Appendix 7

Open Cut Erodibility Assessment

prepared by

Landloch Pty Ltd

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Tomingley Gold Operations Project

Wyoming 1 Open Cut and SAR North Pit Voids Assessment of Long-term Stability to Erosion

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TOOWOOMBA
PO Box 57
HARLAXTON QLD 4350
Phone (07) 4613 1825

PERTH
PO Box 5175
SOUTH LAKE WA 6164
Phone (08) 9494 2835

NEWCASTLE
PO Box 7017
REDHEAD NSW 2290
Phone (02) 4965 7717

Landloch Pty Ltd
A.C.N. 011 032 803
A.B.N. 29011032803

Web site: www.landloch.com.au
Email: admin@landloch.com.au

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1 INTRODUCTION

RW Corkery and Co Pty Ltd, on behalf of Alkane Resources Ltd, engaged Landloch to provide technical support to Tomingley Gold Operations (TGO) with the evaluation of erosion in 'Wyoming 1 Open Cut' and 'SAR North Pit' open cut voids (Voids).

The purpose of this program is to assess the long-term erosional stability of the walls within the Voids, as the Voids are to remain part of the current approved Wyoming 1 Open Cut and proposed SAR North Pit landforms for closure. Of particular focus is the potential for erosion of the final excavated faces of the Voids, to extend outwards from the current Void boundaries and affect adjacent infrastructure, such as waste emplacement areas, residue storage facilities, and water contaminant structures.

The assessment considers impacts during mining operations and post mining for a term of 1,000 years.

1.1 Overview of Tomingley Gold Operations

The general arrangement of the mine is provided in Figure A1 (Appendix A). The Wyoming 1 Open Cut is within the existing Tomingley Gold Operations Mine Site, and the SAR North Pit is included in the proposed San Antonio and Roswell (SAR) Mine Site as part of the Tomingley Gold Extension Project. Further details of the operations are below.

1.1.1 Approved TGO mining operations

Existing mining activities are undertaken in accordance with development consent MP 09_0155. The approved activities would continue under any new development consent, and MP 09_0155 is to be surrendered following receipt of the new development consent and all required approvals for the project. The approved activities include:

- Extraction of ore and waste rock from four open cut pits, with underground mining beneath three of those open cuts.
- Construction of three out-of-pit waste rock emplacements and one in-pit emplacement.
- Construction and use of various haul roads, a run-of-mine pad and associated stockpiles.
- Construction and use of a processing plant to process up to 1.5 million tonnes per annum.
- Construction and use of two residue storage facilities, being Residue Storage Facility 1 (RSF 1) to Stage 9 or a maximum elevation of 286.5 m AHD, and Residue Storage Facility 2 (RSF 2) to Stage 2 or a maximum elevation of 272 m AHD.
- Construction and use of ancillary infrastructure.

1.1.2 Proposed SAR operations

The proposed SAR Operations and additional or modified TGO operations, include the:

- Re-alignment of Newell Highway, Kyalite Road and associated intersections with Back Tomingley West Road and McNivens Lane, and Kyalite Road overpass.
- San Antonio Deposit Open Cut and Underground Mines.
- Construction of two waste rock emplacements, namely the Caloma and SAR Waste Rock Emplacement, and backfilling of the associated open cuts.
- SAR Amenity Bund, Haul Road and Services Road between the SAR Open Cut and the Caloma 2 Open Cut.
- Processing of ore from the SAR deposits using the approved processing plant at a maximum rate of 1.75 Mtpa.
- Increased capacity for Residue Storage Facility 2, from Stage 2 to Stage 9, with a maximum elevation of 286 m AHD.
- Associated surface and underground activities and infrastructure.

In addition, the project would include an extension of the approved mine life, from 31 December 2025 to 31 December 2032.

The general arrangement of the proposed SAR operations is presented in Figure A2 (Appendix A).

1.2 Objectives of the Study

The objectives of this study were to address the NSW Resources Regulator directives regarding the long-term erosional stability of Wyoming 1 Open Cut and SAR North Pit walls, and involved:

- Landform evolution modelling using SIBERIA to evaluate the long-term landform changes due to erosion at timescales of 10, 100 and 1,000 years post closure.
- Inputs to modelling including, but not limited to:
    - A digital elevation model (DEM) at a spatial resolution of 0.3 m;
    - Calibration data based on the observed erosion characteristics of the three most prevalent and relevant lithologies within the Wyoming 1 Open Cut; and
    - Surface conditions within the Voids at closure are assumed to be bare and non-vegetated.
- Key outputs include, but are not limited to:
    - Visual representation and contours of the final Voids and modelled erosion behaviour at the time frames of 10, 100 and 1,000 years post closure;
    - Identification of high-risk erosion areas; and
    - Recommendations of treatment options to address long-term erosion risks.

1.3 Scope of Work

The scope of work included:

- Preparing a desktop review of relevant geotechnical reports to identify the lithologies of interest in the Voids that will remain exposed post mining.
- Capturing high-resolution remote sensing data (imagery and elevation) of Wyoming 1 Open Cut.
- Prepossessing remote sensing data to remove 'noise' and irrelevant data.
- Preparing a digital elevation model of the Wyoming 1 Open Cut and SAP North Pit at a spatial resolution of 0.3 m.
- Analysing high-resolution remote sensing data of Wyoming 1 Open Cut to quantify rill and gully development in berms (as discussed in section 2.3) and to determine erosion rates and parameters for lithologies of interest for use in erosion modelling.
- Deriving landform evolution model input parameters.
- Conducting landform evolution simulations of the stability of a three-dimensional model of the Voids at time frames of 10, 100 and 1,000 years post cessation of mining in each pit.

Geotechnical studies and an assessment of the long-term *geotechnical stability* of pits are excluded from the scope of works. It is understood TGO are addressing these task separately.

2 SITE SETTING

Relevant site setting details for erodibility testing of materials at the mine are detailed in this section. The site was inspected by Simon Buchanan from Landloch on 6 May 2021 with representatives from TGO.

2.1 Climate

The study area is dominated by a sub-humid climate characterised by hot summers and no dry season (NSW National Parks and Wildlife Service, 2003).

Average monthly maximum temperatures in winter tend to range from 16°C to 17°C, and from 31°C to 33°C in summer (BoM, 2020). Summer temperatures can exceed 40°C for short periods.

Average monthly minimum temperatures in winter tend to range from 5°C to 8°C, and from 17°C to 19°C in summer (BoM [Climate], 2021). Frosts are frequent through winter (BoM [Frosts], 2021).

Rainfall is relatively uniformly distributed throughout the year, with a median annual rainfall for Peak Hill of 561 mm. However, rainfall can be extremely variable in late spring and early summer, and can exceed 200 mm in a month.

Average evaporation exceeds the average rainfall throughout the year (NSW National Parks and Wildlife Service, 2003). The annual rainfall erosivity (R-factor) for the region is calculated using Cligen is 1844 MJ.mm/ha.h.y. Rainfall erosivity is a measure of the ability of rainfall to cause erosion. Values for monthly R-factors and erosivity ratings are shown in Figure 1, and are based on criteria presented in *Soils and Construction – Managing Urban Stormwater* (Landcom, 2004). The rainfall erosivity rating is generally low to moderate throughout the year.

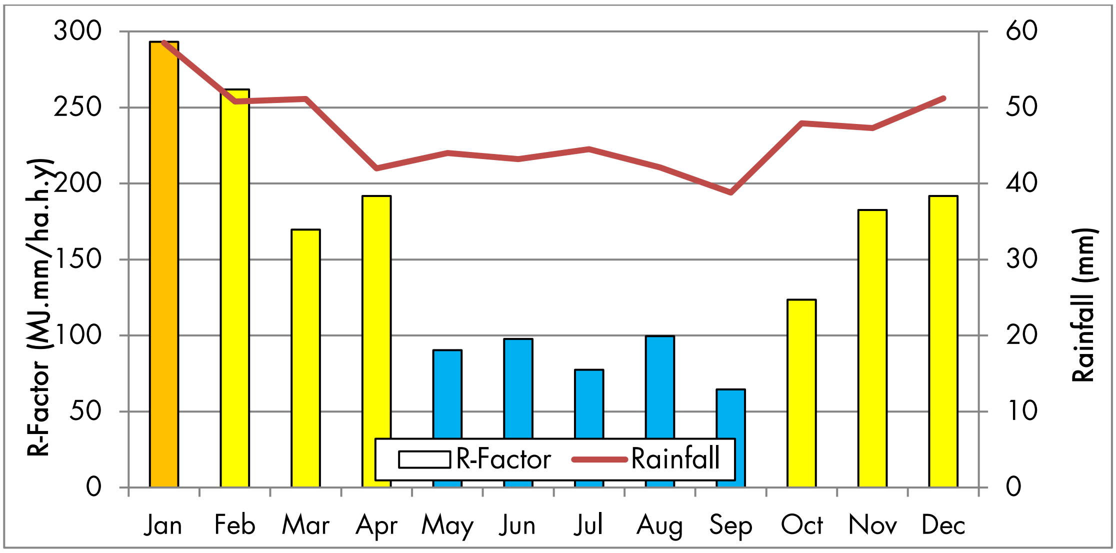


Figure 1: Monthly rainfall and erosivity R-factor for TGO (BoM [Climate], 2021). The R-factor ratings are: Blue-Low, Yellow-Moderate, and Orange-High.

2.2 Geology

The geological setting and basement geology of Wyoming 1 Open Cut and SAR North Pit deposits are the Mingelo Volcanics of Ordovician age (WSP, 2021) (Mining One, 2010). These mainly comprise andesitic phyric lavas and flow breccias with pyroclastic and volcaniclastic rich units.

The overlying saprolite and extremely weathered rock has a soil-like consistency and structure that resembles the underlying Mingelo Volcanics. It is typically pale grey, white, or mottled orange in colour. It has a variable mix of silty clays, sandy gravelly clays, sandy clayey silt with minor, very low strength rock fragment, and clays typically have a very stiff to hard consistency and medium to high plasticity. Saprolite is unconformably overlain by alluvial sediments.

The alluvial cover is of Quaternary to Tertiary age and up to 70 m deep across the mine and compromises:

- Quaternary Alluvium in the upper 10 m of the ground surface. It consists of brown, pale grey clays with variable amounts of sand and gravel, mainly low to medium plasticity with a very stiff to hard consistency.
- Tertiary Alluvium beneath the Quaternary Alluvium is characterised as grey mottled red and orange silty clays with sands and gravels, medium and high plasticity and very stiff to hard consistency.

A simplified sequence of lithology units is presented in Table 1 and illustrated in Figures A3, A4 and A5 (Appendix A).

Table 1: Generalised sequence of lithology units at Wyoming 1 Open Cut and SAR North Pit.

Unit	Approximate Elevation Upper Extent (m)		Description	Status
	Wyoming 1	SAR North		
Alluvials	275	270	Silty clay and clayey silt	Unconsolidated
Saprolite / Weathered Rock	250	230	Extremely to highly weathered versions of the lithified /crystalline rock types.	De-lithified
Volcanic and sedimentary rocks	185	185	Includes sandstone, siltstone, dolerite, basalt, andesite, pepertite, and porphyry.	Lithified and crystalline

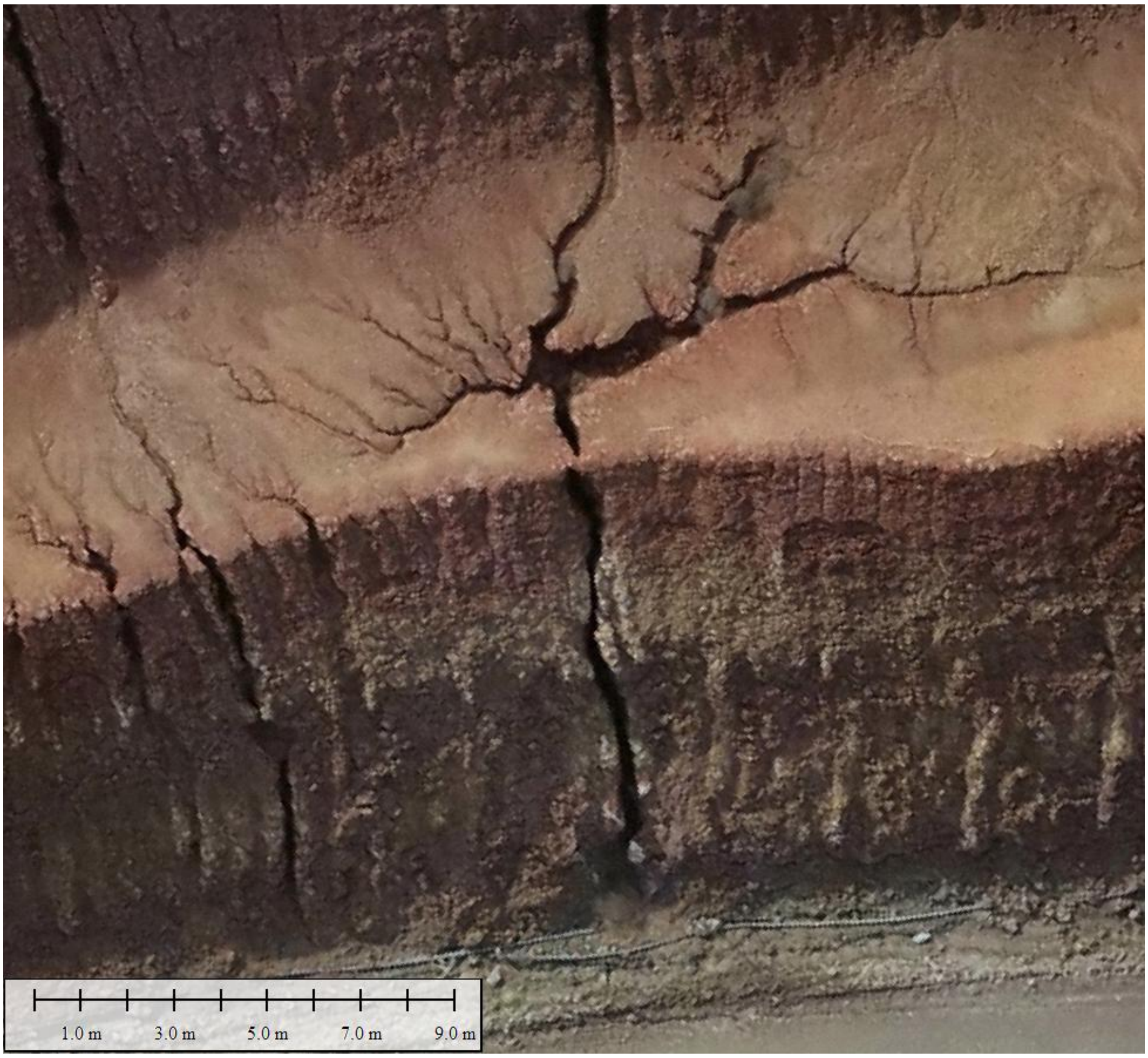
2.3 Existing Pit Conditions

Wyoming 1 Open Cut covers an area of approximately 29 ha and has a depth of approximately 185 m, ranging from 109 m RL to 274 m RL. The SAR North Pit is yet to be formed and is planned to have a depth of 307 m, ranging from -40 m RL to 267 m RL.

The excavation of overburden forms batters with a heavily scarified surface due to the excavator's toothed bucket. It results in tooth-formed troughs in freshly excavated faces that are on average 40 mm deep and at intervals of 0.5–1.0 m (Photograph 1). Once exposed to rainfall and run-off, these troughs become the initiation points for further erosion and provide preferential pathways for runoff water to concentrate and form rills and gullies.

Incidences of tunnel erosion were also observed in the Wyoming 1 Open Cut (Photographs 1 and 2). These typically form with inlets on berms and outlets on the batter. As erosion continues these tunnels can collapse and form gullies.

Photograph 1. Example of scarification on pit walls at TGO resulting from excavating with a toothed bucket. There is also an incidence of tunnel erosion on this batter, as indicated by the blue dashed line.



Photograph 2: Tunnel erosion in the berm batter sequence in Wyoming 1 Open Cut.

2.4 Representative Slopes

A generalised cross-section of pit geometry is provided in Figure 2. The height of the batters is typically 15–20 m, and the width of the berms is 8–16 m. In the unconsolidated and delithified materials ('soft-rock') the gradient of the batters is approximately 45°, and in the lithified materials ('hard rock') it is approximately 60–70°.

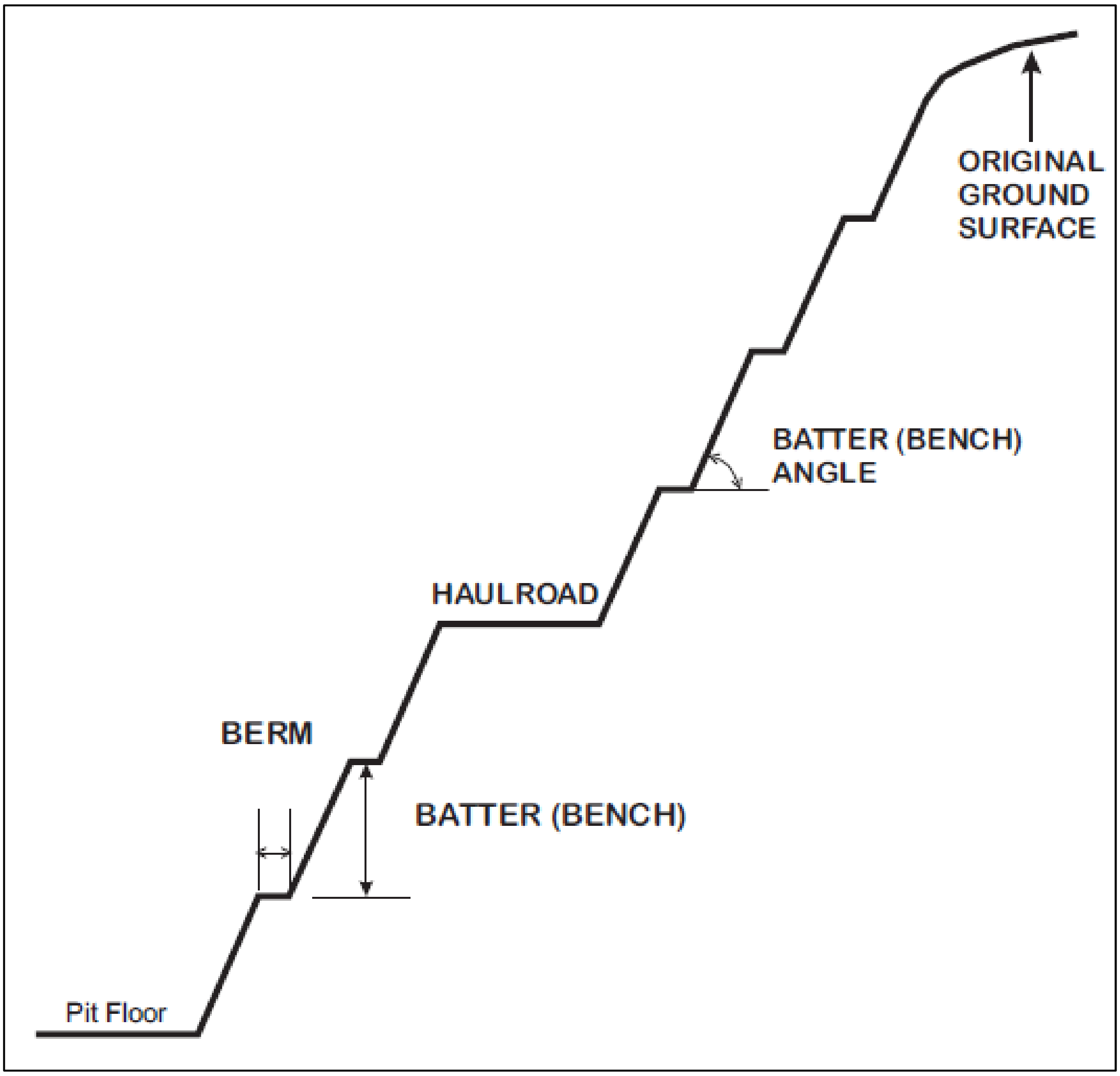


Figure 2. Generalised cross-section of the pit (Mining One, 2010).

