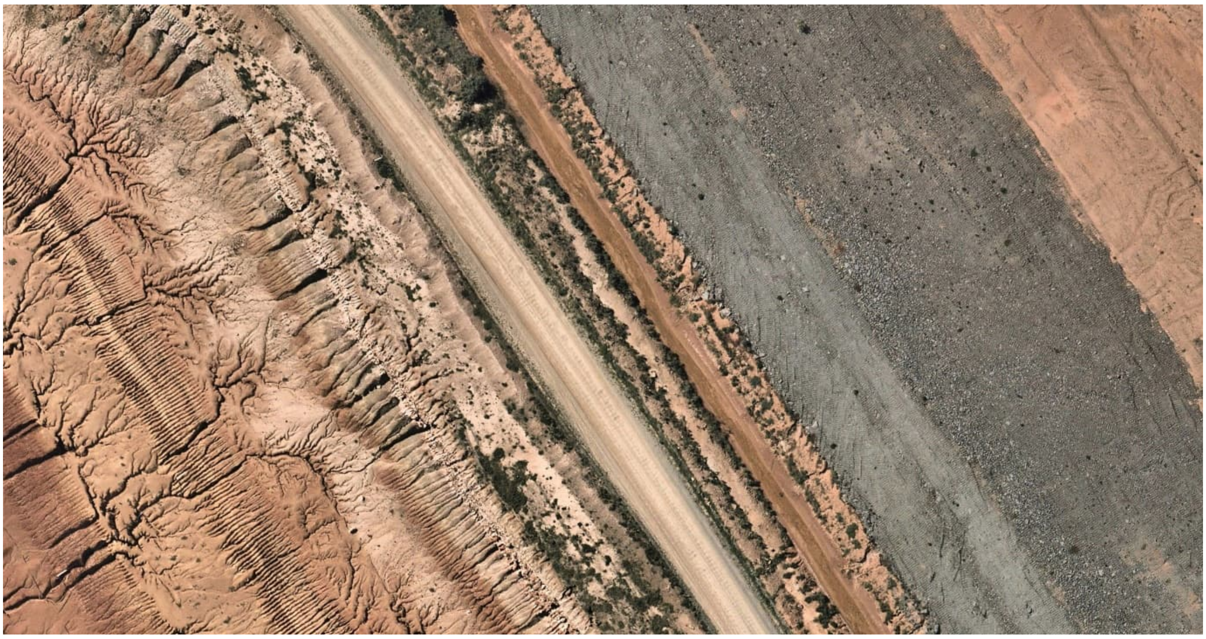

Figure 2-6: Surface runoff to the pit wall from the pit crest (Nearmap, 2021)

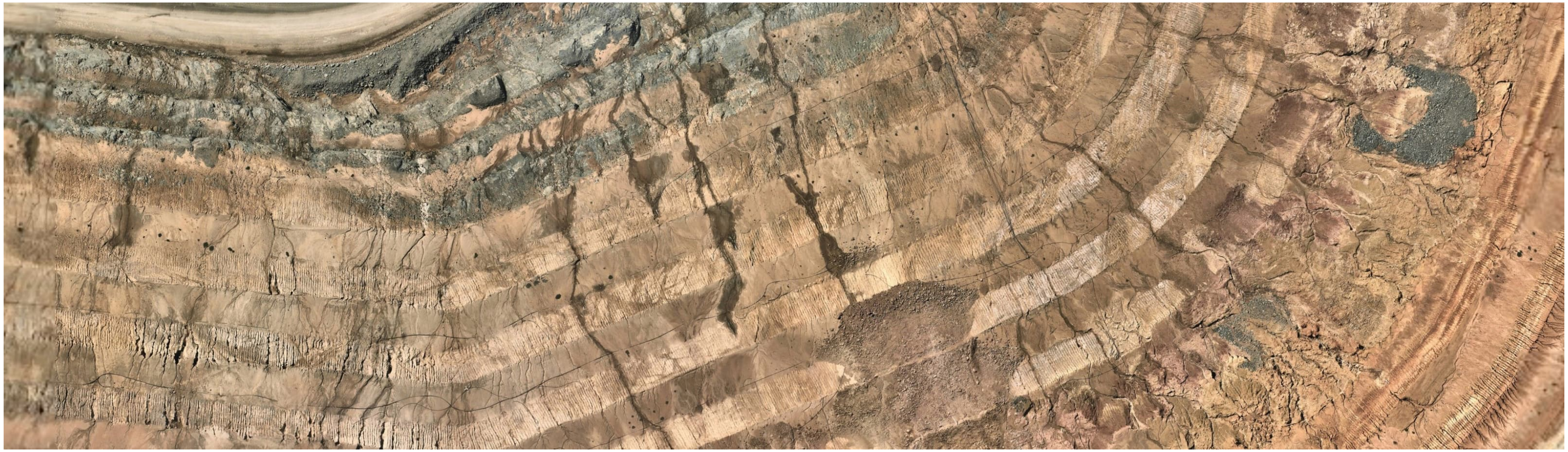

Figure 2-7: Horizontal dewatering can produce near continual seeps that could lead to erosion (Nearmap, 2021)

