

technical memo

Date:	30 June 2025
To:	Maxime Descoteaux , Graymont
From:	Andrew Butler, Epic Environmental
Client name:	Graymont
Project name:	Calliope PRCP
Project number:	BAA250025.01
Subject:	Landform Design Soil Erosion Modelling to Support the Calliope PRC Plan

1 BACKGROUND

The Calliope Limestone Quarry (the Project) is operated by Graymont (Calliope) Pty Ltd (GCPL). The Project includes the operation of an open cut limestone quarry that produces approximately 0.8 million tonnes per annum (Mtpa) of limestone products. The Project commenced operations in 1967 and, noting potential future changes in reserves and yearly sales quantities, has a planned end of mine life (EOML) in 2100. The Project is located approximately 11 kilometres (km) south of the township of Calliope and 30 km south of Gladstone in Central Queensland within the Gladstone Local Government Area (LGA).

GCPL is required to prepare a Transitional Progressive Rehabilitation and Closure Plan (PRC Plan) for the Project. As part of the long-term rehabilitation strategy for the Project, an out of pit waste rock dump (referred to as the Southern Waste Rock Dump – SWRD) will remain at the end of mine life. According to the PRC Plan Guideline, (ESR/2019/4964 Version 3.01), a final landform design is a key component of rehabilitation and closure planning. The final landform design must be consistent with the proposed post mine land use (PMLU) and the proponent must demonstrate that the land will be safe and structurally stable. Therefore, as part of the development of the PRC Plan, there is an expectation that proponents will conduct appropriate soil erosion modelling to predict the long-term stability of the final landform design.

This memo provides the results of soil erosion modelling undertaken to support the development of a stable landform design for the SWRD that meets the requirements of the PRC Plan guidelines and is consistent with the nominated PMLU (grazing).

2 MODEL SELECTION

According to the Queensland Mine Rehabilitation Commissioner’s Technical Paper *Applying erosion and Landscape Evolution Models to assess post-mining landform stability* (Hancock et al. 2025), the choice of model should reflect the prediction requirement, i.e., there is little point in using a complex Landform Evolution Model with many parameters if an erosion rate prediction is required for a simple hillslope for landform design purposes. Hancock et al. (2025) state that the Revised Universal Soil Loss Equation (RUSLE) erosion model is an ideal tool to quantify hillslope erosion rates for simple non-complex landforms. The RUSLE erosion model is also suitable for use on low risk waste landforms that do not contain high risk potentially acid forming (PAF) material for which a Landform Evolution Model would be more appropriate. Waste characterisation at Calliope has demonstrated that waste rock is non-acid forming (NAF) and has a very low risk of saline mine drainage generation (Epic 2024).

RUSLE has previously been employed by other proponents in the preparation of approved PRC Plans. It has been used for assessing post-mine landform stability, particularly for testing different design parameters such

as slope angle and minimum vegetation cover requirements to control erosion to acceptable levels including the following examples:

- Newmont Landco Pty Ltd, PRCP_EPML00863713_V1 (effective 02/02/2023). RUSLE was used to assess erosional stability of one of the final landforms, but not for the main post-mine landforms (waste rock dumps) which had already been constructed and revegetated. Rates of soil loss were predicted to be 150 t/ha/yr if groundcover reaches 60% (the benchmark used which came from an existing landform that had been demonstrated to be stable) and on average 11.2 t/ha/yr if 90% groundcover is achieved (Engeny 2023)
- Queensland Coking Coal Pty Ltd; Qld Coal Aust No.1 Pty Ltd, PRCP_EA0002912_V5 (effective 27/05/2023). RUSLE was used to assess the conceptual post-mining landform design and to inform ground cover requirements for the maintenance of erosion to below c. 6 t/ha/yr. The assessment identified that a ground cover of 100% (vegetation and rock combined) was required to achieve acceptable rates of erosion (Vitrinite 2021).
- Queensland Coking Coal Pty Ltd; Qld Coal Aust No.1 Pty Ltd, PRCP_P-EA-10026508_V1 (effective 05/04/2024). RUSLE was used to assess the conceptual post-mining landform design and to inform ground cover requirements for the maintenance of erosion to below c. 6 t/ha/yr. The assessment and outcomes were identical to the previous example (Vitrinite 2023). RUSLE generated erosion rates similar to the values estimated using a SIBERIA landform evolution model

As the proposed SWRD landform at the Project is both simple in design and will not contain PAF, RUSLE was selected as an appropriate model for predicting erosion rates that could be used to progress the selection of appropriate landform design parameters.