2.5 Post Mining Land Uses

The post mining land uses of the Voids detailed in the MOP (RW Corkery, 2016) are:

- A final landform that is safe, stable and secure.
- Continued secure access to accumulated water storage.
- Continued access to the Wyoming 1 Open Cut portal for mining-related purposes.

The land immediately adjacent to the Voids is to be suitable for agricultural purposes, including grazing and cropping.

The Voids will not be actively revegetated.

3 METHODOLOGY

Erodibility parameters were derived for the lithologies within the Voids that have the potential to erode and form substantial rill and gully erosion beyond the perimeter of the pit. These material erodibility parameters were used to develop input values for landform evolution modelling of DEMs in the Voids.

3.1 Landform Evolution Modelling

Long-term landform evolution simulations were carried out using the SIBERIA landform evolution model.

SIBERIA is a 3-dimensional topographic model that predicts the long-term development of channels and hillslopes in a catchment, based on runoff, erosion, and deposition. The location and speed that rills and gullies develop is forecast by a channelisation function. SIBERIA does not input actual rainfall or material erodibility parameters. Rather, the input parameters used to define this channelisation function are related to both runoff and soil erodibility (Willgoose *et al.* 1989) and must be derived for each test material at each project site.

Channel growth is governed by an activation threshold, which is dependent on discharge and slope gradient. When the activation threshold is exceeded, channel development is predicted. In this way, it is possible for the initial modelled surface to have no gullies, and for channels to develop when the activation threshold is exceeded over time.

SIBERIA has been successfully applied to explain aspects of geomorphology of natural landforms (Willgoose 1994) and has been widely used in the context of mining and subjected to extensive validation. In general, provided the model is adequately calibrated, the validation work indicates SIBERIA predictions of landform development appear to be reasonable (Hancock *et al.* 2000, Hancock *et al.* 2002, Hancock *et al.* 2003). In addition, Hancock (2004) notes that rates of erosion predicted by SIBERIA for a catchment in the Northern Territory compared favourably with estimates of erosion derived using the Caesium-137 method. As the two methods used completely independent input information, this agreement is particularly significant.

The SIBERIA model is, and has been, widely used for assessing the development of constructed landforms on a range of mine sites across Australia and overseas (Willgoose 1995, Willgoose and Riley 1993, Boggs *et al.* 2000, Hancock *et al.* 2003, Hancock and Willgoose 2004, Hancock 2004, Mengler *et al.* 2004, Hancock and Turley 2006).

3.2 Derivation of Erodibility Parameters

Conceptual models were prepared for the lithologies in the Voids that will remain exposed post mining (Figures A3 and A4, Appendix A). The model for Wyoming 1 Open Cut is based on data from *Tomingley Gold Project Geotechnical Report Definitive Feasibility Study* (Mining One, 2010). In particular, 10 bore logs (WYGT06 to WYGT11 and WYGT18 to WYGT21) were relied upon. Geological data for the SAR North Pit are based on data from *Tomingley Gold Extension Project. San Antonio and Roswell Geotechnical Report* (WSP, 2021).

Historical orthophotograph imagery (2014–2020) captured by either an unmanned aerial vehicle or a fixed wing aircraft enabled the temporal dating (± 6 -12 months) for each successive bench/berm formation. Data captured from seven events were relied upon (Table 1).

The current surface of Wyoming 1 Open Cut void was captured by a registered surveyor (Langford & Rowe Consulting Surveyors, Dubbo NSW). Point cloud elevation data of the current surface were captured using a RIEGL terrestrial laser scanner and orthophoto imagery from a real-time kinematic (RTK) unmanned aerial vehicle. These elevation data have a higher resolution than historical data (Table 2).

Table 2. Summary details of remote sensing data.

Date	Data	Resolution	Method
2014, 2015, 2016, 2017, 2018, 2019, 2020	Imagery	80 – 300 mm pixel orthophotos	Unmanned aerial vehicle or fixed wing aircraft
10 Aug 2021	Elevation	Ave. point density 5,062 samples/m^2 Ave. point spacing 14 mm	Terrestrial Laser Scanner
10 Aug **2021**	Elevation	Ave. point density 465 samples/m^2 Ave. point spacing 46 mm	Unmanned aerial vehicle - Orthophoto

Of focus was the unconsolidated and de-lithified (oxidised - soft rock) materials in the upper portion of the Wyoming 1 Open Cut void that overlay the (fresh - hard rock) volcanic and lithified sedimentary units. The lithologies of interest (LOI) are named 'Alluvial', 'Saprolite 1', and 'Saprolite 2'. At Wyoming 1 Open Cut, the saprolite materials have been differentiated based on colour and proximity from aerial imagery. Saprolite 1 is pale yellow/orange material on the western and northern pit walls, and Saprolite 2 is orange/pale brown /grey on the eastern and southern pit walls (Figure A3 – Appendix A).

Erosion rates were derived for each LOI in Wyoming 1 Open Cut, and were relied upon in the modelling of both Wyoming 1 Open Cut This process involved examining and quantifying the rill and gully development at Wyoming 1 Open Cut by interrogating *historical* aerial imagery, in conjunction with recent imagery and captured elevation data.

Using this information, rates of erosion of the benches were calculated for the period of exposure to erosive forces (predominantly rainfall).

Rainfall records for when the void walls were subject to erosion were compared to the long-term average. Based on this comparison, calculated rates of erosion were adjusted to ensure consistency with long-term rainfall records.

The SIBERIA model was run and its erodibility parameters revised reiteratively until erosion predictions were consistent with the observed rates and distribution of erosion.

SIBERIA modelling of the SAR North Pit used a digital elevation model based on the conceptual design of the void. Exploration data shows that the lithologies with the pit at similar Wyoming 1, but differ in depth and thickness. As a conservative measure, modelling of the SAR North Pit used the most erodible of the LOI (Saprolite 1) as surface material for the upper unconsolidated and de-lithified layers.

3.3 SIBERIA Model Settings

Digital elevation models (DEMs) were prepared by Landloch at a resolution of 0.3 m. The Wyoming 1 Open Cut DEM was derived from high resolution elevation data of the existing surface provided by TGO.

The DEM for the SAR North Pit was derived from a conceptual model of the void. Prior to modelling, random roughness (±0.1 m) was added to the SAR North Pit DEM to reduce triangulation gridding artefacts from the surface of the DEMs and to provide a more realistic surface for modelling.

An abandonment bund was created at a distance of approximately 20 m (crest to crest) from the safety bund.

A total of 12 permutations of SIBERIA modelling were conducted to accommodate the following variables:

- Three timescales - 10, 100, and 1,000 years;
- One surface condition - bare (non-vegetated);
- Three surface lithologies at Wyoming 1 Open Cut - Alluvial, Saprolite 1 and Saprolite 2; and
- One lithology at SAR North Pit - Saprolite 1.

The following outputs were produced by SIBERIA:

- Visual outputs showing the evolved DEM and erosion/deposition locations at 10, 100, and 1,000 years; and
- Cross-sections illustrating the extent of erosion and deposition at 10, 100, and 1,000 years.

Outputs from SIBERIA model runs were processed to produce a series of visualisations. These visualisations were used to compare patterns of erosion across each of the simulations.

4 EROSION AND LANDFORM EVOLUTION SIMULATIONS

Visual representation and contours of the final Voids and modelled erosion behaviour at the time frames of 10, 100 and 1,000 years post closure are provided in Appendix B. The principal findings are presented below.

4.1 Erodibility of Materials

Erodibility rates of materials are based on erosion measurements over a period of 44 months (3.7 years) to 68 months (5.7 years). The mean erosion rates calculated for Alluvium was 122 t/ha/yr.; but varied greatly, ranging from 62 t/ha/yr to 218 t/ha/yr. In contrast, the mean erosion rates calculated for Saprolite 1 and Saprolite 2 materials were relatively similar at 145 t/ha/yr and 148 t/ha/yr, respectively (Table 3), and ranged from 139 t/ha/yr to 157 t/ha/yr.

To put these rates in perspective, erosion rates less than 150 t/ha/yr and 151–225 t/ha/yr have 'erosion hazard' rankings of 'very low' and 'low' respectively, according to the *Managing Urban Stormwater: Soils and Construction Volume 1* (Landcom, 2004).

Table 3: Calibration data for the three lithologies of interest.

Lithology	Plot	Area (m^2)	Annual Erosion (t/ha/yr)	Erosion Hazard
Alluvium	All_1A	250	61.9	Very Low
	All_1B	361	82.0	Very Low
	ALL_1C	625	125.8	Very Low
	All_3	782	217.8	Low
Saprolite 1	Sap1_2A	655	144.4	Very Low
	Sap1_2B	1024	142.8	Very Low
	Sap1_3	1082	147.4	Very Low
Saprolite 2	Sap2_2	914	157.4	Low
	Sap2_3	708	139.2	Very Low

Erosion measurements show an increasing trend with depth (Figure 3). In the upper bench (Bench 1) erosion rates are 62–126 t/ha/yr with a mean of 90 t/ha/yr. In Benches 2 and 3, the erosion rates were appreciably higher at 139–218 t/ha/yr with a mean of 158 t/ha/yr. This is not unexpected as the catchment area and runoff volumes for benches increase with depth. As runoff rates increase, the rate of erosion also increases.

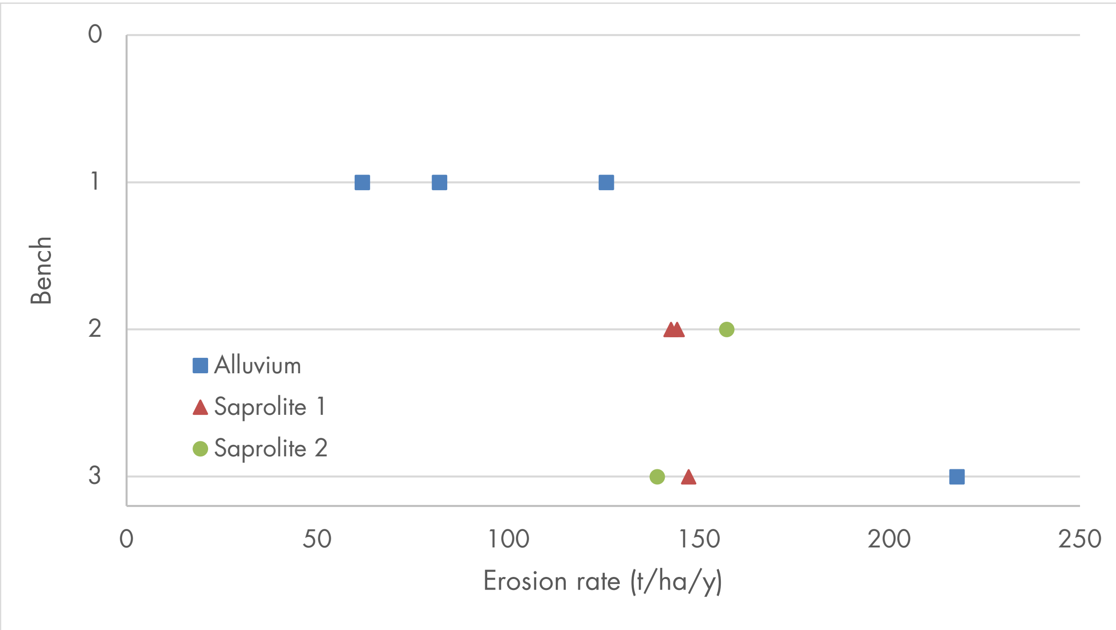


Figure 3: Erosion rates tend to increase with depth.

The rate of advancement of the 'pit/natural surface' interface did not differ greatly between the different lithologies when modelled with SIBERIA (Figure 4). The predicted change in the pit wall was similar for all materials. For this reason, predictions of pit expansion in regard to critical infrastructure are based on the calibration data derived for Saprolite 1 materials as it was the most erosive of the three materials, albeit slightly.

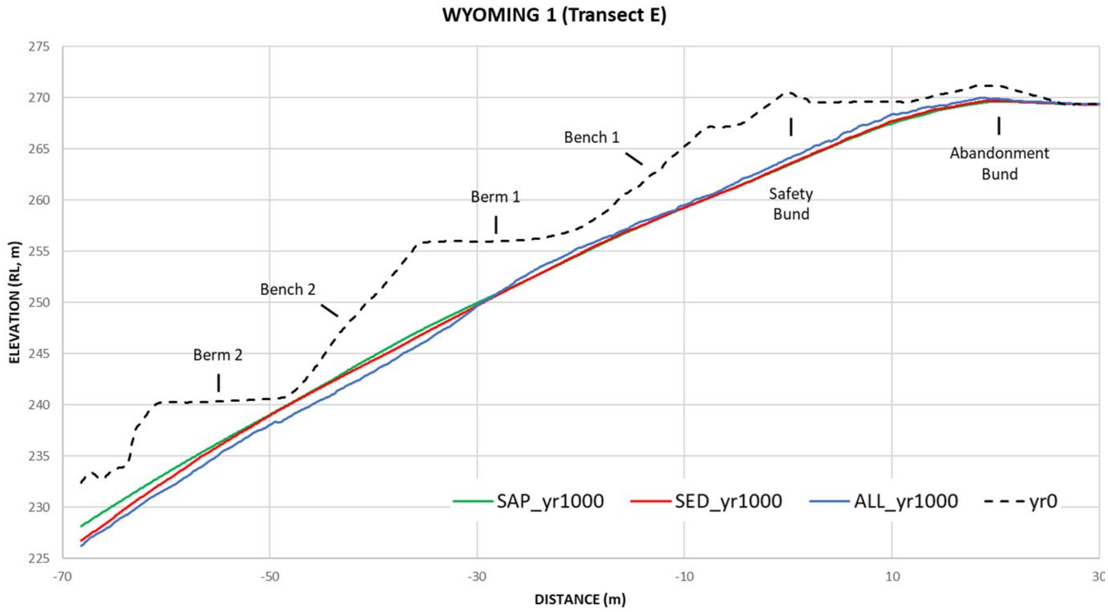


Figure 4: Comparison of predicted erosion of the Alluvial (All), Saprolite 1 (Sap1), Saprolite 2 (Sap2) lithologies of interest at 1,000 years.

4.2 Risk to Infrastructure

Critical infrastructure assets are considered vital and any expansion of the pit voids that would degrade the integrity of these structures could lead to considerable consequences.

Modelling indicates that pit expansion due to erosion is expected to have an average rate of approximately 2 m/100 years. Erosion rates at this low magnitude do not present a risk to any critical infrastructure near either of the voids.

4.2.1 Wyoming 1 Open Cut

The critical infrastructure surrounding Wyoming 1 Open Cut includes the Newell Highway to the east, RSF1 to the north-west, and the yet to be constructed RSF2 to the west (Figure 5). Other nearby infrastructure is the Wyoming Central Dam to the north of the pit, although it is not considered critical.

Figure 5: Critical infrastructure surrounding Wyoming 1 Open Cut.

The approximate distances to infrastructure from the edge of Wyoming 1 Open Cut Void at time intervals of 10, 100, and 1,000 years are presented in Table 4.

It is important to note the pit edge advancement rates are based on an abandonment bund constructed entirely around each void, 20 m outside of the safety bund. Erosion modelling assumes the abandonment bund is a barrier to surface water flows and defines the outer extent of the catchment that feeds runoff into the pit. It can be expected that without an abandonment bund, the rate of expansion of the pit due to erosion will increase where contributing catchment areas are increased.

Table 4: Approximate distances from infrastructure to the edge of pit at time intervals of 10, 100, and 1,000 years.

Transect	Infrastructure	Status	Approximate distances (m) for time intervals (years post closure) of:		
			10	100	1,000
East	Newell Hwy	Critical	110	107	90
North	Wyoming Central Dam	Non-critical	55	52	35
North-west	RSF1	Critical	215	212	200
West	RSF2	Critical	190	187	165

The impact of erosion within the pit, for each transect, is presented in Figures 6 and 7. Initially (i.e. 0–100 years), erosion and deposition will 'soften' the edges of the batters and berms. The upper portion of each batter will erode and deposit on the berms below or overflow and accumulate in the base of the void. As time passes the berms will continue to erode away, resulting in the profile of the pit wall becoming a more linear profile.

