mineral resources
& energy

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Directorate: Mine Environmental Management: Mpumalanga Region

BY REGISTERED MAIL

The Director (s)
Anglo American Inyosi (Pty) Ltd
55 Marshall Street
Johannesburg
2001

For attention: Ms Lerato Mazibuko **Fax:** 011 254 4875
Cc: Ms Olivia Allen **Fax:** 086 582 1561

ACCEPTANCE OF THE SCOPING REPORT SUBMITTED IN TERMS OF REGULATION 21(a) OF THE ENVIRONMENTAL IMPACT ASSESSMENT REGULATIONS, 2014 AS AMENDED FOR THE PROPOSED DEVELOPMENT OF A DISCARD DUMP ON THE FARMS OOGIESFORNTEIN 4 IS AND KLIPFONTEIN 3 IS, SITUATED IN THE MAGISTERIAL DISTRICT OF EMALAHLENI: MPUMALANGA REGION.

The Scoping Report (SR) and Plan of study for Environmental Impact Assessment received by the Department on the 15th of December 2020 refers.

a) The Department has evaluated the submitted SR and Plan of the study for environmental Impact Assessment submitted on the 15th of December 2020 and is satisfied that the documents comply with the mninmum requirements of Appendix 2(2) of the National environmental Management Act, 1998 (as amended) (NEMA) Environmental Impact assessment (EIA) Regulations, 2014 as amended. The SR is hereby accepted **with conditions** by the Department in terms of Regulation 22(a) of the NEMA EIA Regulations, 2014 as amended.

b) You may proceed with the environmental impact assessment process in accordance with the tasks contemplated in the Plan of study for environmental Impact assessment as required in terms of the NEMA EIA regulations, 2014 as amended.

c) It should be noted that the Department requires the following to be provided/included and form part of the final Environemntal Impact Assessment report (EIAr) and Environmental Management Programme (EMPr) to be submitted.

- The **draft EIAr and EMPr** must be made available to the interested and affected parties (I&Aps) for comments as required in tems of regulation 40 (1) of the EIA Regulations, 2014 as amended.
- Please ensure that comments from all relevant stakeholders including the responses are submitted to the Department with the Environmental Impact Assessment Report (EIAr). **This includes but is not limited to the South African Resources Agency (SAHRA), Department of Agriculturea, Forestry and Fisheries (DAFF), Department of Water and Sanitation (DWS), Mpumalanga, Mpumalanga Tourism and Parks Agency (MTPA), Municipality**. Proof of correspondence with the various stakeholders must be included in the EIAr. Should you be unable to obtain comments, proof of the attempts that were made to obtain comments should be submitted to the Department. Please note that the above mentioned commentes and responses from public participation regarding the EIAr and not the scoping report.
- The adjacent landowners, the lawful occupiers and communities must also be consulted and proof and results of such engagements must be attached in the EIAr. The provisions of regulation 41 (2) (e) of the EIA Regulations, 2014 as amended must be used where necessary.
- Public Participation Process must be transparent and all comments received during the process must be incorporated into the comments and response report of the final Environmental Impact Report.
- The EIAr must include all relevant specialist studies.
- The EIAr must include a detailed plan on the mitigation of impacts on all sensitive area and spicies and this must be supported by specialist reports.
- A final site map, in A3 size that superimposes the proposed activities and the sensitive areas must be attached in the EIAr. This map must be inline with specialist recommendations of the specialist studies to be conducted.

- Furthermore, it must be reiterated that, should an application for Environmental Authorisation be subjected to any permits or authorisations in terms of the provisions of any Specific Environmental Management Acts (SEMAs), proof of such application will be required.
- Any other matters required in terms of Appendix 3 (3) and Appendix 4 of the EIA Regulation 2014 must be included in the EIAr .

d) Please note that upon receipt of the final Environmental Impact Assessment Report, the report will be forwarded to the Department of Water and Sanitation (DWS) for comments. It is only upon receipt of positive comments from the DWS that your application will be processed further.

e) The EIA must be submitted in terms of the time frames as stipulated in the EIA Regulations, 2014 as amended and must be in terms of **Appendix 4 or the ofical EIA template of the department.**

f) Your attention is brought to Section 24F of the NEMA which stipulates "that no activity may commence prio to an environmental authorisation being granted by the competent authority".

For any enquiry regarding this application please contact the above mentioned Official

Yours faithfully

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REGIONAL MANAGER: MINERAL REGULATION

MPUMALANGA REGION

DATE...18\03\2021...

APPENDIX B

Zibulo Discard Facility Options Analysis

GOLDER

REPORT

Option Analysis Report for Zibulo Discard Facility

Anglo American Inyosi Coal (Pty) Ltd

Submitted to:

Ms Melissa Hallquist-Waites
Anglo American Coal
Supply Chain
Ground floor security
55 Marshall Street
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Submitted by:

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19117180-335996-5

January 2021

Distribution List

1 eCopy to Anglo American Coal

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1.0 BACKGROUND AND PROJECT OBJECTIVE

Anglo American Inyosi Coal (AAIC) Zibulo Colliery is located roughly adjacent to Ogies in the Mpumalanga Province. The mine has two parts namely an underground development located approximately 25 km south west of the town and a small opencast section located immediately north-west of the town. The mine produces an annual eight million run of mine (ROM) tonnes of export thermal coal, with seven million tonnes per annum coming from its underground sections and the remaining one million tonnes from its opencast pit. Underground operations incorporate bord and pillar continuous miner methods while the contractor-run pit utilises a small dragline and truck and shovel methods.

Coal from the underground operation is transported to the Phola Coal Processing Plant via a 16 km conveyor. The plant is a 50:50 joint venture between Anglo American (Anglo) and South32, receiving run of mine coal predominantly from AAIC's Zibulo operation and South32's Klipspruit operation. The coarse and fine discard produced from the Phola processing plant is currently deposited onto a surface discard facility on South32's Klipspruit mine. The facility is reaching capacity and by 2022 alternative discard placement options may be required which could include expansion of the existing facility, or development of company specific solutions. This report addresses a risk mitigating proposal by AAIC's to seek authorisation for an alternative coal discard disposal facility. The facility could be located on a greenfield site or coal discard could be disposed of at the existing Zibulo opencast in close proximity to the processing plant. It is the preference of AAIC in contemplating a new discard disposal facility that such facility be located on property under their direct control, should they go forward with construction of such a site.

The material deposited on the Zibulo discard dump will be deposited as a single stream consisting of coarse discards and filtered fines with the moisture content of the filter cake being around 20 – 23%. This is the same material specification reporting to the existing facility.

This report provides the results of the option formulations to obtain a preferred option in support of the permitting process.

2.0 OPTIONS FORMULATION

2.1 Discard site options

Two options were considered as part of the options assessment as described in the bullets below and the locations are shown on Figure 1.

Option 1: A greenfield site on land owned by AAIC:

The first option considered the availability of a greenfields site within reasonable proximity to the Phola Plant. This narrowed the area of interest to land at the site of the Zibulo opencast or underground operations.

While the opencast operation is close to the Phola Plant there is insufficient land available for development of a greenfield site as the property is constrained in its eastern extent by a wetland and drainage area, to the north by the N12 National highway and to the west by the R545 provincial road. The area to the south of the existing opencast contains additional coal reserves which form part of the pit life and which have been authorised for opencast mining. Consequently, there is no available greenfield site on non-mined land in the immediate proximity to the opencast operation.

The Zibulo underground operation are located approximately 18 km due south of the Zibulo open cast operations. While there is land available in proximity to the existing infrastructure, the distance over which coal discard would need to be transported for disposal is considerable. Notwithstanding this, the possibility of a greenfield site in proximity to the Zibulo underground operation was taken forward into the options analysis for further consideration.

Option 2: A brownfield site within the footprint of the existing Zibulo opencast pit

The second site option considered the disposal of coal discard onto a site contained within the footprint of the existing opencast Zibulo pit. Two options presented themselves namely developing a discard facility on the surface of rehabilitated land or a scenario where discard disposal into available opencast void space would commence immediately and develop into an aboveground discard facility extending over rehabilitated areas as well. These two options are represented schematically in Figure 2 and Figure 3 respectively. In summary:

- Option 2a: Placement of discard above the backfilled Zibulo pit only; and
- Option 2b: Placement of discard as backfill in the void and above the backfilled Zibulo pit.

The technical considerations inherent in the options are described in Golders Basis of Design report.

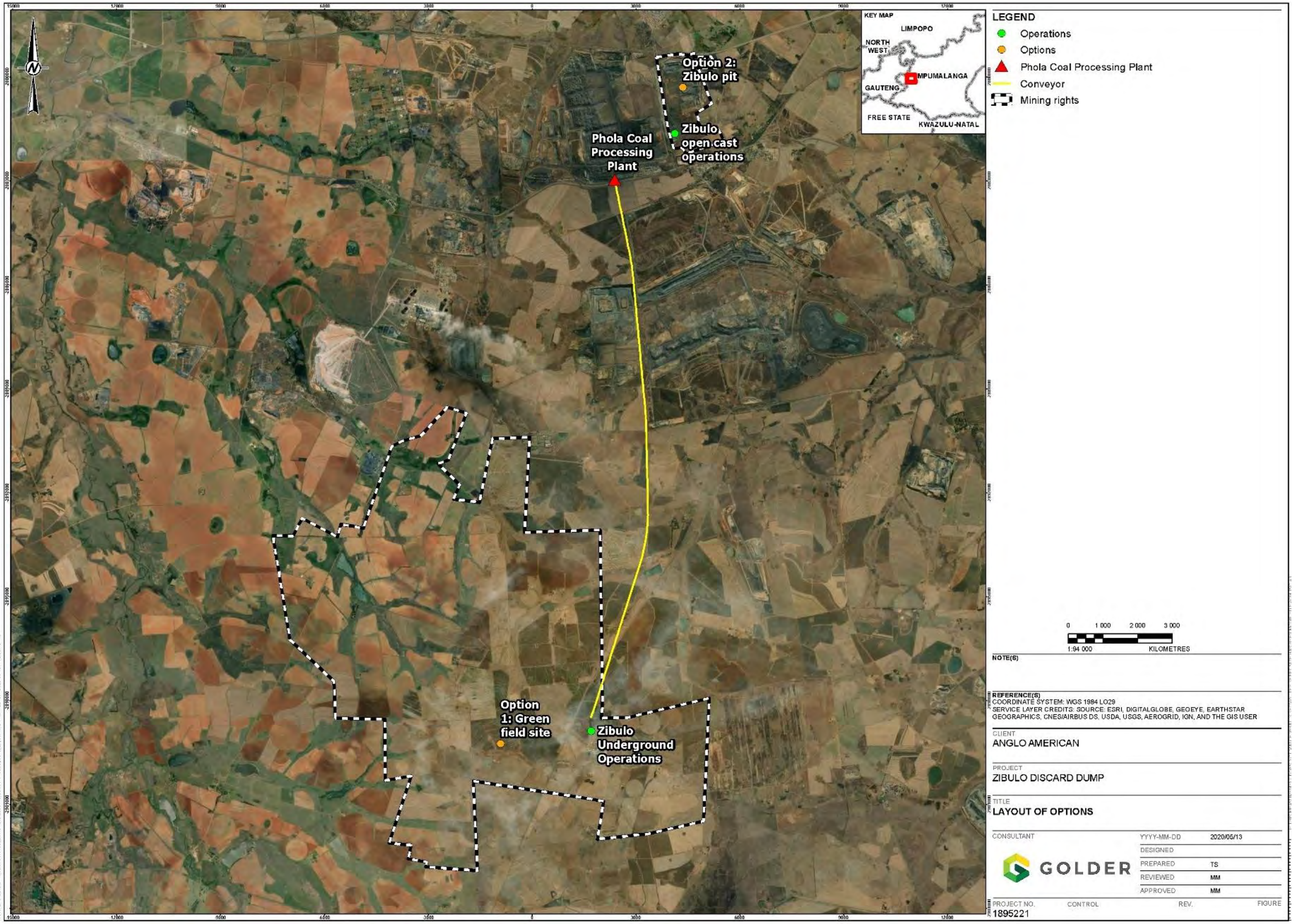

Figure 1: Layout of options

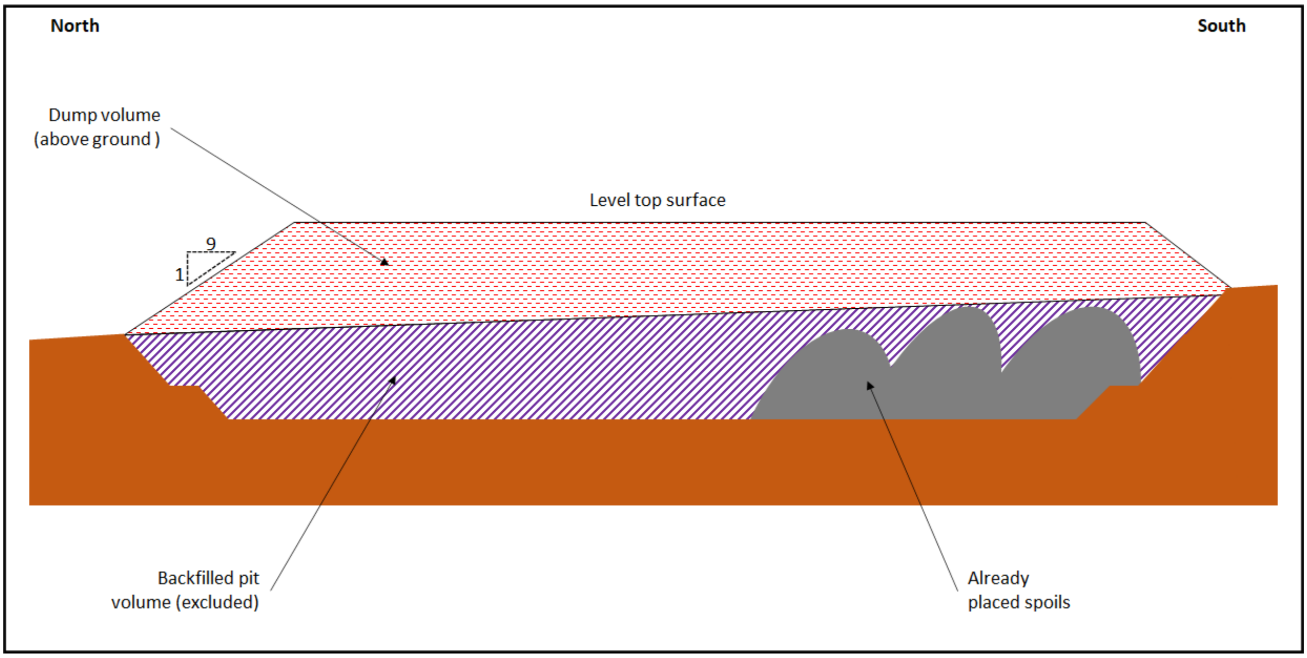

Figure 2: Option 2a schematic section showing discard placement on top of backfilled spoil

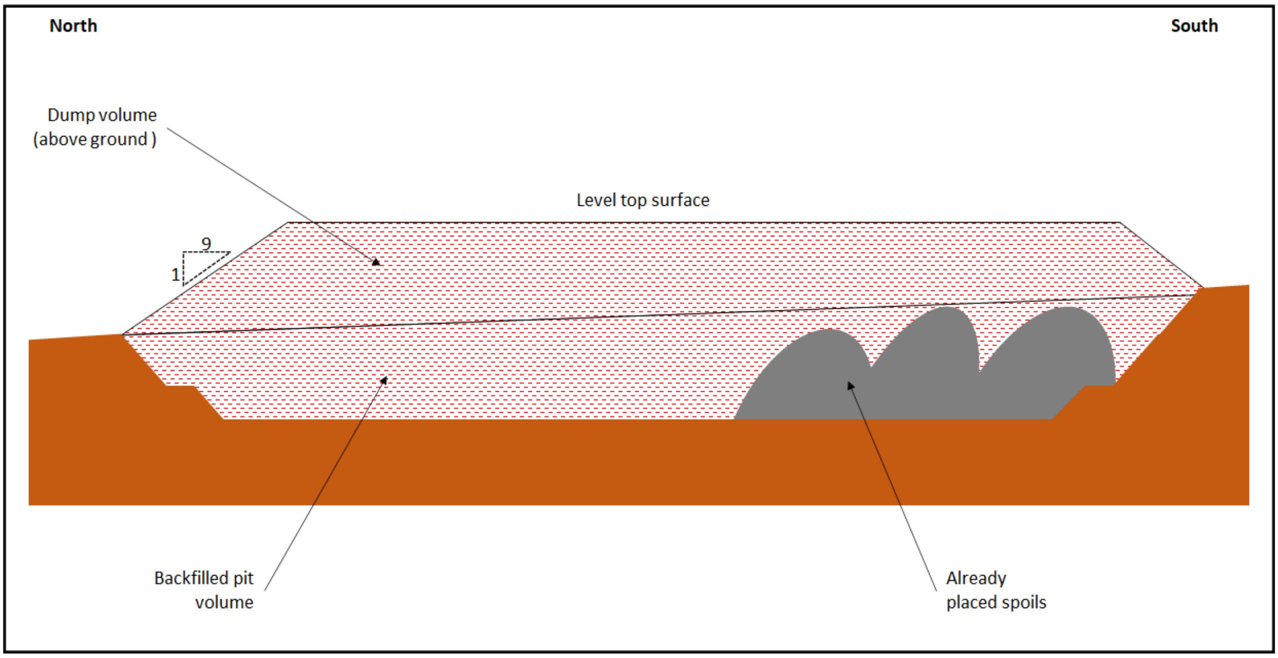

Figure 3: Option 2b schematic section showing discard placement as pit backfill and aboveground

3.0 OPTIONS MATRIX

A standard approach was followed in considering the three options. This entailed the evaluation of a suite of characteristics that relate to cost, engineering and technical aspects, environmental risk and or benefit, social aspects and regulatory complexity together with time considerations.

Evaluation was undertaken on the basis of expert opinion and options were qualitatively ranked and then a weighting was applied. The ranking system used is reflected in Table 1, and the weightings used are reflected in Table 2.

The options matrix is presented as Table 3.

Table 1: Scoring system for risk and impact ranking

Description	Scoring
Lowest negative risk/impact	1
Lower negative risk/impact	2
Medium risk/impact	3
Large negative risk/impact	4
Largest negative risk/impact	5

Table 2: Relative weightings

Aspect	Weighting
Economic	20
Engineering/ technical	30
Environmental	30
Social	10
Regulatory	10
Total	100

Table 3: Options matrix

	Option 1		Option 2a		Option 2b	
Description	Green fields site located near the Zibulo underground operations		Placement of discard above the backfilled Zibulo pit		Placement of discard above the backfilled Zibulo pit and within void	
Aspect	**Component**	**Score**	**Component**	**Score**	**Component**	**Score**
Economic	Highest CAPEX as a new footprint needs to be prepared and lined with a geomembrane	5	Nominal CAPEX to prepare the dump footprint to allow for placement of discard. No barrier system foreseen for in-pit disposal as seepage would be contained inside the pit.	3	Nominal CAPEX to prepare the dump footprint to allow for placement of discard, but this can be offset by existing rehabilitation OPEX to the point that negligible CAPEX is required. No barrier system is foreseen for in-pit disposal as seepage would be contained inside the pit.	1
	CAPEX required to install a return conveyor line (i.e. north to south) adjacent to the existing south to north conveyor	5	Short length of conveyor required to connect the Phola Plant to the Zibulo pit	2	Short length of conveyor required to connect the Phola Plant to the Zibulo pit	2
	High OPEX operating the additional conveyor line	4	Much lower OPEX due to shorter conveyor line	1	Much lower OPEX due to shorter conveyor line	1
	OPEX required for additional water treatment due to new site.	4	Negligible additional OPEX as treatment system is existing.	1	Negligible additional OPEX as treatment system is existing.	1
	Largest closure cost provision due to new standalone facility	4	Lower closure provision as the discard forms part of the existing disturbed pit area	2	Lower closure provision as the discard forms part of the existing disturbed pit area	2
Score		22		9		7
Weighted Score		4.4		1.8		1.4
Engineering/ technical	Possible footprint constraints	3	Adequate available airspace	1	Adequate available airspace	1
	High level of QA/QC required for the installation of the geomembrane system.	3	No geomembrane foreseen	1	No geomembrane foreseen	1

	Option 1		Option 2a		Option 2b	
Description	Green fields site located near the Zibulo underground operations		Placement of discard above the backfilled Zibulo pit		Placement of discard above the backfilled Zibulo pit and within void	
Aspect	**Component**	**Score**	**Component**	**Score**	**Component**	**Score**
	Probable need for new PCD, water treatment and new stormwater management system	3	Possible to use existing stormwater management system	1	Possible to use existing stormwater management system	1
	More precise engineering design approach is possible	1	Unknown uncertainties due to variable nature of backfilled overburden	3	Unknown uncertainties due to variable nature of backfilled overburden	3
Score		10		6		6
Weighted Score		2.5		1.5		1.5
Environmental	New facility will have a significant impact in the sterilisation of a greenfields footprint area	5	Brown fields facility will have a zero impact in the sterilisation of new footprint areas	1	Brown fields facility will have a zero impact in the sterilisation of new footprint areas	1
	Lower risk of spontaneous combustion due to careful management of discard placement and application of cover.	2	Lower risk of spontaneous combustion due to careful management of discard placement and application of cover.	2	Lower risk of spontaneous combustion due to careful management of discard placement and application of cover.	2
	A new facility will increase the risk of groundwater and surface water pollution during operations which will have to be mitigated	4	The proposed facility will be developed on an area where the ground water and surface water has been impacted. These additional impacts however not to a significantly higher risk.	2	The proposed facility will be developed on an area where the ground water and surface water has been impacted. These additional impacts however not to a significantly higher risk.	2
	Risk of disturbing wetlands	3	No wetland disturbance on brownfields site	1	No wetland disturbance on brownfields site	1
Score		14		6		6
Weighted Score		3.5		1.5		1.5
Social	Largest social impact in terms of social acceptance	5	Lower social impact and hence more likely to accept the dump	3	Lower social impact and hence more likely to accept the dump	3

	Option 1		Option 2a		Option 2b	
Description	Green fields site located near the Zibulo underground operations		Placement of discard above the backfilled Zibulo pit		Placement of discard above the backfilled Zibulo pit and within void	
Aspect	**Component**	**Score**	**Component**	**Score**	**Component**	**Score**
	Significant visual interference	5	The new facility will blend in with already disturbed mining area landform and therefore lower visual interference.	3	The new facility will blend in with already disturbed mining area landform and therefore lower visual interference.	3
Score		10		6		6
Weighted Score		1.0		0.6		0.6
Regulatory	A rigorous permitting process associated with a new greenfield site	3	Less rigorous permitting process associated with a brownfield site option	2	Less rigorous permitting process associated with a brownfield site option	2
	The assumption is that no additional land will be required as the new facility will be developed on Zibulo land.	1	No additional land required.	1	No additional land required.	1
Score		4		3		3
Weighted Score		0.4		0.3		0.3
Time frame	Timeline requirements to implement project will be significant.	4	Shorter permitting timeframe. A phased implementation is feasible because the discard footprint expansion is slower than the rate of backfilling.	2	Shorter permitting timeframe. A phased implementation is feasible because the discard footprint expansion is slower than the rate of backfilling.	2
Score		4		2		2
Weighted Score		0.4		0.2		0.2
Total Score		**64**		**32**		**30**
Total Weighted Score		**12.2**		**5.9**		**5.5**

4.0 SITE OPTIONS SUMMARY

The summarised ranking based on Table 3 is included as Table 4 below.