3 MODEL DESCRIPTION AND INPUTS

The RUSLE erosion model is expressed as follows (Renard et al. 1997):

$$A = R \times K \times L \times S \times C \times P$$

Where:

A = estimated average soil loss in tonnes per hectare per year

R = rainfall-runoff erosivity factor

K = soil erodibility factor

L = slope length factor

S = slope steepness factor

C = cover-management factor

P = support practice factor

The source of the site specific data for RUSLE inputs at the project is provided below:

- R Factor was derived from Q Spatial layer of USLE R factor centred on Calliope (<https://www.data.qld.gov.au/dataset/soils-universal-soil-loss-equation-series/resource/802d9acc-241f-4430-b3ca-15b08b883b0f>). The value used is 3897 MJ.mm/ha/hr/yr
- K Factor derivation described in **Section 3.1**
- L Factor was calculated from

$$L = (X_h / 22.13)^m$$

Where:

X_h = the horizontal slope length in metres was derived the flow accumulation length using a hydrological and slope raster within a GIS application and a site specific digital elevation model (DEM) for the final landform

$$m = \beta / (1 + \beta)$$

Where:

$$\beta = (\sin a / 0.0896) / [3.0 \times (\sin a)^{0.8} + 0.56], \text{ and where 'a' is slope in degrees}$$

- S Factor was calculated from the following depending on slope angle:
 $S = 10.8 \sin a + 0.03$ for slopes < 5.15 degrees (< 9%)
 $S = 16.8 \sin a - 0.50$ for slopes ≥ 5.15 degrees ($\geq 9\%$)
- C Factor was varied to simulate the effects of different rates of vegetation and groundcover. The C Factor values used for established vegetation cover were derived from published sources (IECA 2008) and ranged from 1 to 0.03 representing ground cover of between 0 and 80% newly established grass to be conservative. The adoption of well-established grass cover (more applicable to long-term stability assessment) would result in lower C Factor values and erosion rate predictions for any given cover %
- P Factor (erosion control practice factor) is the ratio of soil loss compared to a nominated surface condition ploughed up and down the slope. The value is reduced by practices that decrease both the velocity of runoff and the tendency of runoff to flow directly downhill. The rehabilitation will include cross ripping along the contour which provides additional erosion protection. Rip lines would be expected to result in ridges of at least 75 mm and a P Factor of 0.7 (based on calculations of P factor for contour cultivation in Rosewell 1993)

3.1 K Factor

Soil analytical data for the Project is available from 23 samples taken previously from five topsoil stockpiles for topsoil suitability assessment. The data included soil organic carbon content and laser diffraction particle size analysis. This data has been used to develop a site-specific K Factor value for the Project according to the RUSLE nomograph which is solved by the following equation (Rosewell 1993):

$$K = [(2.77 \times M^{1.14}) \times 10^{-7} \times (12 - OM)] + [4.28 \times 10^{-3} \times (SS - 2)] + [3.29 \times 10^{-3} \times (PP - 3)]$$

Where:

$$M = (\text{silt \%} + \text{very fine sand \%}) \times (100 - \text{clay \%})$$

Silt plus very fine sand includes particles between 2 and 100 μm in diameter (derived from site data)

Clay includes particles less than 2 μm in diameter (derived from site data)

OM is soil organic matter % (derived from site organic carbon content data multiplied by 1.72)

SS is the soil structure class in RUSLE (as no data was available for stockpiled soil structure class 4 for massive unstructured soils was adopted to be very conservative)

PP is the permeability class in RUSLE (derived from a look up table based on site specific soil texture grade data)

Soil textures were generally silty loam to silty clay with a high proportion of silt plus very fine sand (median approximately 60%) and relatively low OM content (median approximately 0.6%). This resulted in a median K Factor of 0.051 (**Table 1**) which is 'high' according to the classification of Rosewell and Loch (2002). The K Factor is in line with expectations given the high proportion of silt plus very fine sand in the stockpiled topsoil.