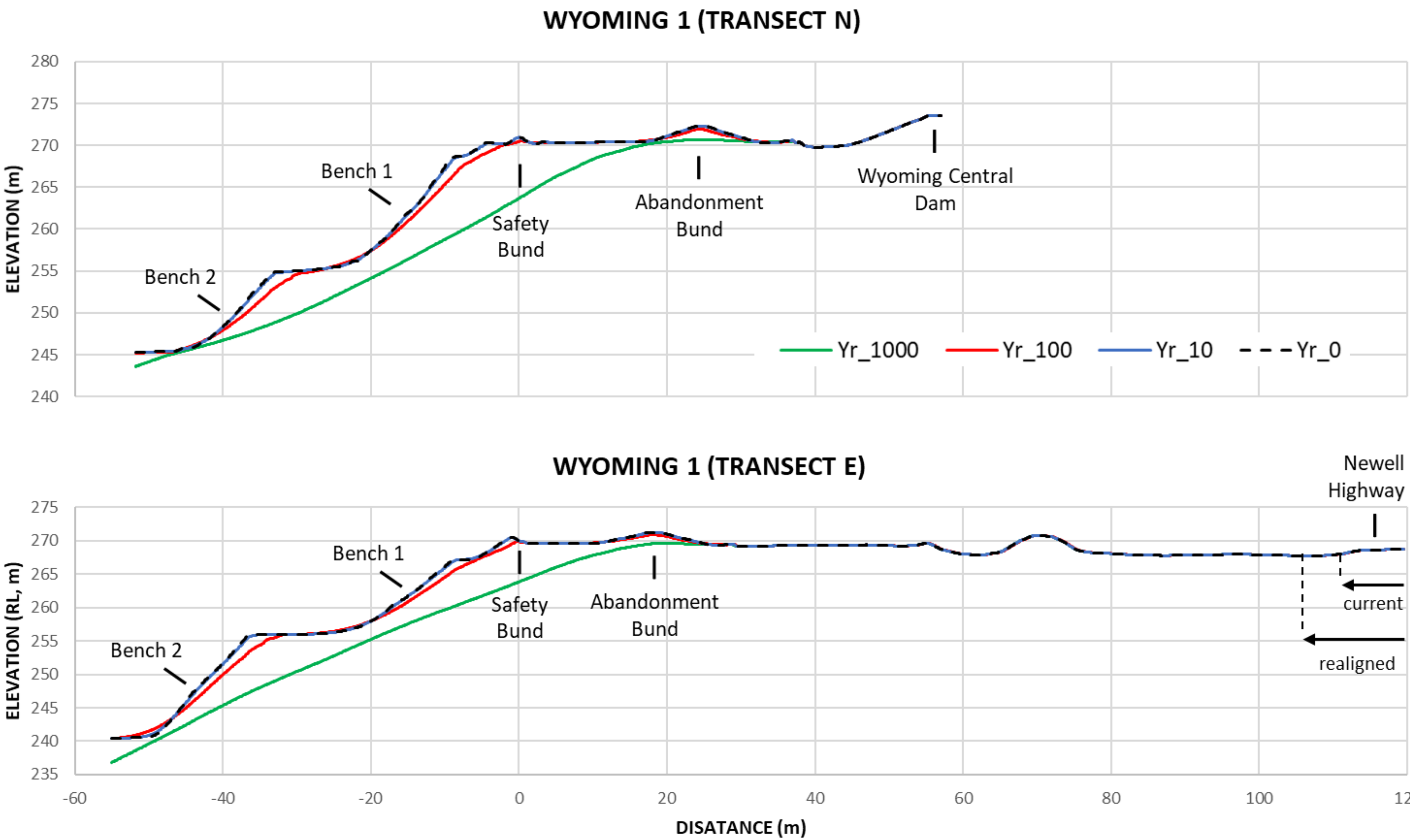


Figure 6: Cross-sections Transect N and Transect E of the residual Wyoming 1 Open Cut at timescales of 0, 10, 100, and 1,000 years.

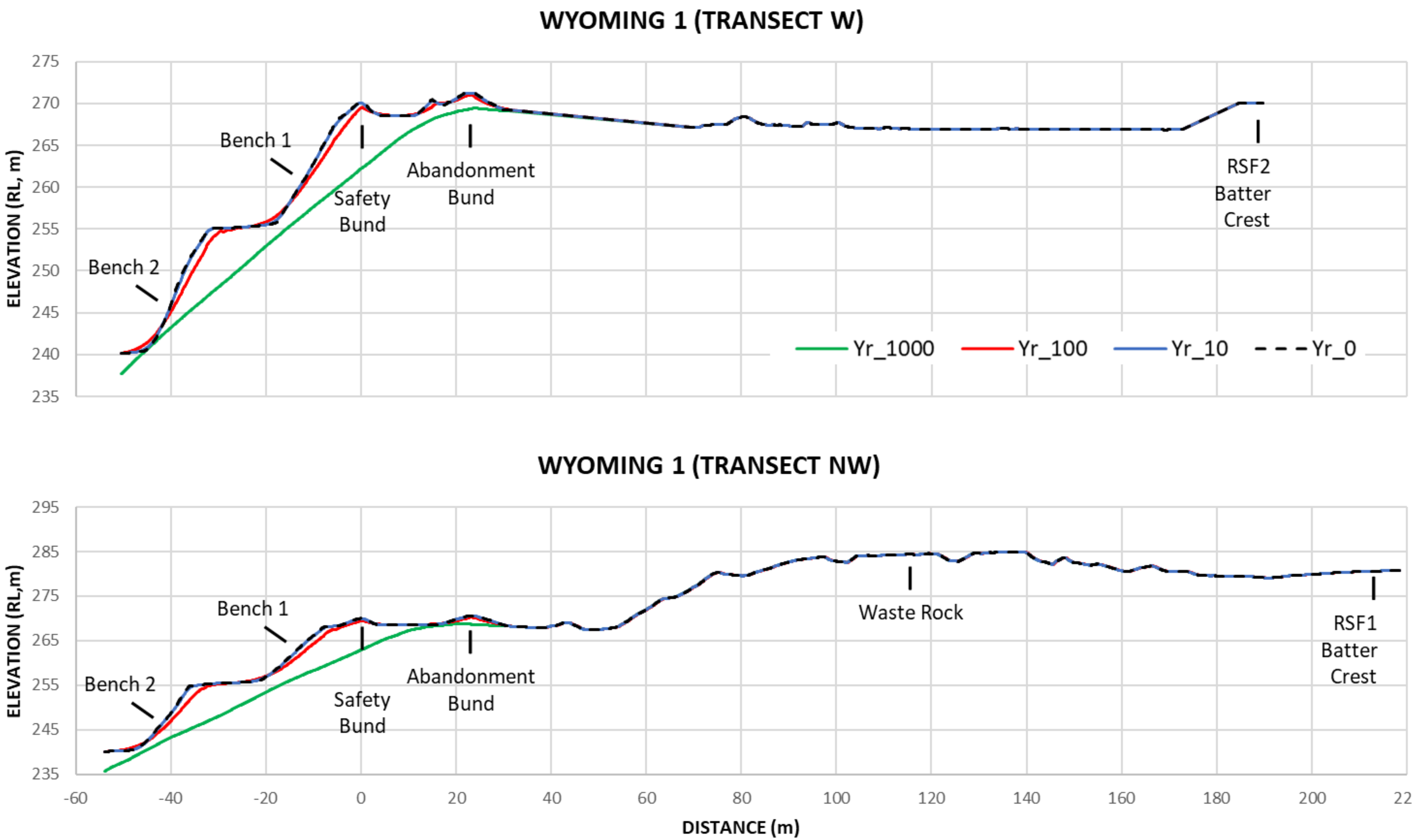


Figure 7: Cross-sections Transect W and Transect NW of the residual Wyoming 1 Open Cut at time intervals of 0, 10, 100, and 1,000 years.

4.2.2 SAR North Pit

The critical infrastructure surrounding the SAR North Pit is the SAR Waste Rock Emplacement to the southeast that adjoins the pit. Other nearby infrastructure includes the SAR Storage Dam to the north-east, Amenity Bund to the north-northeast, and the Eastern Farm Dam to the east-southeast (Figure 8).

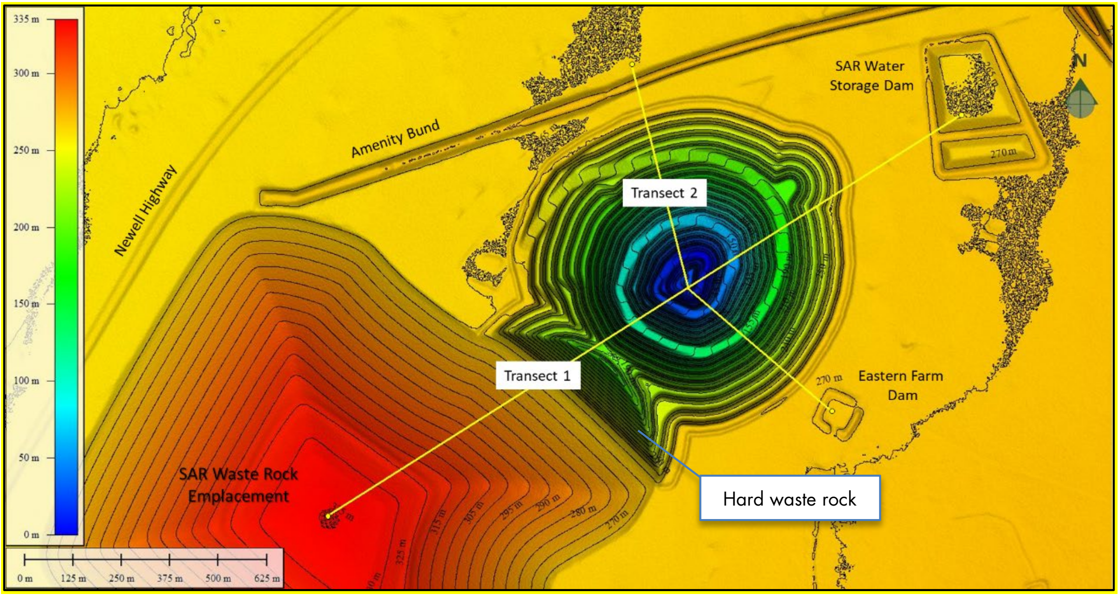


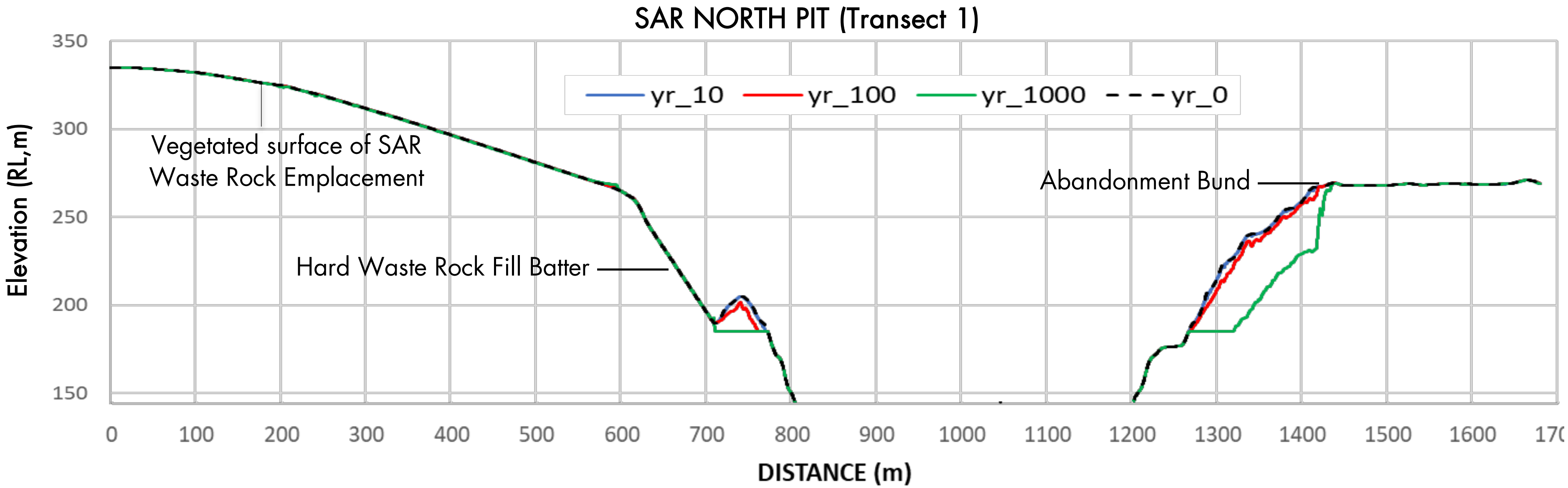
Figure 8: Critical infrastructure surrounding the SAR North Pit.

The approximate distances to infrastructure from the edge of SAR North Pit at time intervals of 10, 100, and 1,000 years are presented in Table 5.

Table 5: Approximate distances from infrastructure to the edge of pit at time intervals of 10, 100, and 1,000 years.

Transect	Infrastructure	Status	Approximate distances (m) for time intervals (years post closure) of:		
			10	100	1,000
1	SAR WRE	Critical	0	0	0
1	SAR Storage Dam	Non-critical	275	272	225
2	Amenity Bund	Non-critical	90	87	60
2	Eastern Farm Dam	Non-critical	90	87	70

The impact of erosion within the pit, for each transect, is presented in Figure 9. Similar to the Wyoming 1 Open Cut Void the berms will continue to erode away with time and result in a more linear shaped profile than a benched profile.



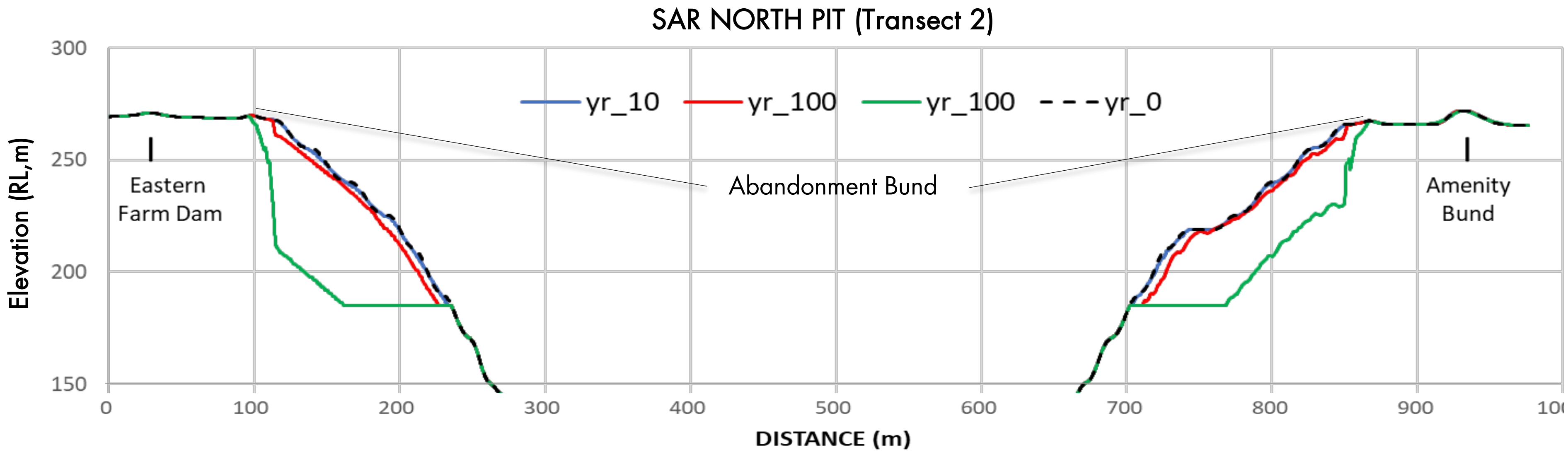


Figure 9: Cross-sections Transect 1 and Transect 2 of the residual SAR North Pit at timescales of 0, 10, 100, and 1,000 years.

4.3 Deposition within Voids

All materials eroding from batters and berms will remain in the Void and deposit eventually in the pit base. Predictions of deposition volumes and the resultant levels of the pit base are presented in Table 5 and are presented graphically in Figure 10 and Figure 11.

Table 6: Predicted deposition volumes and residual levels at time intervals of 10, 100, and 1,000 years.

Time scale (years)	Pit Base Deposition (M m^3)		Pit Base Elevation (RL m)	
	Wyoming 1 Open Cut	SAR North Pit	Wyoming 1 Open Cut	SAR North Pit
0	0	0	109	0
10	0.21	0.13	136	19
100	1.80	1.46	147	66
1,000	13.31	14.44	185	189

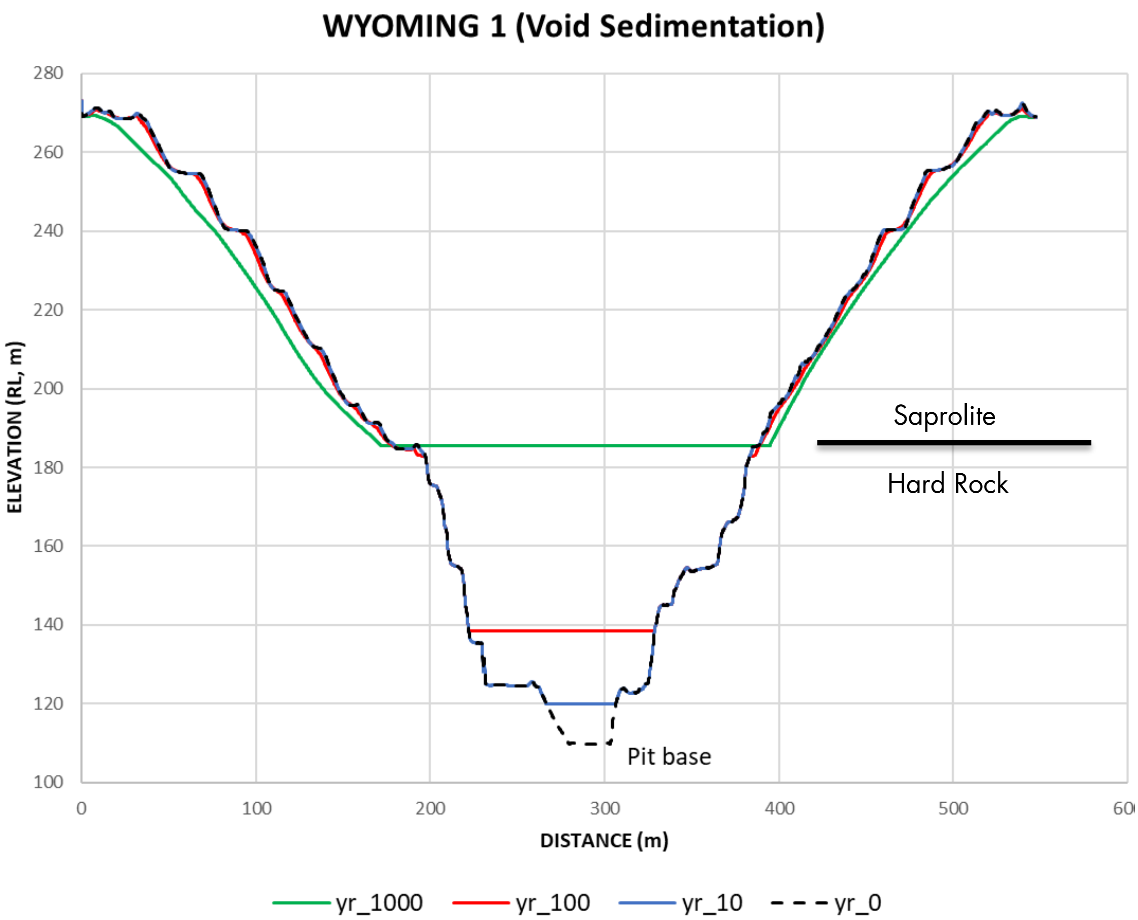


Figure 10: Conceptual representation of deposition levels of eroded sediment into Wyoming 1 Open Cut at time intervals of 10, 100, and 1,000 years.