Table 4: Ranking of options

Option No.	Option name	Weighted Score	Ranking
1	Greenfields site	12.2	3
2a	Placement of discard above the backfilled Zibulo pit	5.9	2
2b	Placement of discard above the backfilled Zibulo pit and within void	5.5	1

From the evaluation of alternatives in relation to site it is clear that the two options that relate to development of a discard facility within the footprint of the existing opencast mine are clearly the better option from both an engineering/technical, financial and environmental perspective. This is largely due to proximity and the fact that no new land take is required. Separation between the two options on the opencast pit is not large in relation to their weighted scores but the best performing option is that both use discard to backfill the final voids and ramps and then develop a discard facility that stands proud of the surface. There is no logical reason to backfill and level spoils prior to placement of discard. Consequently, Option 2b is favoured.

5.0 DISCARD TRANSPORT TO OPENCAST SITE

The movement of discard from the Phola Plant to the opencast site requires careful consideration. Three alternatives were considered at a high level and will require some refinement as project planning progresses beyond a prefeasibility stage. For completeness however they are discussed in this section and presented in the accompanying figure (Figure 4).

As mentioned previously the Phola Plant is a shared facility between AAIC and South 32. This facility lies to the west of the provincial road R545 while the Zibulo opencast lies to the immediate east of the road. Furthermore, to the immediate south of the Phola Plant the R555 runs and is developed on its northern side through to the junction with the R545. In the figure the Phola Plant property boundary is indicated as a brown polygon and the position of the Zibulo Opencast pit as indicated in grey. One important additional site is highlighted in purple immediately north-east of the junction between the R545 and R555: this is the position of the local grain silo which attracts considerable traffic during the crop season with noticeable congestion of agricultural trucks and tractor wagon combinations entering and leaving the silo during harvest.

The three transport alternatives considered are indicated and discussed below.

5.1 New build conveyor between Phola Plant and Zibulo opencast

There is an existing conveyor linking the South 32 Klipspruit extension project to feasible a plant. This conveyor alignment is indicated in green in Figure 4. It includes a bridge crossing of the R545 and appoint immediately north of the grain silo.

The proposal would be to develop a dedicated conveyor (indicated in red in the figure) that would follow the alignment of the existing conveyor. The proposed new conveyor would lie to the immediate north of the existing conveyor and cross the R545 on a dedicated bridge crossing. Soon after the crossing of the R545 transferred to a conveyor running north to the opencast pit would take place to convey discard to the pit area for final disposal. Should there be any limitation through either time to commission or mechanical failure at any point in time the discards transport alternative to be considered as a backup would be to transport discard via mine roads limiting public contact with such vehicles to the existing crossing point of the R545 (see 5.2 below).

The advantages of the proposed conveyor are that it's is confined to mine property belonging to either South32 or AAIC. In addition, the recent development of the incoming Klipspruit extension conveyor great opportunity for infrastructure alignment with minimal disruption to either mining operation. Some optimisation in engineering will be required as the project advances beyond prefeasibility to address the transfer point on the western side of the R545 as space is reasonably constrained between the existing conveyor (green) and Klipspruit extension access road lying to its immediate north.

This is the favoured transport alternative.

5.2 Mine road between Phola Plant and Zibulo opencast

It is important to note that there is a reinforced road crossing at a point immediately to the north of the Klipspruit conveyor crossing of the R545. There is an established four-way intersection as this is the entrance to the extension project and allows transport across the R545 directly onto the Kiipspruit mine. This presents an opportunity.

Consequently, there is the potential to transport coal discard from the Phola Plant across the property of South32 Klipspruit to the existing crossing of the R545 and thereafter to deviate to the north-east onto the Zibulo property following an existing road to the south-western point of the opencast pit. Some optimisation of this route the Zibulo property would be needed with time as a portion of the existing road would be lost as the opencast mine expands to the south. However, that is not deemed material to the consideration of this alternative as a potential route because the access road (yellow line East of R545) that will be affected by the mine will need to be relocated in any event as part of the Zibulo opencast expansion and consequently would continue to be available in its new position on the mine property for discard haulage.

The disadvantage of this option is that it will necessitate a long-term haulage across the property of a neighbouring mining house with associated complexities in relation to transportation and safety. It also has the disadvantage of necessitating regular crossing of the R545 with associated accident risk. Importantly, there is considerable congestion on the R545 during the crop season as agricultural vehicles (trucks and tractors and trailers) bring grain to the existing silos. Queues of vehicles commonly form at the entrance to the grain silo rendering this portion of road highly congested during parts of the year. For this reason the development of a dedicated conveyor to transport discard to the Zibulo opencast was favoured notwithstanding its higher cost.

5.3 Public road use

There is potential to make use of the existing public road network to transport discard from the Phola Plant to the opencast site. The route is indicated in white in Figure 4. It would exit the Phola Plant site at an existing exit and vehicles hauling discard to Zibulo opencast would move in an easterly direction on the existing R555 past the entrance to South 32 Klipspruit Colliery to the junction between the R555 and R545. At this point trucks approaching the mine would turn to the north onto the R545 and access the opencast immediately adjacent to the pit at an entrance yet to be created. There is a short term alternative that could present itself which would see trucks turning onto the mine property to follow the mine road indicated in yellow.

They are a number of significant constraints associated with use of the public road network and these include the developed nature of the R555 between the possible entry point at Phola Plant and the junction with the R545. The junction itself is congested with considerable coal product haulage already taking place. Most importantly, during the cropping season the R545 is extremely congested as agricultural transport enters and exits the grain silos. In particular, it must be noted that this transport includes tractor drawn grain wagons which move at a slow pace on the roads.

This alternative is not favoured nor considered practical given the existing road constraints.

Figure 4: Map indicating conceptual alignment of proposed discard transport alternatives. A public road route in white, a proposed mine Road crossing the South 32 property in yellow and proposed new conveyor route in red. The alignment of an existing coal conveyor is indicated in green.

6.0 CONCLUSIONS

The culmination of this options analysis can be summarised as follows: the development of a brownfields discard facility that will include both discard back full into ramps and final voids and aboveground development of the facility on rehabilitated land (Option 2B). Discard will be supplied to this facility via a proposed dedicated conveyor linking the Phola Plant to the opencast pit site.

Golder Associates Africa (Pty) Ltd.

Justin Walls
Senior Closure Engineer

Philip Barnard
Associate

JW/PB/nbh

Reg. No. 2002/007104/07
Directors: RGM Heath, MQ Mokulubete, MC Mazibuko (Mondli Colbert), GYW Ngoma
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APPENDIX A

Document Limitations

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APPENDIX C

Zibulo Discard Facility

Storm Water Management Plan

TECHNICAL MEMORANDUM

DATE 24 March 2021 **Project No.** 19117180 Memo 006

TO Melissa Hallquist-Waites, Anglo American Inyosi Coal

CC Olivia Allen, Johan Jordaan

FROM Givarn Singh **EMAIL** gsingh@golder.co.za

ZIBULO DISCARD FACILITY STORMWATER MANAGEMENT PLAN

1.0 INTRODUCTION

Anglo American Inyosi Coal (Pty) Ltd (AAIC) proposes to develop a discard facility at its opencast operations at Zibulo Colliery, situated near Ogies in the Mpumalanga Province, South Africa. This memorandum details the proposed stormwater management plan for the facility and forms part of the impact assessment to support the various legislative requirements.

1.1 Background

Anglo Coal Inyosi Zibulo Colliery comprises both underground and opencast mining operations. The mine produces an annual eight million run of mine (ROM) tonnes of export thermal coal, with seven million tonnes per annum coming from its underground sections and the remaining one million tonnes from its opencast pit. The underground operations incorporate bord and pillar continuous mining methods while the contractor-run box cut development (Zibulo Opencast) utilises a small dragline and truck and shovel fleet. The opencast area commenced in 2009 and supplies coal to local and international markets.

The coarse and fine discard produced from the processing operations is currently deposited onto a surface discard facility on South32's Klipspruit Colliery. The facility is reaching capacity and by 2021 an alternative discard facility is required to service the discard requirement of Zibulo Colliery.

A storm water management model (SWMM) is prepared for the proposed new discard facility using the PCSWMM modelling software. The objectives of the SWMM are to:

- Delineate clean and dirty storm water sub-catchments;
- Locate alignments for clean and dirty storm water conveyance channels;
- Determine cross-sections and vertical profiles of storm water conveyance channels; and
- Determine dimensions of clean and dirty storm water channels to convey storm water runoff resulting from the design storm event.

The guiding principles for the above work are taken from government regulation No. 704 of 4 June 1999 – Regulations on use of Water for Mining and related activities aimed at the Protection of Water Resources

(National Water Act No. 36 of 1998) (Department of Water Affairs and Forestry, 4 June 1999), specifically clause 6. The regulation is commonly referred to as GN704.

2.0 CLIMATE AND RAINFALL

2.1 Climate

Zibulo Opencast is located in the Highveld Coalfields, an area that experiences warm, temperate climate with maximum temperatures exceeding 27°C in the summer months and temperatures below 2°C during the winter months. The Highveld is a summer rainfall region with November, December and January experiencing the highest rainfall months, and little to no rain in the winter months.

2.2 Rainfall

Two sources of rainfall data were used for the water balance model and stormwater manager plan.

- For historic sequences and calibration purposes the precipitation depths measured at the on-site weather station were used. Hourly rainfall data received from the client covers the period from Jan 2016 to Dec 2020.
- For future scenarios (as well as historic periods with missing site data) synthetic rainfall records using a stochastic rainfall simulator were generated. The simulator was calibrated to ensure the rainfall sequences generated are statistically equivalent to the long-term historic record selected. This data was sourced through the Daily Rainfall Data Extraction Utility (Kunz, 2004)

The metadata for two rainfall stations that were analysed are presented in Table 1. The selection of the two stations was based on the stations being the closest to the site with reasonably long and reliable records.

Table 1: Metadata for the rain gauges

Station Name	Station No	Distance (km)	Latitude (deg)	Longitude (deg)	Record (years)	Reliable (%)	MAP (mm)	Altitude (mamsl)
Strehla	0477762 W	9.11	26°14’	29°03’	74	69.4	681	1 573
Cologne	0478009 W	7.39	26°08’	29°01’	74	65.6	673	1 622

The unpatched and patched daily rainfall data for the stations are plotted in Figure 1 and Figure 2. Strehla station has only 8% patched data and Cologne station has 13% patched data. The average monthly rainfall depths are presented in Figure 3.

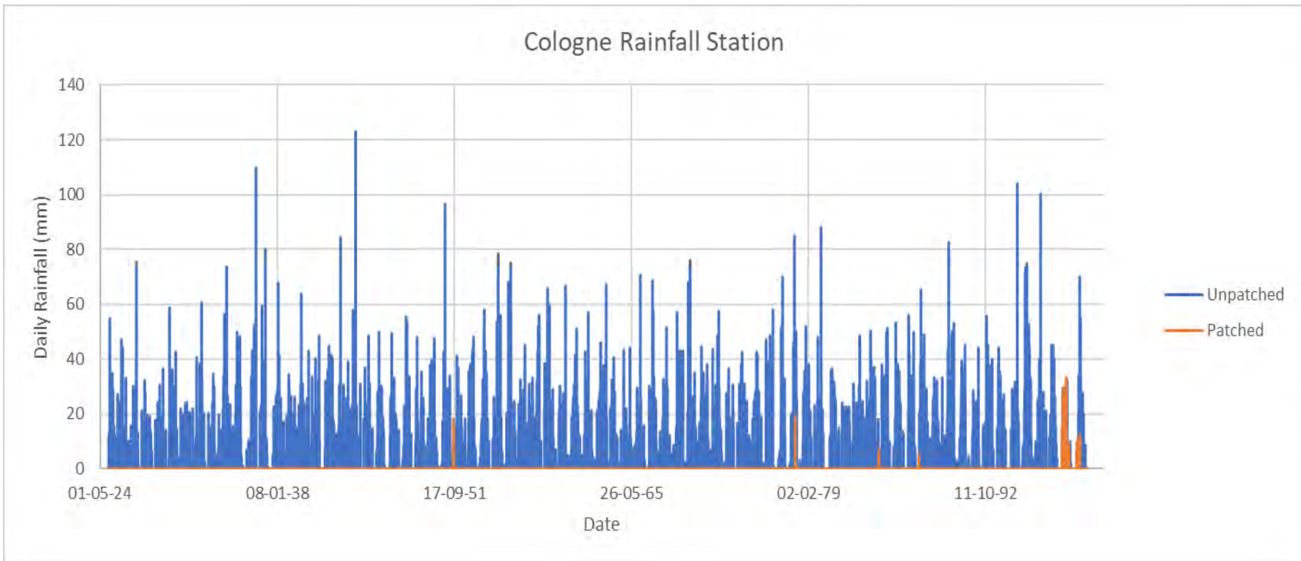


Figure 1: Cologne station daily rainfall

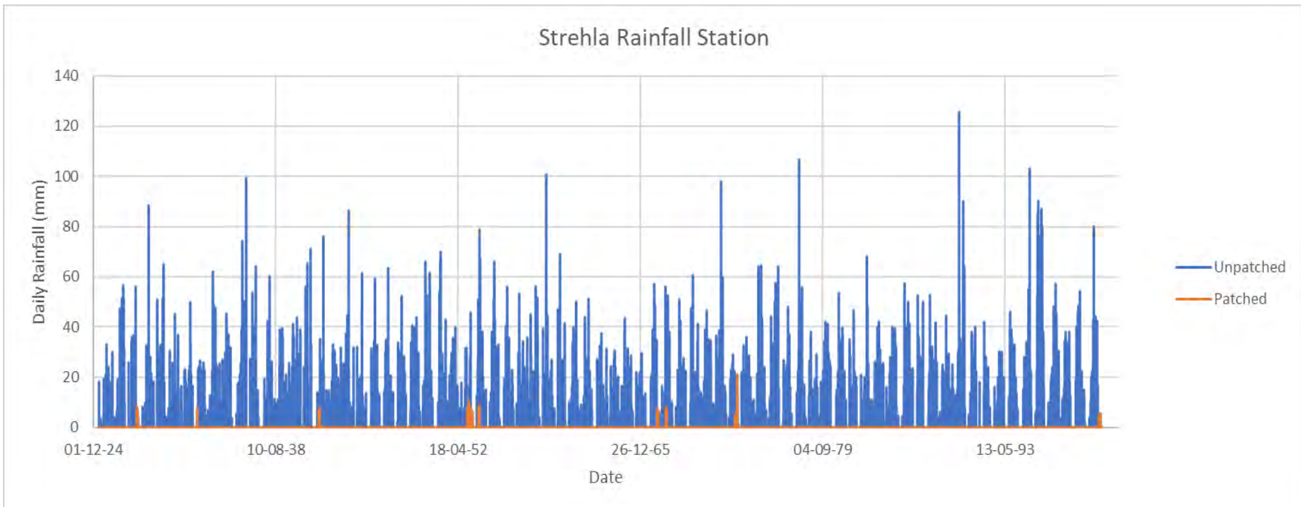
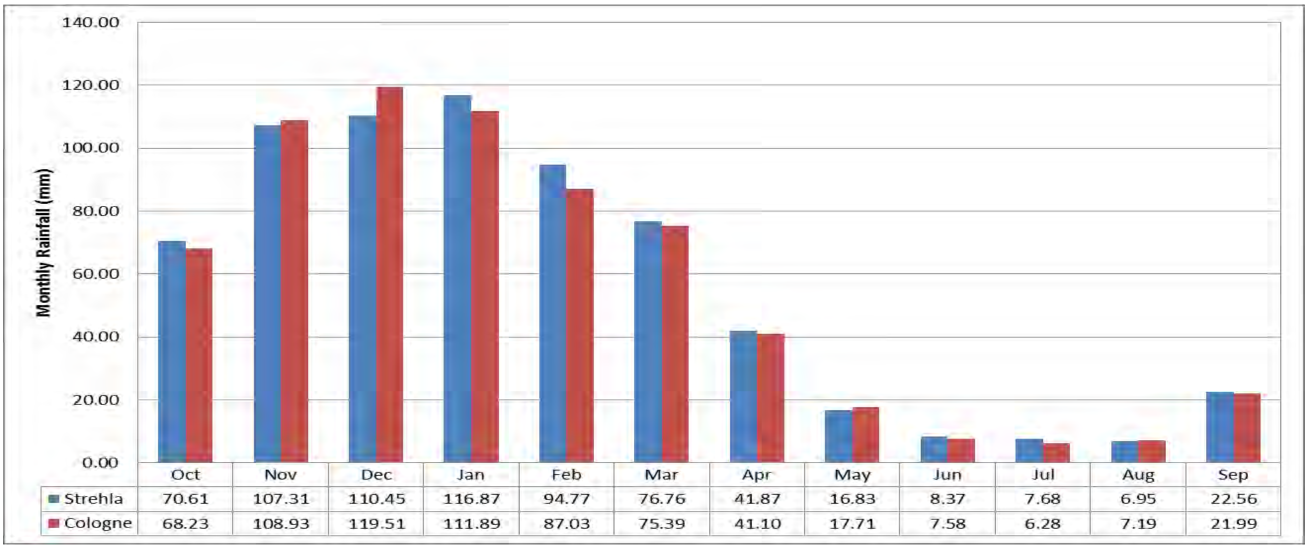


Figure 2: Strehla station daily rainfall



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Strehla	70.61	107.31	110.45	116.87	94.77	76.76	41.87	16.83	8.37	7.68	6.95	22.56
Cologne	68.23	108.93	119.51	111.89	87.03	75.39	41.10	17.71	7.58	6.28	7.19	21.99

Figure 3: Average monthly rainfall for the stations analysed

Figure 4 shows a plot of the cumulative rainfall over time indicating a slight difference between the two stations for the period between 1985 and 1994. While Strehla station is slightly further from Zibulo Opencast, the percentage patched data is lower and was thus selected for use in the study.

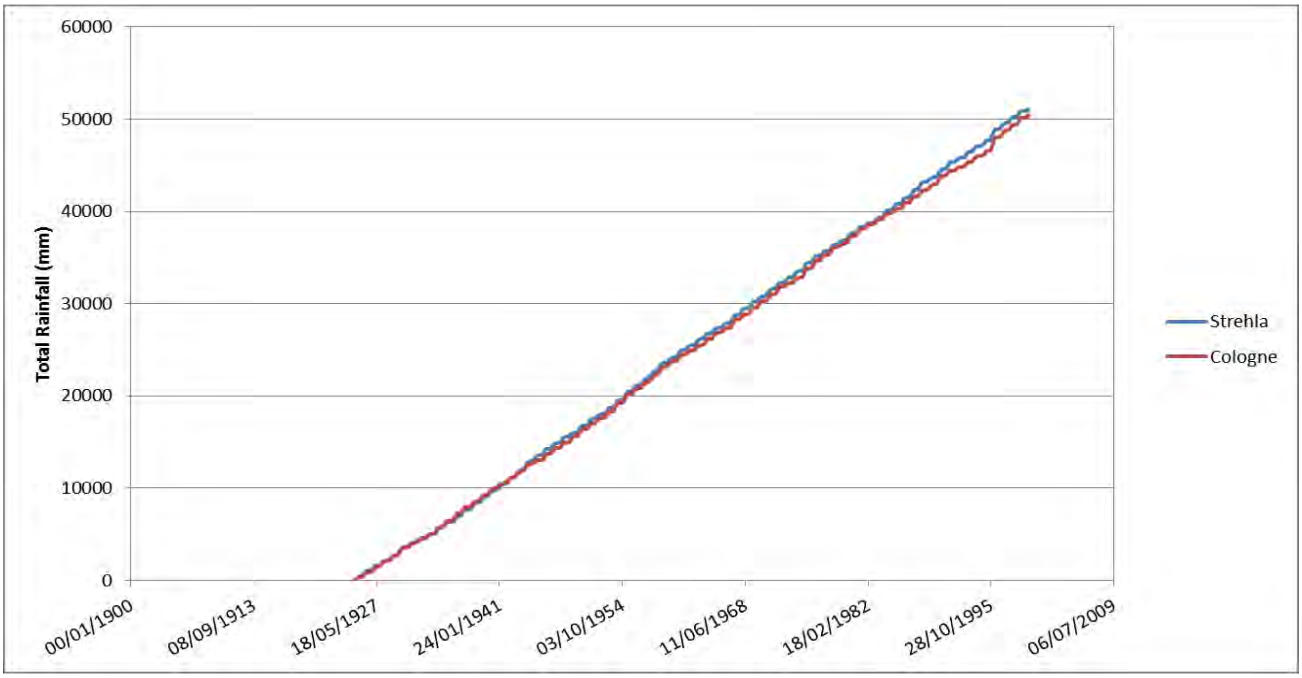


Figure 4: Cumulative Rainfall for the stations

The regional rainfall statistics are therefore based on the Strehla station data. The cumulative distribution function of annual rainfall is presented in Figure 5. The analysis shows that:

- The Mean Annual Precipitation (MAP) is 681 mm/annum (mm/a) with 50% of the years receiving from 487 mm/a to 782 mm/a, and
- The amount of rainfall varies considerably from year to year. The annual rainfall varies from 372 mm/a to 1 050 mm/a. A dry year (defined as the 5^{th} percentile) will receive 450 mm/a and a wet year (defined as the 95^{th} percentile) can receive 950 mm/a.

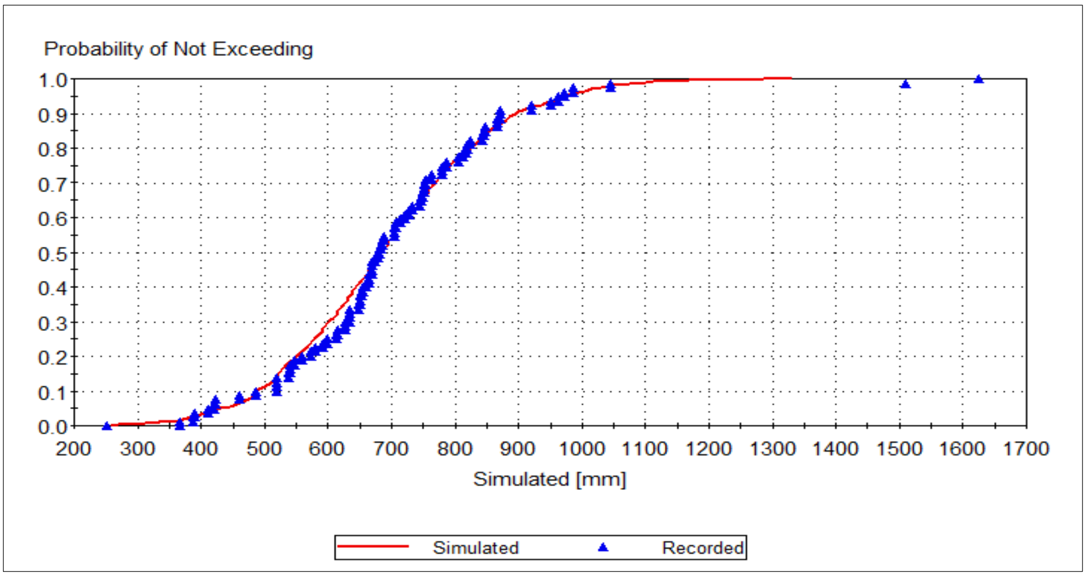


Figure 5: Cumulative distribution function of annual rainfall at the Strehla rain gauge

The boxplot of monthly rainfalls is presented in Figure 6. It provides a visual summary of:

- The centre of the data (the median - the centre line of the box),
- The variation (interquartile range - the box height),
- The skewness (the relative size of box halves), and
- The presence or absence of outliers ("far outside" values represented by the 1st and 99th Percentile).