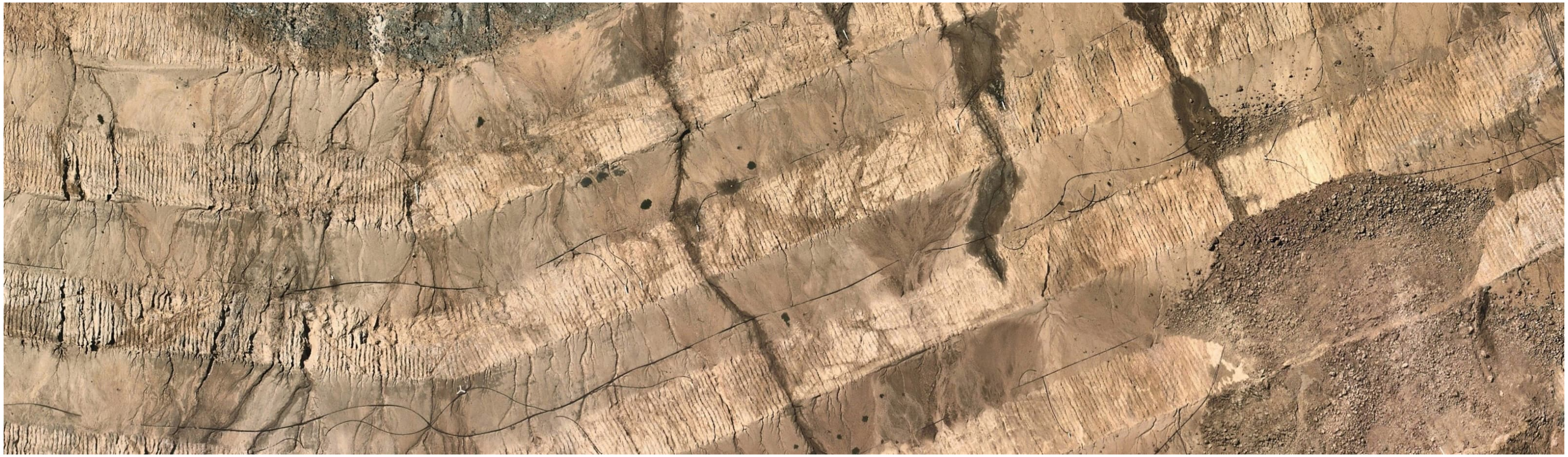

Figure 2-8 Horizontal seeps have been connected to pipes to reduce erosion risk (Nearmap, 2021)

3.0 Open pit (final void) design for closure

A requirement for this report is to provide further information on how the final pit walls will be designed and then developed for mine closure. This report addresses the questions raised in **Section 1.1.1.**

The OPC Project has been supported by feasibility level and detailed engineering designs for the development and operation of the open pits, underground mine and integrated waste landforms. There have also been technical (and other) studies undertaken to support the engineering studies during the EIS approvals process.

The EIS level of assessment has documented how the open pit design will be safe, stable, non-polluting, and sustainable. Ongoing assessment and design work will be undertaken over the mine life to develop detailed designs for rehabilitation of the open pits. These designs need to enable integration of the operational and closure aspects of the pit walls.

The OPC Project open pits have deeply weathered and oxidised zones extending to depths of 50 to 100 m bgl. The pit walls have been designed and will be built using standard open pit mining and construction methods, which is entirely appropriate to ensure viable economic and mine safety outcomes. The open pits will however, transition from an operational phase to a closure phase that will need to preserve the integrity of Lake Cowal.

SLR suggests that the detail design phase for the OPC Project open pits could extend the viewpoint of the pit walls, from a geotechnical and mine safety lens, to a landform design perspective that provides a sustainable outcome for the site and the stakeholders on the adjoining land.

3.1 EIS final void closure and rehabilitation objective

The E42 and GR open pits will be approximately 500 m and 100 m below the pre-mine surface at the end of mining. The water body in E42 will be in the order of 400 m depth and the final water level will be within the oxide zone of the pit walls at about 100 m bgl. Based on the water balance model by ATW, 2023), the groundwater elevation may not reach equilibrium in the E42 open pit at approximately 90 m below the final void crest for several hundred years after closure.

The E41 open pit will be approximately 200 m below the pre-mine surface at the end of mining. The water body in E41 will be in the order of 130 m depth and the final water level will be within the oxide zone of the pit walls at 70 m bgl after 140 years.

3.2 Designing for closure

The proposed strategy for the E42 and GR final voids and the E41 final void is to optimise the pit wall designs for closure over the life of mine by:

- implementing ICMM best mining practice, including integrated mine planning and designing for closure;
- integrating landform design factors with those outlined by INAP cover design principles; and
- conforming with leading industry practice and the principles being developed for mining landform design.