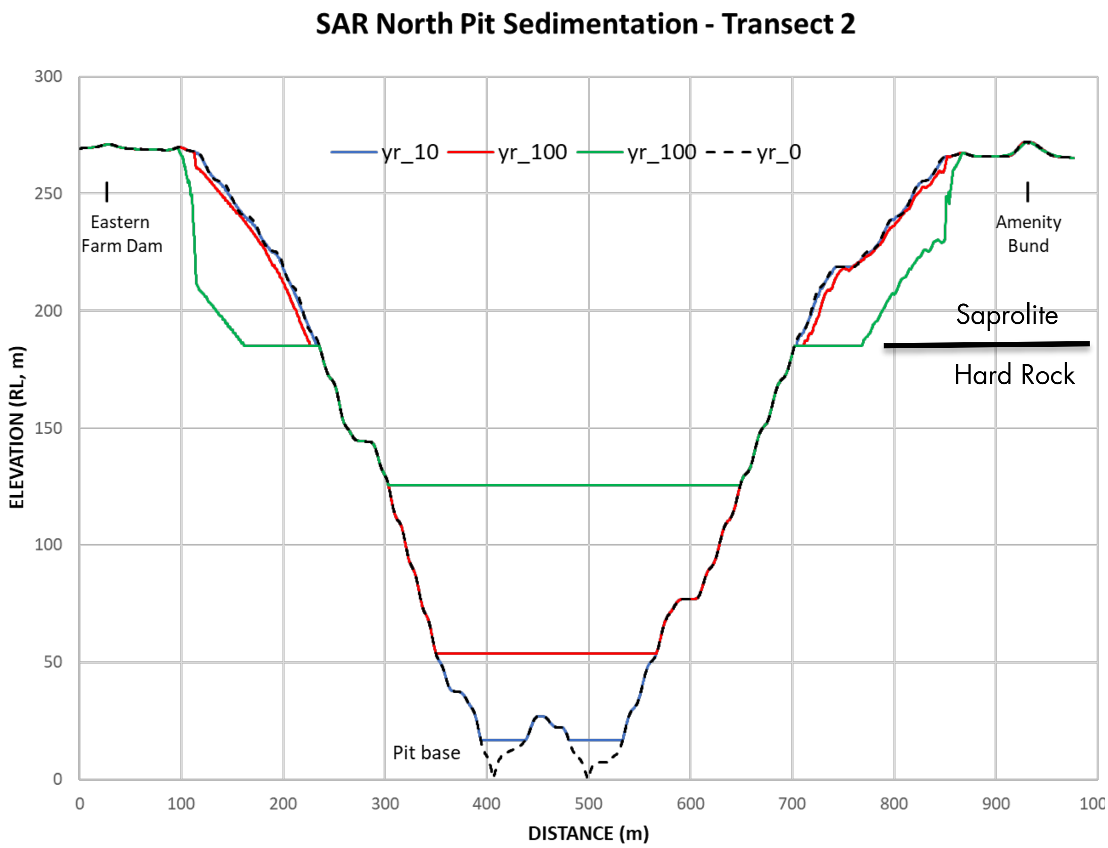


Figure 11: Conceptual representation of deposition levels of eroded sediment into SAR North Pit at time intervals of 10, 100, and 1,000 years.

5 DISCUSSION

The purpose of this erodibility assessment was to evaluate the long-term erosional stability of the walls within the Voids. Of vital importance is the risk of erosion to critical infrastructure around the Voids, as posed by any creep or expansion of the pit at the surface.

The current approved mine life for TGO is to December 2025, with concerted interest in extending it to December 2032. Based on this erosion assessment and modelling works conducted, there will be negligible pit edge creep of Wyoming 1 Open Cut during operations. To ensure this, the integrity of the safety bund must be maintained, and no surface runoff from the surrounding land is to flow into the pit in an uncontrolled (erosive) manner.

The landform evolution modelling timeframes of 100 and 1,000 years aim to evaluate changes due to erosion within the pit and immediate surrounds, once the mine is closed. Modelling indicates pit edge creep due to erosion is expected to have an average rate of approximately 2 m/100 years.

The critical infrastructure identified near Wyoming 1 Open Cut includes the Newell Highway, RSF1, and RSF2. They are situated at distances between 110–215 m from the current edge of the pit. At these predicted rates of erosion, the risk to critical infrastructure from the pit advancement is considered negligible for at least 1,000 years.

The critical infrastructure near the SAR North Pit is the SAR WRE. The current design includes the placement of hard (competent) waste rock at the interface of the pit and WRE, that is highly resistant to erosion. This will severely hinder the advancement of the pit edge towards the WRE and ensures that the risk to the stability of the WRE structure from undercutting is low.

The predicted expansion rates of the pit edge from erosion assume an abandonment bund is installed around each pit at a distance of 20 m from the safety bund (except at the interface of the SAR WRE and the SAR North Pit). From an erosion perspective, the abandonment bund needs to function as a 'catchment break' to prevent surface runoff from outside the bund flowing into the pit, thereby reducing the magnitude of erosive energies applied to the pit walls. In practice it may not be possible, or desirable, to prevent water entering the Voids. Therefore, any concentrated flows directed into the Voids will need to be managed and controlled via structures that are resistant to erosion from these flow conditions.

SIBERIA modelling assumed the whole of the modelled pit surface consisted entirely of one material (i.e. Alluvium, Saprolite 1, or Saprolite 2). This is due to the limitations of the SIBERIA model, as it does not have the capacity to model multiple material layers in simulations.

By assuming a uniform surface, SIBERIA diverges from reality as the pit walls do not consist of a uniform material as modelled. They comprise Alluvium near the surface, underlain by the more erodible Saprolite materials. However, expansion of the pit edge will be driven by the most erosive material. As Saprolite materials erode at a higher rate, this will lead to undercutting and localised collapses at the interface with the Alluvium. Hence, the predicted pit edge expansion rate of 2 m/100 years based on the more erodible Saprolite 1 materials is considered reasonable for evaluating the risks to critical infrastructure.

6 RECOMMENDATIONS

The erosion modelling undertaken in this assessment is based on the current surface within Wyoming 1 Open Cut. Any appreciable alteration to the gradient and length of batters (i.e. backfilling with less erodible materials) will change the erosion rate of the surface and, in-turn, impact the advancement rate of the pit edge. Commonly, but not always, erosion rates are likely to decrease when gradients are decreased. It is recommended that if any substantial changes are made to the shape of the pit wall, then further SIBERIA modelling should be undertaken using a DEM of the revised surface.

There would be benefit in revisiting this program in 5 to 10 years' time to compare the SIBERIA predicted rates of erosion with actual rates of erosion. This would evaluate the reliability of the modelling, and if necessary, further erosion modelling could be conducted based on measured data extrapolated to a longer-term.

7 REFERENCES

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APPENDIX A: FIGURES AND MAPS

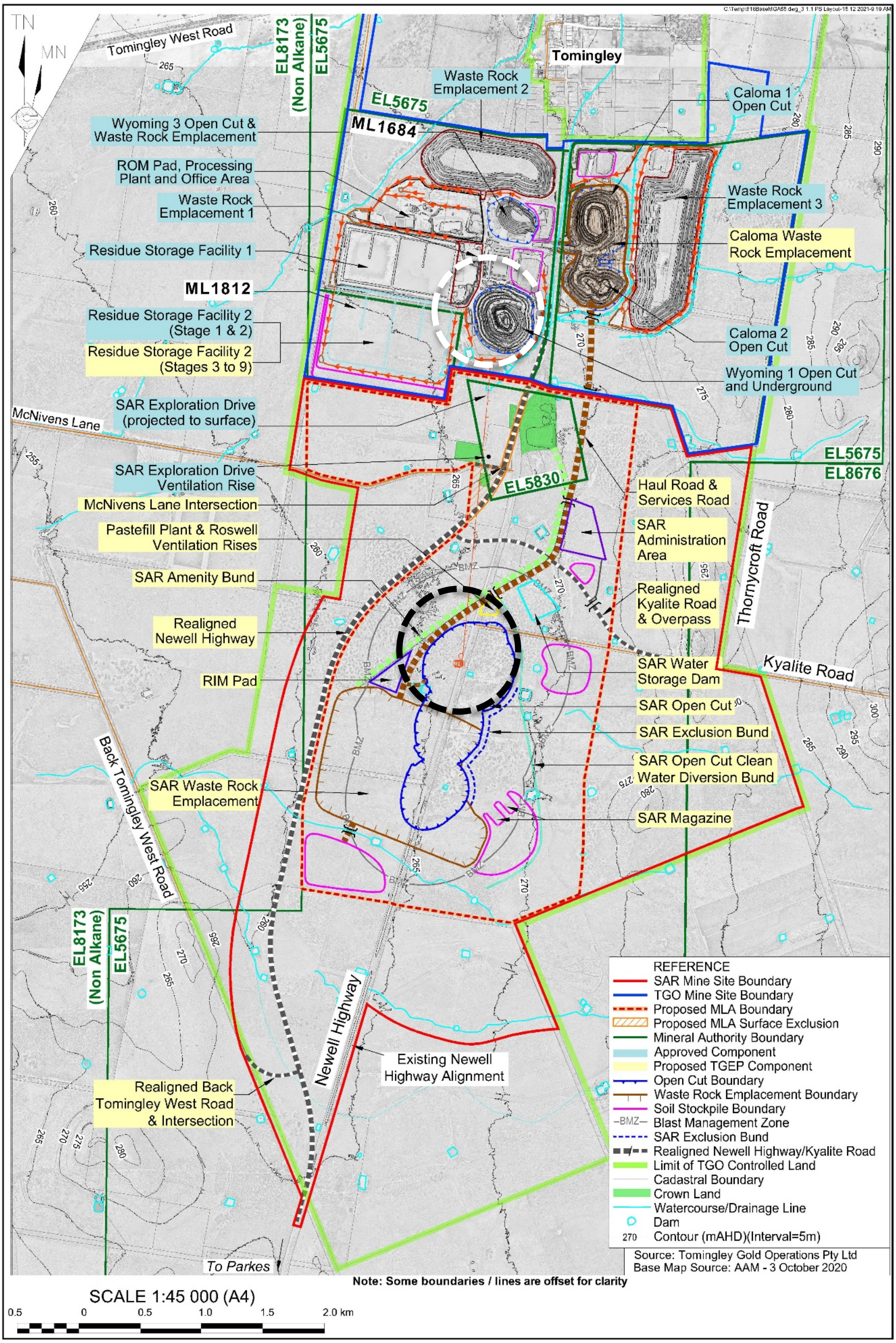


Figure A 1. General arrangement of the TGO and the TGEP (Courtesy RW Corkery, 2021) with Wyoming 1 Open Cut (white dashed circle) and SAR North Pit (black dashed circle) highlighted.

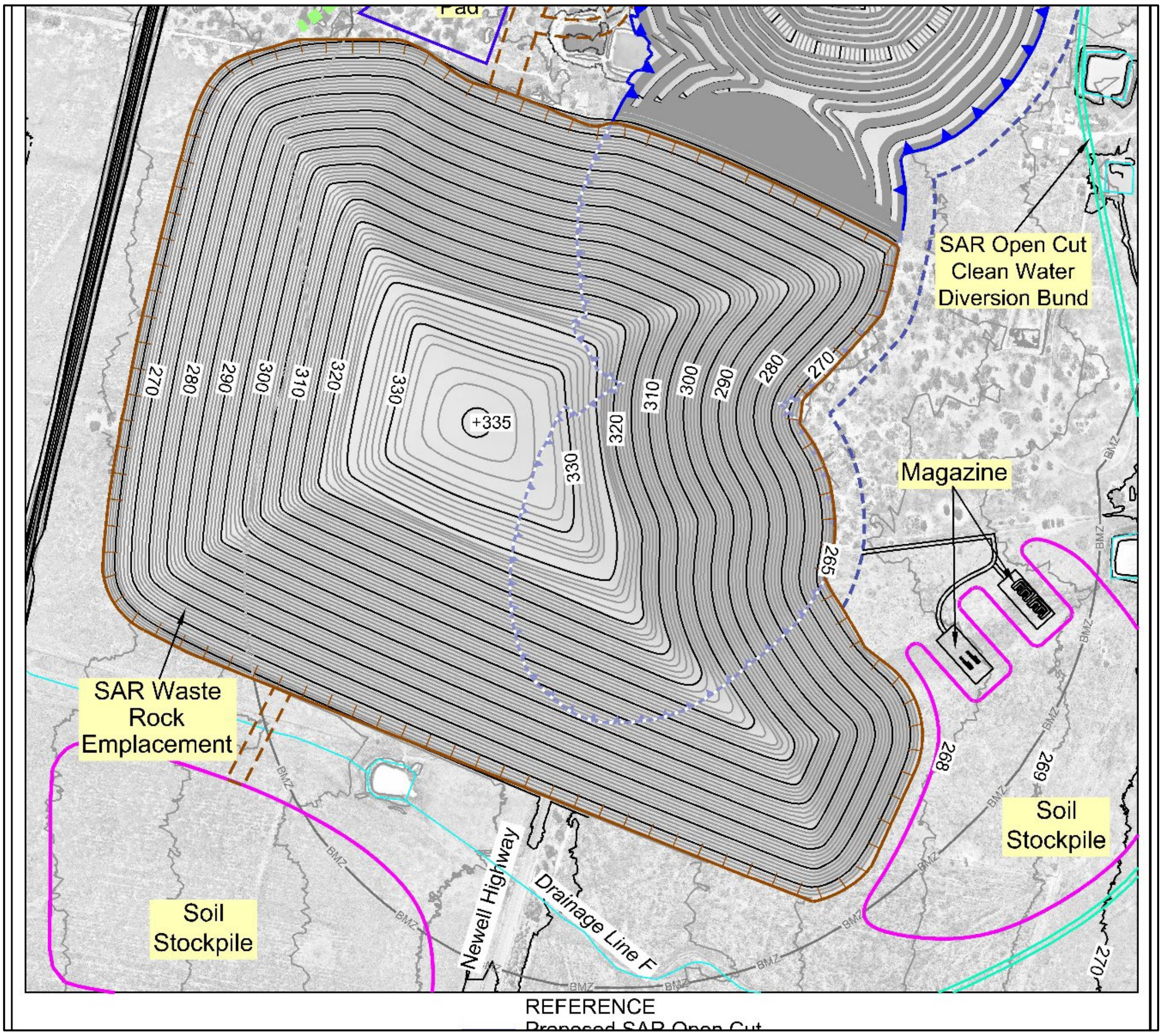
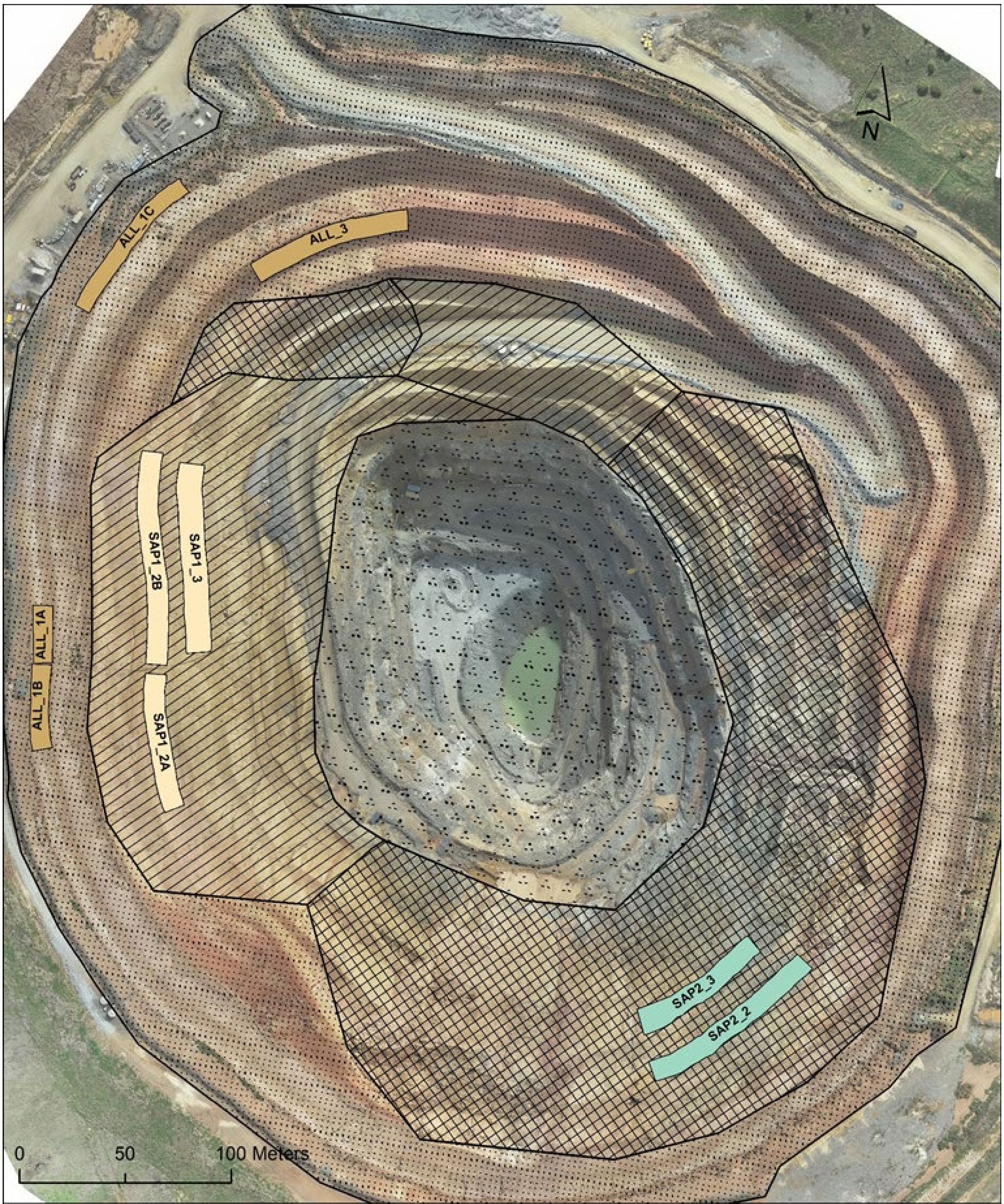


Figure A 2. Conceptual layout of the post-mining surface of the SAR North Pit. The current plan is for the two southern pits to be backfilled with waste rock, and the SAR North Pit will remain as a void (Courtesy RW Corkery, 2021).



Geological Domains

- Alluvials
- Saprolite 1
- Saprolite 2
- Volcanic

FID	Geo_Domain	Label	Area (m2)	Age_yrs
0	Alluvials	ALL_1A	250.45	5.7
1	Alluvials	ALL_1B	361.003	5.7
2	Alluvials	ALL_1C	624.914	3.7
4	Saprolite 1	SAP1_2A	655.328	3.7
8	Saprolite 2	SAP2_3	708.397	3.7
3	Alluvials	ALL_3	782.225	3.7
7	Saprolite 2	SAP2_2	914.259	3.7
5	Saprolite 1	SAP1_2B	1023.713	3.7
6	Saprolite 1	SAP1_3	1081.539	3.7

Figure A 3. Calibration areas within Wyoming 1 Pit and conceptual model of the lithologies of interest.