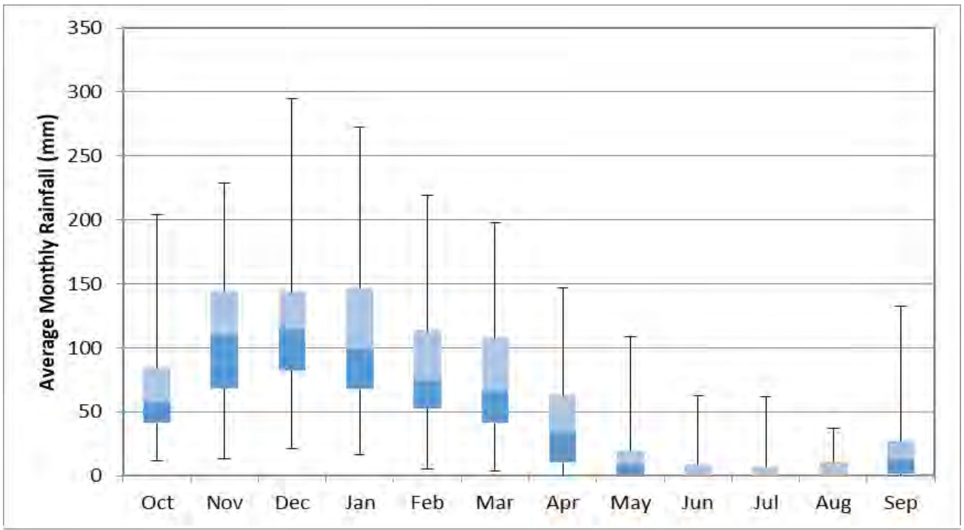


Figure 6: Box plot of monthly rainfall from Strehla Station record (0477762 W) from 1925 to 1999

The analysis of monthly rainfall shows that:

- The dry season occurs between May and September and receives less than 9% of the annual rainfall,

- The wet season occurs between October and April and receives more than 91% of the annual rainfall. On average, 74% of the annual rain falls within a period of 5 months (November to March), and
- The wettest month is January with a median around 113 mm/month. The maximum monthly rainfall recorded is 265 mm/month.

Several probability distributions were fitted to the recorded 24-hour maximum annual storm events. The Log Pearson III distribution (LP3) fitted the data best. Storm depths for the various specified recurrence intervals, based on this fitted distribution, are presented in Table 2.

Table 2: 24-hour storm rainfall for various annual recurrence intervals

Return Period in years	2	5	10	20	50	100	200
LP3 Distribution (mm/d)	54	72	83	95	110	121	133

In respect of climate change, the DWS National Integrated Water Information System (NIWIS) indicates a marginal rainfall change of a 3.2% decrease in the B20G1 hydrological catchment (Figure 7).

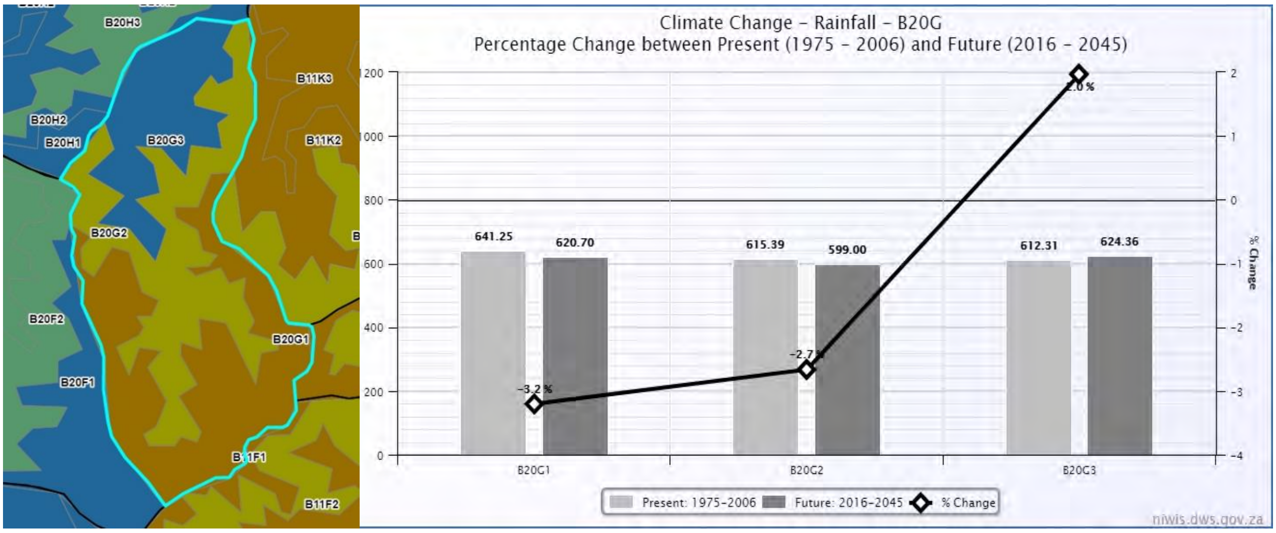


Figure 7: Rainfall changes expected (NIWIS[1])

The DWS NIWIS has indicated that the expected wet spells will increase by 14.5% in the B20G1 area. Due to the low impact climate change is expected to have on rainfall in the region, the current design based on the 1-in-50-year storm event is assumed to be adequate to handle the minor changes expected from the rainfall due to climate change, noting that the channels have sufficient freeboard at the given design event peak flow.

2.3 Methodology

The United States Environmental Protection Agency Storm Water Management Model (EPA SWMM) was used to construct the rainfall-runoff model – refer https://www.epa.gov/water-research/storm-water-management-model-swmm. The Computation Hydraulics International (CHI Water – www.chiwater.com) PCSWMM model was used as the software interface for coding and running the EPA SWMM model. The model uses the US Soil Conservation Service rainfall distributions (Type I to Type IV), adapted for South African conditions (Schimdt & Schulze, 1987a). The project falls in a region of South Africa having a Type III rainfall distribution.

A topographic survey was received from the client. The survey was processed in CAD software to obtain digital elevation model (DEM) of the study area. The discard facility was developed in CAD and a DEM developed from the elevation analysis of the discard facility design. This DEM was used to obtain watershed boundaries defining the local sub-catchments.

A channel layout was designed to intercept clean and dirty runoff from the corresponding sub-catchments separately. The design rainfall analysis (Table 2) was used to develop rain gauges which were then applied to the sub-catchments. The analysis was run using the 1-in-50-year recurrence interval storm event following GN-704 regulation. Parameters, relating to the catchment response to rainfall, were applied to the sub-catchments. The model was run, necessary adjustments made to optimise, and finalised.

The surface topography of the discard facility currently drains to the north. Once completed, the discard facility's surface is planned to drain towards the north as well. The intention of the stormwater management for the facility is to collect the contaminated runoff from the catchment using an unlined, engineered perimeter channel around the boundary of the facility which directs water northwards towards a low point which infiltrates in the pit. A series of bench channels are placed at 45 m horizontal intervals (5 m vertical) along the side slopes of the facility. This is to reduce the catchment sizes and hence the runoff to the respective channels. The accumulation of energy and shear forces along the slopes, which results in erosion, is therefore also fragmented. These channels are constructed out of the discard material and hence have the same hydraulic properties as the facility's sub-catchments. The bench channels are sloped southward and join the perimeter channel. At the junction of the bench channels and the perimeter channel, energy dissipators must be installed to reduce the incoming flow velocities and allow the water to change flow direction. All contaminated runoff reports to the infiltration pit at the northern base of the facility. The infiltration pit has not been sized as part of the stormwater assessment.

2.4 Model Layout

The key in Table 3 applies to the symbols use in the model imagery to represent the stormwater management of the discard facility:

Table 3: Key to Model Symbols

SYMBOL	DESCRIPTION
	Clean water channel, river diversion
	Discard bench channel

SYMBOL	DESCRIPTION
	Perimeter channel
	Berm
	Clean sub-catchment
	Dirty sub-catchment

Figure 8 shows the model layout and the sub-catchments which are relevant to the proposed infrastructure.

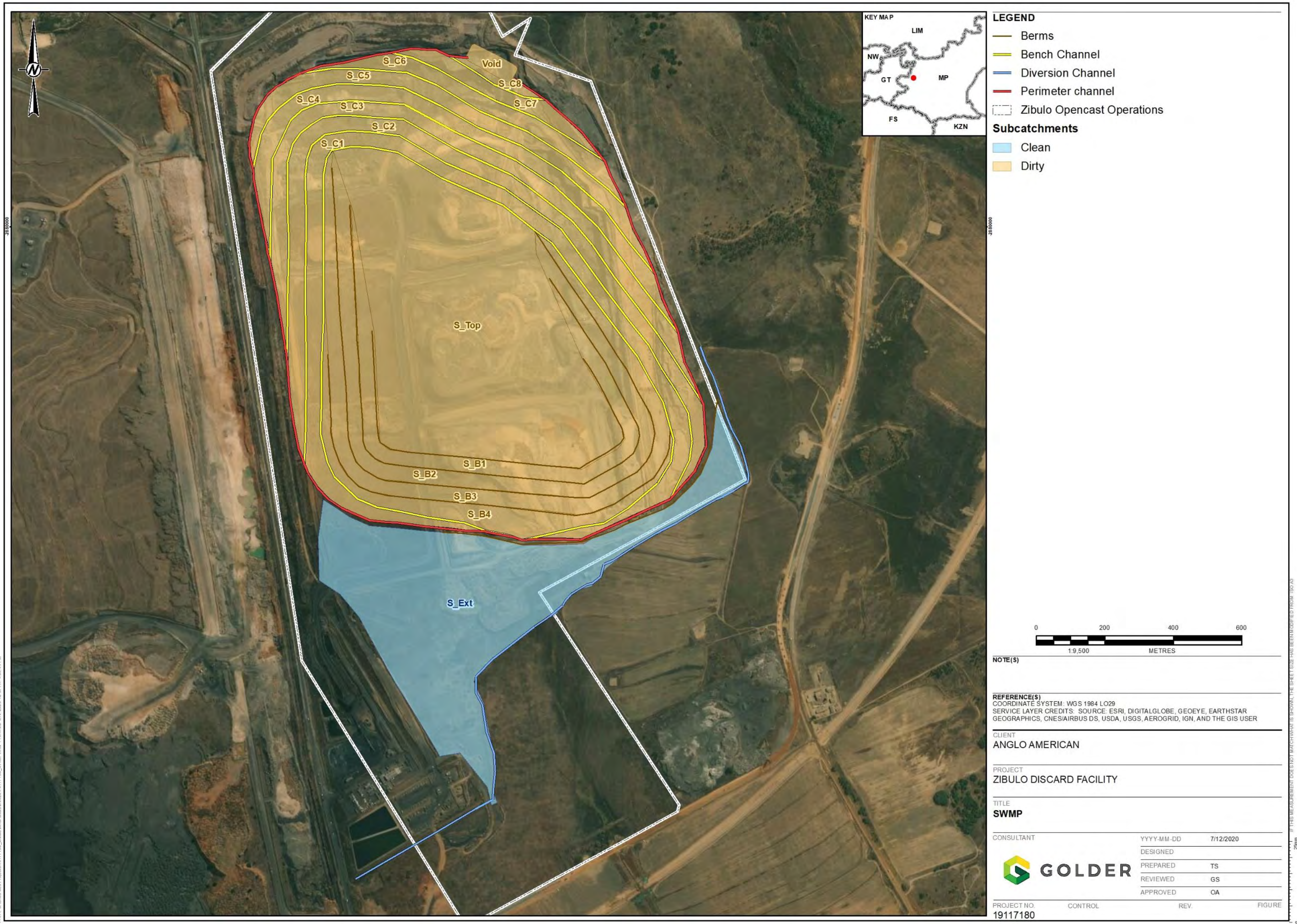


Figure 8 : Zibulo Discard Facility Stormwater management plan layout.

2.5 Input Parameters

Detail layouts and tables of input parameters are presented in APPENDIX A. Design rainfall used for the model was determined as described in Section 2.2. The 1:50-year return interval rainfall depth for the site is 110 mm, and the SCS-SA rainfall distribution is Type III. The resulting rainfall intensity distribution is shown in Figure 9.

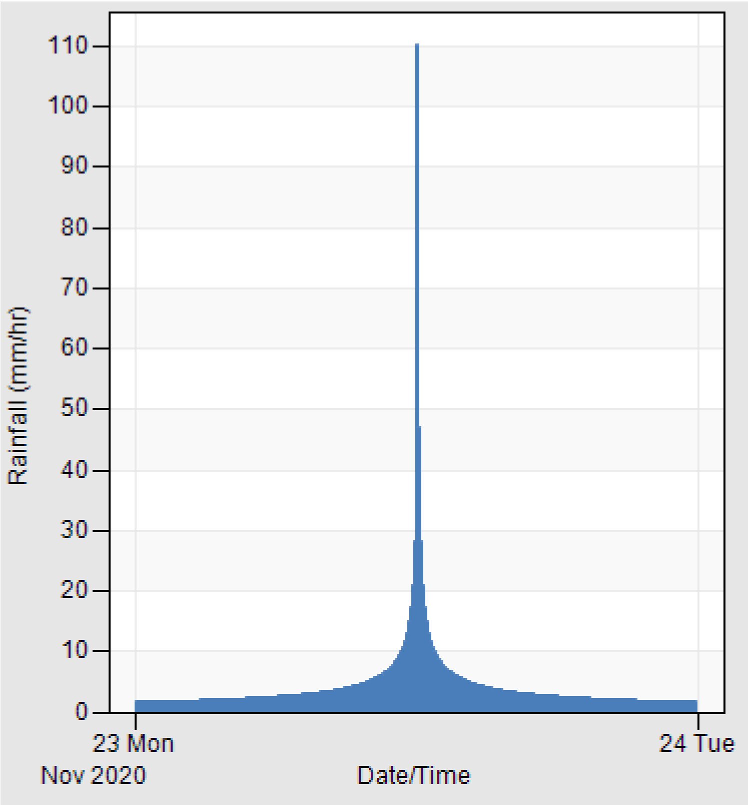


Figure 9: 1-in-50-year return interval SCS-SA Type III design rainfall distribution.

Roughness of sub-catchments and channels affect time of concentration of runoff from the sub-catchments, which in turn influences the peak flow reporting from the catchment. Roughness estimations for different land uses are estimated in studies and published in tables in literature. Tables distinguish between roughness values for overland flow (sheet flow) and channelized flow (concentrated flow). (Chow, 1959) and (United States Environmental Protection Agency, May 2017) were consulted for roughness estimates for the catchments and channels. The manning's n, a roughness factor, for the discard facility was taken as 0.035. The perimeter channel's Manning's n was taken as 0.015. The sub-catchment details are given in detail in Table 5 under Appendix A.

Abstractions remove water from the runoff in the form of depression storage and infiltration. Exact determination of depression storage is not practical and is based on estimates and experiential judgements. However, the magnitude thereof is insignificant in the large design event used for these models, and therefore high-level estimates are adequate, and are taken in the order of 0.5 mm for rough areas and 0.05 mm for impervious areas e.g., concrete, hardstand, roofs, etc. The EPA-SWMM model offers a variety of infiltration models. For this model, the Modified Green-Ampt model was selected. It takes account of soil hydraulic characteristics based on soil type. The model uses three parameters:

- Suction head (mm)
- Conductivity (mm/hr)

- Initial deficit (fraction)

The soil type of the discard facility is assumed to represent a loamy sand with high infiltration ability. The parameters in Table 4 were therefore applied to the infiltration model.

Table 4: Provisional estimates of soil parameters for Green-Ampt Infiltration. Loamy sand was chosen for the soil type of the discard facility (United States Environmental Protection Agency, May 2017).

USDA Soil Texture Classification	Avg. Capillary Suction	Saturated Hydraulic Conductivity	Initial Moisture Deficit for Soil (Vol. of Air / Vol. of Voids, expressed as a fraction)	
	(mm)	(mm/hr)	Moist Soil Climates (Eastern US)	Dry Soil Climates (Western US)
Sand	49.5	235.6	0.346	0.404
Loamy Sand	**61.3**	**59.8**	**0.312**	**0.382**
Sandy Loam	110.1	21.8	0.246	0.358
Loam	88.9	13.2	0.193	0.346
Silt Loam	166.8	6.8	0.171	0.368
Sandy Clay Loam	218.5	3.0	0.143	0.250
Clay Loam	208.8	2.0	0.146	0.267
Silty Clay Loam	273.0	2.0	0.105	0.263
Sandy Clay	239.0	1.2	0.091	0.191
Silty Clay	292.2	1.0	0.092	0.229
Clay	316.3	0.6	0.079	0.203

The average slopes of the sub-catchments were determined from the DEM.

The benched channels were designed as trapezoidal channels with a berm on the outer side to ensure that water does not spill into the downslope strip as shown schematically in Figure 10 below.

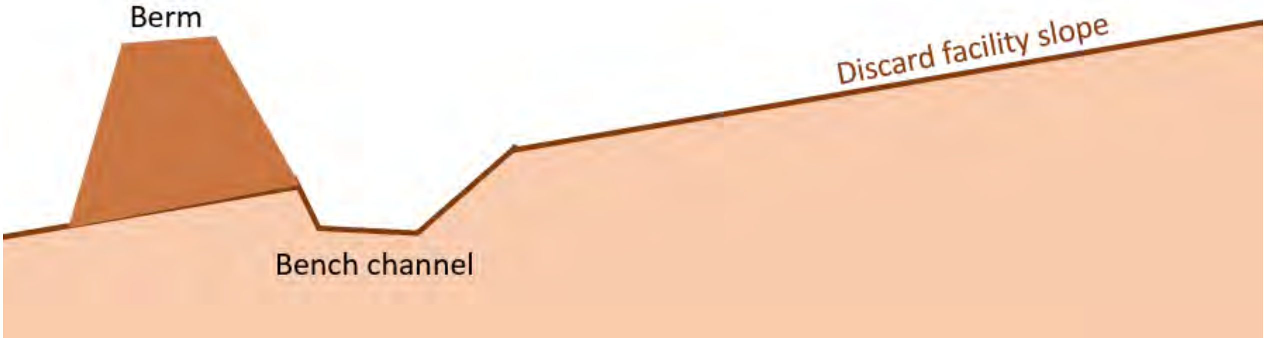


Figure 10: Bench channel cross-section schematic.

The perimeter channel is an unlined trapezoidal channel with a berm on the outer end to prevent clean water entering the channel from the sides as well as to avoid splash over from the channel into the clean catchment. The channel has two legs which extend around the discard facility and meet at the infiltration pit to the north of the facility. A schematic cross section of the channel is shown in Figure 11 below.

Figure 11: Perimeter channel cross-section schematic.

One-meter high rockfill berms with side slopes of 1:2 are proposed on the southern end of the discard facility side slopes to attenuate the runoff reducing the flow velocity reporting into the perimeter channel at the base of the facility. The berms are to be designed as a cascading system water filtering through the rockfill voids with the intention to increase the flow lag and increase the flow length which in turn will reduce the energy of runoff from the southern end. These berms are displayed in the stormwater management layout in Figure 8 above.

There is currently a diversion channel which directs clean water towards the west of the Zibulo site and away from the discard facility. A one-meter berm with 1:2 side slopes is proposed to the southwest of the discard facility to ensure that any clean runoff from the clean sub-catchment shown in Figure 8 is directed away from the dirty channels and contributes to the existing clean diversion channel. Following planned mining southward of the discard facility, this diversion channel is to be re-routed and re-sized which falls out of the scope of this project.

2.6 Results

Detail layouts and tables of results are presented in Appendix A. The hydraulic profile of the east and west legs of the perimeter channel (as proposed) are shown in Figure 12 and Figure 13 respectively. In the figures, the high point represents the south of the discard facility which slopes northward, and the low point is the infiltration pit where the contaminated runoff is directed towards. The channel sizes and the respective velocities and flow rates are given in Table 6 under Appendix A.

The trapezoidal bench channels were sized to be 0.7 m high with a left side slope of 1:2 and a right slope of 1:9 to represent the slope of the facility. The trapezoidal perimeter channel is sized to be one meter high, with a bottom width of 2 m and 1:2 side slopes. The channel details are shown in Appendix A.

Due to the high velocities of the runoff in the bench and perimeter channels it is recommended that energy dissipators be installed at the junction of the bench channels and the perimeter channels as well as at the discharge points into the infiltration pit. A combination of drop chutes and stilling basins is recommended to reduce the energy for the runoff and hence reduce the flow velocities. The contour channels will also require erosion protection such as riprap or similar.

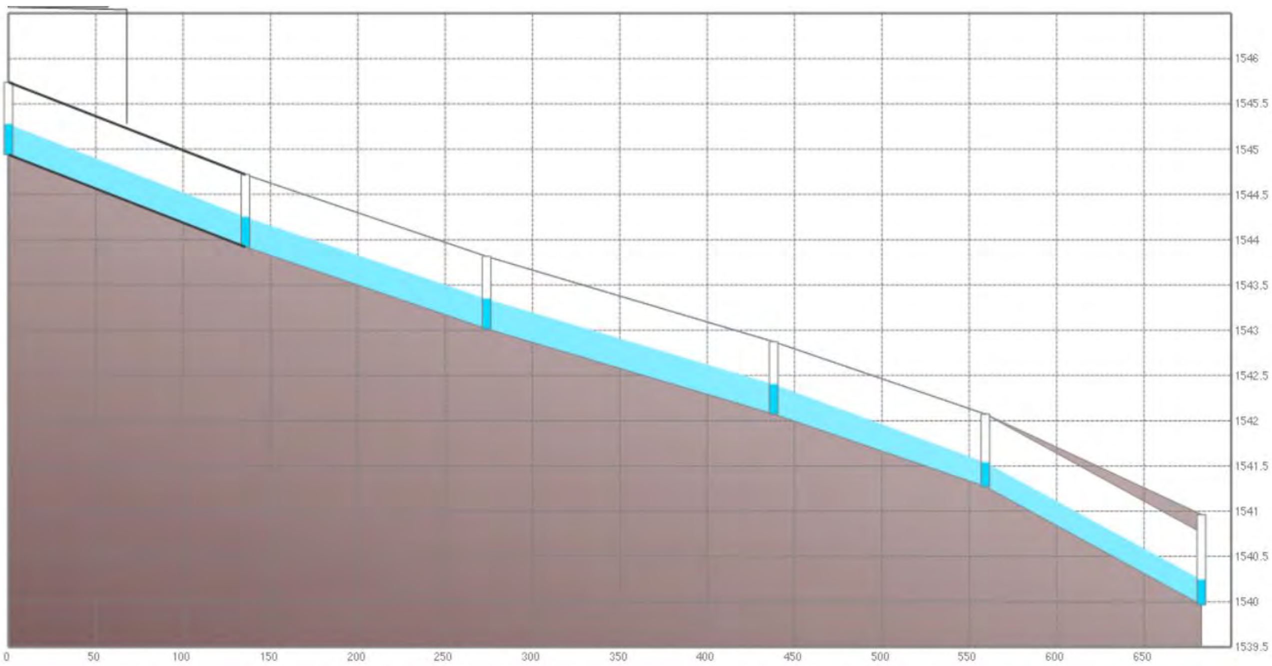


Figure 12: Eastern leg of the perimeter channel with water the water depth displayed in blue (units in meters).