3.3 Landform design (Canadian Landform Design Institute)

Landform design is an emerging, integrated, multidisciplinary process to successfully reconstruct mine land (CLDI, 2021).

- It allows industry, regulators, and communities to work together to manage costs and risks, minimize liability, and produce progressively reclaimed landscapes with confidence and pride. Done well, landform design leads to a positive mining legacy — it is a pillar of sustainable mining.
- The Institute's vision is that all mining occurs with the end in mind. The end is defined as successful reclamation — that which satisfies the needs of all involved: the mining company, the regulator, Indigenous peoples, and local communities.
- The vision is achieved through the mission, which is to make landform design routine in the mining industry worldwide by 2030.

The principles of landform design require integrated planning:

- collaboration with multiple environmental, technical soil, legal, regulatory, and financial stakeholders;
- integration over time from concept to closure; and,
- clearly defined rehabilitation goals, design objectives, design criteria and material specifications.

These detailed and integrated closure and rehabilitation processes are to be developed at suitable points in the mine life and are being considered by CGO through development of this response to the NSW Resource Regulator to address their concerns in **Section 1.1.**

3.4 Landform design objectives

The completed engineering studies have defined the proposed geometry of the OPC Project pit walls (**Section 2.1**). The OPC Project pit wall designs were primarily driven by financial outcomes and a requirement for geotechnically stable slopes with a suitable factor of safety. The work by Mining One (2021) acknowledges that there is the potential for ongoing detail design work to optimise the pit wall designs in the hard oxide (HOX) and soft oxide (SOX) zones.

The ongoing studies that are proposed to be developed over the life of mine could integrate the mining and geotechnical design objectives with the following landform design objectives.

- Landform geometry:
  - Standard OPC Project development uses linear slopes with benches, berms and batters.
  - The landform design objectives could be to create an open pit landform design that supports operational development and long term mine closure outcomes.
  - Long term erosion on some areas of the pit walls is likely to lead to localised slumping and the evolution of the 45-degree batters to angle of repose slopes.
  - The final landform design objectives could be to build these inevitable slopes into the landform design and to then provide permanent stability with vegetation or engineering options before they occur as un-planned failures.

- Hydraulic design:
  - The landform geometry defines how and where surface water flows down and across the benches and berms on the pit walls.
  - Surface water designs could be developed to minimise surface flow velocity and move water from the weathered oxide zones to the fresh rock.
  - This may require moving away from a lateral slope around the pit wall to rounding off flow into durable rock armoured drainage channels so surface runoff can be controlled.
- Pedolith and regolith chemical and physical properties:
  - The chemical and physical properties of the pit wall define how these materials can be used.
  - There are technical gaps in the knowledge of the material properties that can be addressed through proposed pit wall development to optimise the following design objectives.
  - There could be chemical solutions available to stabilise the materials on the slopes.
- Revegetation:
  - Soil cover is promoted by sustainable plant growth and vegetation cover.
  - Objectives for revegetation of the pit walls could be to promote soil cohesion using interactions between plant roots and the soil mineral particles (silt, sand, and clay) and improving the shear strength to contribute to erosion control in a direct relationship between the physical bonds formed in the contact areas of these particles and chemical bonds or cementation between them.

The landform design objectives for the final pit walls will need to be evaluated and then documented by CGO in the Rehabilitation Plan as the objectives are defined.

Figure 3-1: Slope evolution to steady state conditions

3.5 Landform design criteria

Whereas landform design objectives provide overarching strategies, the landform design criteria are measurable parameters. Compliance with the design criteria enable the objectives to be met.

The open pit wall design criteria including slope angles and bench and berm geometry for the open pit walls in the HOX and SOX zones were defined in the geotechnical studies by Mining One. CGO will take these geotechnical studies through increasingly rigorous levels of design as the mine is developed. All soft oxide (SOX) and hard oxide (HOX) pit designs have the same parameters with 9 m bench height, 45° batter angle, and 10.3 m berm width resulting in an inter-ramp angle of 25°. Slumping of some areas of the oxide zones was acknowledged in a review of the pit designs and the recommendations were that a detailed review of the causes of the slumping be undertaken and incorporated as learnings into new designs (AMC, August 2023).

The development of suitable landform design criteria that can actually be achieved from a mine closure perspective is dependent on the material specifications, and the degree of work completed in this area, while entirely appropriate for the EIS, is not at a level detail design applicable for mine closure. In the same way that the rigour in the mine plans and designs evolves over the mine life, so will the final landform designs for the final void pit walls.

Before any erosion modelling is considered by the NSW Resource Regulators, SLR believes that (what will become) the final open pit walls, should be mapped in detail and developed into a detailed conceptual model to verify the soil fertility, chemical and physical properties of the exposed material, that are collectively referred to as the material specifications.

3.6 Material specification

The soil profile and regolith analyses (including the constraints of some of those analyses) supported by measured geotechnical parameters, are summarised in **Section 2.0.**

The final <u>landform design criteria</u> for the pit walls will need to be based on, and define, the material specifications (measurable fertility, chemical and physical properties).