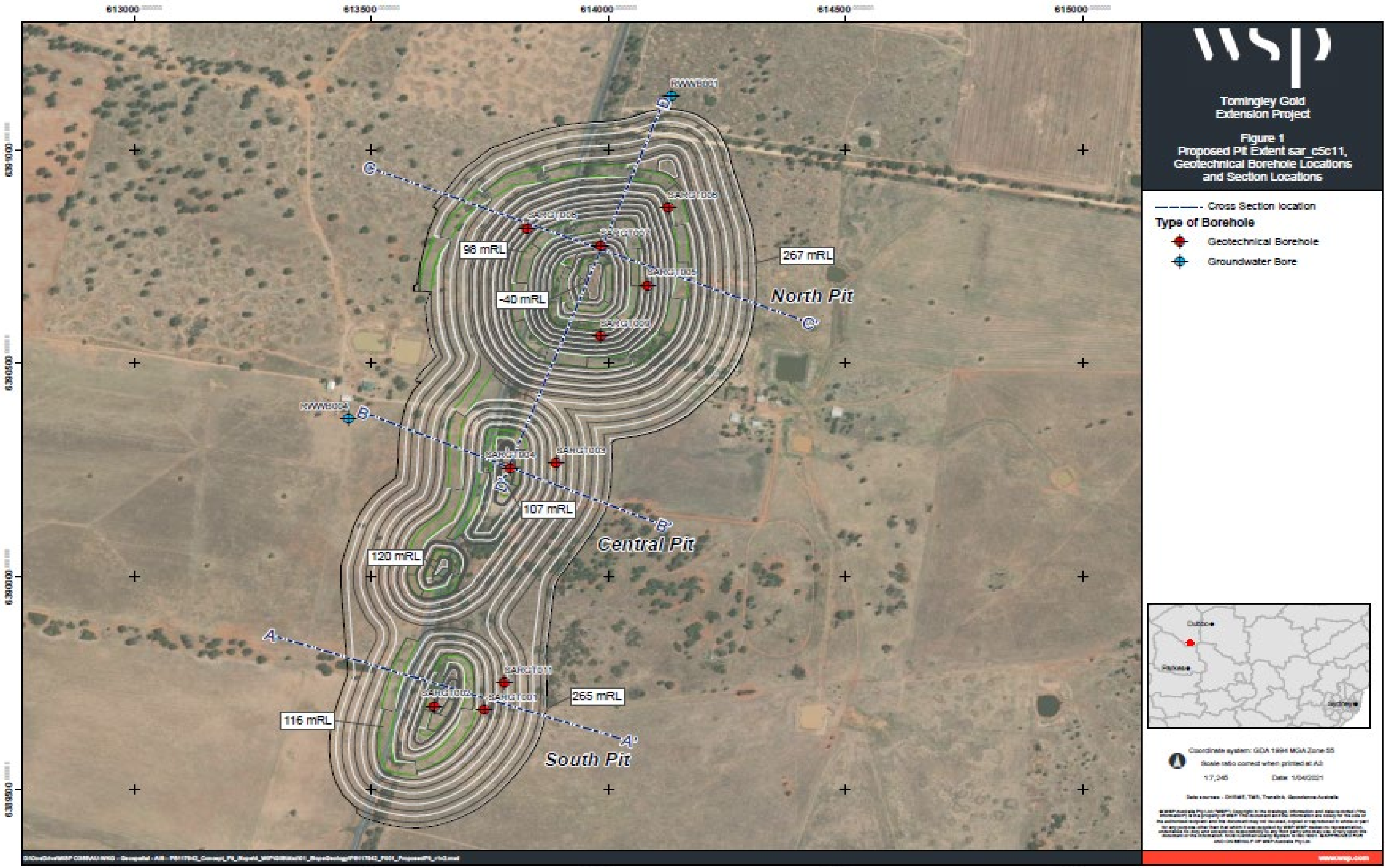


Figure A 4: Proposed extent of the North, Central, and South Pits of the SAR Open Cut. Locations of geotechnical boreholes and cross sections shown (WSP, 2021).

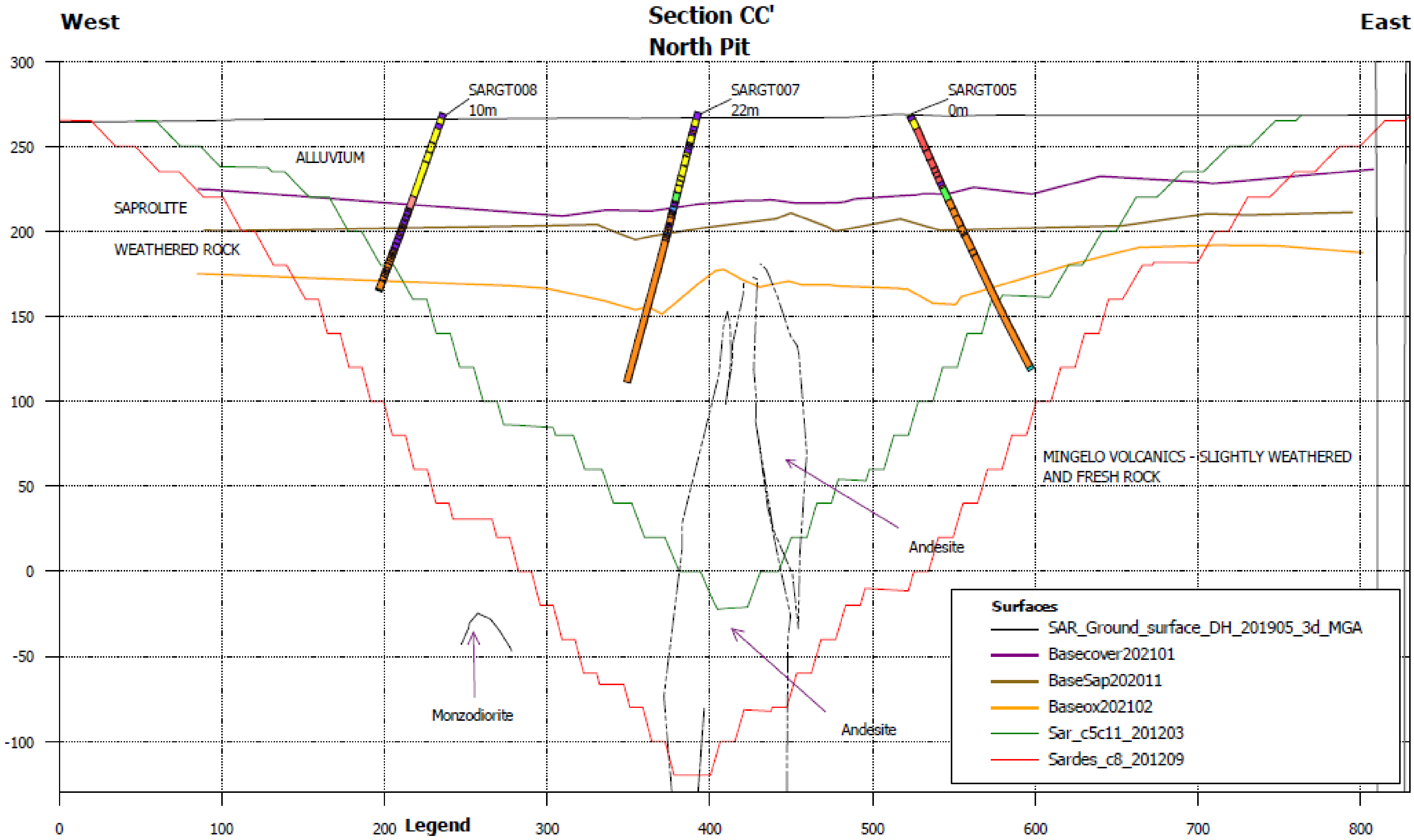


Figure A 5: Cross-section of lithologies of the SAR North Pit at Transect DD displayed in Figure A4 (WSP, 2021).

APPENDIX B: SIBERIA OUTPUT IMAGES

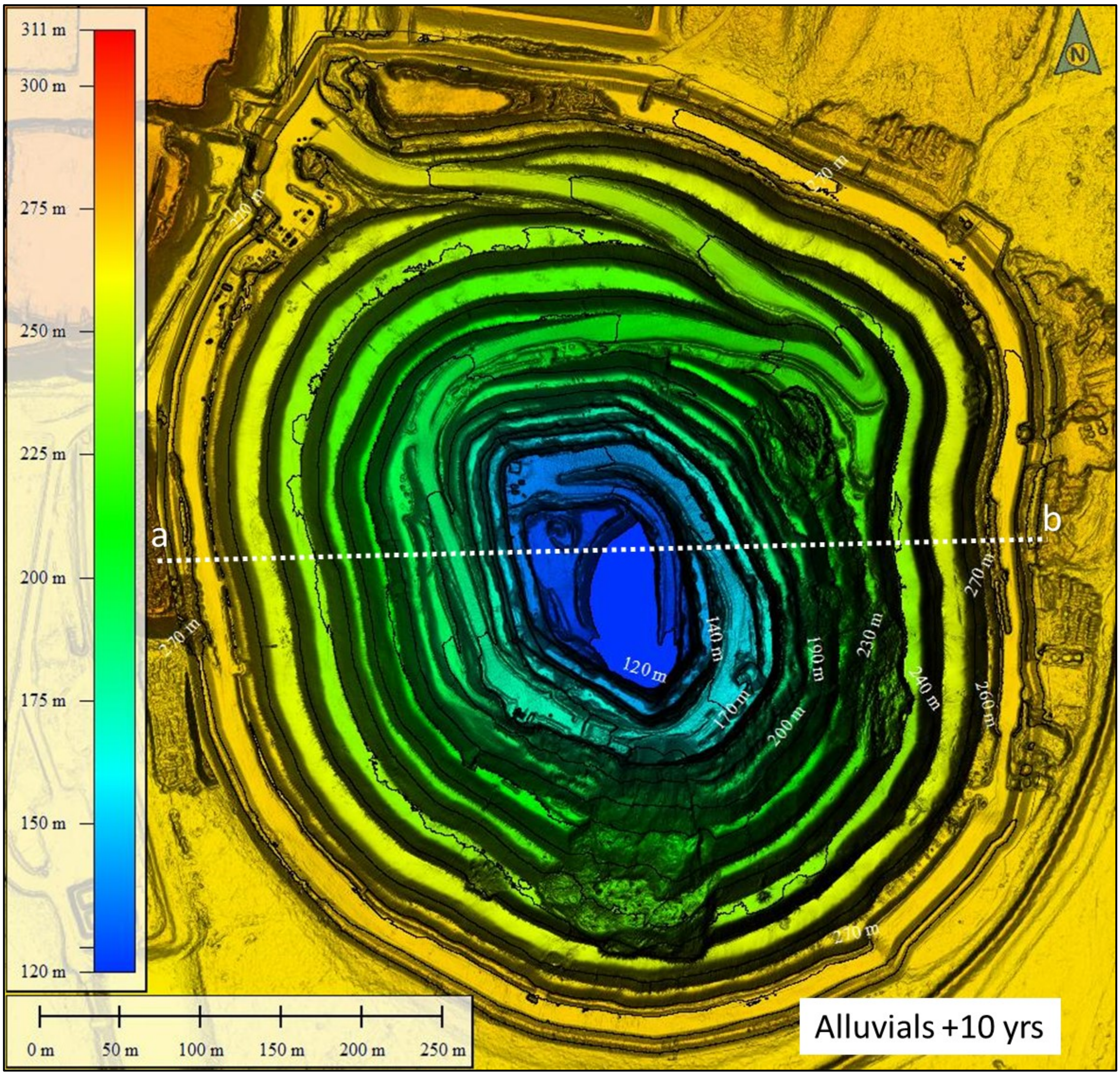


Figure B 1: Landform evolution model output after 10 years at the Wyoming 1 Pit with an Alluvial surface in a bare (unvegetated) condition.

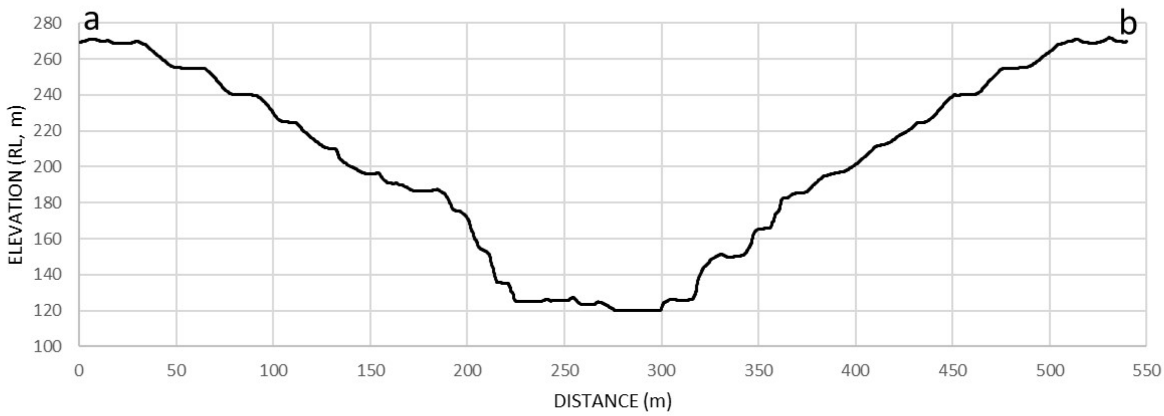


Figure B 2: Cross section of the transect in Figure B 1. Note the interface of the batters and berms is distinct and similar to present day conditions.

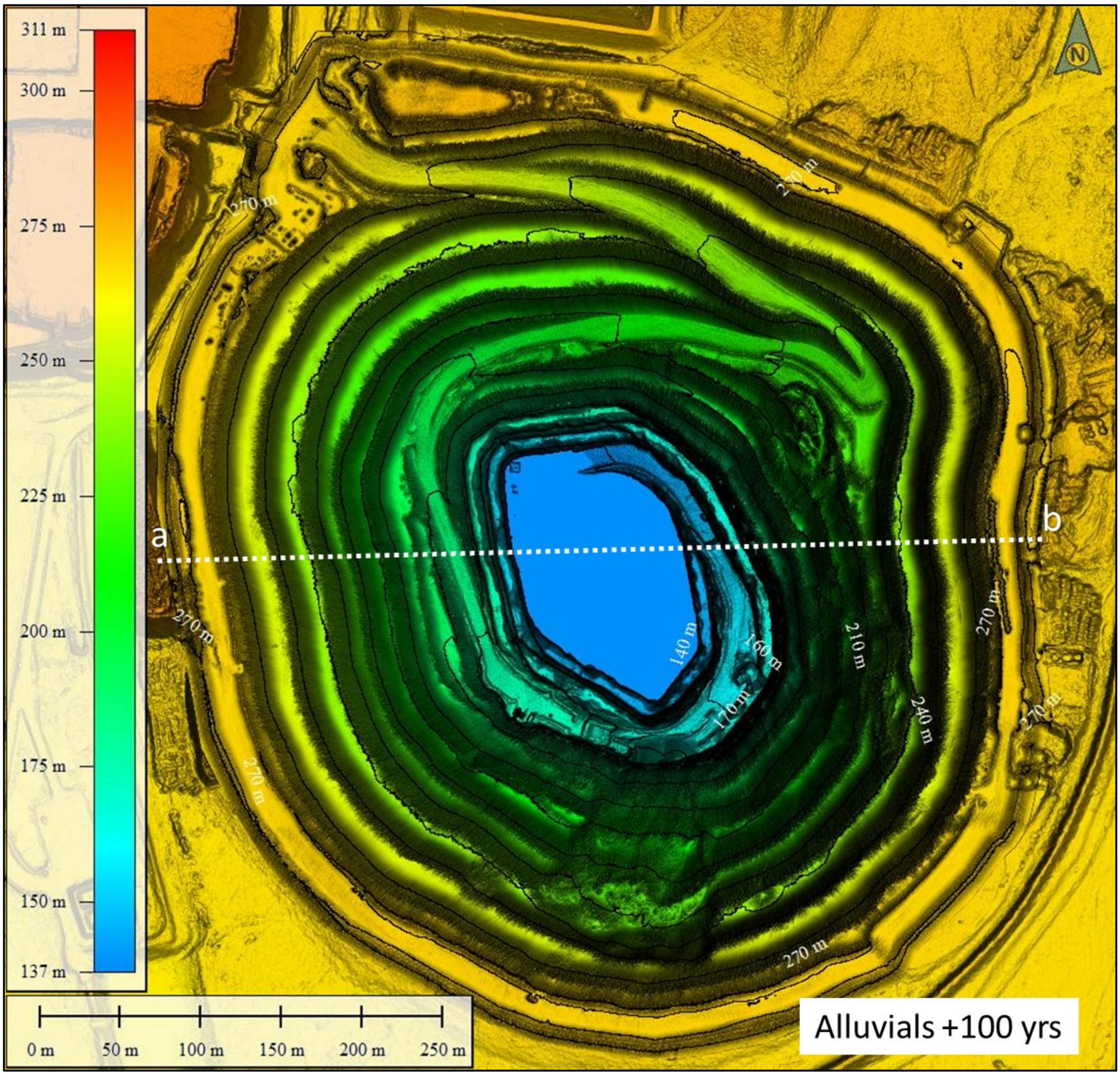


Figure B 3: Landform evolution model output after 100 years at the Wyoming 1 Pit with an Alluvial surface in a bare (unvegetated) condition.

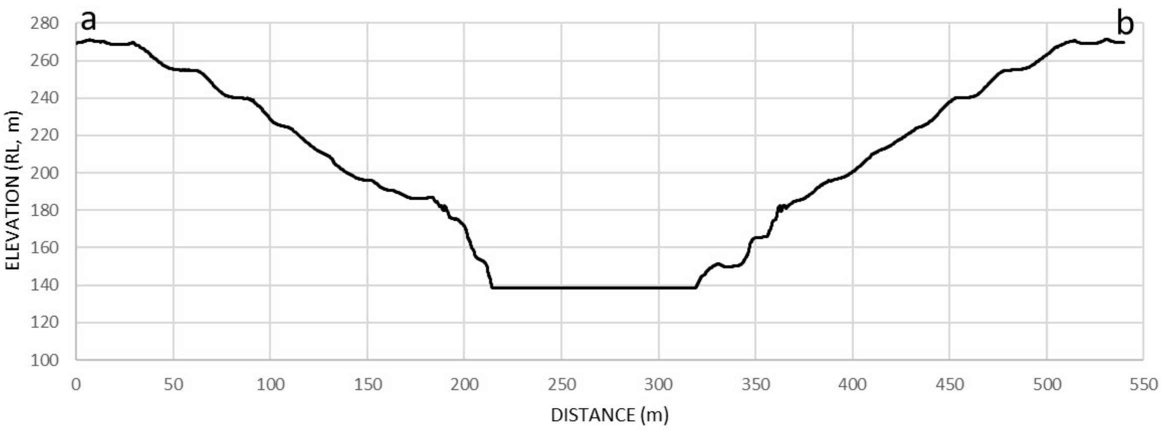


Figure B 4: Cross section of the transect in Figure B 3. Note the interface of the batters and berms has smoothed relative to present day conditions due to erosion at the crest of the berm and deposition at the toe of the batter.