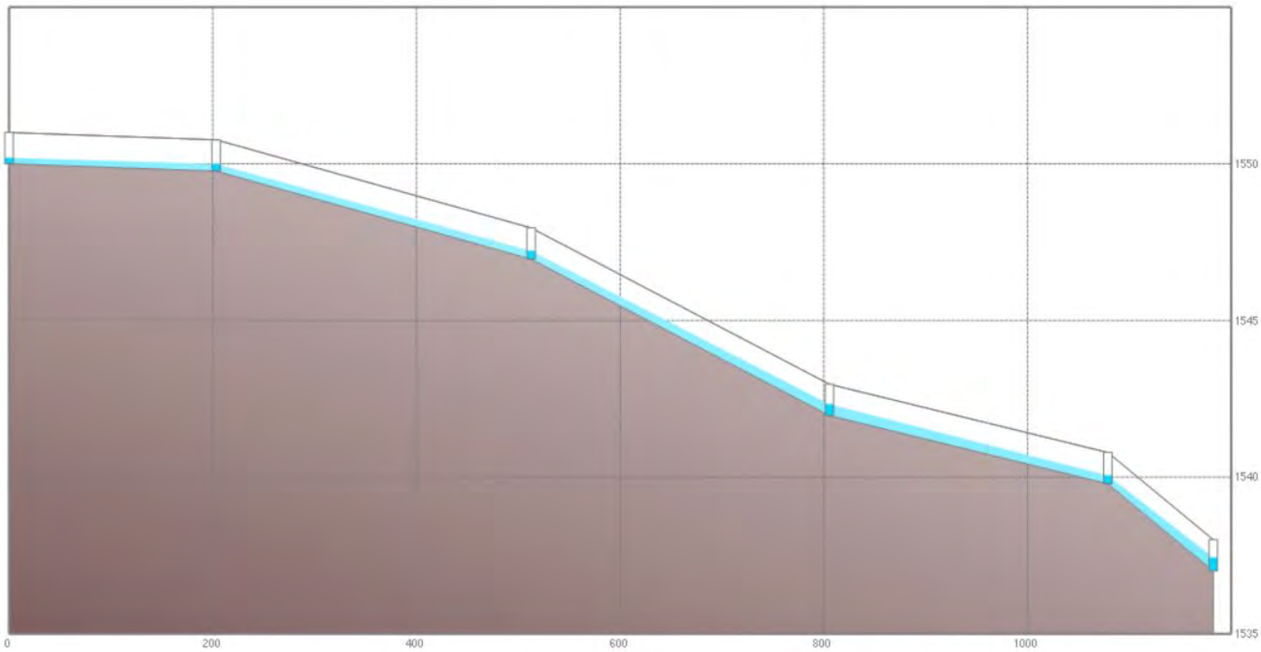


Figure 13: Western leg of the perimeter channel with water the water depth displayed in blue (units in meters).

3.0 CONCLUSION

This memorandum details the conceptual stormwater model for the proposed Zibulo Discard Facility. The detailed engineering design phase must identify all necessary technical specifications and additional infrastructure required to give effect to a robust stormwater system at construction and operational phase.

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APPENDIX A

Sub-catchment and channel details

Table 5: Discard Facility sub-catchments details.

Name	Tag	Area (ha)	Flow Length (m)	Zero Imperv (%)	Suction Head (mm)	Conductivity (mm/hr)	Initial Deficit (frac.)	Infiltration (mm)	Runoff Depth (mm)	Runoff Volume (ML)	Peak Runoff (m^3/s)	Runoff Coefficient
S_Top	Top Area	48.6302	972.604	25	61.3	59.8	0.4	104.46	5.47	2.66	0.69	0.05
S_B1	South	7.9728	159.456	25	61.3	59.8	0.4	82.46	27.35	2.18	0.58	0.249
S_B2	South	10.7782	215.564	25	61.3	59.8	0.4	97.46	32.59	3.51	0.87	0.25
S_B3	South	10.9678	219.356	25	61.3	59.8	0.4	105.31	36.54	4.01	1.01	0.257
S_B4	South	6.1551	123.102	25	61.3	59.8	0.4	100.06	74.91	4.61	1.46	0.428
S_C1	North	15.541	310.82	25	61.3	59.8	0.4	71.69	38.14	5.93	1.69	0.347
S_C2	North	12.2368	244.736	25	61.3	59.8	0.4	71.15	38.72	4.74	1.47	0.352
S_C3	North	9.1742	183.484	25	61.3	59.8	0.4	82.46	27.34	2.51	0.66	0.249
S_C4	North	8.0836	161.672	25	61.3	59.8	0.4	70.34	39.58	3.2	1.16	0.36
S_C5	North	6.5121	130.242	25	61.3	59.8	0.4	82.46	27.36	1.78	0.48	0.249
S_C6	North	4.2461	84.922	25	61.3	59.8	0.4	82.46	27.38	1.16	0.32	0.249
S_C7	North	2.742	54.84	25	61.3	59.8	0.4	82.46	27.39	0.75	0.21	0.249
S_C8	North	0.6298	12.596	25	61.3	59.8	0.4	82.44	27.47	0.17	0.05	0.25
Void	Void	0.8109	16.218	25	61.3	59.8	0.4	68.92	41.24	0.33	0.18	0.375

Table 6: Channel flow results for the stormwater management plan.

Channel Description	Channel ID	Length (m)	Depth (m)	Bottom width (m)	Left side slope (1:_)	Right side slope (1:_)	Slope (m/m)	Max. |Flow| (m^3/s)	Max. |Velocity| (m/s)	Max/Full Depth
Perimeter channel	C143	285.777	1	2	2	2	0.00728	1.458	2.19	0.27
Perimeter channel	C144	310.471	1	2	2	2	0.01057	1.457	2.45	0.24
Perimeter channel	C145	223.755	1	2	2	2	0.01484	1.446	2.74	0.22
Perimeter channel	C146	184.49	1	2	2	2	0.01947	1.435	2.56	0.24
Perimeter channel	C147	212.323	1	2	2	2	0.01365	1.78	2.98	0.24
Perimeter channel	C148	149.97	1	2	2	2	0.02916	1.853	3.14	0.24
Perimeter channel	C149	249.051	1	2	2	2	0.01503	1.929	2.71	0.28
Perimeter channel	C150	112.773	1	2	2	2	0.01055	1.953	2.57	0.29
Perimeter channel	C153	106.575	1	2	2	2	0.01822	0.059	0.32	0.09
Perimeter channel	C154	259.811	1	2	2	2	0.00223	0.244	0.77	0.14
Perimeter channel	C155	143.157	1	2	2	2	0.00216	0.239	0.7	0.15
Perimeter channel	C156	203.172	1	2	2	2	0.00115	0.234	0.61	0.17
Perimeter channel	C157	309.35	1	2	2	2	0.00908	1.034	1.8	0.23
Perimeter channel	C158	292.864	1	2	2	2	0.01704	1.893	2.46	0.3
Perimeter channel	C159	273.491	1	2	2	2	0.00797	2.079	2.69	0.3
Perimeter channel	C160	103.615	1	2	2	2	0.02689	2.405	2.77	0.33
Perimeter channel	C161	162.134	1	2	2	2	0.00524	2.402	1.93	0.43
Perimeter channel	C162	79.316	1	2	2	2	0.00189	2.402	2.14	0.4

Channel Description	Channel ID	Length (m)	Depth (m)	Bottom width (m)	Left side slope (1:_)	Right side slope (1:_)	Slope (m/m)	Max. |Flow| (m^3/s)	Max. |Velocity| (m/s)	Max/Full Depth
Perimeter channel	C163	271.101	1	2	2	2	0.01176	2.473	3.05	0.31
Perimeter channel	C164	176.684	1	2	2	2	0.02109	2.498	3.89	0.26
Perimeter channel	C165	119.753	1	2	2	2	0.04628	2.511	4.6	0.22
Bench Channel	C181	89.127	0.8	0.5	9	2	0.00745	0.133	0.47	0.24
Bench Channel	C182	107.36	0.8	0.5	9	2	0.00298	0.106	0.39	0.23
Bench Channel	C183	80.005	0.8	0.5	9	2	0.0092	0.1	0.53	0.19
Bench Channel	C184	64.581	0.8	0.5	9	2	0.00697	0.097	0.5	0.23
Bench Channel	C185	123.864	0.8	0.5	9	2	0.01081	0.161	0.62	0.23
Bench Channel	C186	115.45	0.8	0.5	9	2	0.00377	0.128	0.42	0.24
Bench Channel	C187	124.402	0.8	0.5	9	2	0.00414	0.122	0.42	0.27
Bench Channel	C188	147.395	0.8	0.5	9	2	0.01162	0.305	0.73	0.3
Bench Channel	C189	93.786	0.8	0.5	9	2	0.0046	0.276	0.54	0.33
Bench Channel	C190	140.411	0.8	0.5	9	2	0.00504	0.246	0.55	0.3
Bench Channel	C191	82.903	0.8	0.5	9	2	0.00645	0.228	0.54	0.31
Bench Channel	C192	88.949	0.8	0.5	9	2	0.00605	0.231	0.61	0.3
Bench Channel	C193	153.299	0.8	0.5	9	2	0.00485	0.121	0.46	0.22
Bench Channel	C194	137.784	0.8	0.5	9	2	0.01018	0.104	0.56	0.19
Bench Channel	C195	152.041	0.8	0.5	9	2	0.00376	0.087	0.37	0.21
Bench Channel	C196	74.246	0.8	0.5	9	2	0.00194	0.078	0.26	0.25

Channel Description	Channel ID	Length (m)	Depth (m)	Bottom width (m)	Left side slope (1:_)	Right side slope (1:_)	Slope (m/m)	Max. |Flow| (m^3/s)	Max. |Velocity| (m/s)	Max/Full Depth
Bench Channel	C197	128.771	0.8	0.5	9	2	0.00952	0.615	0.89	0.39
Bench Channel	C198	135.622	0.8	0.5	9	2	0.00752	0.535	0.78	0.39
Bench Channel	C199	138.023	0.8	0.5	9	2	0.00655	0.507	0.72	0.39
Bench Channel	C200	164.35	0.8	0.5	9	2	0.00574	0.486	0.68	0.4
Bench Channel	C201	121.237	0.8	0.5	9	2	0.0066	0.447	0.73	0.36
Bench Channel	C202	123.654	0.8	0.5	9	2	0.01058	0.426	0.82	0.33
Bench Channel	C203	118.711	0.8	0.5	9	2	0.00648	0.539	0.69	0.45
Bench Channel	C204	145.714	0.8	0.5	9	2	0.00361	0.499	0.61	0.43
Bench Channel	C205	121.931	0.8	0.5	9	2	0.00869	0.499	0.8	0.37
Bench Channel	C206	117.518	0.8	0.5	9	2	0.00773	0.495	0.76	0.38
Bench Channel	C207	91.555	0.8	0.5	9	2	0.00493	0.458	0.53	0.48
Bench Channel	C208	103.368	0.8	0.5	9	2	0.00208	0.445	0.57	0.42
Bench Channel	C215	150.212	0.8	0.5	9	2	0.0068	0.576	0.76	0.41
Bench Channel	C216	103.776	0.8	0.5	9	2	0.00618	0.527	0.73	0.4
Bench Channel	C217	123.834	0.8	0.5	9	2	0.00462	0.483	0.65	0.41
Bench Channel	C218	156.725	0.8	0.5	9	2	0.00912	0.471	0.81	0.35
Bench Channel	C219	143.025	0.8	0.5	9	2	0.01196	0.467	1.01	0.34
Bench Channel	C220	93.211	0.8	0.5	9	2	0.00643	0.498	0.65	0.42
Bench Channel	C228	151.89	0.8	0.5	9	2	0.00223	1.272	0.66	0.69

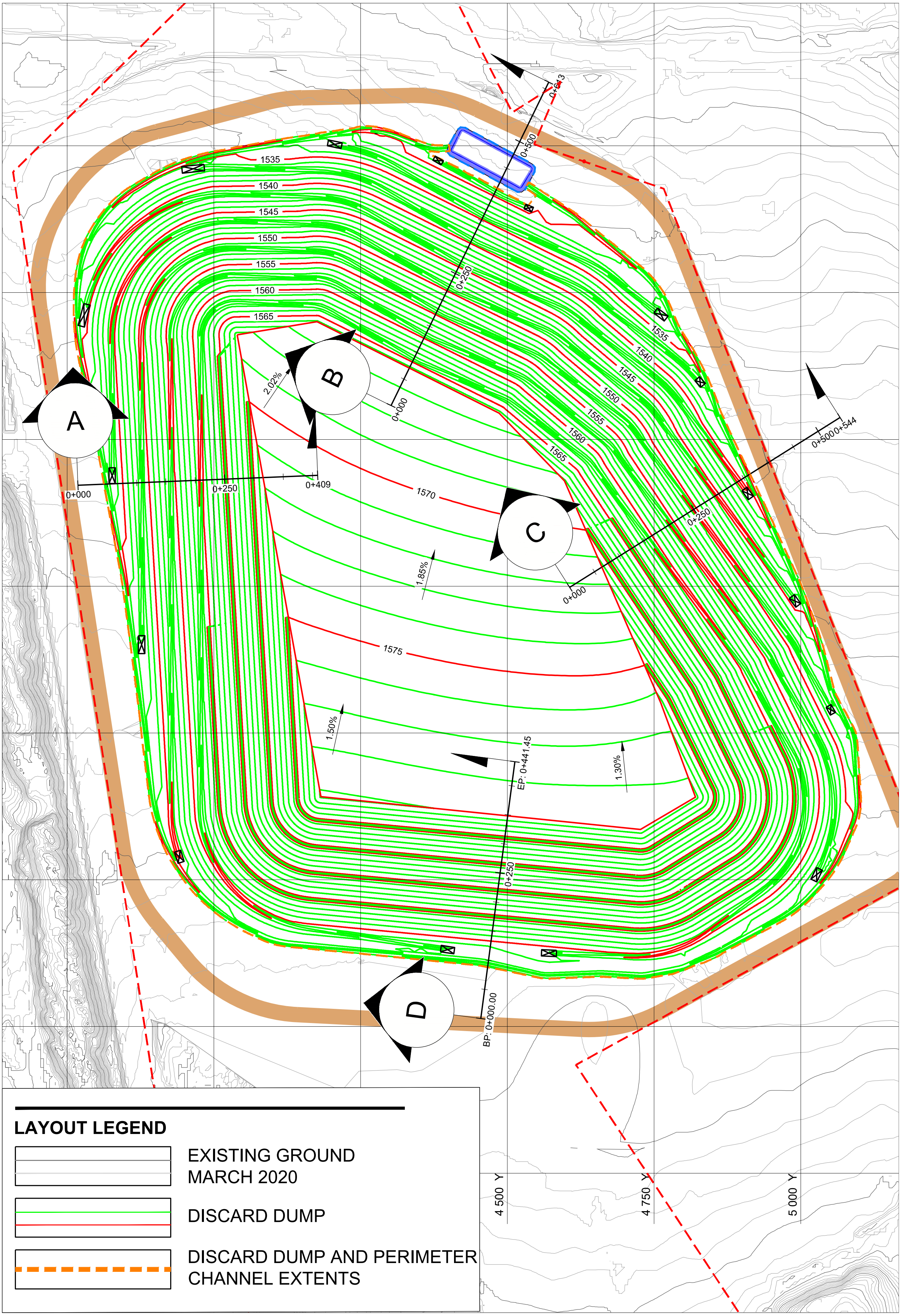
Channel Description	Channel ID	Length (m)	Depth (m)	Bottom width (m)	Left side slope (1:_)	Right side slope (1:_)	Slope (m/m)	Max. |Flow| (m³/s)	Max. |Velocity| (m/s)	Max/Full Depth
Bench Channel	C229	84.904	0.8	0.5	9	2	0.00438	1.226	0.84	0.59
Bench Channel	C230	78.387	0.8	0.5	9	2	0.01045	1.232	1.08	0.52
Bench Channel	C231	97.042	0.8	0.5	9	2	0.01024	1.215	0.78	0.65
Bench Channel	C232	151.121	0.8	0.5	9	2	0.00218	1.179	0.71	0.64
Bench Channel	C233	229.88	0.8	0.5	9	2	0.00941	1.113	0.8	0.6
Bench Channel	C234	194.177	0.8	0.5	9	2	0.00445	1.12	1.4	0.5
Bench Channel	C235	187.803	0.8	0.5	9	2	0.00034	0.334	0.38	0.46
Bench Channel	C236	124.909	0.8	0.5	9	2	0.00689	0.311	0.67	0.31
Bench Channel	C237	168.862	0.8	0.5	9	2	0.01154	0.299	0.77	0.31
Bench Channel	C238	247.041	0.8	0.5	9	2	0.00481	0.295	0.56	0.33
Bench Channel	C239	166.071	0.8	0.5	9	2	0.00633	0.289	0.62	0.31
Bench Channel	C240	232.704	0.8	0.5	9	2	0.0094	0.293	0.74	0.29
Bench Channel	C241	183.788	0.8	0.5	9	2	0.00992	0.244	0.78	0.25
Bench Channel	C242	155.484	0.8	0.5	9	2	0.00527	1.231	0.83	0.62
Bench Channel	C243	149.603	0.8	0.5	9	2	0.00511	1.147	0.87	0.56
Bench Channel	C244	70.868	0.8	0.5	9	2	0.01359	1.124	0.83	0.59
Bench Channel	C245	143.204	0.8	0.5	9	2	0.0033	1.123	0.74	0.6
Bench Channel	C246	121.639	0.8	0.5	9	2	0.00836	1.083	0.83	0.59
Bench Channel	C247	207.841	0.8	0.5	9	2	0.00443	1.103	0.79	0.58

Channel Description	Channel ID	Length (m)	Depth (m)	Bottom width (m)	Left side slope (1:_)	Right side slope (1:_)	Slope (m/m)	Max. |Flow| (m^3/s)	Max. |Velocity| (m/s)	Max/Full Depth
Bench Channel	C248	415.675	0.8	0.5	9	2	0.0083	1.044	0.97	0.5
Bench Channel	C249	93.55	0.8	0.5	9	2	0.01189	0.993	1.53	0.38
Bench Channel	C250	196.638	0.8	0.5	9	2	0.00375	0.186	0.47	0.28
Bench Channel	C251	116.93	0.8	0.5	9	2	0.00942	0.167	0.63	0.22
Bench Channel	C252	152.661	0.8	0.5	9	2	0.00845	0.154	0.55	0.24
Bench Channel	C253	252.836	0.8	0.5	9	2	0.00371	0.128	0.42	0.24
Bench Channel	C254	148.82	0.8	0.5	9	2	0.0053	0.121	0.46	0.23
Bench Channel	C255	191.085	0.8	0.5	9	2	0.00629	0.115	0.49	0.21
Bench Channel	C256	137.913	0.8	0.5	9	2	0.01054	0.11	0.48	0.22
Bench Channel	C257	265.684	0.8	0.5	9	2	0.00433	0.104	0.42	0.21
Bench Channel	C258	174.19	0.8	0.5	9	2	0.01731	0.098	1.12	0.11
Bench Channel	C259	147.243	0.8	0.5	9	2	0.00791	0.429	0.74	0.36
Bench Channel	C260	136.614	0.8	0.5	9	2	0.00344	0.347	0.5	0.4
Bench Channel	C261	59.094	0.8	0.5	9	2	0.00288	0.321	0.56	0.35
Bench Channel	C262	104.151	0.8	0.5	9	2	0.01219	0.314	0.72	0.32
Bench Channel	C263	304.022	0.8	0.5	9	2	0.00519	0.287	0.58	0.32
Bench Channel	C264	211.551	0.8	0.5	9	2	0.00762	0.267	0.66	0.29
Bench Channel	C265	297.402	0.8	0.5	9	2	0.00652	0.237	0.45	0.35
Bench Channel	C266	141.435	0.8	0.5	9	2	0.00125	0.195	0.38	0.33

Channel Description	Channel ID	Length (m)	Depth (m)	Bottom width (m)	Left side slope (1:_)	Right side slope (1:_)	Slope (m/m)	Max. |Flow| (m^3/s)	Max. |Velocity| (m/s)	Max/Full Depth
Bench Channel	C267	135.915	0.8	0.5	9	2	0.01088	0.197	0.69	0.23
Bench Channel	C268	255.806	0.8	0.5	9	2	0.01468	0.192	0.88	0.2
Bench Channel	C269	154.87	0.8	0.5	9	2	0.00364	0.061	0.36	0.18
Bench Channel	C270	158.773	0.8	0.5	9	2	0.00441	0.106	0.42	0.25

APPENDIX D

Zibulo Stability Analysis Section Locations



1535
1540
1545
1550
1555
1560
1565
1570
1575
A
B
C
D
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0+250
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0+500
0+613
0+544
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BP: 0+000.00
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1.85%
1.50%
1.30%
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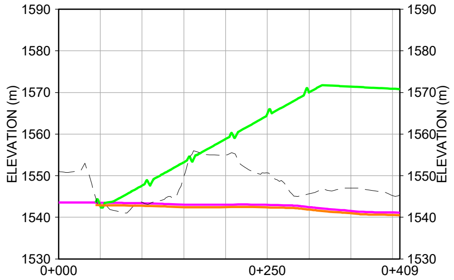
5 000 Y
LAYOUT LEGEND
EXISTING GROUND MARCH 2020
DISCARD DUMP
DISCARD DUMP AND PERIMETER CHANNEL EXTENTS



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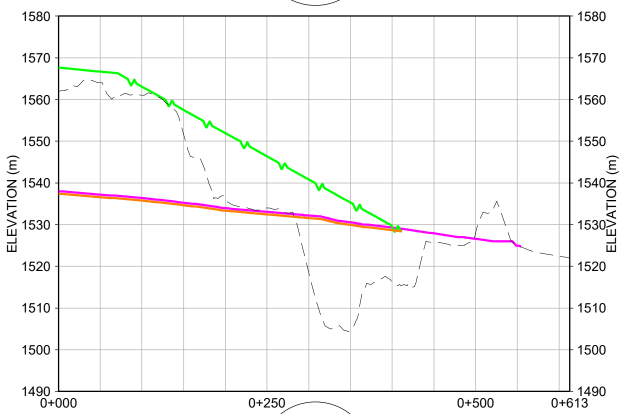

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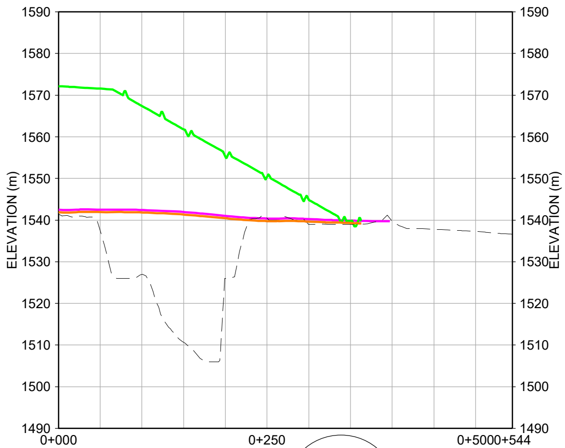

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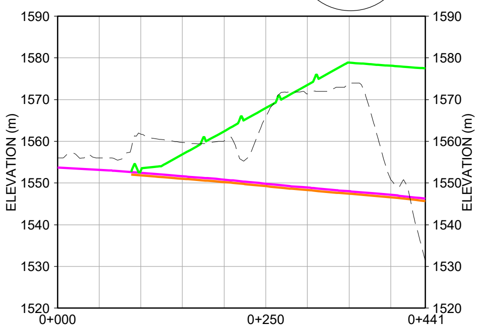

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VERT. SCALE 1: 5
D

SECTION LEGEND

- EXISTING GROUND MARCH 2020
- DISCARD DUMP
- RECEIVED LANDFORM
- 600mm TOPSOIL STRIPPING OFF RECEIVED LANDFORM
- LANDFORM CORRECTION

APPENDIX E

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REPORT

Anglo American

Technical Design Report for the Zibulo Colliery Discard Facility

Submitted to:

Anglo American Coal

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TABLES

FIGURES

APPENDICES

Abbreviation	Description
µm	Micrometre
AAIC	Anglo American Inyosi Coal
AEP	Annual Exceedance Probability
cm/s	Centimetre Per Second
DHSWS	Department of Human Settlement, Water and Sanitation
EIA	Environmental Impact Assessment
EMPr	Environmental Management Programme Report
FoS	Factor of Safety
GPS	Global Positioning System
Ha	Hectares
IWWMP	Integrated Water and Waste Management Plan
kN/m	Kilonewton per Meter
kPa	Kilo Pascal
LoM	Life of Mine
LS	Linear Shrinkage
LL	Liquid Limit
Mamsl	Metres Above Mean Sea Level
m^3/day	Cubic Metres Per Day
ML	Megalitre
Mm^3	Cubic Metre
m/year	Metres Per Year
Mt	Million Tons
NEMWA	National Environmental Management Waste Act
NP	Nominal Pressure Class (Piping)
NWA	National Water Act
PCD	Pollution Control Dam
PCSWMM	PC Storm Water Management Model
PE	Polyethylene
PI	Plasticity Index
PSD	Particle Size Distribution
RWD	Return Water Dam
SANS	South African National Standards
SWMP	Stormwater Management Plan
TLB	Tractor Loader Backhoe
t/m^3	Tons Per Cubic Metre
UCS	Unconfined compressive strength
USCS	Unified Soil Classification System
WULA	Waste Usage Licence Application
WUL	Water Use Licence

1.0 INTRODUCTION

Golder Associates Africa Pty (Ltd) (Golder) has been appointed by Anglo American Inyosi Coal (AAIC) to design an alternative discard facility at Zibulo Colliery with preference to the use of an existing Anglo-American property (including the open cast facility). The existing facility is currently in operation and will soon reach full capacity. The mine approached Golder to complete an option analysis and technical design of the discard facility. The discard facility has been designed to accommodate 26 Mm^3 (36.7 million tonnes) of discard material.