The materials that could be used on the final pit walls may include:

- Pedolith units (A and B Vertosol soil horizons)
- Regolith (saprolite and saprock units) comprised of alluvium, colluvium, lacustrine sediment and weathered in-situ rock units
- Fresh rock that could be obtained from open pit development or from underground development
- Plants – local species or species selected for specific design criteria with a natural affinity for development in this area (**Figure 3-2**)
- Geosynthetics

We believe that more work is required to be undertaken during development of the GR, E41 and E46 open pits and the on the pit cutback in E42 to map pit walls where the final void will interface with the Lake Cowal, lake protection bund (LPB) into high, moderate, and low risk profiles associated with surface water management, vegetation potential, erosion, and seepage.

We feel this is required to verify observations from measured data and aerial images that include the following.

Figure 3-2: Successional development of vegetation on the pit walls.

4.0 Erosion and landform evolution

One of the requirements for this report is that the NSW Resource Regulator is of the opinion that landform evolution modelling should be done for the OPC Project open pits.

SLR agrees that landform evolution modelling can be a useful tool for environmental assessment, but we also feel that this type of work needs to be used in an appropriate way as part of a series of technical assessments that include erosion modelling supported by erosion measurement and soil and regolith mapping.

SLR does not agree that landform evolution modelling of landforms such as the open pits (at this stage of project development) is required for an EIS. We understand that CGO is continuing with a series of rehabilitation and closure studies that may lead to landform evolution assessment of the final voids when a final landform has been developed to then verify long term performance.

There seems to be no valid reason to undertake landform evolution modelling on the pit walls when these surfaces do not represent an as yet undefined, final landform surface. Landform evolution modelling is not typically proposed on the as-built surface of a tailings beach or an operating waste dump.

Our opinion is based on the following.

4.1 Purpose of modelling

All numerical modelling methods used for environmental assessment of erosion or landform evolution are subject to the following constraints.

- Measurement and modelling are done at various levels of reliability.
  - **Concept level** when the data used in the model may be inferred or measured from static analyses including but not limited to particle size distribution, cation exchange capacity, organic carbon content.
  - **Feasibility level** of assessment when the data used in the model is measured from static analyses and from kinetic flume-based measurements on a representative material that quantify erosion rates under different simulated rainfall intensity and duration (e.g. 30/hr rainfall event) and under different slope angles.
  - **Detailed level of assessment** when the data used in the model is measured from static analyses and from flume-based measurements on the **full range** of material types that will be used on a mine landform to quantify erosion rates under different simulated rainfall intensity and duration (e.g. 30/hr rainfall event) and under different slope angles for a full range of materials.
- Regarding erosion and landform design modelling this can be undertaken using various software including USLE, RUSLE, WEPP, MINErosion, SIBERIA and $CAESAR_{LISFLOOD}$. Each modelling method is almost certainly going to provide different results.
- Modelling is used to forecast potential outcomes for future conditions, usually because field observations and measurements are not possible or available for the site in questions or from sites with similar attributes.
- Future conditions being evaluated might include analyses being done for:
  - single rainfall events or long-term climate analysis.

  - evaluating the potential performance of different slope lengths, angles and geometric configurations (e.g. linear slopes of geomorphic design);
  - as-placed bare soil, at Year 1 through to,
  - long term landform evolution outcomes e.g. Year 100+.

Numerical models are subject to inherent assumptions and limitations that generate inherent uncertainty in the results.

  - Climate assumptions may use average climate data, or simulated climate data but these methods are deterministic and provide one outcome (stochastic analyses should be used to evaluate a range of climate outcomes).
  - Climate change should also be evaluated in the numerical analyses when there is a need for detailed results with a high degree of reliability.
  - Model results become increasingly less reliable as the forecasts are pushed further out into the future.
  - Mine rehabilitation landforms are not static and they will evolve over time because:
    - the as-placed soil cover system is subject to pedogenesis (soil profile reformation) that includes soil fertility, chemical and physical aspects;
    - land use changes and may include a base case (do-nothing), partial vegetation cover or complete cover; and
    - beyond design basis (unplanned) events will impact future forecasts because these events were beyond the battery limits of the model e.g. extreme natural events such as earthquake, unprecedented flood event, fire or drought.
- Numerical modelling should be used to forecast potential outcomes for future conditions.
- Forecasts for future conditions should be validated with field observations and field measurements when this becomes possible.
- Numerical models should be calibrated with measured data and the model inputs should then be updated so the model can be validated with a measurable degree of reliability.

4.2 Design basis memorandum

A design basis memorandum (DBM) is a Canadian and USA approach used in engineering projects. A DBM is typically a 10 to 20 page document, with a nested hierarchy that includes the rationale, design objectives, design criteria, principles, assumptions, and constraints used for detailed engineering and the final design product. It is quite detailed and essentially forms a contract and may evolve and be updated as a project develops. If there is buy-in among the mine, the regulator, and Indigenous and local communities, then meeting the design basis should be sufficient for completion and signoff.