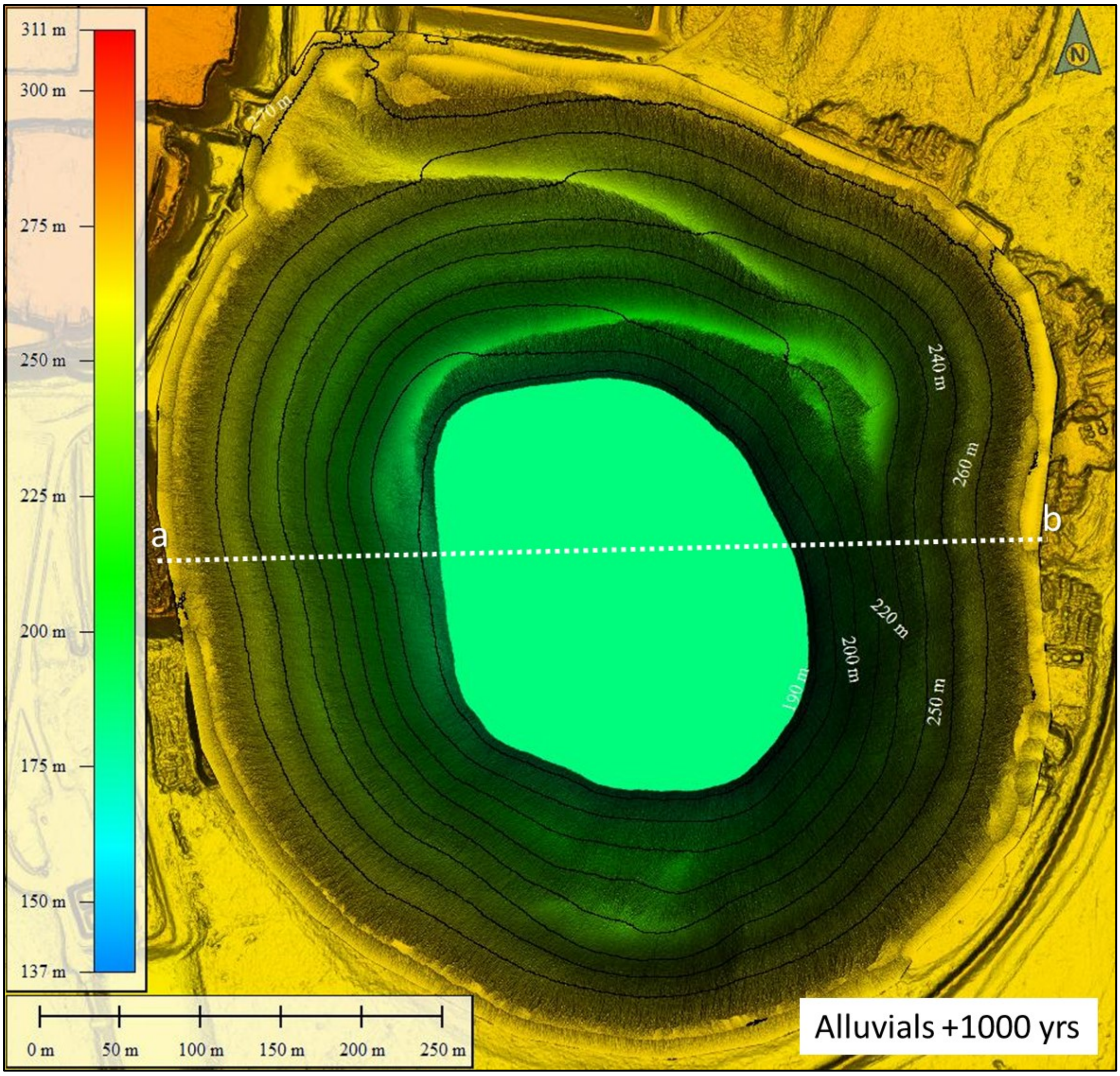


Figure B 5: Landform evolution model output after 1000 years at the Wyoming 1 Pit with an Alluvial surface in a bare (unvegetated) condition.

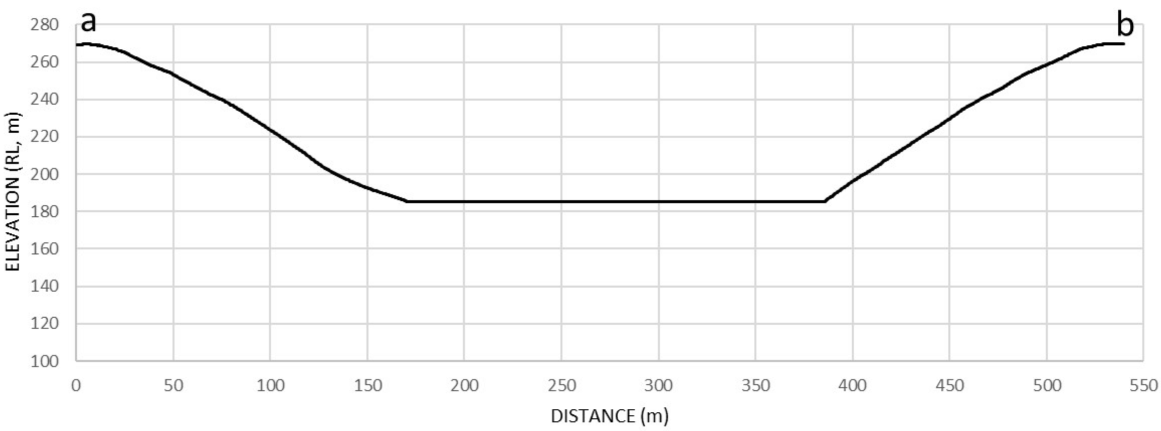


Figure B 6: Cross section of the transect in Figure B 5. Note the interface of the batters and berms is no longer detectable due to erosion of the pit wall.

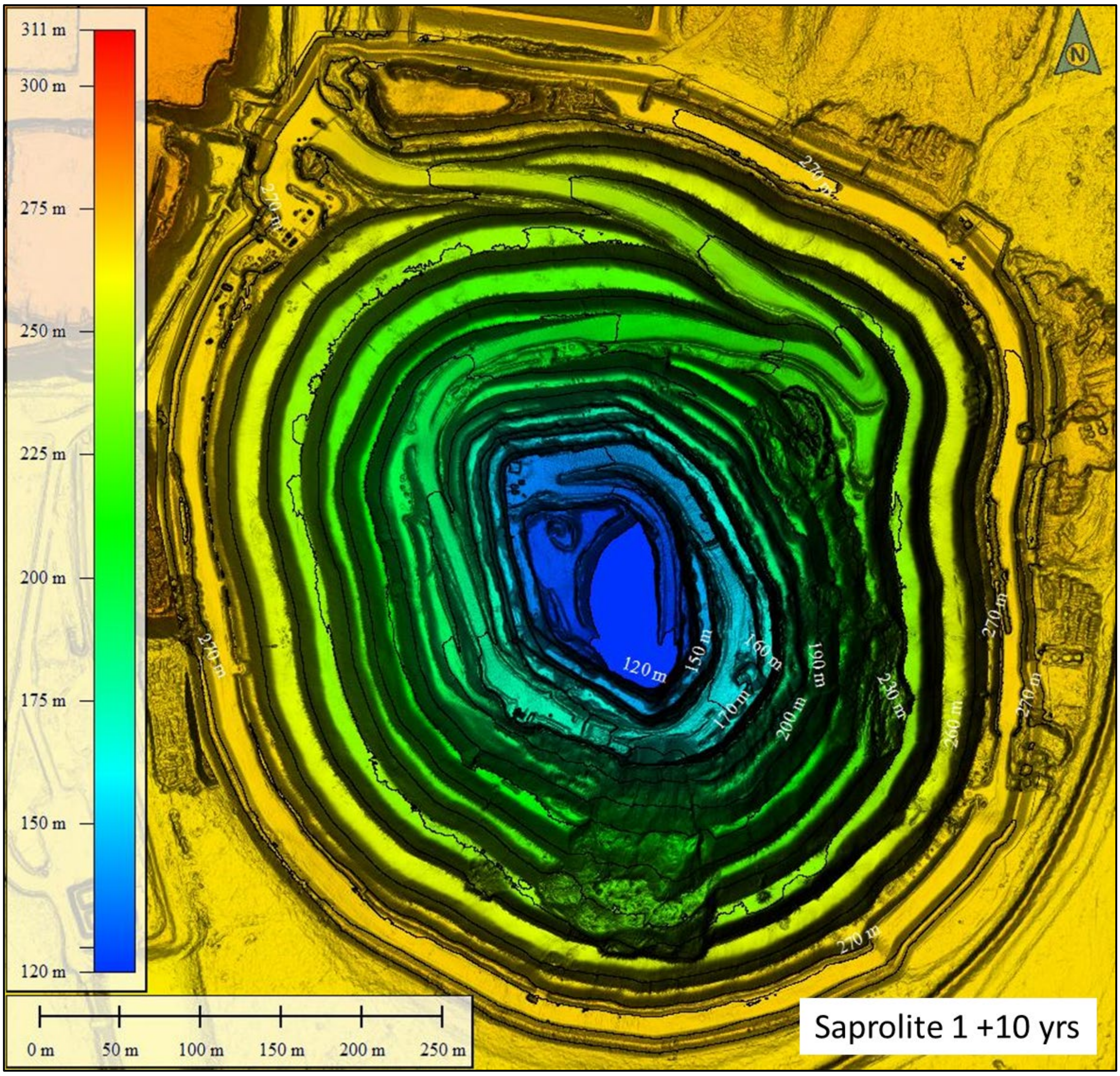


Figure B 7: Landform evolution model output after 10 years of the Wyoming One Pit with a Saprolite 1 surface in a bare (unvegetated) condition.

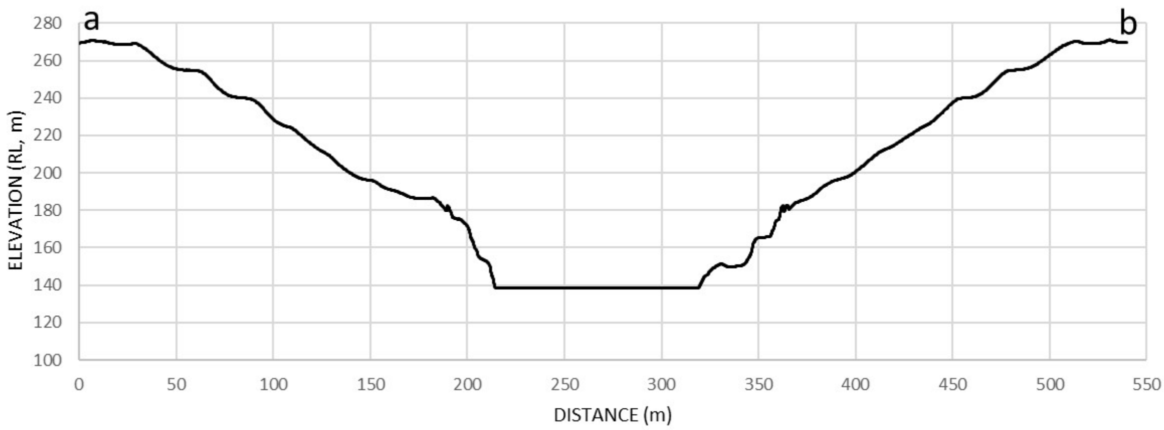


Figure B 8: Cross section of the transect in Figure B 7. Note the interface of the batters and berms is distinct and similar to present day conditions.

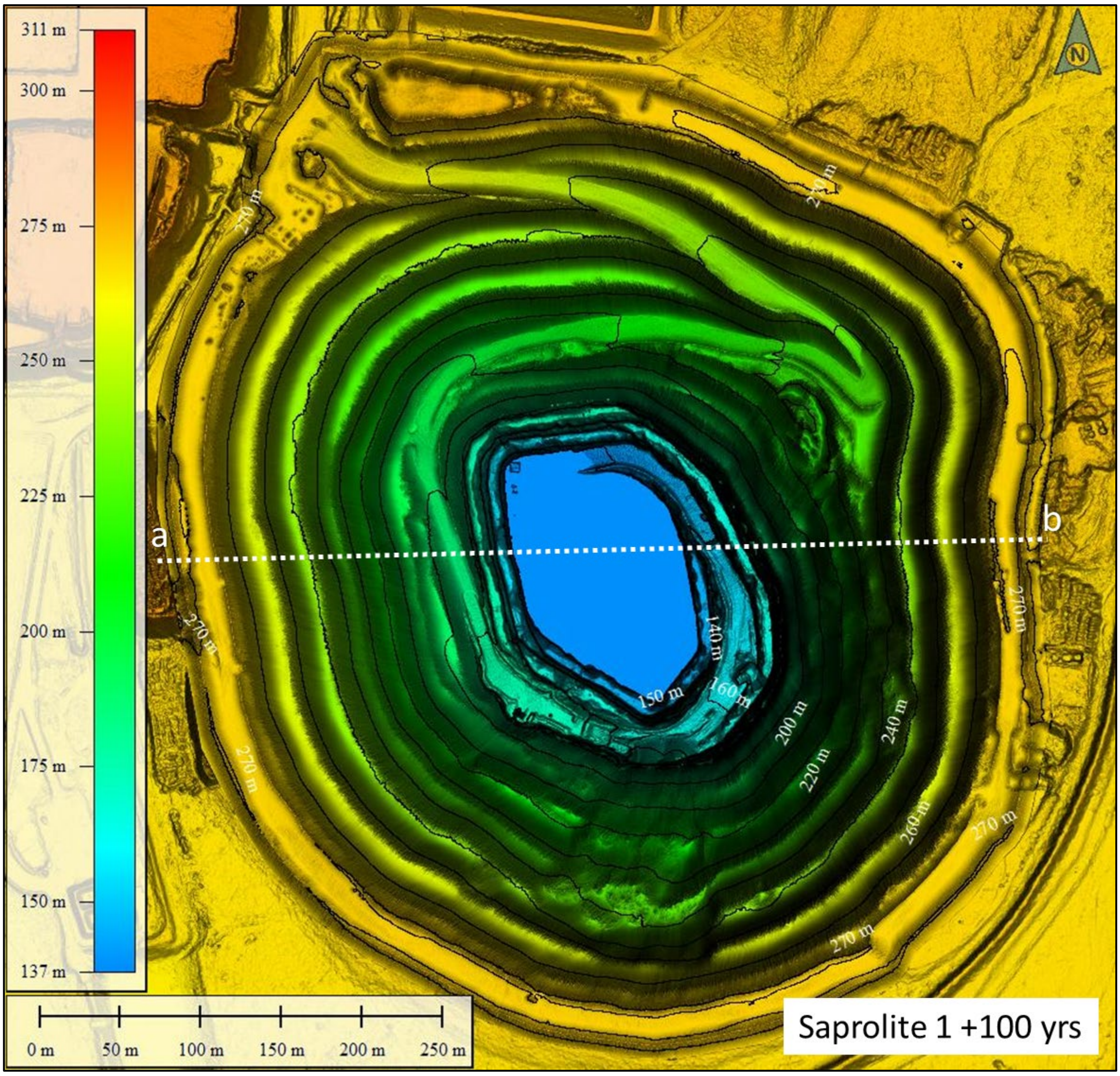


Figure B 9: Landform evolution model output after 100 years of the Wyoming One Pit with a Saprolite 1 surface in a bare (unvegetated) condition.

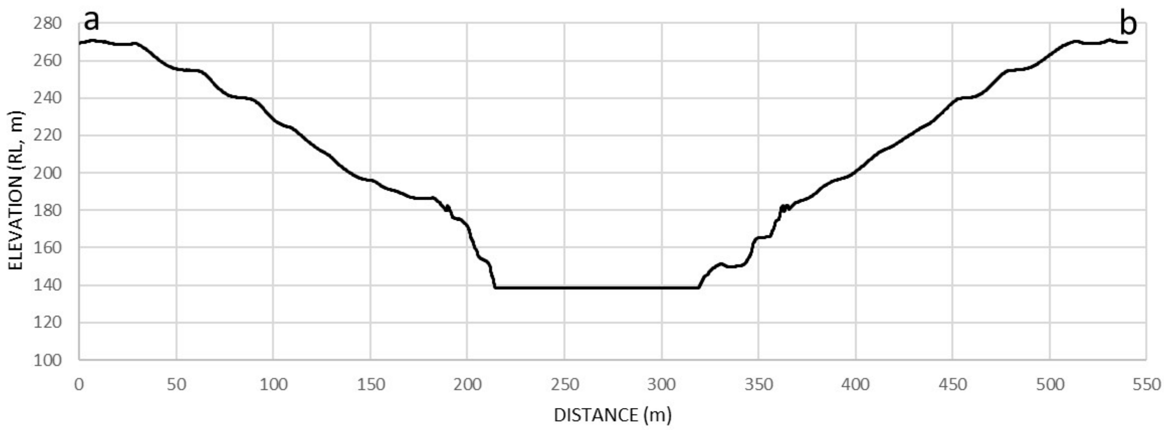


Figure B 10: Cross section of the transect in Figure B 9. Note the interface of the batters and berms has smoothed relative to present day conditions due to erosion at the crest of the berm and deposition at the toe of the batter.