Table 1: Details of site specific soil properties used for K Factor determination

Soil property	Median value
Clay content (%)	31.6
Very fine sand and silt content (%)	59.1
Soil organic matter content (%)	0.60
Soil structure class	4 (Massive)
Soil permeability class	4 (Slow to moderate - 5-20 mm/h)
M	4268

Soil property	Median value
K Factor	0.051

3.2 Landform Design

During Stage 1 development of Pit 4 North, from 2027 – 2060, waste rock will need to be stored in the out of pit SWRD (Graymont 2025) until the void floor is large enough to allow progressive void backfilling from north to south. The footprint of the SWRD is constrained by the topographic setting of the Project, the proximity of the final extent of open cut pit 3-4 and the flood protection bund to the west of the Project. The preliminary design specifications for the SWRD were developed within these constraints. This resulted in a proposed design with parameters shown in **Table 2** and **Figure 1**.

Table 2: Preliminary SWRD design parameters

Slope aspect	Average slope angle (%)	Slope length at mid-point (m)
North	23.1	95
East	23.0	95
South	22.6	95
West	10.1	141
Top	0.4	NA

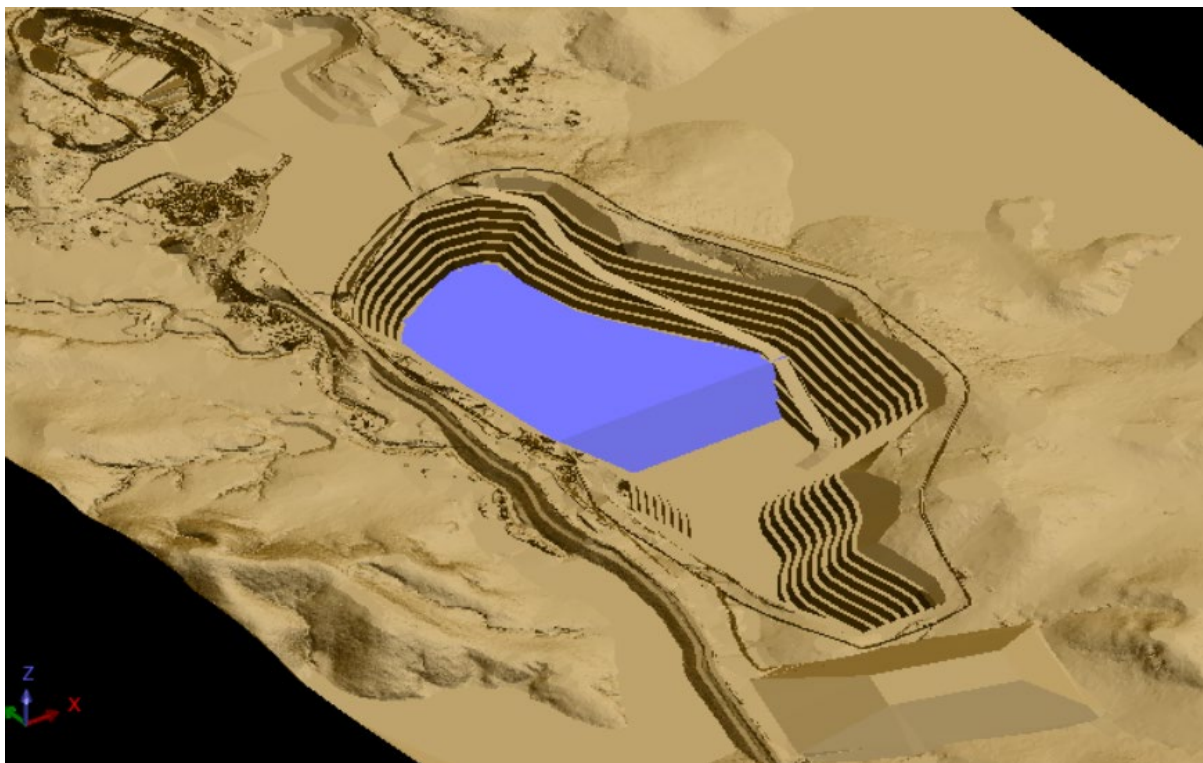


Figure 1: SWRD location and preliminary design (bottom right) and pit 3-4 final extent at end of mine life (Source: Graymont 2025)