Ideally, a DBM would be the joint product of all these groups, but in practice it is typically produced by the mine with input from the other groups. Often there is a DBM for the mine site as a whole, and a slightly more detailed one tailored for each landform. The DBM is a living document, updated as more information becomes available, as preferences change, and as more is learned. The DBM becomes a commitment of the mine and annual progress is tracked against it.

4.3 Design basis memorandum: numerical modelling

In much the same way that a DBM provides a clearly defined approach to undertake an engineering study, SLR recommends the same approach be developed for numerical modelling projects.

A numerical modelling DBM (NMDBM) can be used to define:

- What modelling methods will be used
- Inferred data used in the model
- Measured data available or that will be required to be collated for the project
- Assumptions
- Limitations
- Exclusions – may include beyond design basis events[2] particularly low-frequency, high-magnitude (i.e., extreme) natural events such as earthquakes or unprecedented floods.

A numerical modelling DBM (NMDBM) will ensure that numerical modelling results are fit for purpose and align with site, corporate and or regulatory requirements.

4.4 Erosion modelling for the integrated waste landforms

The premise of the erosion modelling work undertaken for CGO by Landloch (2023) is:

(i) That there is an acceptable erosion per tonne per hectare per year (t/ha/yr) rate and

(ii) If the erosion rate is maintained below the 5t/ha/yr then the landform and cover design objective for erosion is being met and the landform design is successful.

Landloch (2023) defined a tolerable erosion rate of <5t/ha/yr for the integrated waste landform (IWL) slopes. This equates to < 0.03 mm of erosion per year assuming the soil has a density of 1.5. It is understood that this tolerable erosion value of <5t/ha/yr is based on approaches developed by the USA Department of Agriculture (Wischmeier and Smith 1978) and methods developed by Wright and Siddoway, (1982). Setting tolerable erosion rates developed for low slopes on well developed, mature and maintained agricultural systems does not seem to be an acceptable approach to SLR and we question if methods developed in the USA in 1978 and 1982 for agricultural purposes are appropriate for mine land rehabilitation in Australia in 2023.

SLR agrees that erosion from a constructed mine landform must be minimised to ensure that the design objectives are maintained. We also suggest that ongoing maintenance of a constructed mine landform is a probable outcome of many rehabilitated mine landforms post closure just as ongoing land management is required in state forests, national parks, the agricultural and grazing sectors and land managed by traditional owners. To verify that a tolerable erosion rate is being met there must be site-based erosion measurements. A per hectare value can also have limited benefit as there may still be localised erosion leading to an unacceptable outcome at one location but essentially no erosion on the remaining area of the landform. This would require establishing controlled catchments on rehabilitated slopes and measuring suspended and bedload sediment concentrations and loads being mobilised

[2] Wison Luangdilok PhD, MS, BS, Peng Xu, in Advanced Security and Safeguarding in the Nuclear Power Industry, 2020.

from the slopes. The measurements would be aligned with monitoring to identify if localised failure is occurring.

4.5 Integrated waste landform (IWL) cover design used for erosion control

Existing trials on site verify that the use of a soil-rock cover improves resistance to rill and gully erosion. The concept is to cover erosion prone material soil-rock matrix and a layer of growth media to support vegetation. This is typically 300 mm deep rock mulch underlay overlain by low salinity and gypsum treated topsoil (Landloch 2023). The CGO soil-rock matrix rehabilitation cover system is suitable for the proposed linear [1V:5H, 20%] profile batters of the Northern and Southern WRDs provided that > 50% vegetation cover can be maintained. The CGO soil-rock matrix rehabilitation cover system is suitable for the proposed linear [1V:4H, 25%] profile batters of the IWL provided that > 60% vegetation cover can be maintained. Existing vegetation trials at CGO provides cautious optimism that established vegetation cover levels in the order of 70% can be sustained based on average annual rainfall totals.

5.0 Conclusions and Recommendations

5.1 Re-define how the open pits are considered

The OPC Project open pits are being designed for economic viability and mine safety operational aspects. The designs for the most developed project components are at feasibility study (FS) level (AMC, 2023). Open pit design typically excludes a requirement for major inputs related to mine closure, as they are allowed to unravel and erode into the void. This is not the case at CGO where the open pits interface with Lake Cowal and therefore have unique design considerations.

To facilitate improved outcomes CGO could redefine and contextualise the operational open pits for the project and site teams, not just as open pits, but as landforms that will need to be designed and managed to enable post closure stakeholder concerns to be managed and met. This approach is consistent with the principles of the Landform Design Institute (CLDI, 2021), that represents leading industry practice in this field.

The stability of the CGO open pit final landforms and particularly the weathered oxide zone of the open pits will need to be maintained into perpetuity, meaning that the slopes will need to be designed, built, and maintained and monitored in the same way that a tailings storage facility embankment is required to be managed.

5.2 Build and maintain a knowledge base

The ICMM Mine Closure Guideline (2019) and the Landform Design Institute (2021) refer to developing and maintaining an integrated knowledge base.