2.0 BACKGROUND

2.1 Project evolution

The mine produces an annual eight million run of mine (ROM) tonnes of export thermal coal, with seven million tonnes per annum coming from its underground sections south-east of the town and the remaining one million tonnes from its opencast pit immediately north-west of the town. Underground operations incorporate bord and pillar through continuous mining methods while the contractor-run open pit, utilises a small dragline and truck and shovel methods.

Coal from the underground operation is transported to the Phola Coal Processing Plant via a 16 km overland conveyor. The plant is a 50:50 joint venture between Anglo American (Anglo) and South32. The coarse and fine discard produced by Phola is currently disposed of in a surface discard facility on South32, Klipspruit. The facility is reaching capacity (110 ha) and by 2021 an alternative discard facility may be required by Anglo.

2.2 Site location

AAIC's Zibulo Colliery is located adjacent to Ogies in the Mpumalanga Province. It is due east of the Klipspruit Colliery and south of Phola. The locality map of the mine is shown in Figure 1 and in Appendix A (refer to Drawing No. 01). The existing open cast facility is located adjacent to the N12 highway and Klipspruit discard facility.

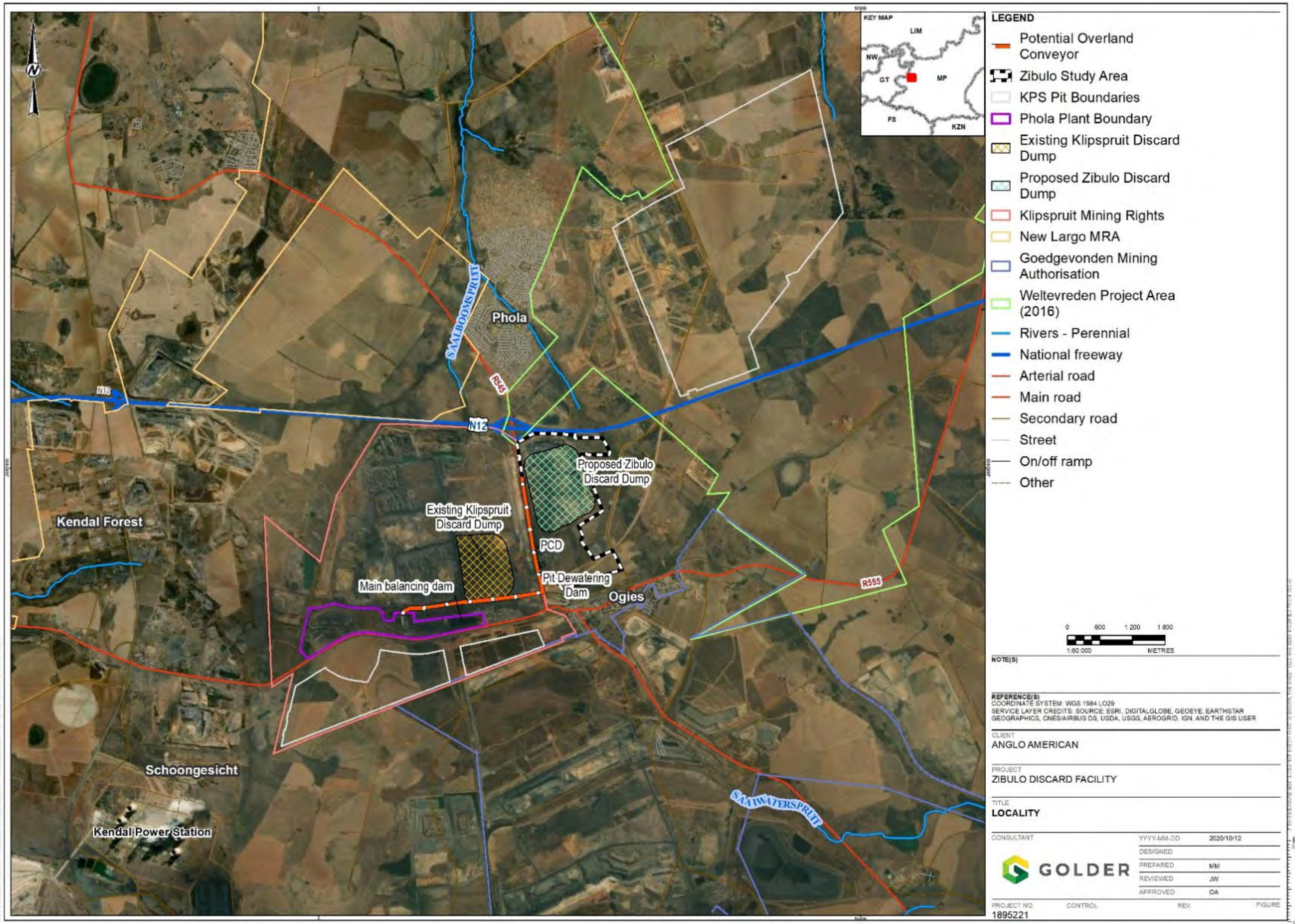

Figure 1: Zibulo discard facility locality map.

3.0 DESIGN CRITERIA

The design criteria for the discard dump were generated taking the project site and material-specific characteristics into account. The design of the facility and associated infrastructure was completed in compliance with the following:

- Applicable regulatory regulations and technical guidelines;
- Industry practice, technical standards, and guidelines;
- Project information provided by AAIC; and
- Anglo American Corporate Standards:
  - Anglo American Technical Standard for Mineral Residue Facilities and Water Management Structures Standard (AA TS 602 001); and
  - Anglo American Technical Standard for Classification, Design Criteria, and Surveillance Requirements for Mineral Residue Facilities and Water Management Structures Specification (AA TS 602 102).

The latest design criteria used in the design of the facility is summarized in Section 3.1 and 3.2.

3.1 General site

The general site design criteria include information that is specific to the Zibulo site and is informed by climate data, expected seismic activity and natural geotechnical conditions as summarised in Table 1. This design criteria are based on the preferred Option 2a as indicated by the Options Analysis Report (Golder, 2021a).

Option 2a is the placement of discard above the backfilled Zibulo pit only (i.e., no placement of discard into the void).

Table 1: General site design criteria

Description	Criterion	Rev	Latest source of Information	Notes
Site climatic data				
Mean annual precipitation (MAP)	719.8 mm	Rev 0	Golder	
Mean annual evaporation (MAE)	1 729 mm	Rev 0	Golder	
1 in 100 AEP, 24-hour rainfall depth	144.6 mm	Rev 0	Golder	
1 in 200 AEP, 24-hour rainfall depth	161.8 mm	Rev 0	Golder	
Flood line data	Flood line data based on EIA 2009	Rev 0	Golder	
Dominant wind direction	Easterly winds	Rev 0	Golder	
Average wind speed	0.7 – 2.0 m/s	Rev 0	Golder	
Site seismic data				

Description	Criterion	Rev	Latest source of Information	Notes
Peak ground acceleration (PGA)	No information available			Requirement as per MR2 (Clause 6.3.2)
Geotechnical investigation and material parameters				
Subgrade material on which the facility will be constructed	Brownfields site on top of mined out spoils (Option 2a)		Golder	Confirmed as detailed in the Options Analysis Report
Permeability of natural materials	2.55×10^{-7} cm/s – 2.64×10^{-6} cm/s		Golder	Confirmed in outcome of the geotechnical study work and is provided in Table 2

3.2 Discard facility

The geotechnical characteristics of the discard material have been based on the Geotechnical Investigation for Zibulo Discard Facility (Golder, 2021b) in addition to the Geotechnical Investigation for Klipspruit Colliery Discard Dump Expansion (Golder, 2020a). The reports indicate that samples from the topsoil, dump rock spoils, soft spoils and coal discard were tested to determine the geotechnical properties of the material. It was assumed that that the properties of the material tested in 2020 will remain similar to that of the discard material to be deposited of at the coal discard facility. The Table 2 summarises the geotechnical characteristics of the discard material and the dragline spoils. Figure 2 and Figure 3 illustrates the particle size distribution for the aforementioned materials, respectively.

Table 2: Discard facility design criteria

Description	Value	Rev	Latest source of Information	Notes
Production criteria				
Life of facility (Remaining)	15 years	Rev 1	AAIC	Based on production schedule received
Facility start date	Q1 2022	Rev 1	AAIC	Based on BOD comments received
Contingency based on average discard production	400,000 m^3	Rev 1	AAIC	Confirmed via email from Ms L Mazibuko on 30 October 2020
Average coal discard production	1.73 Mm^3/year (2.48 Mt/year)	Rev 2	AAIC	Based on production schedule received
Total discard capacity requirement	26 Mm^3	Rev 1	AAIC	Based on production schedule received on 23 March 2020 from Ms Hallquist-Waites
Discard material properties				
NEMWA R635 waste type	Type 3	Rev 0	Golder	Golder (2021c) Risk Assessment Report No. 19117180-334408-2 Draft

Description	Value	Rev	Latest source of Information	Notes
Required barrier class	Class C liner required; however, it has been motivated that no liner will be constructed due to the plan to manage the excess pit water. Refer to Section 5.2.	Rev 0	Golder	Water treatment discussed in Golder (2021d) Hydrology/ Hydrogeology Report No 19117180-337629-10
Percent passing 37.5 mm	82.3%	Rev 0	Based on the Specialised Testing Laboratory gradings results	Average PSD results from 4 coal discard samples. Additional geotechnical work was also carried out.
Percent passing 10.0 mm	34.5%	Rev 0		
Percent passing 5.0 mm	18.3%	Rev 0		
Percent passing 2.0 mm	6.8%	Rev 0		
Percent passing 0.075 mm	2.2%	Rev 0		
Percent passing 37.5 mm	98.7%	Rev 1	Based on additional laboratory testing for neighbouring Klipspruit coal discard samples	Average PSD results from 3 coal discard samples. Refer to Golder Report No. 19131502-335398-1.
Percent passing 9.5 mm	79.3%	Rev 1		
Percent passing 4.75 mm	66.0%	Rev 1		
Percent passing 2.0 mm	51.3%	Rev 1		
Percent passing 0.075 mm	15.0%	Rev 1		
Discard material dry density	1 432kg/m^3	Rev 0	Golder assumed.	Analogous discard material from Klipspruit. Assumed an achievable density of 85% for fresh, loose, and uncompacted end-tipped material. More geotechnical work may be required.
Bulk sample of discard material compacted dry density	1 526 – 1 696 kg/m^3	Rev 0	Golder	
In-situ discard material compacted dry density	1755 kg/m^3	Rev 0	Golder	Analogous discard material from Klipspruit.
Infiltration rate of bulk sample	3.7 m/day	Rev 0	Golder	Analogous discard material from Klipspruit. FoS to be applied to value since only one double ring infiltrometer was conducted.

Description	Value	Rev	Latest source of Information	Notes
Permeability of the coal discard material	9.0 x 10^{-7} cm/s	Rev 0	Golder	The samples were recompacted to 93% of MDD using standard Proctor density at OMC. Refer to Golder Report No. 19131502-335398-1.
Coefficient of consolidation	No test work			Required for settlement modelling. Additional geotechnical test work may be required, pending DWS review comments.
Shear strength parameters	Φ = 39.2° c' = 0 kPa	Rev 0	Golder	MR2 8.3.3 requirement for slope stability modelling. Values were obtained from the Geotech report of the neighbouring Klipspruit discard facility (Golder, 2020a) with similar discard material properties. Shear box test work completed. Refer to Golder Report No. 19131502-335398-1.
Dragline dump rock spoils material properties				
Dragline spoil characteristics	Clayey gravel with plastic fines and occasional poorly graded gravels and gravel sands mixture	Rev 0	Golder	Report No. 19117180-333746-1
Percent passing 37.5 mm	69.8%	Rev 0	Golder	Report No. 19117180-333746-1
Percent passing 9.5 mm	44.4%	Rev 0		
Percent passing 4.75 mm	39.0%	Rev 0		
Percent passing 2.0 mm	35.0%	Rev 0		
Percent passing 0.075 mm	18.8%	Rev 0		
Compacted dry density	1 935 – 2 023 kg/m^3	Rev 0	Golder	Report No. 19117180-333746-1
Permeability	2.55 x 10^{-7} cm/s	Rev 0	Golder	The samples were recompacted to 93% of MDD using standard Proctor effort at OMC. Refer to Golder Report No. 19117180-333746-1.

Description	Value	Rev	Latest source of Information	Notes
Coefficient of consolidation	Average c_v value of 44.63 m^2/yr (also see section 4.8.2)	Rev 0		Required for settlement modelling; Refer to Report No. 19117180-333746-1; Additional test work may be required.
Shear strength parameters	Φ = 35° c' = 0 kPa	Rev 0	Golder	Consolidated undrained triaxial test work completed; Refer to Report No. 19117180-333746-1.
Dragline soft spoils material properties				
Dragline spoil characteristics	Clayey sand with occasional silty clay	Rev 0	Golder	Report No. 19117180-333746-1
Percent passing 37.5 mm	96.8%	Rev 0	Golder	Report No. 19117180-333746-1
Percent passing 9.5 mm	85.6%	Rev 0		
Percent passing 4.75 mm	82.4%	Rev 0		
Percent passing 2.0 mm	79.2%	Rev 0		
Percent passing 0.075 mm	48.0%	Rev 0		
Compacted dry density	1 877 – 1 910 kg/m^3	Rev 0	Golder	Report No. 19117180-333746-1
Permeability	3.04×10^{-7} cm/s	Rev 0		The samples were recompacted to 93% of MDD using standard Proctor effort at OMC. Refer to Golder Report No. 19117180-333746-1.
Coefficient of consolidation	Average c_v value of 11.15 m^2/yr (also see section 4.8.2)	Rev 0		Required for settlement modelling; Refer to Report No. 19117180-333746-1; Additional test work may be required.
Shear strength parameters	Φ = 33.5° c' = 0 kPa	Rev 0	Golder	Consolidated undrained triaxial test work completed; Refer to Report No. 19117180-333746-1.
Discard geometric criteria				
Number of phases in which the discard dump will be constructed	1	Rev 1	Deposition profile	AAIC has confirmed that the dump will be constructed in a single stage.

Description	Value	Rev	Latest source of Information	Notes
Raising scheme.	Construction of 5 m lifts (Refer to Drawing No. 09 in Appendix A).	Rev 0	AAIC review comments on BOD Rev0	Confirmed by AAIC
Deposition method.	Trucking, dozing and compaction.	Rev 0	AAIC review comments on BOD Rev0	Confirmed by AAIC
Maximum height, approximately 30m	The maximum height was based on the stability of the facility as per Anglo Standards, as well as the capacity requirements as per the 3D model.	Rev 1		Confirmed via final 3D capacity design model requirements and stability analysis.
Allowable yearly lift height.	5 m	Rev 1		Confirmed through the 3D model results.
Discard material placement.	In-situ density should not exceed 15% voids: 300mm lifts compacted to a specified number of passes with a vibratory roller. Specification to be included into OPS Manual.	Rev 0		A compaction specification of 93% Standard Proctor is recommended, which also adheres to the DWAF (2005) requirements.
Discard facility top area slope.	Between 1V:50H to 1V:77H	Rev 1	Golder	Based on final 3D capacity design model.
Downstream embankment slope.	1V: 9H	Rev 0	Golder	Based on previous experience and confirmed during modelling.

The particle size distribution of the discard material is presented in Figure 2. Four bulk samples were tested in addition to three samples from the Klipspruit facility. A particle size distribution was also completed for the dragline spoils as shown in Figure 3.

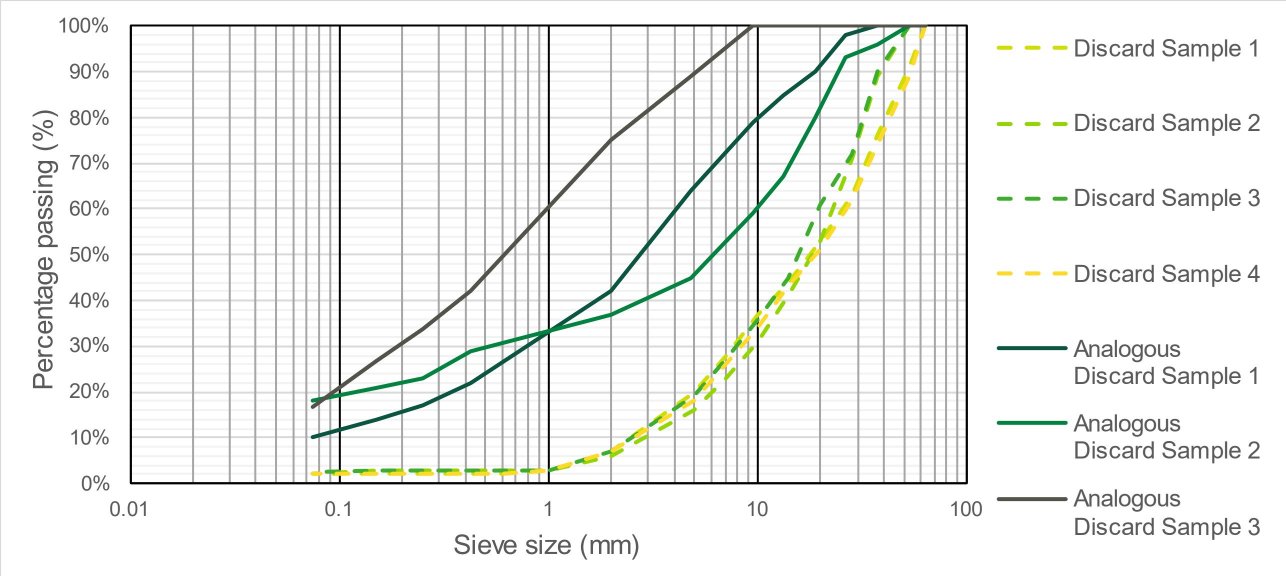

Figure 2: PSD of discard material

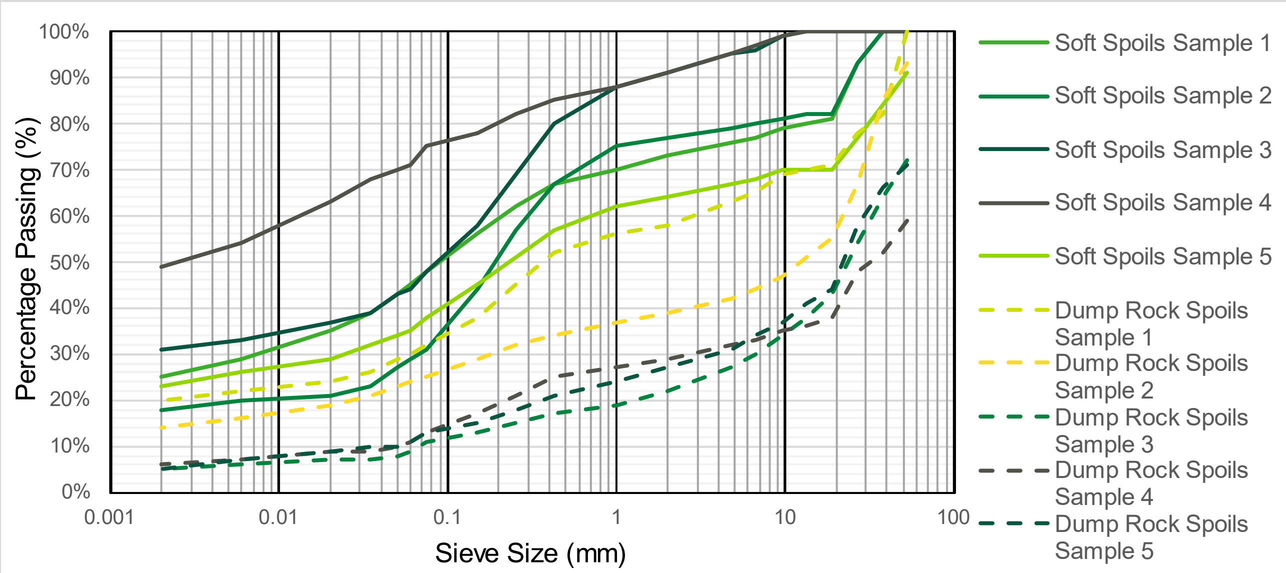

Figure 3: PSD of dragline spoils

The design's geotechnical characteristics of waste facilities are described by the Minimum Requirements for Waste Disposal by Landfill (Department of Water Affairs and Forestry, 2005). Furthermore, the National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008) also recommends the characterisation of residue stockpiles and deposits, as well as the necessary geotechnical investigations.