However, initial RUSLE model runs based on this design indicated that the maximum rate of erosion for some of the slopes may be unacceptably high (greater than 10 t/ha/yr). In addition, the slopes for the preliminary SWRD design would exceed the maximum slope limitation for Class 3 land suitability for beef cattle grazing PMLU for the final landform (Short 2023). Class 3 land is defined by a maximum 15% slope for the topography limitation and 12% slope for the erosion hazard limitation (for non-sodic soils like those observed at the Project).

GCPL reviewed mine planning and waste placement sequencing to determine if additional pit backfilling could be conducted to reduce the amount of material remaining in the SWRD at end of mine life and allow for a final landform design that includes shallower slopes to minimise erosion and optimise slopes for the proposed grazing PMLU.

Although the SWRD will remain as per the preliminary design during the operational phase, at the end of mine life, the SWRD will be reprofiled to create slopes of 12% or less. Any excess material will be placed in the southern end of the pit 3-4 void. The proposed SWRD final landform (and proposed in-pit placement of waste rock) is shown in **Figure 2** and the design specifications are presented in **Table 3**.

Table 3: Proposed final SWRD design parameters

Slope aspect	Average slope angle (%)	Slope length at mid-point (m)
North	12.0	117
East	11.8	117
South	12.0	117
West	9.9	40
Top	0.2	NA