A comprehensive knowledge base for the OPC Project open pits is required to be developed to ensure that all relevant technical aspects are being utilised and evaluated for the final landform designs for the open pit walls (Mining One 2020, AMC, 2023).

The knowledge base provides the foundation for the landform design. The knowledge base may include tabulated data, detailed conceptual models and 3D CAD models that bring together the soil fertility, geological logs, geotechnical parameters, groundwater level and flow and vertical and horizontal dewatering, surface water management, and the final landform design components including vegetation and other remediation measures.

5.2.1 Regolith chemical properties

The pedolith and saprolith Vertosol samples analysed from the open pits are saline and sodic. It is probable that the exchangeable sodium concentration of samples from the regolith strata below the pedolith were impacted by the use of sodium montmorillonite that is used as a drilling fluid and this will inflate the exchangeable sodium percentage (ESP) values. Regardless of what the actual ESP values may be oxide materials are prone to rill and gully erosion.

It would be beneficial to collect samples from the pit walls are they are developed to verify the actual chemical and physical properties of the strata will be left on the final pit walls. This data can be used to map the salinity and sodic potential of the pit walls and also be utilised to verify required application rates of gypsum or other soil ameliorants.

5.2.2 Geotechnical aspects

A significant amount of geotechnical data has been collected from boreholes that have intersected the Cover Sequence. A better understanding of these material property variations will assist in the refinement of the geotechnical and geochemical models that will facilitate the development of a more accurate erosion model, when required.

It is unclear what geotechnical testing analyses have been undertaken on the alluvium, colluvium, saprolite and saprock. Interrogation of the laboratory test database for the Cover Sequence could be undertaken, and the material strengths correlated to the refined subunits identified and could be collated with other pit wall soil fertility and geochemical data.

Where possible, back analysis of past failures in the Cover Sequence could be undertaken to develop material strength parameters to complement those already derived from laboratory testing.

Mapping of the existing faces is not currently possible as the berms are completely full of rill. It is anticipated that mapping was undertaken as the faces became exposed. Further mapping can be undertaken as cutbacks proceed.

Interrogation of the structural database should be undertaken to determine the geotechnical characteristics of each of the major joint sets. Particularly whether the structures are open or healed the nature of infill materials which is an important consideration when determining the potential for interconnected fracture flow.

5.2.3 Hydrogeology and hydrology

It is uncertain whether laboratory permeability testing on core samples from the oxide layers or in-situ permeability testing has been undertaken. If a permeability database does exist, this should be interrogated to determine whether there are discrete subunits, or zones, that are more or less permeable. If identified, the more permeable zones could be targeted for the purposes of dewatering.

If not already undertaken, large scale pumping tests within the oxide layer would yield valuable permeability information that could be used for dewatering design.

The location and construction details of the currently installed sub horizontal drain holes should be interrogated. These should be examined with reference to any existing monitoring data from piezometers installed in the pit walls. This should enable an assessment of the efficacy and historic performance of the sub horizontal drain holes.

The network of pipes intercepting water from the sub horizontal drains to the point of outflow needs to be well considered and be low maintenance as access to the benches to remediate any damaged pipework or blockages may not be possible. Consideration must be given to determine how the dewatering network including the pipelines will be maintained and monitored post closure. Suitable pit wall design for the final landform will be critical to achieve ongoing access to these areas.

When there is better understanding of the permeabilities of the oxide materials it will facilitate the design of the sub horizontal drain holes to depressurise the oxide slopes during mining and post closure, if required.

The current drainage system requires maintenance and upgrading. Partly due to the impacts of recent flood events particularly in 2022-23. The aerial photos show that erosion gulleys have been formed in the Cover Sequence by water overtopping the pit crest and running down the pit face. The importance of such drains is often underestimated. Drains need to be fit for purpose and capable of managing the volumes of run-off water resulting from most rainfall events. Poorly designed drains crack along their length permitting the ingress of water into the slope causing destabilisation. Alternatively, drains are under designed which results in overtopping causing the formation of erosion gulleys.

Consideration needs to be given to the design of a permanent drain that will ensure that all storm water does not enter, or over top, the pit wall. It is common for some degree of cracking to develop behind pit crests. This cracking has the potential to impact the integrity of the drains. It must be ensured that the drains are regularly inspected and maintained.

This approach to surface water management will also need to be applied to the pit walls that interface with Lake Cowal to ensure the drains do not become point sources for hydraulic failure mechanisms.

It is possible that some of the slumps in the Cover Sequence may have been caused by seepage permeating from Lake Cowal with the resulting increased pore pressure and soil saturation causing the localised slope failures. The nature of this potential interconnection needs to be established. If open channels of permeability exist these are only likely to open and become more established with time and will cause an enduring hindrance to the establishment of a stable pit slope. Consideration could be given curtain grouting if a hydraulic connection is established.