Apart from the regulatory requirements, Golder utilised the information generated from the geotechnical investigative work to conduct the stability analysis and to complete the design of the facility (e.g., founding conditions for structures, embankment construction, etc.).

4.0 DISCARD DUMP DESIGN

4.1 Site description

The mine currently has an approved area for placement of discard which is known as the existing Zibulo pit facility. This facility has the required storage volume for placement of discard up to Year 2036. The general layout of the proposed discard facility footprint (refer to purple highlighted area) is illustrated in Figure 4 (refer to Drawing No. 02 in Appendix A) Refer to Drawing No. 03 for the layout plan and sections of the facility. Additional cross-sections of the facility are also provided in Appendix A (refer to Drawing No. 07).

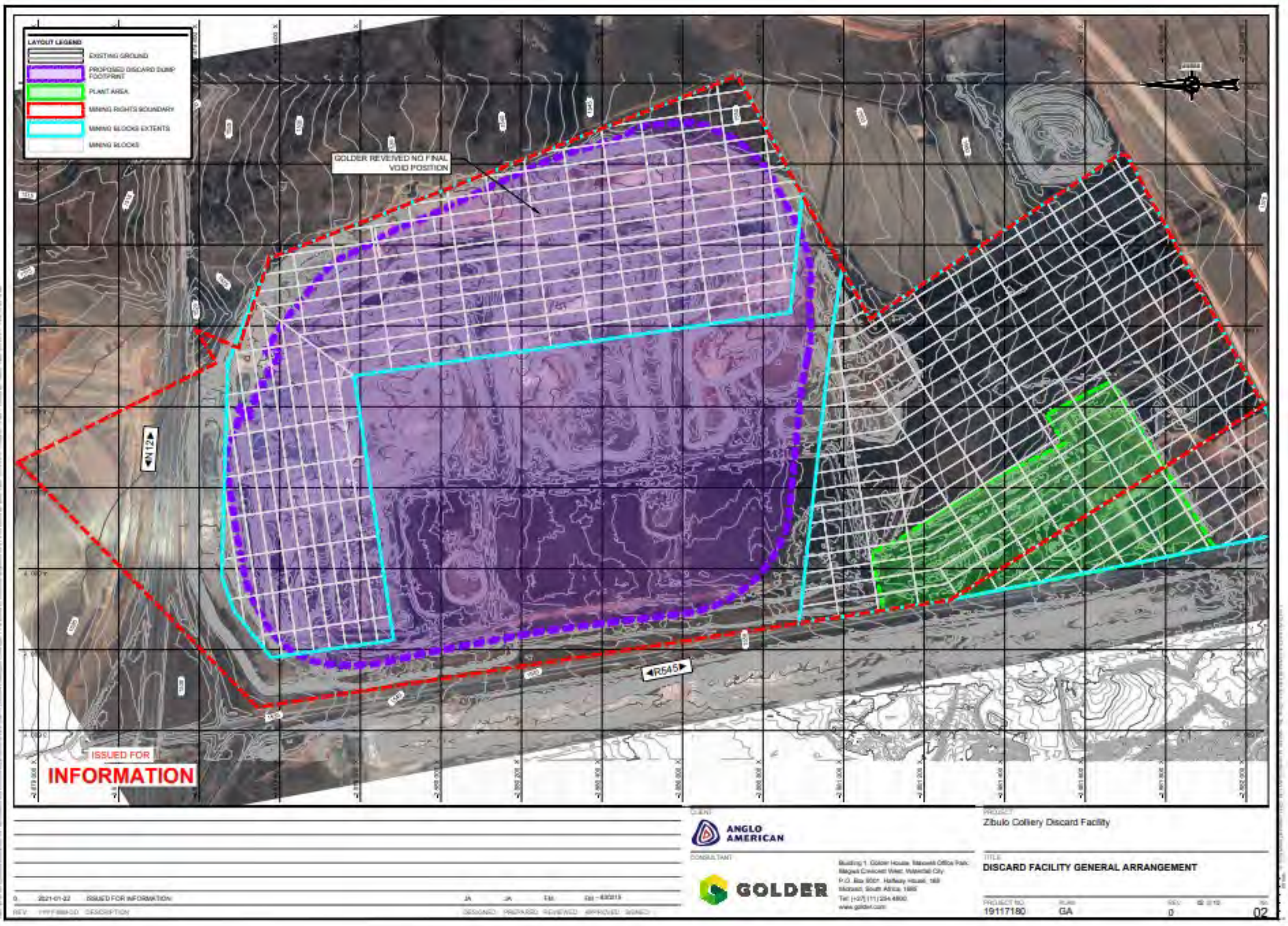

Figure 4: General layout of discard facility

The proposed discard facility will be backfilled over the shaped and rehabilitated dragline spoil. The proposed landform preparation of the facility prior to the development of the discard dump is presented in Appendix A (refer to Drawing No. 04). The design of the proposed discard facility is described in subsequent sections of this report.

4.2 Discard production

The coal discards that are to be placed in the proposed discard facility will be generated from the underground Zibulo mining operations at the open cast operations. Figure 5 shows the expected discard material production volumes over 15 years. The total estimated discard volume that will be produced is 26 Mm^3. This volume will be produced at an average rate of 1.73 Mm^3/year (2.48 Mt/year) over the life of the facility which will reach full capacity in 2036.

A contingency allowance of ~400,000m^3 was made to allow for some additional storage capacity.

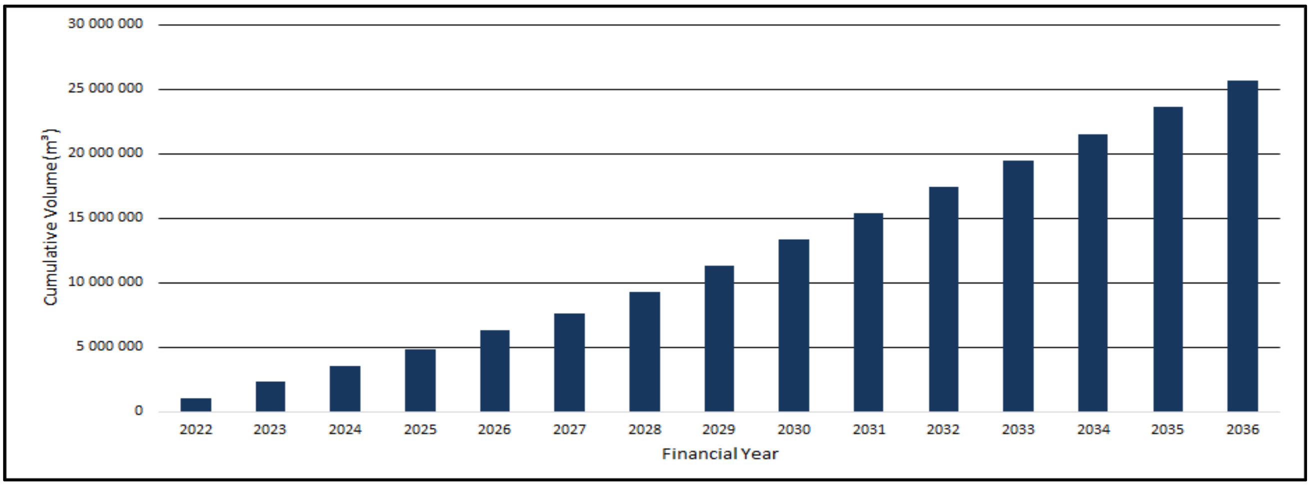

Figure 5 Predicted Zibulo production schedule over the LoM

4.3 Stage development

The discard dump will be developed in 5 meter operational lifts (as indicated in Table 2 and Figure 6 (Drawing No. 09 in Appendix A) presenting the discard facility staged approach). A total number of six lifts will be constructed. The top area of each operational lift will be operated in the form of a "saucer". Operational sumps will be implemented at the lowest points from where excess water will be pumped to the collection sump at the toe of the dump. The final stage will be shaped in the form of a dome shape.

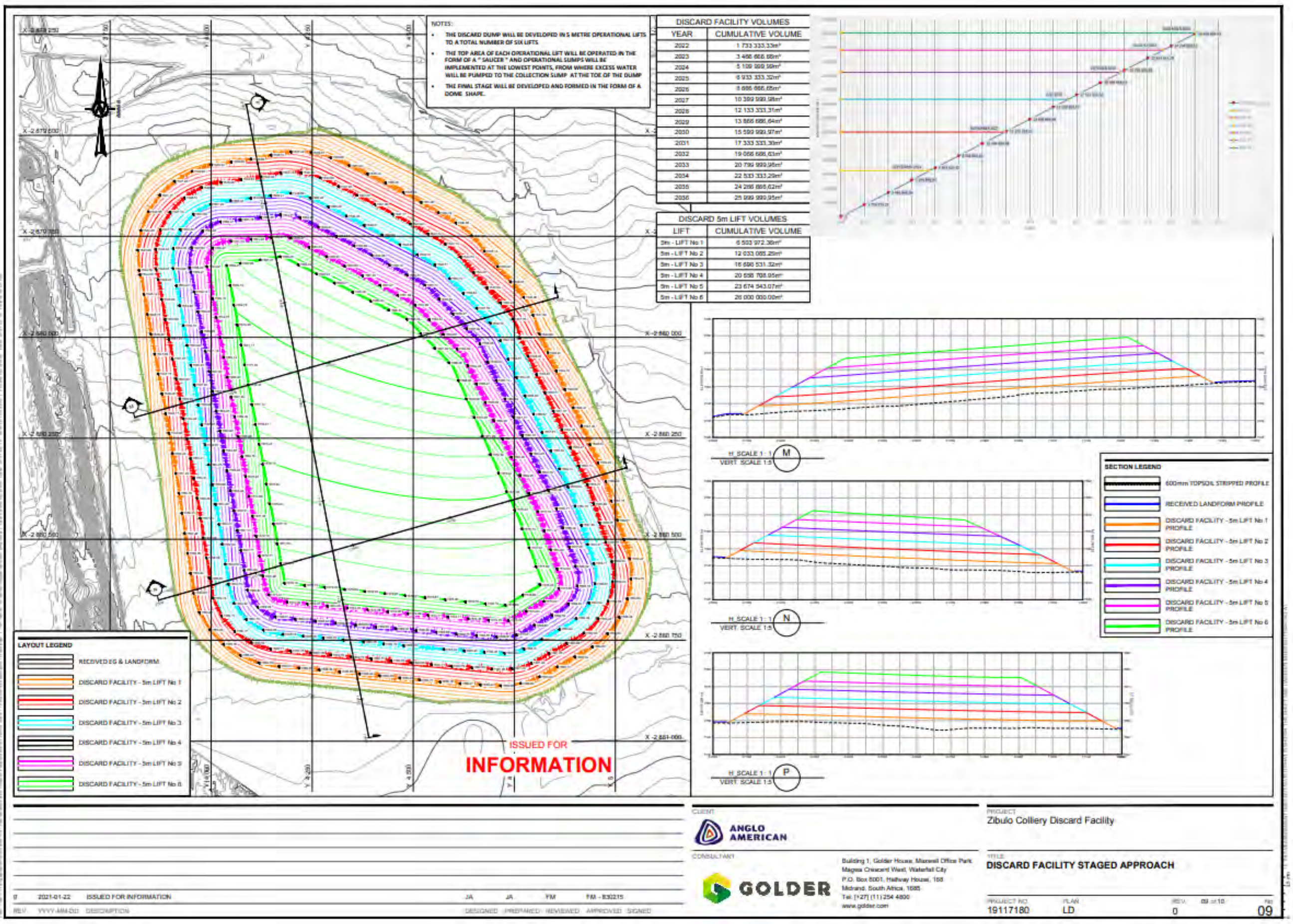

Figure 6: General layout of discard facility with staged approach

4.4 Progressive facility development

Previous experience in the design of similar facilities has proven that certain complexities are to be overcome during the design process, when a multiple number of extensions are required to a facility over the entire LOM. This is mainly due to the change in the planned deposition rate that may, at times, be higher or lower than anticipated. In other instances, there may be a change in available technology to place discard material on the facility more economically and the geometry of the lifts may need to be altered in order to accommodate the restrictions of conveyance and disposal equipment (e.g., conveyor systems).

The proposed discard facility was designed and to be implemented through the initial construction within one phase, with the planned commencement in 2022. The design drawings for the discard facility are presented in Appendix A. Models of the discard facility were based on survey information received from AAIC.

The mine will place spoil material in the final voids of the existing pit once open pit operations have ceased. According to AAIC (e-mail from Mr Nxele on 9 July 2020) the discard will be deposited as a single stream consisting of coarse discards and filtered fines. The filter cake is dewatered but is not dry, with an expected moisture content of 20 – 23%. It is therefore our understanding that this is a dry placed discard waste facility and not a hydraulically placed tailings storage facility. The discard dump will be placed in 5 m lifts on the footprint. The available volume within the final void was assumed to be zero based on the survey provided by the mine. The volume was modelled using AutoCAD Civil 3D and the results were presented in Appendix A.

During the one phase, discard material will also be deposited above the backfilled pit. The discard dump has the following attributes:

- Covers an area of ~ 140 ha;
- Available airspace volume of 26 Mm^3;
- Planned commencement is 2022;
- Life of phase is approximately 15 years; and
- Completion date of phase should be 2036 based on the planned deposition rate.

Placement of discard material will primarily be on the backfilled soft and dump rock spoils (after being levelled), which will extend to cover the entire proposed footprint of the facility.

Once the discard facility has been completed and shaped to form the 1V:9H outside slope, the facility will have reached final capacity and will, as a result, be closed off to further placement of discard materials. The final layout of the facility is presented in Figure 7 (refer to Drawing No. 05 in Appendix A). A typical section of the rehabilitated side slope of the discard facility is also presented in Appendix A (refer to Drawing No. 10).

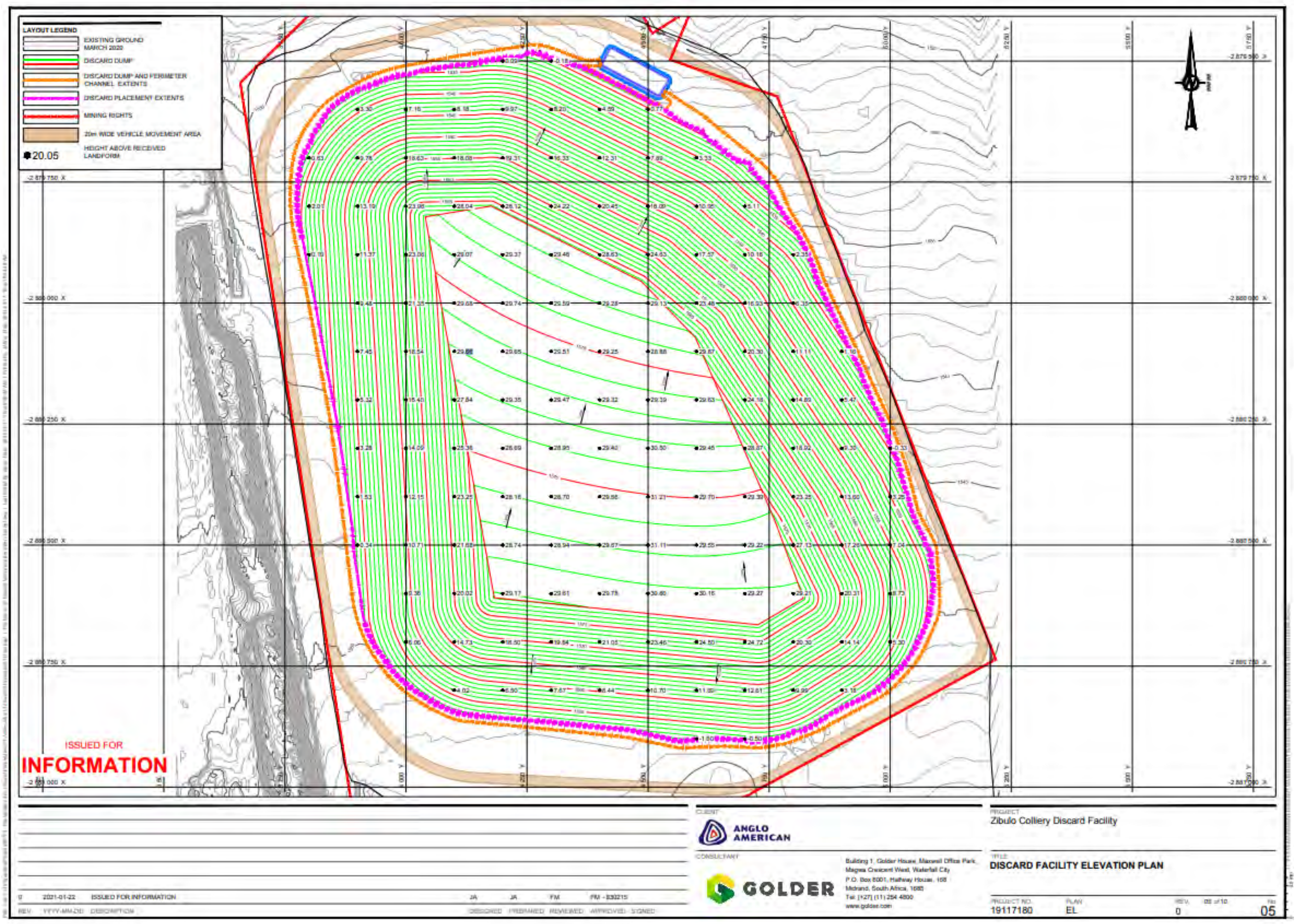

Figure 7: Final rehabilitated discard facility

Table 3 summarises the proposed discard dump characteristics.

Table 3: Discard dump characteristics

Description	Units	Value/Description
Final Height	m	~30 m (1567 to 1579 mamsl)
Total Volume	Mm³	26
Life of Facility	Years	15

4.5 Cover design

Typically, a cover thickness of approximately 600mm, as referenced in the Klipspruit report (Golder, 2019c), is used to cover discard dump facilities. The available cover thickness of Zibulo was based on the stockpiled material on site. According to the dump geometry (i.e., top surface and side slopes), the available soil cover equates to 519 mm on average. It is believed that this will be adequate if properly placed, vegetated and maintained.

4.6 Storm water management

The operational and post-closure storm water management plans (Golder, 2021d) were developed to fulfil the requirements of the National Water Act, 1998 (Act 36 of 1998) (NWA) and particularly, Government Notice 704 contained in Government Gazette 20118 of June 1999 (hereafter referred to as GN 704), which deals with the separation of clean and dirty water. The NWA published by the Department of Human Settlement, Water and Sanitation (DHSWS) requires adequate separation of clean and contaminated storm water and the protection of the water resources from contaminated water sources (Department of Water Affairs and Forestry, 4 June 1999). These regulations were used to guide the design of the storm water drainage plan and the applicable recurrence interval for the design (the post closure channels were sized for the 1:50-year 24-hour storm event).

4.6.1 Proposed storm water management plan for the discard facility

The water management plan consists of clean water and dirty water channels to manage clean and dirty runoff from the corresponding sub-catchments separately. The channels were sized for the 1:50-year 24-hour storm event, in accordance with the GN-704 regulation.

The design provides for storm water to be free draining from the discard facility. It is proposed that the contaminated runoff from the discard facility is collected in an unlined, engineered, trapezoidal perimeter channel around the boundary of the facility and drained in the direction of the discard facility’s surface topography, which is currently in the northern direction, towards a void in the pit. An estimated 90% of the length of the perimeter channel will be constructed over the void footprint, with the remainder constructed over unmined ground but near the pit boundary. Contaminated conveyances are required to be watertight. However, seepage from the perimeter channel will report to the pit and will be managed with pit water.

It is essential to note that the in-pit spoils are susceptible to differential settlement over time by means of a variety of mechanisms. Moreover, the spoils do not stand up to erosive forces imposed by flowing water. It will therefore be necessary to prepare a well-engineered pioneering layer to construct the channel on. This will consist of excavating the spoils from the pit edge inwards for a distance of at least 5 m beyond the furthest edge of the channel alignment. The depth of excavation will be determined by the geotechnical engineer. The excavated void will be levelled and compacted, following which the spoils will be constructed back into the excavation in well compacted layers. At least one layer of geogrid reinforcement will be included in the compacted spoils raft. The objective of the design will be to create a longitudinally stable profile and to ensure that there are no major threats to the stability of the discard facility. A layer of dump rock will be constructed over the compacted spoils and this layer will also be stabilised and strengthened by at least a single layer of geogrid reinforcement. The channel will then be constructed of imported soil compacted in layers, followed by topsoiling and seeding to ensure that a stable root matrix is established as soon as possible and will be sustainable. Riprap will need to be provided to protect the channel where shear forces exceed the vegetations’ stabilising effect. Refer to the engineering drawings for typical details of the above design.

It must be noted that the above design will need to be monitored carefully and routinely during operation of the discard facility and that it is inevitable that settlements and erosion will still occur, therefore maintenance will be ongoing. The channel must also be operated proactively and is not a passive part of the infrastructure. Blockage and damage of the channel can lead to environmental incidents as well as localised failure of the placed discard, which will in turn lead to break out of the slope contour channels.

At capping and closure of the discard facility, the topsoil can be stripped from the channel, the channel can be backfilled using the material from the perimeter berm in compacted layers, and the cover material continued over the channel to ensure free drainage of clean runoff to the natural receiving catchment.

The perimeter channel would have two legs extending around the discard facility and would meet at the void, which is located north of the facility. Thus, all the contaminated runoff reports to the void, however, the void was not sized for the storm water assessment. This will be done once the detailed mine plan is available. A berm must be constructed on the outer end of the perimeter channel to prevent clean water from entering the channel from the clean catchment and to serve as an additional backstop to splashing spillage from the contaminated runoff channel.

A series of trapezoidal bench channels constructed with discard material on the side slopes of the discard dump are also recommended to be implemented at 45 m horizontal intervals (5 m vertical) along the side slopes of the facility with a berm on the outer side to avoid water spilling into the downslope strip. The bench channels would aid in a reduction of the catchment sizes, resulting in less runoff to the respective channels and fragmentation of energy and shear forces accumulating along the slopes that causes erosion. These channels slope in the southern direction and would join the perimeter channel. The channels will need to be monitored routinely as some erosion of the slope catchments can be expected, which will carry discard into the channels and reduce their capacity. Overtopping due to reduced capacity could have a detrimental knock-on / domino effect on successive contour berms.

Energy dissipation structures should be installed at the junction of the bench channels and perimeter channels, in addition to the discharge points leading to the voids, to lower the high incoming flow velocities and allow for change in flow direction. Sedimentation can be expected where the contour channels discharge runoff into the perimeter channel, and this will require regular maintenance to keep the system functional. Drop chutes and stilling basins are both recommended to lower the energy and flow velocities. Erosion protection, such as riprap, is required for the contour channels.

Rockfill berms are proposed for the facility’s side slopes on the southern end for the runoff to attenuate resulting in lower flow velocities reporting into the perimeter channel. A cascading water filtering system is recommended through the berm’s rockfill voids to increase the flow lag and flow length resulting in less energy from runoff at the southern end.

Currently, a diversion channel directs clean water away from the discard facility in the western direction. A berm is also proposed for the southwestern side of the facility to direct clean runoff from the clean sub-catchment away from the dirty water channels and collect in the existing clean diversion channel. The diversion channel should be re-routed and re-sized for planned mining southward of the discard facility, which is not within the scope of this project.