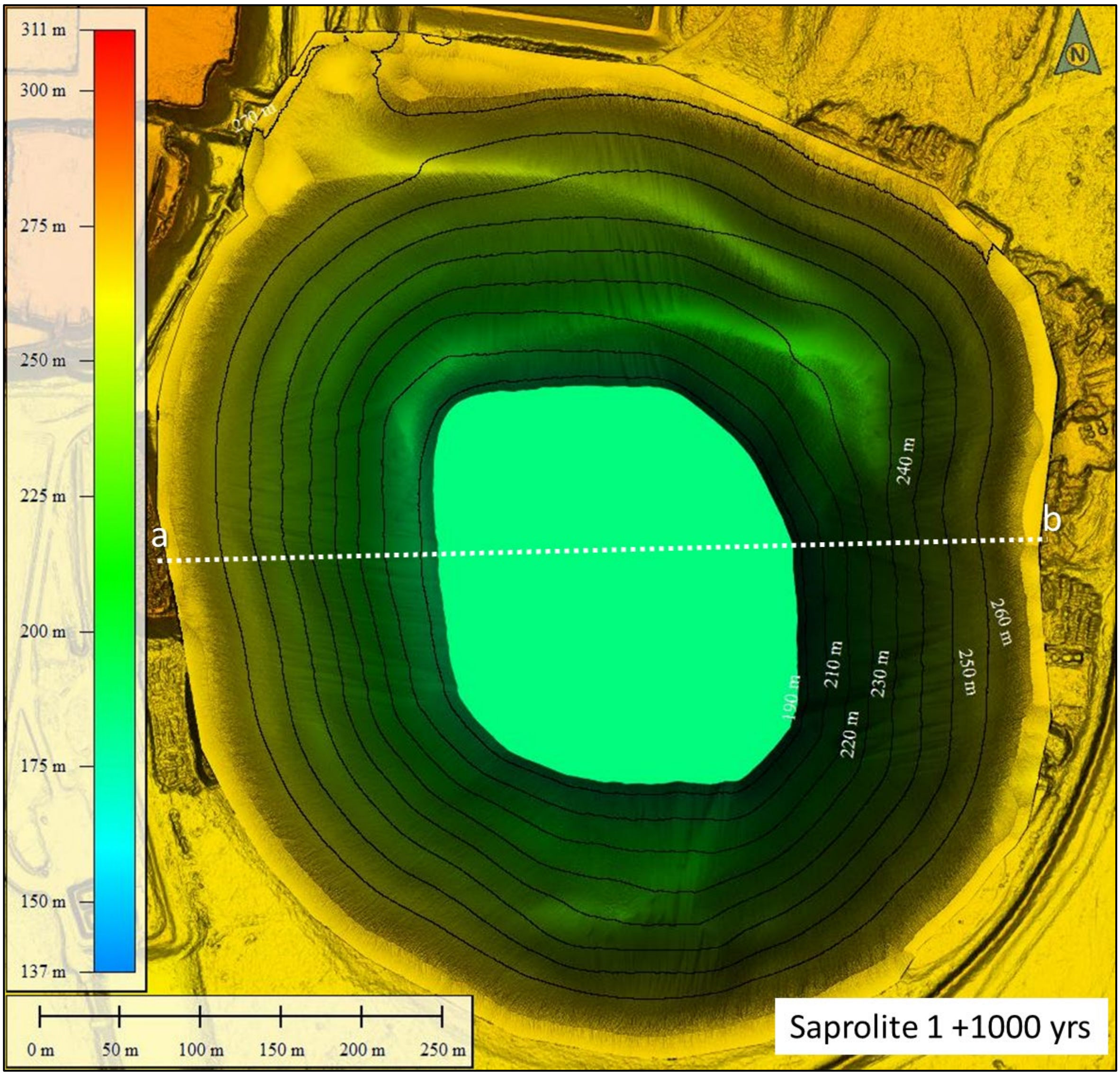


Figure B 11: Landform evolution model output after 1,000 years of the Wyoming 1 Pit with a Saprolite1 surface in a bare (unvegetated) condition.

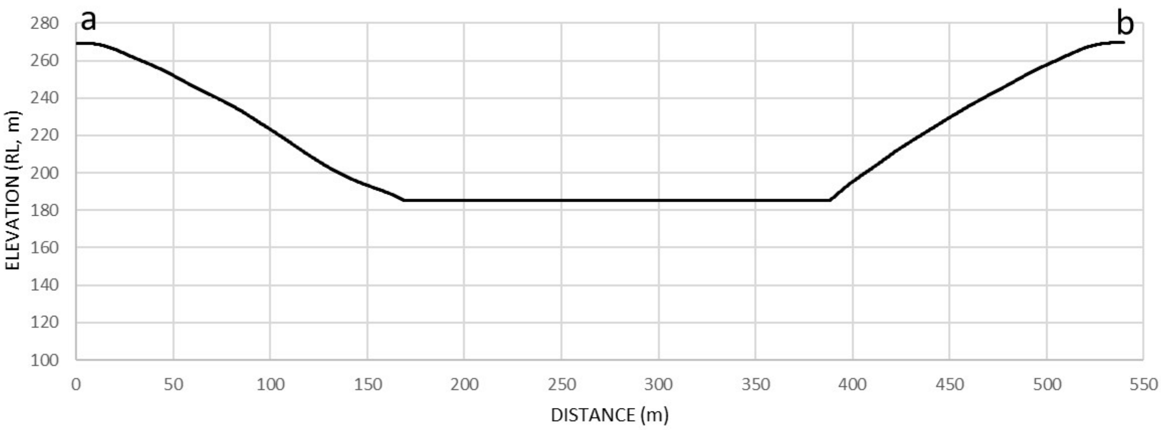


Figure B 12: Cross section of the transect in Figure B 11. Note the interface of the batters and berms is no longer detectable due to erosion of the pit wall.

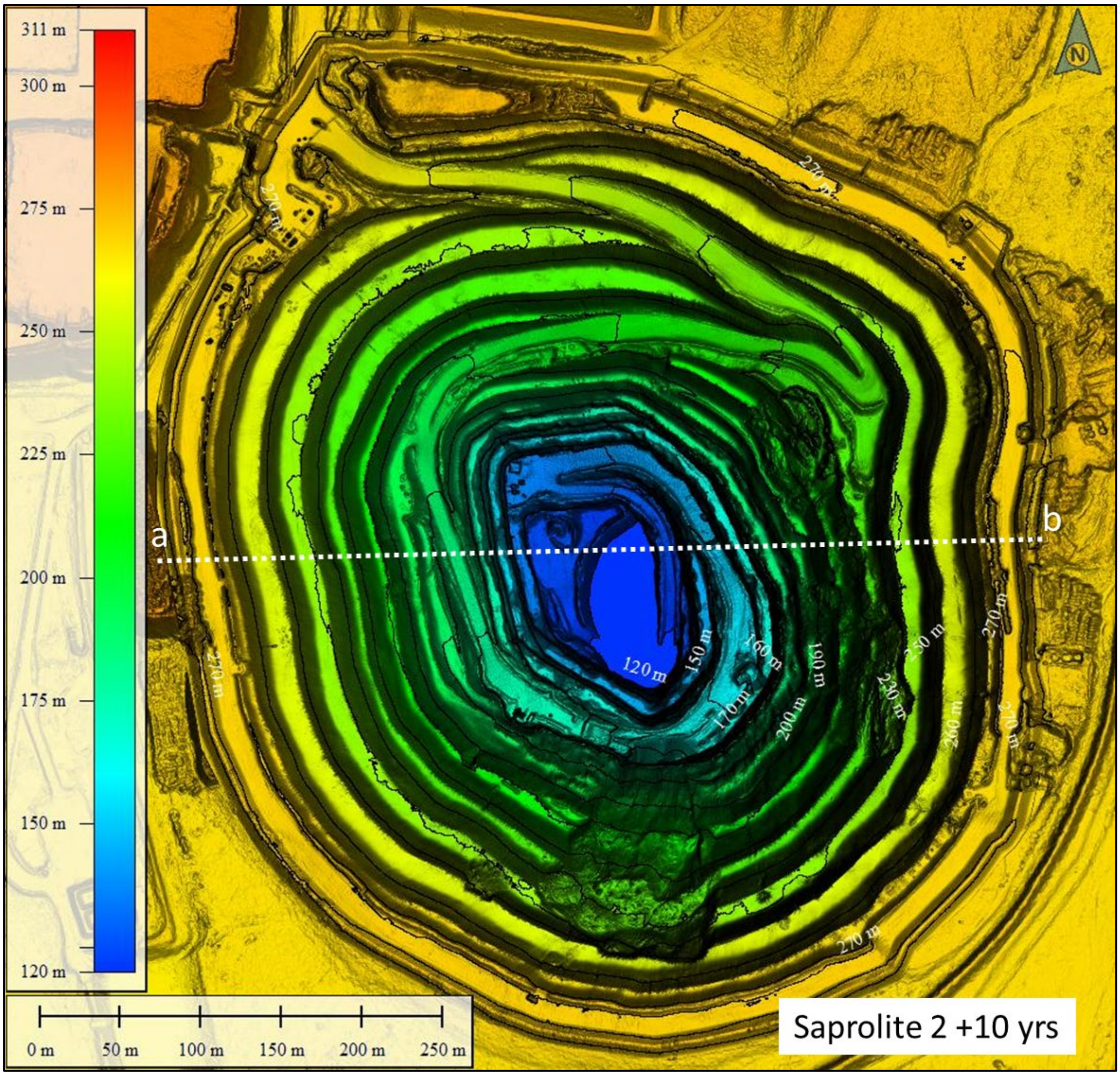


Figure B 13: Landform evolution model output after 10 years of the Wyoming 1 Pit with a Saprolite 2 surface in a bare (unvegetated) condition.

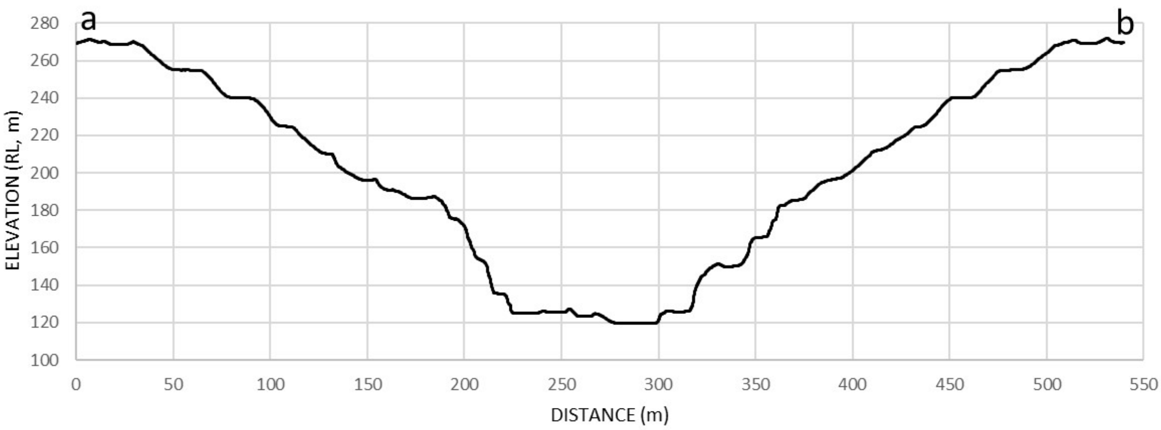


Figure B 14: Cross section of the transect in Figure B 13. Note the interface of the batters and berms is distinct and similar to present day conditions.

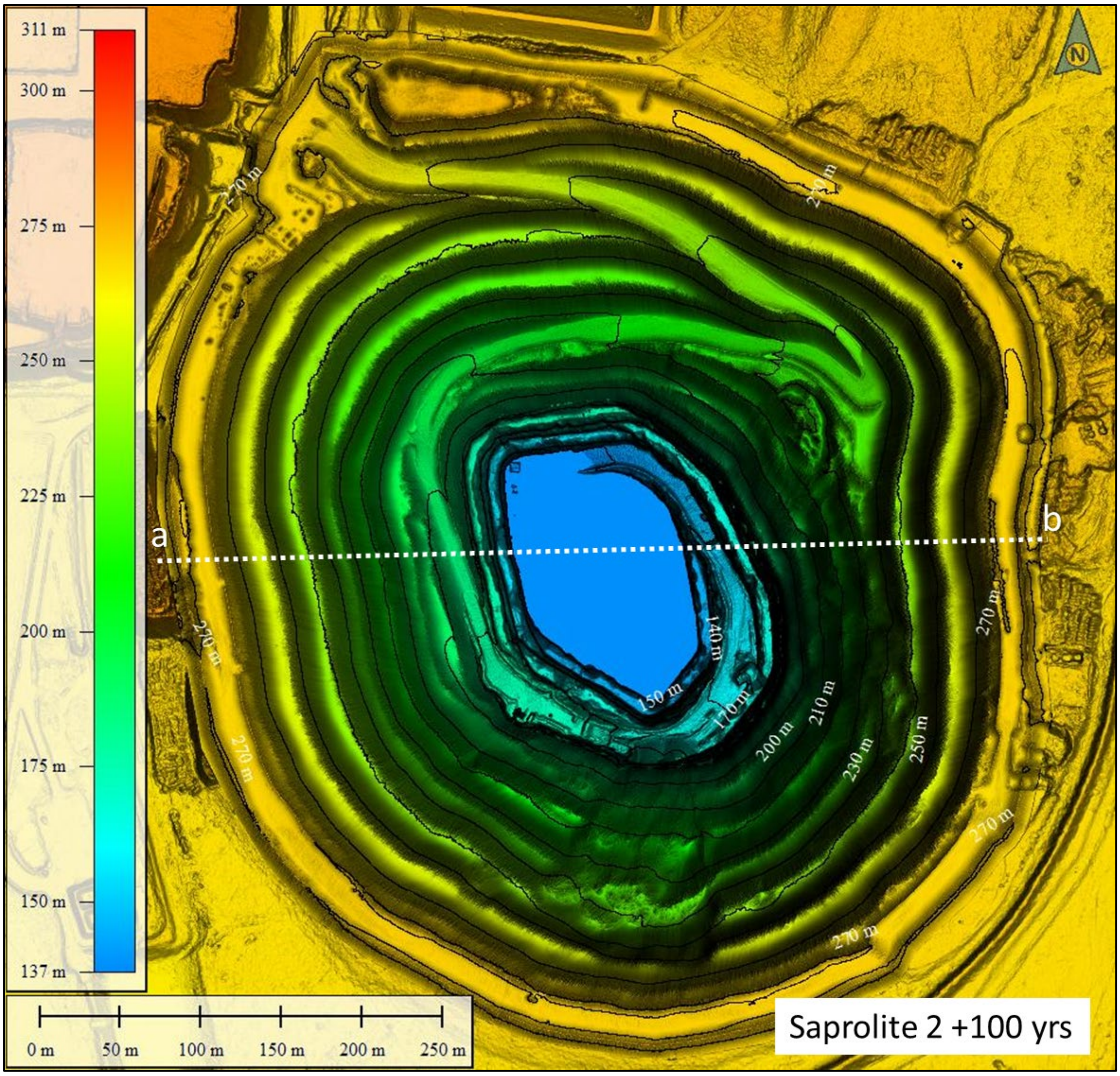


Figure B 15: Landform evolution model output after 100 years of the Wyoming 1 Pit with a Saprolite 2 surface in a bare (unvegetated) condition.

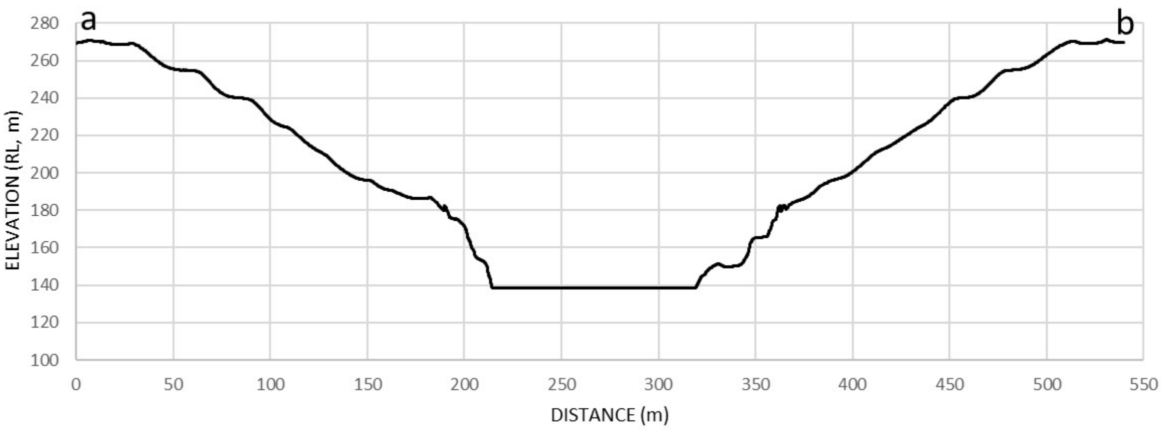


Figure B 16: Cross section of the transect in Figure B 15. Note the interface of the batters and berms has smoothed relative to present day conditions due to erosion at the crest of the berm and deposition at the toe of the batter.

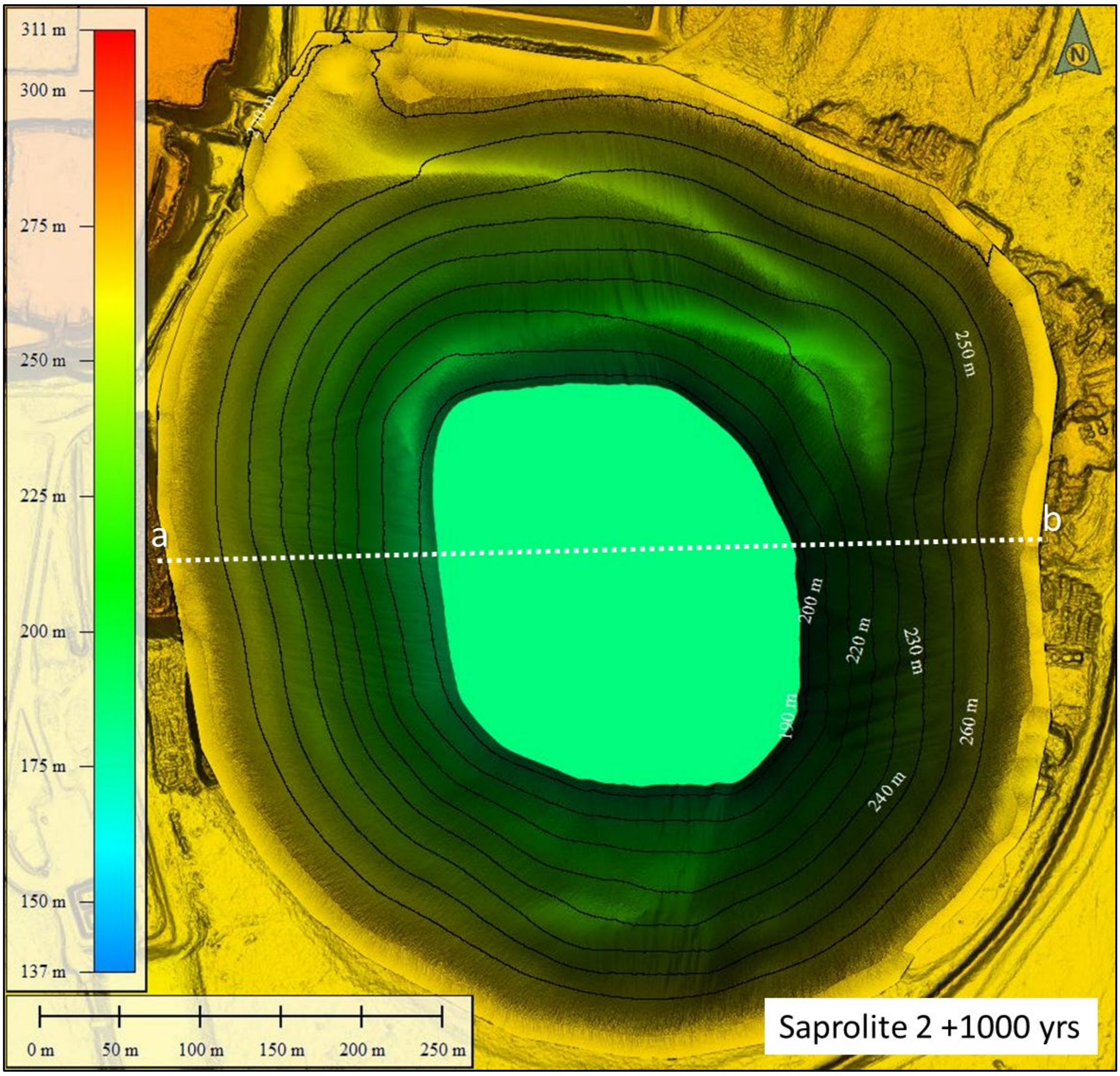


Figure B 17: Landform evolution model output after 1,000 years of the Wyoming 1 Pit with a Saprolite 2 surface in a bare (unvegetated) condition.