5.3 Adopt a staged process of landform design

The information requested by the NSW Resource Regulator is not available at the level of detail the regulator may require (at this point in time). The approach by CGO presented in the EIS remains the base case for the post closure management of the oxide zones in the pit walls, and the detail in the EIS is consistent with contemporary requirements.

CGO will progress the open pit closure strategy from the concepts presented in the EIS through to detailed design, thereby enabling thorough numerical evaluation of the pit walls. A key component of the numerical assessment and design process would be to collate project knowledge on aspects of the oxide zone of the open pits as a platform to develop final landform designs.

The open pit final landform design process requires a knowledge base, stakeholder engagement, and a full range of landform design inputs to be:

- Built up in the early years of the approved open pit continuation project (that is at Feasibility Study level and has no fatal flaws (AMC, 2023)), then be,
- Actioned progressively over the mine life in line with leading industry practice (ICMM, 2019 and CLDI, 2021).
- SLR recommends CGO develops a staged work program with a clear schedule that will enable a viable landform to be developed for the final voids and take the EIS concepts for the final voids to detailed design.

5.4 Final landform design considerations

Final landform pit wall design options should be evaluated to develop pit wall, slope angles and geometric configurations that will maximise long term geotechnical stability, erosional stability and maintain (perpetual) access to the critical slopes so that ongoing maintenance and monitoring can be undertaken to ensure the pit wall remains safe, stable and non-erosive.

5.4.1 Base case for pit wall stability

The base case for achieving stability on the oxide zone of the pit walls is to remediate sodic strata on as-built benches, berms and batters with chemical amelioration (gypsum) and use a combination of rock armour and revegetation initiated with durable hydro mulch to maintain a stable and non-erosive profile.

5.4.2 Geomorphic design principles

Engineered slopes comprising benches, berms and batters will inevitably erode and may slump to a natural angle of repose that is determined by the material properties. It may be beneficial to design and construct some areas of the slopes to a sustainable final landform design under controlled conditions using geomorphic principles that enable the slopes to be stabilised and maintained, rather than trying to manage the slopes after unplanned failure, that could hinder access to the area due to safety concerns.

5.4.3 Revegetation

One plant species that may be a viable solution for the pit walls is Vetiver grass that is recommended for erosion control in Vertosol strata in Queensland (Cheetam and Walton, 2014). Holanda et al, (2022) state that vetiver grass:

- has biotechnical characteristics that promote an efficient soil and also a dense and deep root system up to 2 m depth;
- is recognized for its ability to conserve soil and stabilize slopes (Mickovski et al. 2005; Mickovski and Beek 2009; Donjadee and Tingsanchali 2013; Amiri et al. 2019);
- can grow in extreme environments, not only in relation to temperature, but tolerance to long periods of drought and flooding, common in riverbanks, and tolerance to saline soils, contaminated with heavy metal or soil low fertility or with high pH (Barbosa and Lima 2013; Teixeira et al. 2015; Bernardino et al. 2016; Amiri et al. 2017; Aloui et al. 2018; Itusha et al. 2019);
- is present in the most varied climates, mainly tropical and subtropical, adapted to different altitudes and climatic conditions (Truong 1999); and
- is widely used in the recovery of degraded areas, emphasizing erosion control, since its root system has many cylindrical fibres capable of presenting an average tensile strength of 310 MPa.

5.4.4 Revegetation trials

The CGO oxide zones within the open pits present unique differences and challenges to traditional rehabilitation and revegetation approaches compared to the integrated waste landforms.

It would be prudent to develop and then implement field trails on site, which would facilitate the evaluation of the numerous vegetation and proprietary erosion control geo-synthetics available to manage erosion hazards. Revegetation trials should evaluate the range of chemical and physical aspects that may influence vegetation.

The application of native or introduced pasture species or introduced species such as vetiver grass may be a viable way of providing ongoing dewatering of the oxide pit walls, maintaining structural integrity and reducing erosion (Cheetham and Walton, 2014).

Revegetation trials could be undertaken to verify that the selected species are tolerant of saline/sodic chemical conditions and the other chemical and physical properties of the regolith units in the oxide zone.

The success of the vegetation is the regolith units of the oxide zone of the pit walls is also related to topography, elevation, slope, and aspect, which influence vegetation structure and dynamics. The slope controls vegetation size, composition, and distribution by influencing wind speed, soil water and nutrient content, solar radiation intensity, and seed dispersal distance (Moeslund et al., 2013). Vegetation species may also be affected by fire, and this should also be factored into revegetation and erosion trials or assessments.

Deep-rooted species are potentially better adapted to steeper slopes because of wind conditions but also due to soil stability issues. Litter depth and by association recycling of nutrients decreases with slope as more vegetation litter may be lost by wind and gravity, leading to spatial variations in soil moisture, nutrient status, and soil temperature, and this may then indirectly influence fire hazards.

Aspect influences solar radiation, precipitation, and wind, which in turn impact vegetation composition, structure, and growth. In the southern hemisphere, south facing slopes receive less sunlight and this is exacerbated in open pits particularly on the batters. Conversely the north facing slopes will receive more sun and be exposed to increasing levels of evaporation and transpiration that may have an adverse effect on sustainable growth of vegetation and increase fire hazards if the vegetation dies off during droughts.