The general layout of the storm water management plan is presented in Figure 8 (refer to Drawing No. 06 in Appendix A). Typical drainage cross-sections are also provided in Appendix A (refer to Drawing No. 08). The detailed storm water management plan is described in the in the storm water management memorandum presented in Appendix C.

Groundwater that is abstracted should be treated, re-used, or discharged into the environment. Clean runoff conveyed in channels should be monitored for quality before discharge to the environment.

A topographic survey received from AAIC was used to prepare a model to determine cross-sections and vertical profiles of the storm water channels and for the sub-catchment delineation around the discard facility. The final discard facility design (before rehabilitation) was used for the model.

4.6.2 Maintenance

Frequent maintenance of the diversion channels is essential. Maintenance will include excavation of sediments, reinstatement of channels eroded out during storms, removal of washed down vegetation, refuse, etc. Erosion protection is recommended to reduce the need for additional maintenance of storm water infrastructure caused by uncontrolled erosion.

As mentioned in the previous section, energy dissipators should be installed at the junction of the bench channels and perimeter channel, in addition to the discharge points leading to the voids. Additionally, drop chutes and stilling basins are both recommended to lower the energy and velocities. Erosion protection, such as riprap, is required for the contour channels.

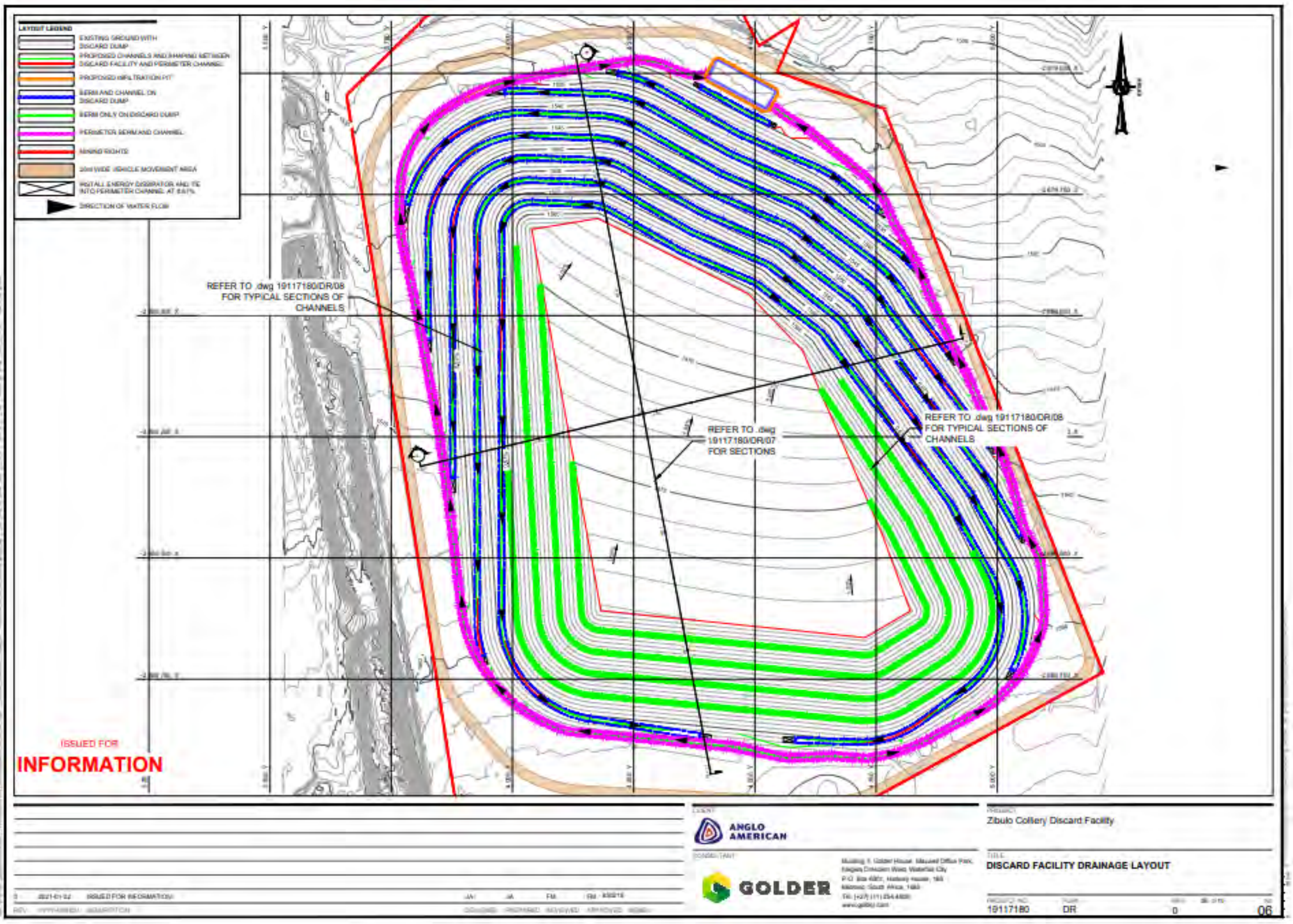

Figure 8: Proposed stormwater management plan layout

4.7 Stability analysis

A stability assessment was undertaken for the proposed Zibulo discard facility to provide the factors of safety associated with the facility under specific loading conditions. In accordance with local regulations and industry-leading, best practice guidelines, limit-equilibrium stability assessments for the final discard facility have been undertaken for static and post-seismic loading conditions.

4.7.1 Model approach

4.7.1.1 Methodology

The slope stability of four selected discard facility sections (based on the maximum height of the facility) has been assessed using Slide2 version 9.012, a computer software program produced by RocScience. The 'Method of Slices', as proposed by Morgenstern-Price, was used to assess the two-dimensional stability. This method is based on limit equilibrium principles, which satisfy both force and moment equilibrium under either constant or variable ratios of horizontal to vertical inter-slice forces.

A probabilistic analysis was also undertaken to allow for uncertainty and variability of the material strength parameters since some test pits were inaccessible and testing was only done on some of the dragline spoil samples and an analogous discard sample from Klipspruit. The probabilistic slope stability analyses were performed using Low and Tang's (2007) First Order Reliability Method (FORM) (Low, 2003), in conjunction with Slide's built-in Monte-Carlo method to calculate the reliability index. The Latin-Hypercube sampling method was assumed for 100,000 simulations of the global minimum slope.

4.7.1.2 Target outcomes

The stability is expressed in terms of a factor of safety (FoS) against failure, which can be defined for static conditions and pseudo-static conditions. The slope stability design criteria adopted for this project is to satisfy the Anglo-American Corporate Standards (2016) and the Department of Water Affairs and Forestry (1998) in which the factor of safety (FoS) against failure is defined as follows under static conditions:

- FoS > 1.3 – No loss of containment;
- FoS > 1.5[1] – Loss of containment; and
- FoS > 1.1 to 1.2 – Post seismic conditions (depending upon the confidence of parameters assigned).

The target minimum FoS values also comply with industry-leading, best practice guidelines such as Australia National Committee on Large Dams Inc. (ANCOLD) and Canadian Dam Association (CDA).

4.7.1.3 Static stability

The Mohr-Coulomb strength model was used to simulate the shear strength of the discard material and in situ dragline spoils by defining values for both the friction angle and the apparent cohesion. Drained shear strength parameters were applied to the model for the discard material.

Since the dragline spoils are assumed to be partially saturated, undrained shear strength parameters have been applied to the material layer. The vertical stress ratio (peak undrained strength ratio), estimated from past experience, was adopted in the short-term static and post-seismic analyses to represent the ratio of the shear strength to the vertical stress at small and large strains, respectively.

4.7.1.4 Post-seismic analysis

Post-seismic analysis represents the case whereby earthquake loading induces excess pore pressures within the foundation materials, i.e., the dragline spoils. Drained and undrained shear strength parameters are adopted for dilative and contractive materials, respectively, with appropriate adjustments made to reflect the loss of strength as a result of the seismic loading.

4.7.2 Model inputs

4.7.2.1 Model geometry

The geometry of four selected discard dump sections (refer to Appendix D for locations of sections) adopted for the stability analysis is presented in Figure 9 to Figure 12. The water table was based on the assumption that only the spoils would remain saturated before the pit is dewatered.

Data extracted from the geotechnical investigation has been extrapolated to assess sections of the facility that fall outside of the investigation extent. Existing dragline spoils located below the discard were assumed to be levelled prior to placement of the discard material. The thickness of the spoil material was based on the Multichannel Analysis of Surface Waves (MASW) Survey available for three portions of the facility and has been modelled between 30 m to 40 m deep at elevations between 1 500 mamsl and 1 545 mamsl.

[1] The 1.5 FoS value for static conditions with likely loss of containment is stipulated as the target minimum FoS value by GN R632 (Department of Environmental Affairs, 2015) and the Minimum Requirements for Waste Disposal by Landfill (Department of Water Affairs and Forestry, 1998).

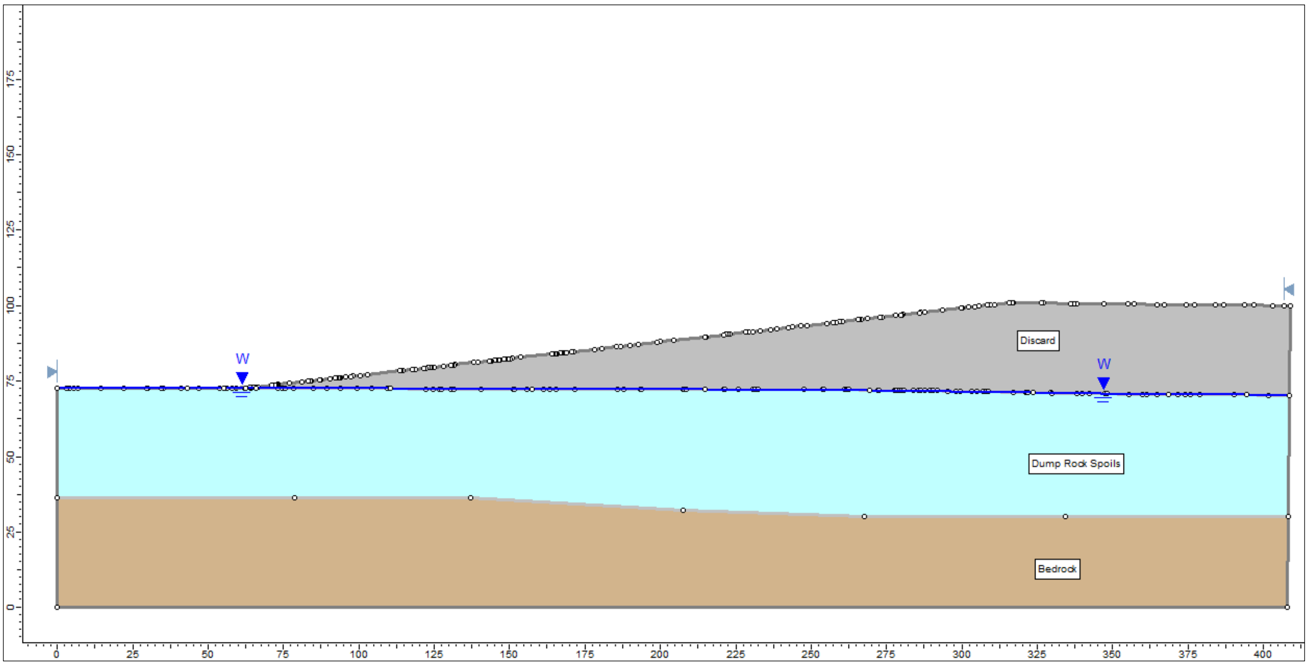

Figure 9: Section A-A: Section through Western spoils

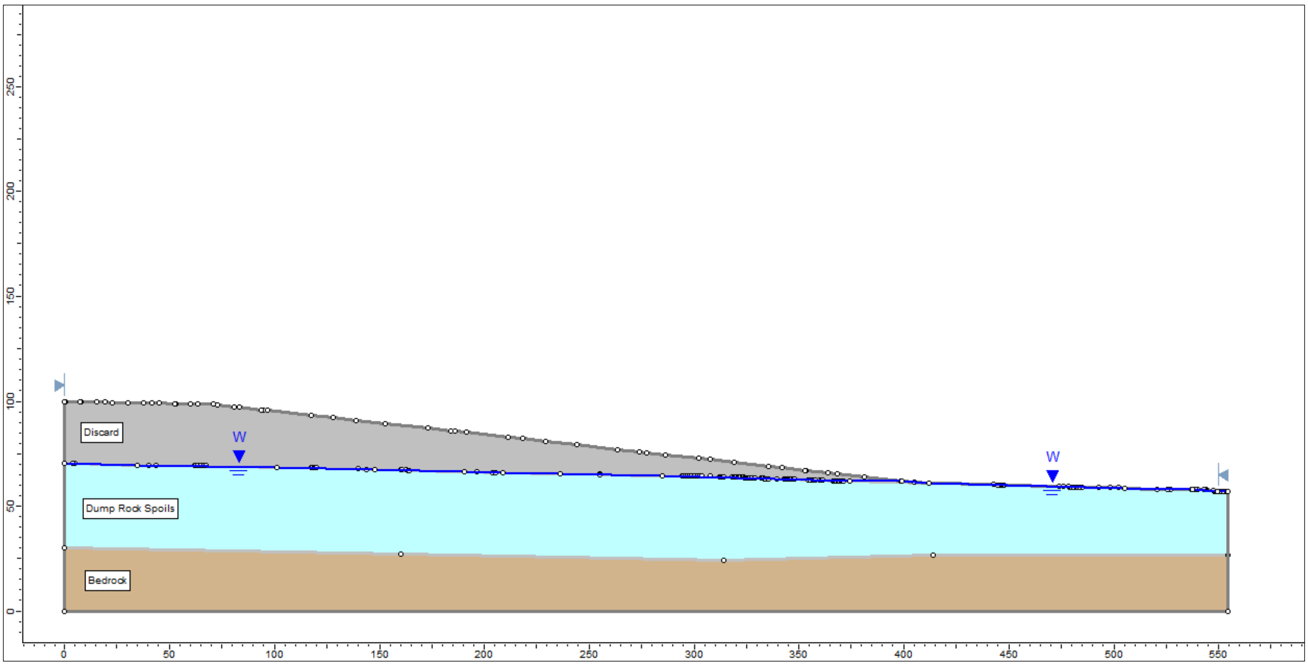

Figure 10: Section B-B: Section through Northern spoils

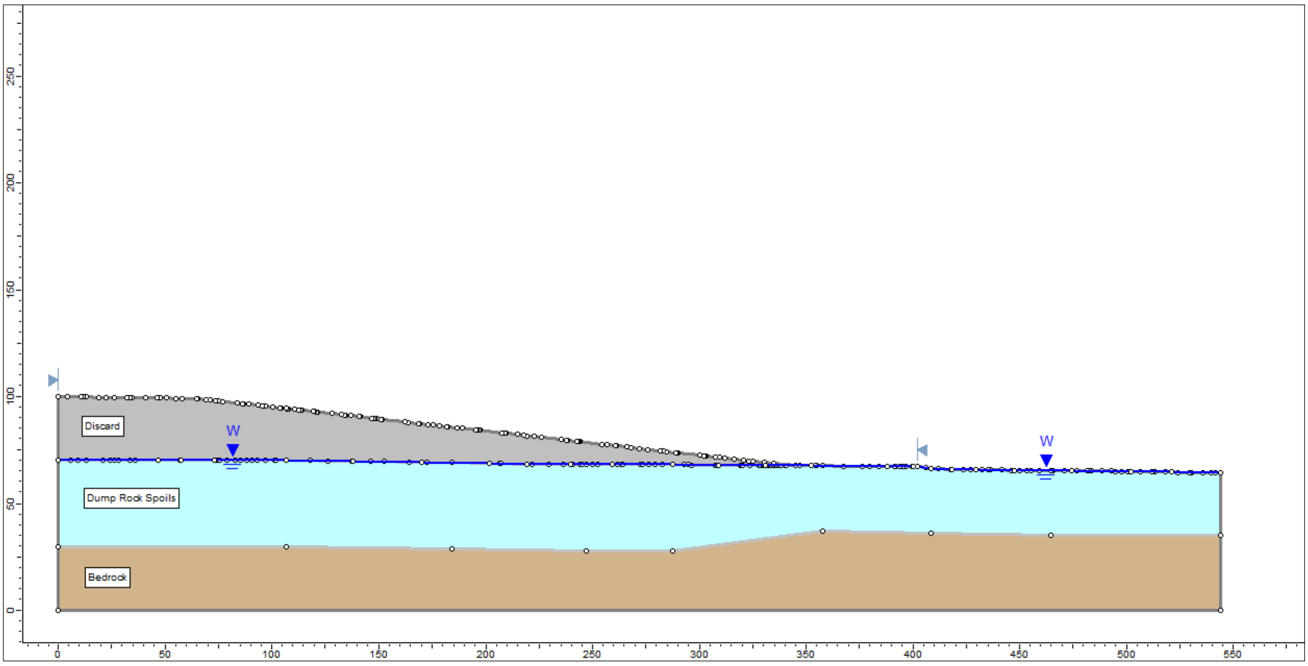

Figure 11: Section C-C: Section through Eastern spoils

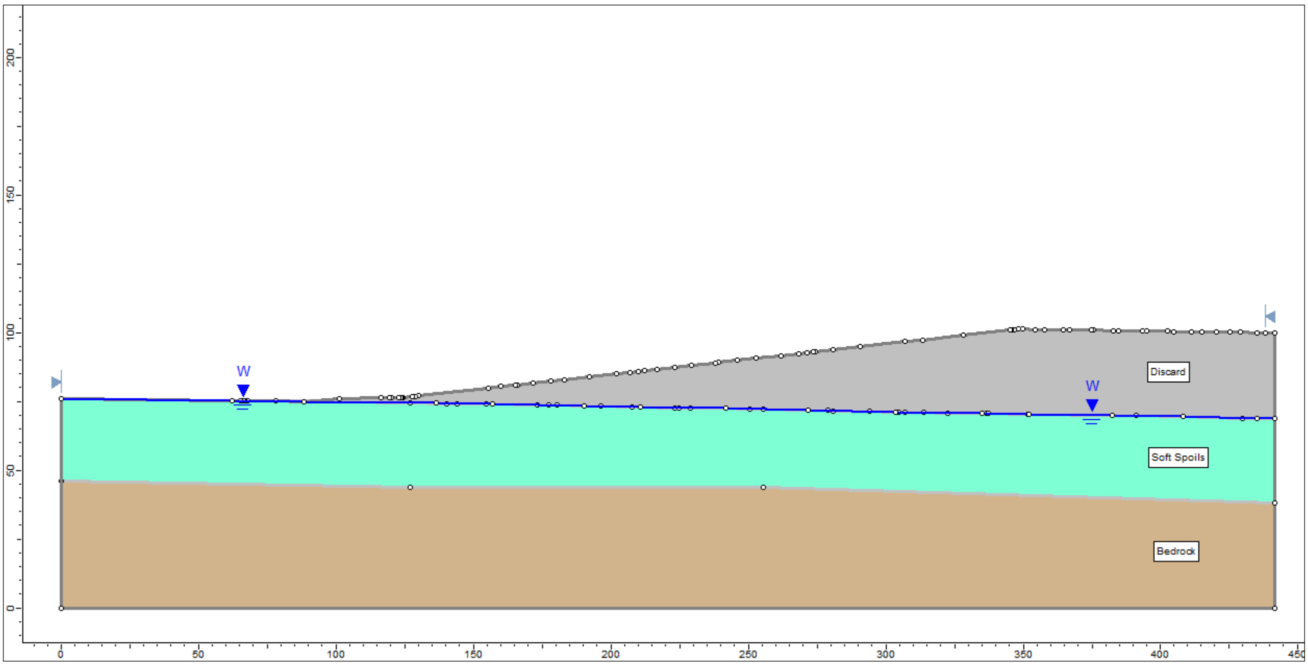

Figure 12: Section D-D: Section through Southern spoils

4.7.2.2 Material properties

The material strength parameters used in the slope stability analyses are shown in Table 4.

Table 4: Slope stability material strength parameters

Material	Colour Identifier	Unit Weight [γ] (kN/m^3)	Cohesion [c'] (kPa)	Friction Angle [ϕ] (˚)	Peak undrained strength ratio [s_u/σ'_v] (-)	Post-seismic strength ratio [$s_{u(liq)}/\sigma'_v$] (-)
Discard Material		17.2	0	35	-	-
Dragline Dump Rock Spoils[1]		19	0	35	0.25	0.1
Dragline Soft Spoils[1]		19	2[3]	30[3]	0.25	0.1
Bedrock[2]		24	Infinite strength			

[1]Undrained shear strength parameters applied to dragline spoils under short-term static and post-seismic conditions.
[2]Bedrock was assumed to have infinite strength.
[3]Average shear strength parameters obtained from laboratory testing of samples for Zibulo were adjusted to a lower value in relation to the parameters indicated from laboratory testing conducted for Klipspruit with similar material properties.

The material strength parameters listed in Table 4 were estimated by reviewing the available laboratory and field data captured during the geotechnical investigation, previous studies with similar material and relevant literature, such as Franki (1995). Values for the cohesion, friction angle and unit weight were selected based on the available information and laboratory test results.

Coal discard was recorded on several test pits during a geotechnical investigation for Klipspruit (Golder, 2020a). A high shear strength of 39.2° was recorded in a direct shear test of the coal discard material. However, a lower value was selected for the stability analysis since the grading envelope between the Zibulo and Klipspruit discard samples indicated variability.

The probabilistic analysis was carried out using drained material strength parameters, as summarised in Table 5.The strength properties of the material were modelled using normal distributions, with a coefficient of variation (CoV) estimated through established typical ranges in literature (Baecher & Christian, 2003). For the soft spoils, a higher CoV was selected to reflect the variability (and uncertainty) in the material.

The standard deviation was estimated from the assumed mean value and selected CoV through the formula expressed below.

$$CoV = \frac{\sigma}{\mu}$$

where, σ is the standard deviations
μ is the mean

Table 5: Slope stability probabilistic material strength parameters

Material	Colour Identifier	Parameter	Mean	Standard deviation	CoV
Discard Material		Friction Angle	35	4.20	0.12
Dragline Dump Rock Spoils		Friction Angle	35	0.28	0.008
Dragline Soft Spoils		Friction Angle	30	5.00	0.17
		Cohesion	2	4.00	2.00

4.7.2.2.1 Available information

At the time of performing the slope stability assessment, the following information was available:

- Golder geotechnical investigation reports (Report No. 19117180-333746-1 (Golder, 2021b) and Report No. 19131502-335398-1 (Golder, 2020a));
- Proposed discard dump geometry; and
- Laboratory testing on discard material and dragline spoil material samples.

4.7.3 Phreatic surface

According to the geotechnical investigation, the material was generally observed as slightly moist to moist within the investigated area. No groundwater seepage was observed in the test pits excavated during the geotechnical investigation. However, the investigation was undertaken during the dry season in addition to the pits being dewatered for mining. Therefore, a phreatic surface was assessed for a potential water table that may occur during the wet season. The phreatic surface was assumed to occur along the pit surface, i.e., the dragline spoils, with the assumption that a phreatic surface could occur from a water build-up in the pit prior to dewatering.

4.7.4 Results of stability analysis

The stability analysis yielded the results summarised in Table 6. Output is provided in Figure 13 to Figure 19.