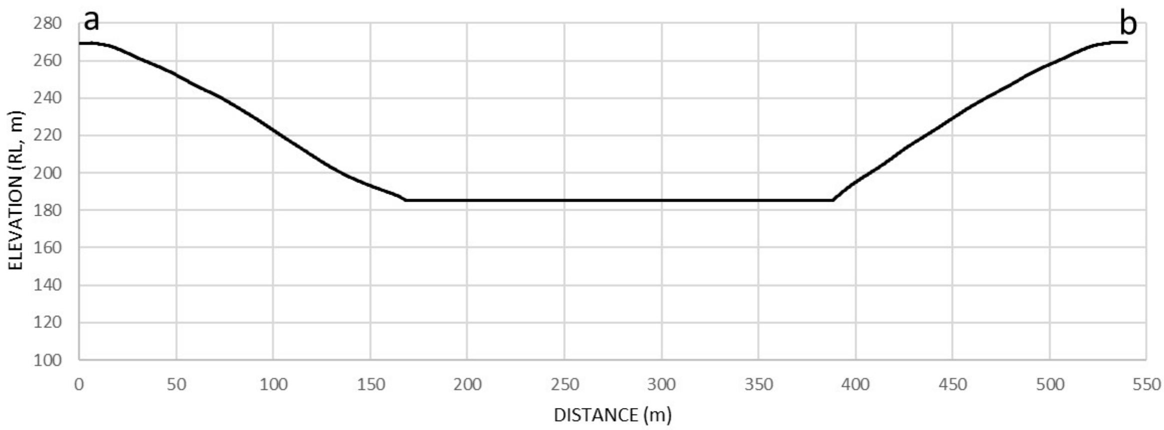


Figure B 18: Cross section of the transect in Figure B 17. Note the interface of the batters and berms is no longer detectable due to erosion of the pit wall.

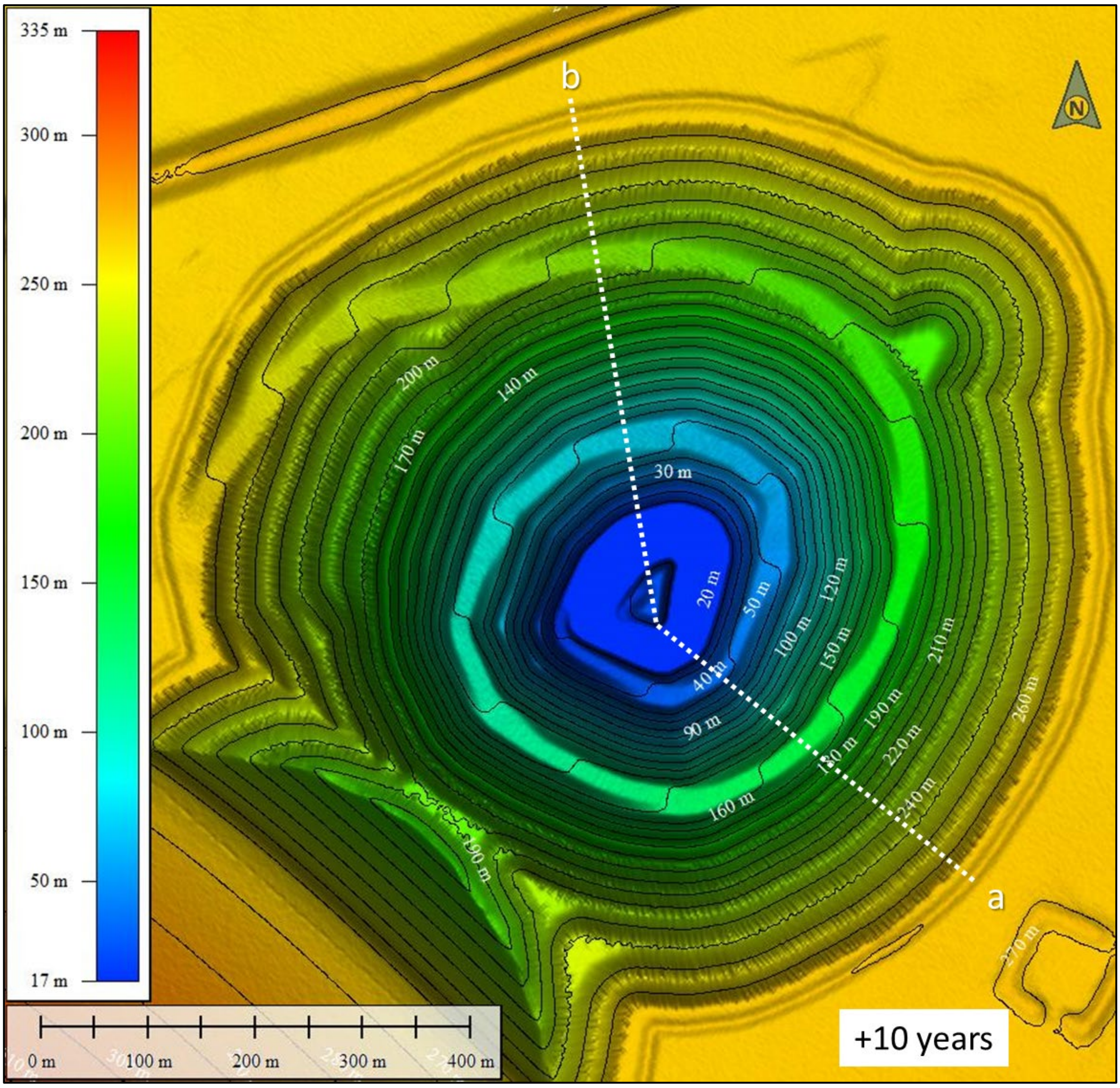


Figure B 19: Landform evolution model output after 10 years of the SAR North Pit with a Saprolite 1 surface in a bare (unvegetated) condition.

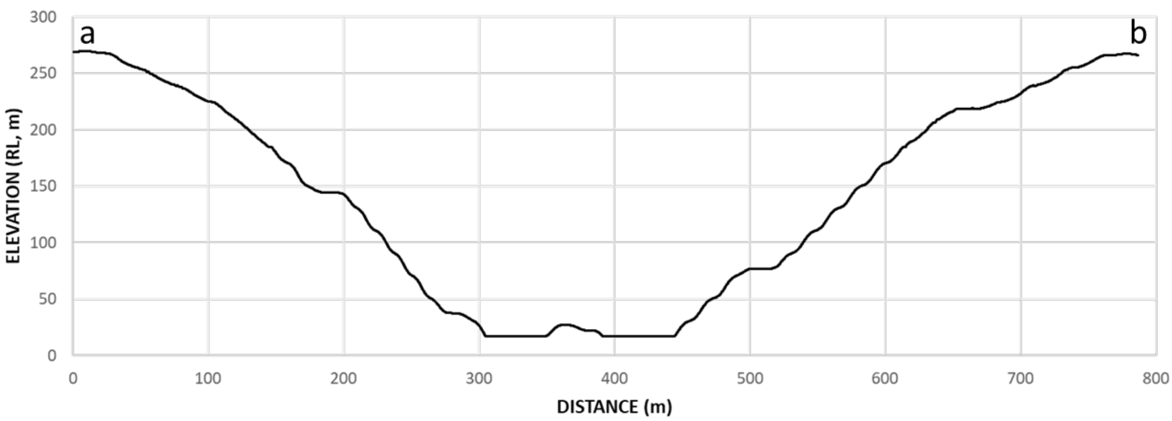


Figure B 20: Cross section of the transect in Figure B 19. Note the interface of the batters and berms is distinct and relatively sharp.

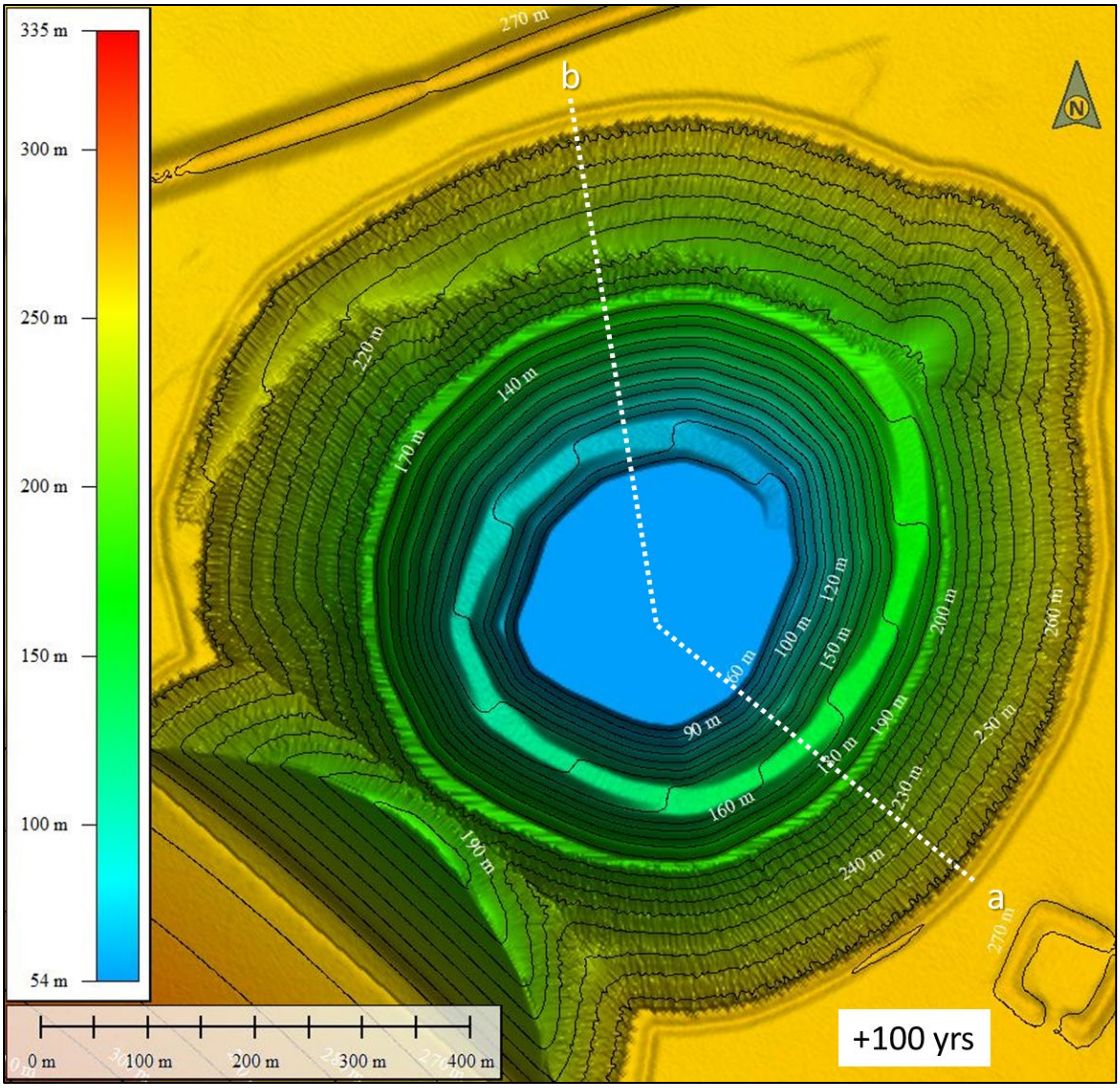


Figure B 21: Landform evolution model output after 100 years of the SAR North Pit with a Saprolite 1 surface in a bare (unvegetated) condition.

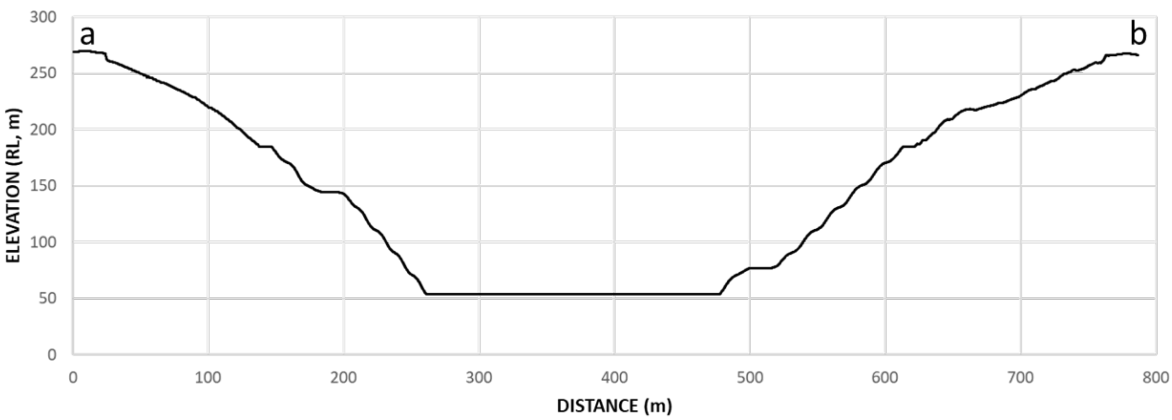


Figure B 22: Cross section of the transect in Figure B 21. Note the interface of the batters and berms has smoothed relative to the 10 year simulation due to erosion at the crest of the berms and deposition at the toe of the batters.

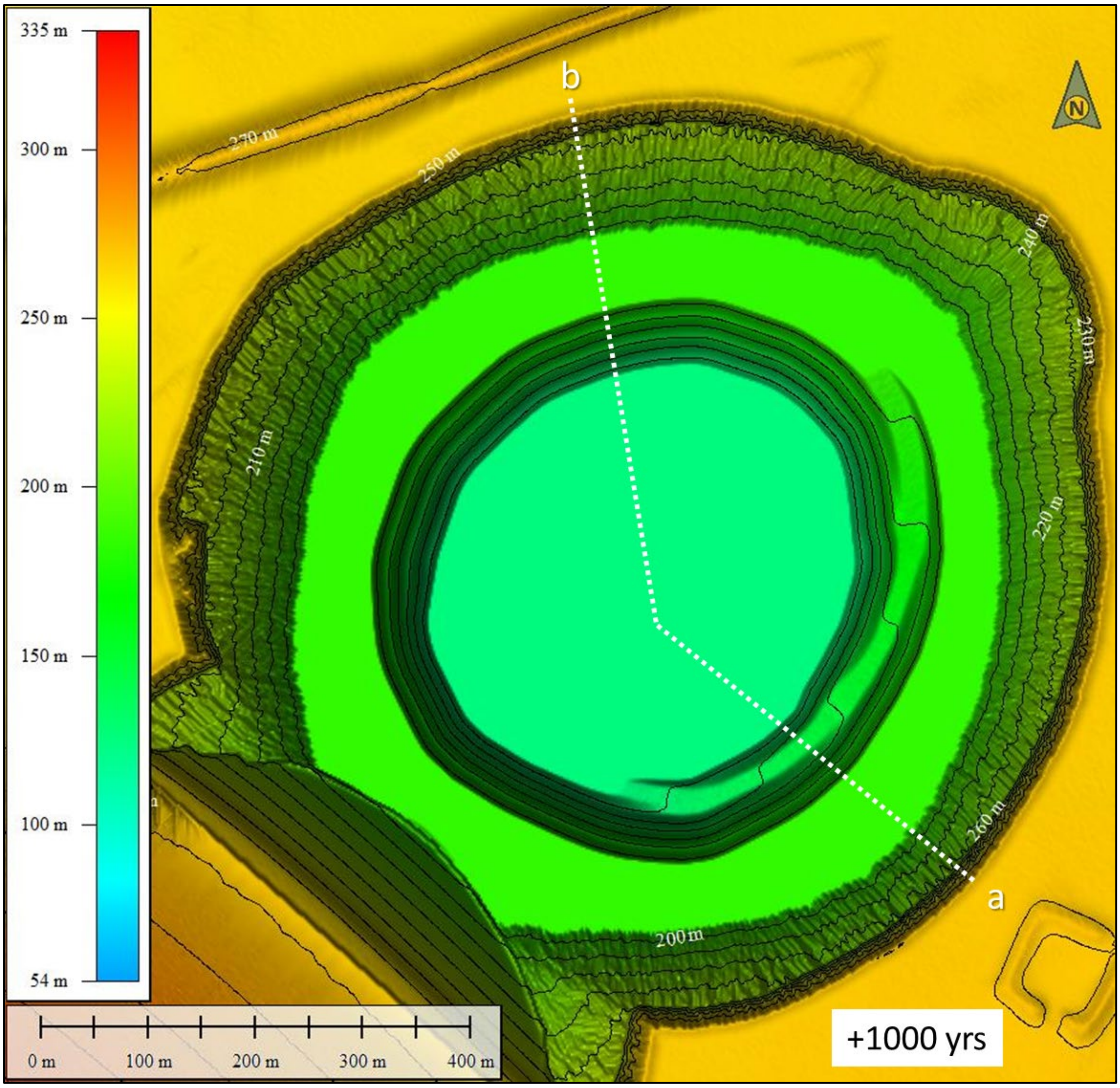


Figure B 23: Landform evolution model output after 1,000 years of the SAR North Pit with a Saprolite 1 surface in a bare (unvegetated) condition.

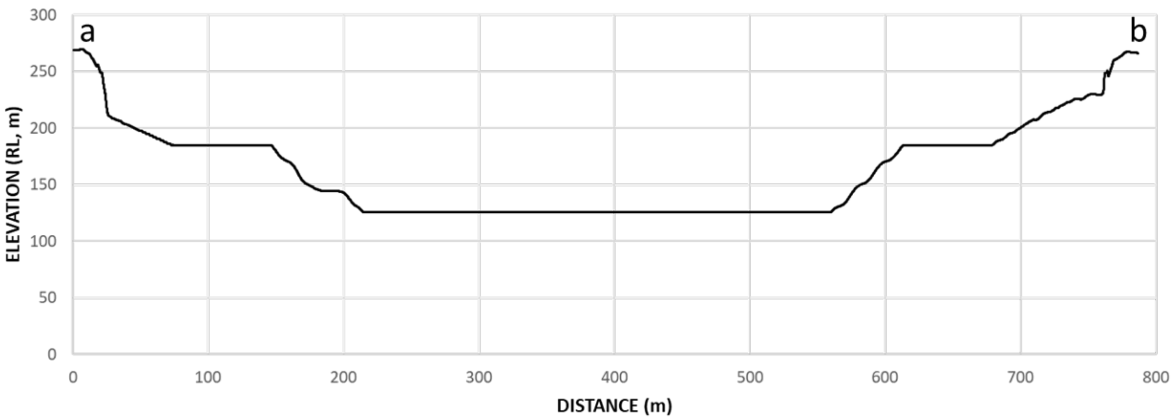


Figure B 24: Cross section of the transect in Figure B 23. Note the interface of the batters and berms is no longer detectable due to erosion of the pit wall.

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