Rock will undoubtedly form part of the mitigation process to maintain slope stability. CGO should identify suitable resources to obtain durable rock for pit wall remediation. CGO should also verify required rock volumes to determine if there will be a deficit of material for remediation. The field trails to be undertaken on site could also evaluate a range of geo-synthetic materials.

5.4.5 Surface water management

The closure objective is for surface runoff from with the mine lease to be directed to the main E42 ramp, that will be developed into a suitable engineered drain to move the surface runoff into the pit. Surface water flow is occurring unchecked on the pit walls. Controlling, directing, and channelling surface flow on what will become the final landform will be critical to reduce the potential for erosion.

5.4.6 Seepage management

The horizontal dewatering bores and an extensive pipe network are required to maintain stability in the oxide zone. It is unclear whether these bores will be required when the open pit transitions into rehabilitation, and if they are how these bores would be maintained. An assessment of pit wall stability in the oxide zone should be done to verify what may occur if the horizontal bores are decommissioned and what effect this may have on the final landform design.

5.5 Erosion measurement and erosion and landform evolution modelling

The NSW Resource Regulator is seeking landform evolution modelling of the open pits (**Section 1.1.2**). Landform evolution modelling requires a final landform design, and while there is a feasibility study level design for the development of the open pits (that will be taken through to detail design and implementation by CGO in due course), the final void landform design for the pit walls, has not been clearly defined. SLR see no value in undertaking extremely detailed numerical analyses of the existing pit walls or the proposed pit walls using SIBERIA for example, when this assessment would be based on a broad series of assumptions including using one material type over the entire surface of the pit walls when the material types in the pit walls have significantly different chemical and physical properties within the soil and regolith profile (**Table 2-1** and **Figure 2-5**). SLR does not discount the value of erosion measurement, erosion modelling and landform evolution modelling of the final void pit walls, however we feel that the work needs to occur in a staged approach that reflects the processes defined in Section 0 to provide value to CGO and the NSW Resource Regulator.

When there is a final landform design for the CGO oxide pit walls that includes defined and viable remedial measures it would then be feasible to undertake numerical analyses including erosion measurement and hydraulic and landform evolution modelling to verify how the proposed design is likely to perform under post-closure conditions.

5.6 Monitoring

The stability of the open pit final landforms and particularly the weathered oxide zone of the open pits will need to be maintained into perpetuity. Monitoring of the performance of the pit walls is crucial and consideration needs to be given to the infrastructure required for the long-term monitoring. This may include the installation of VWPs, inclinometers and surface crack meters. Most of the equipment should have facility to be read remotely as access to the benches may not be possible.

6.0 References

1 Mining One (2020) GEOTECHNICAL PRE-FEASIBILITY STUDY - COWAL EXPANSION PROJECT Job No. 9108_M, 9110_G Doc No. 6171v2_FINAL.

2 Evolution Mining Limited, August 2021," CGO Open Pit Expansion PFS, Chapter 5. Mining Technical Pre-Feasibility Report".

3 Mining One, 18th June 2021, "Numerical Modelling Stage 1 Conventional Cutback".

4 Hoek E, Marinos PG. Predicting tunnel squeezing problems in weak heterogeneous rock masses. Tunnels and Tunnelling International 2000;132(11):45e51.

5 Hynes-Griffin, M.E. and Franklin, A.G., (1984), "Rationalizing the Seismic Coefficient Method", US Army Corps of Engineers, Mississippi.

6 Coffey, 10 September 2020, EMM Consulting Pty Ltd, Cowal Underground Development EIS, Mine Site Hydrogeological Assessment

7 SLR, April 2023, "Cowal Gold Operations (CGO), Slope Stability Analysis for the Proposed Lake Protection Bund".

8 SNC Lavalin Australia, January 2003," Lake Bund Final Design Report, Lake Protection System Design, Cowal Gold Project", Document number 334371-000-4GRA-0002.

9 Cheetam M. & Walton R. (2014). Waterways and Gully Stabilisation in Vertosol Soils: Dry Creek, Condamine Catchment, QLD, in Vietz, G; Rutherfurd, I.D, and Hughes, R. (editors), Proceedings of the 7th Australian Stream Management Conference. Townsville, Queensland, Pages 171-177.

10 Honlanda et al (2022) Evaluation of the root system of Vetiver grass (Chrysopogon zizanioides L. Roberty) using different sampling method. Francisco Sandro Rodrigues Holanda , Luiz Diego Vidal Santos , Alceu Pedrotti , Renisson Neponuceno de Araújo Filho , Lucas Resmini Sartor , Valter Rubens Alcantara Santos-Sobrinho, Rayssa Juliane Souza de Jesus , Priscila Angel de Oliveira Silva and Keila Maria Araújo Andrade. Environmental Systems Research (2022) 11:16.

Making Sustainability Happen