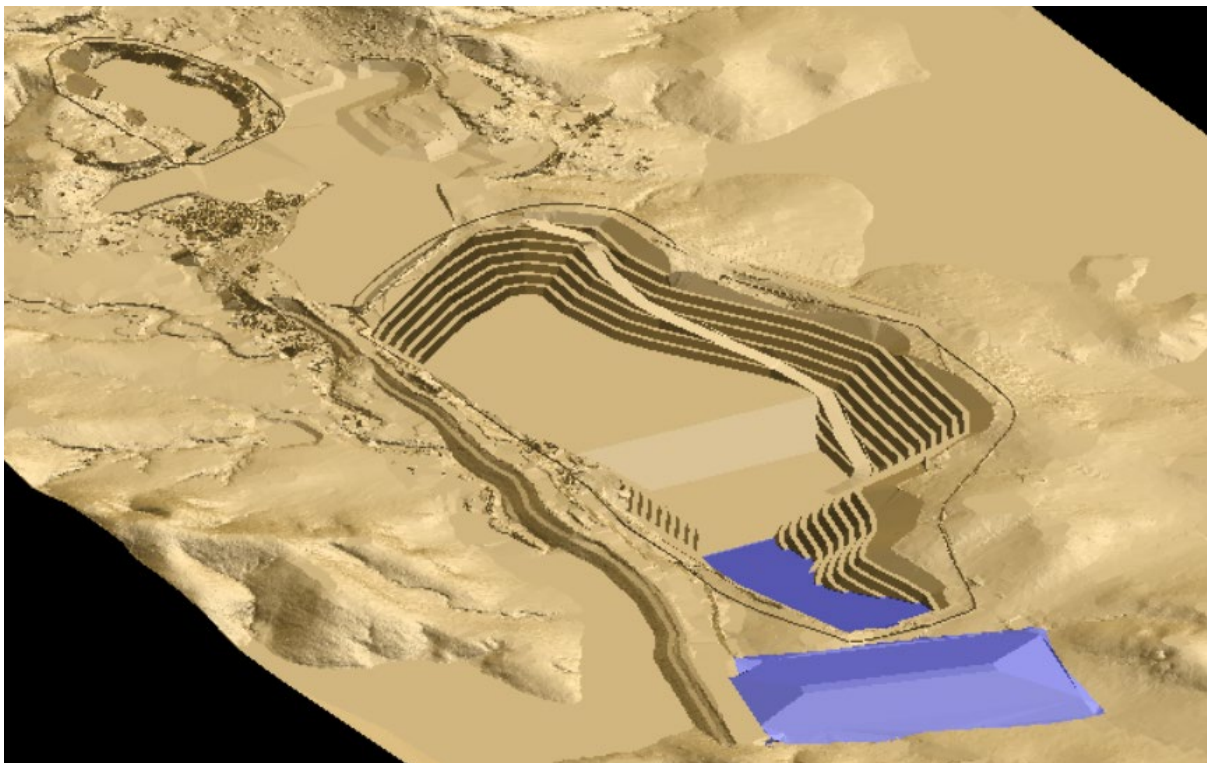


Figure 2: SWRD location and proposed final design (bottom right) showing in-filling of the southern end of pit 3-4 and end of mine life (Source: Graymont 2025)

4 RESULTS

The predicted erosion rates generated by the RUSLE modelling for the preliminary landform design are presented in Table 4. The results are based on the design parameters in **Table 2** and the RUSLE inputs in **Section 3** with a C factor of 0.03 (equivalent to 80% groundcover of newly established grass cover).

Table 4: Predicted erosion rate for the preliminary SWRD landform design

Slope aspect	Average erosion rate (t/ha/yr)
North	13.7
East	13.7
South	13.5
West	4.9
Top	0.37
Whole of landform	9.6

Although overall rates of erosion from the landform were below 10 t/ha/yr, the rates of erosion on three of the four sides of the SWRD exceeded 10 t/ha/yr, above generally accepted sustainable rates of erosion.

The predicted erosion rates generated by the RUSLE modelling for the proposed final landform design are presented in **Table 5** and shown in **Figure 3**. The results are based on the design parameters in **Table 3** and the RUSLE inputs in **Section 3** with a C Factor varying from 0.03 to 1 to reflect a range of groundcover scenarios.

Table 5: Predicted erosion rate for the proposed SWRD final landform design under a range of ground cover scenarios

C Factor (equivalent ground cover)	Slope aspect	Average erosion rate (t/ha/yr)
1.00 (0%)	North	210
	East	210
	South	210
	West	160
	Top	11
	Whole of landform	190
0.45 (20%)	North	93
	East	93
	South	93
	West	74
	Top	4.7
	Whole of landform	86
0.22 (40%)	North	46
	East	45
	South	46
	West	36
	Top	2.3
	Whole of landform	42
0.10 (60%)	North	21
	East	21
	South	21
	West	16
	Top	1.1
	Whole of landform	19
0.03 (80%)	North	6.2
	East	6.2
	South	6.2
	West	4.9
	Top	0.32
	Whole of landform	5.7

The proposed changes to final landform design for the SWRD reduced predicted maximum erosion rates to 6.2 t/ha/yr under 80% ground cover for individual slopes and to under 6 t/ha/yr for the whole landform. Predicted rates of erosion would be expected to fall in the long term once the grass cover is well established and the C Factor increases.

5 CONCLUSION

The erosion modelling has demonstrated that acceptable rates of erosion can be achieved through modifying the preliminary SWRD design. The improved design also provides a landform that is suited to the development of the nominated grazing PMLU.

Additionally, it has been demonstrated that acceptable rates of erosion can also be achieved through modification of the ground cover factor (C Factor). Additional modelling will be undertaken during the detailed design phase to determine the minimum groundcover requirements for long-established pasture prior to rehabilitation of the final landform.



Overview - Mining Leases

Legend

- Mining leases
- Cadastre (DCDB)
- Waste rock dump annual soil loss with 80% vegetation cover (t/ha/yr)**
- <= 2
- 2 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- > 20

This map has been compiled from the best information available to Epic Environmental. While effort has been made to create an accurate reference, it is not survey-verified, and some information may not be correct. Area calculations, boundaries and measurements displayed are GIS derived approximations that may vary between datasets due to differences in projection systems and data collection methods.

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**Graymont
Calliope Limestone Quarry**

Figure 3
Predicted erosion rate for the SWRD final landform design with 80% ground cover



0 30 60 m

Scale: 1:2,200@ A3
Datum: GDA2020
Projection: MGA zone 56

Data Source:
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