Table 6: Results of slope stability analysis

Embankment Section	Factor of Safety					
	Static (Long-Term)	Figure Reference	**Static (Short-Term)**	Figure Reference	**Post-Seismic**	Figure Reference
Section A-A	5.3	Figure 13	2.2	Figure 14	1.0[1]	Figure 15
Section B-B	4.9	Figure 17	1.9	Figure 18	0.8[2]	Figure 19
Section C-C	5.1	Figure 21	2.1	Figure 22	0.9[3]	Figure 23
Section D-D	4.9	Figure 25	2.4	Figure 26	1.1[4]	Figure 27

[1]With a post-peak strength ratio of 0.15, the FoS is expected to be 1.4.
[2]With a post-peak strength ratio of 0.15, the FoS is expected to be 1.2.
[3]With a post-peak strength ratio of 0.15, the FoS is expected to be 1.3.
[4]With a post-peak strength ratio of 0.15, the FoS is expected to be 1.6.

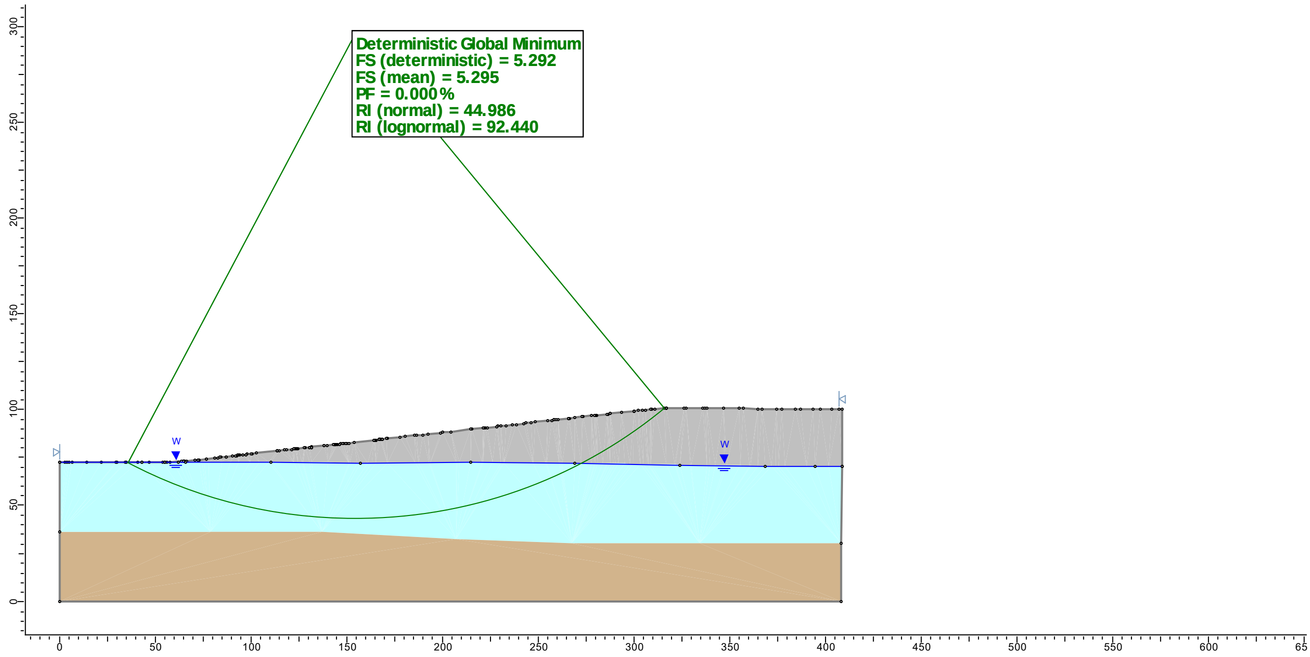

Figure 13: Section A-A long-term static condition (with drained parameters)

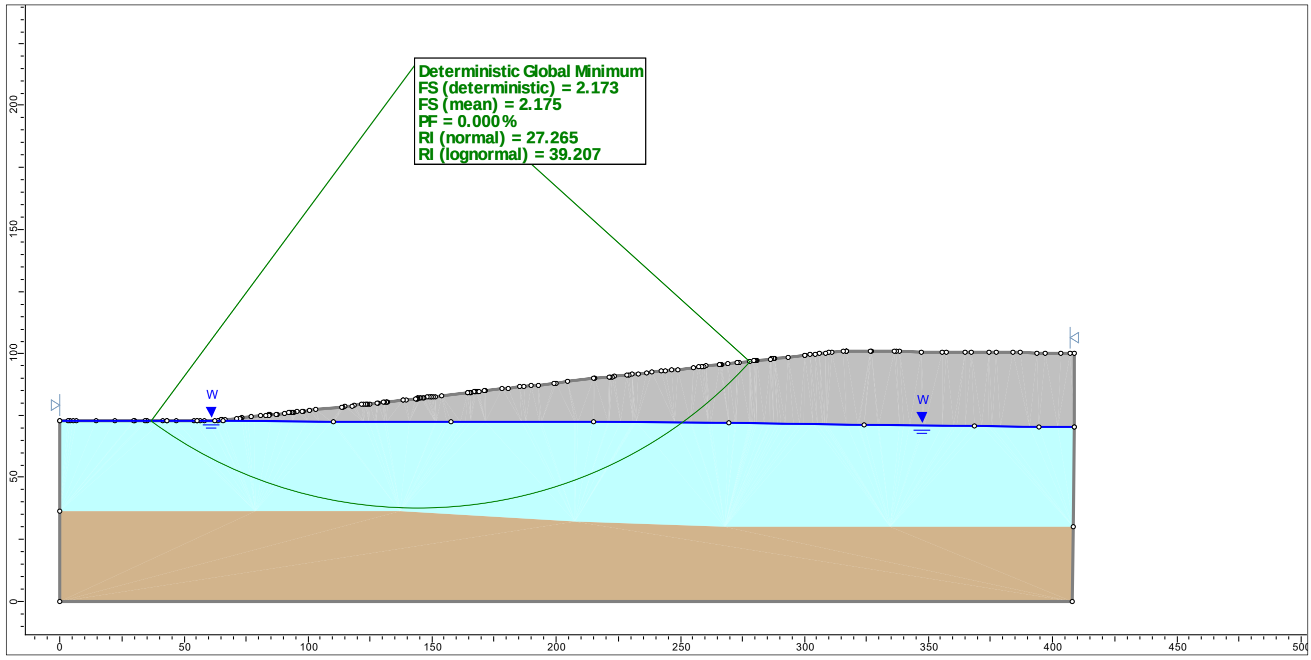

Figure 14: Section A-A short-term static condition

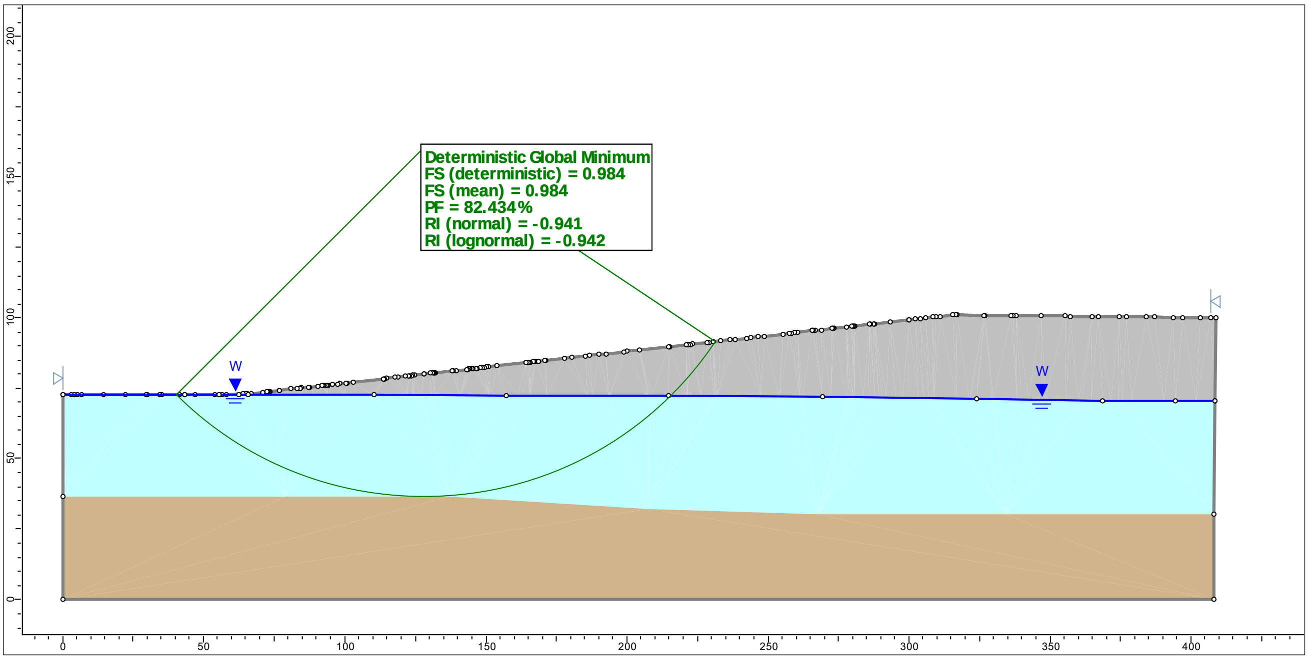

Figure 15: Section A-A post-seismic condition (with a post-seismic strength ratio of 0.1)

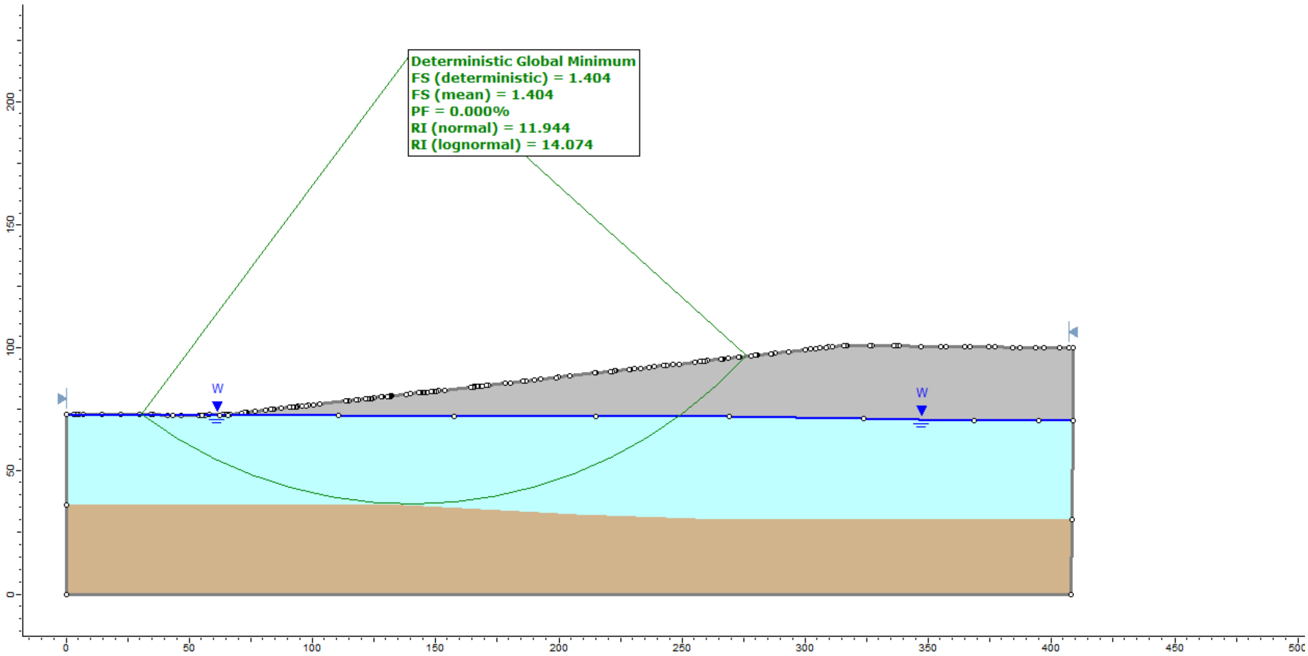

Figure 16: Section A-A post-seismic condition (with a post-peak strength ratio of 0.15)

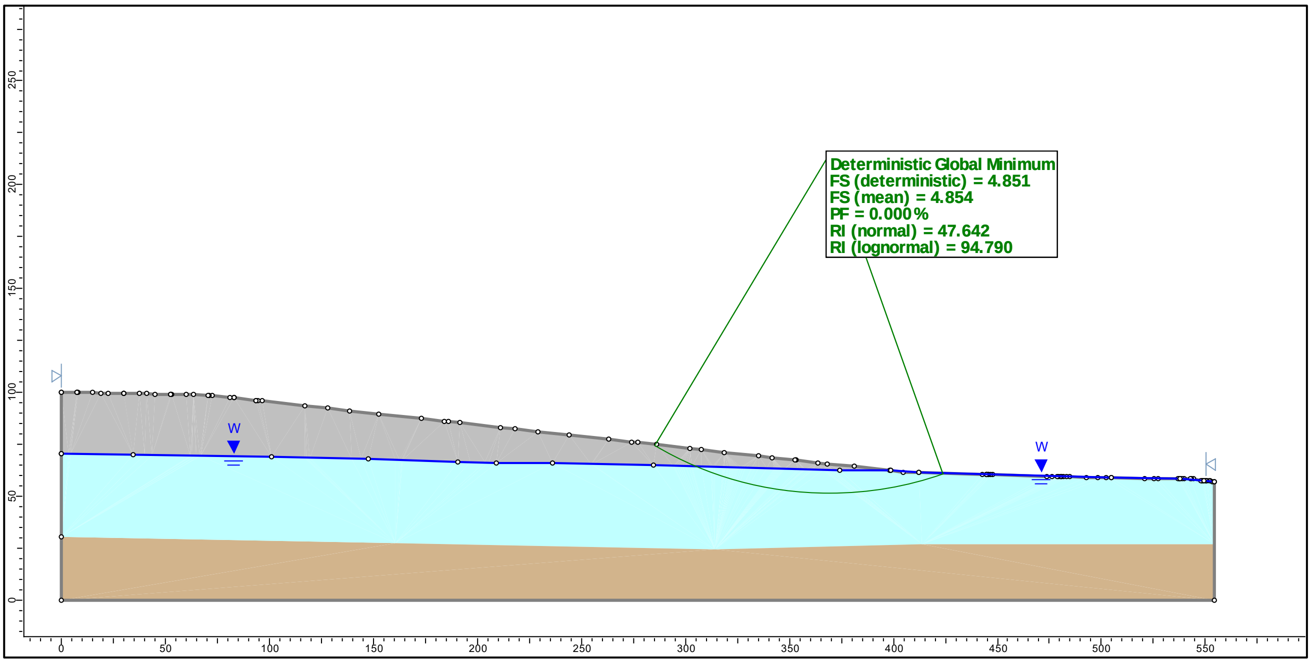

Figure 17: Section B-B long-term static condition (with drained parameters)

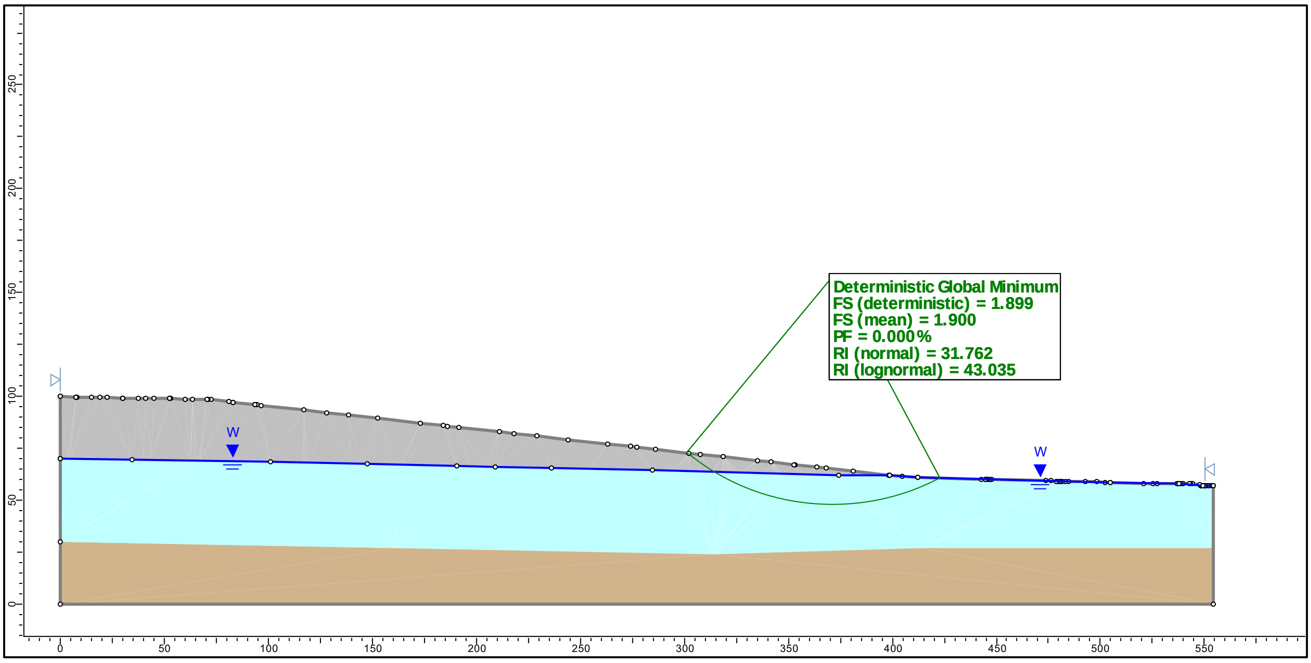

Figure 18: Section B-B short-term static condition

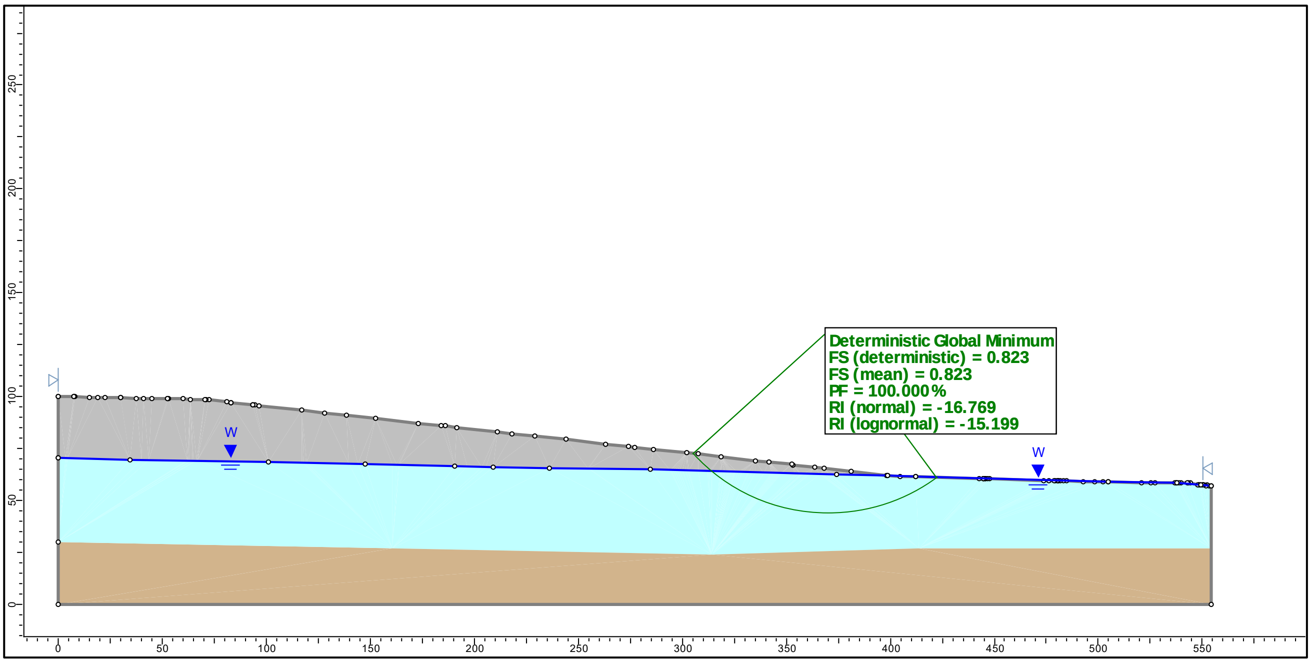

Figure 19: Section B-B post-seismic condition (with a post-seismic strength ratio of 0.1)

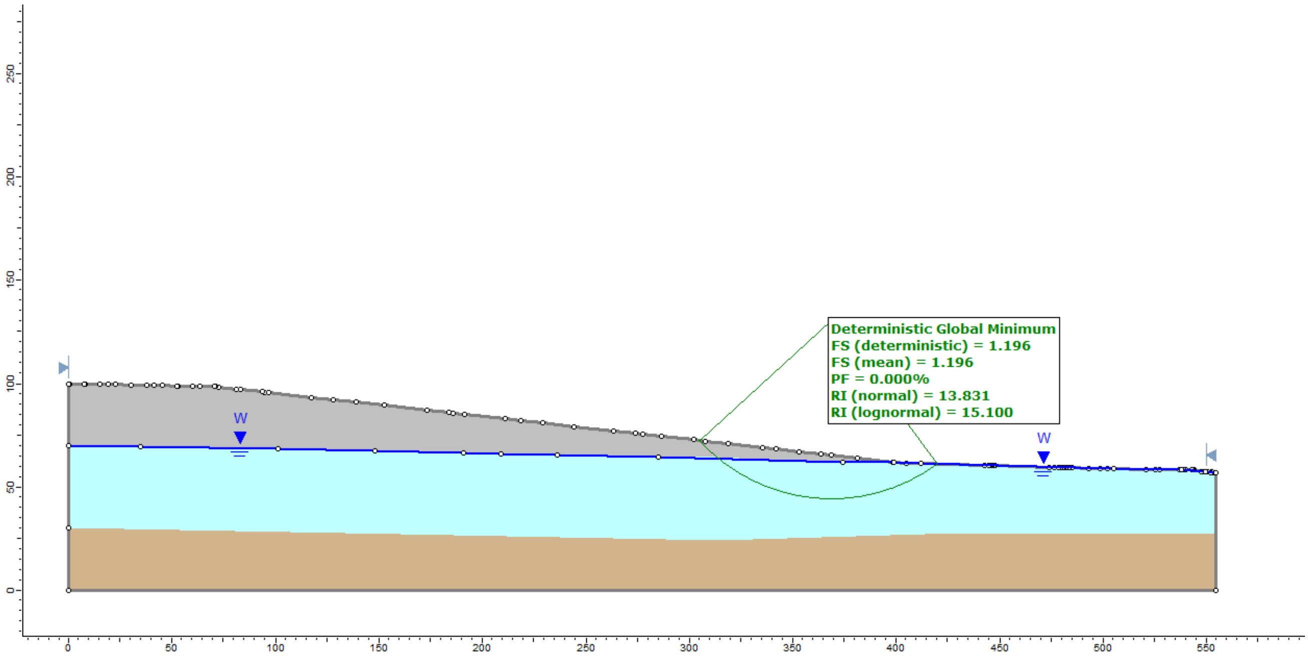

Figure 20: Section B-B post-seismic condition (with a post-peak strength ratio of 0.15)

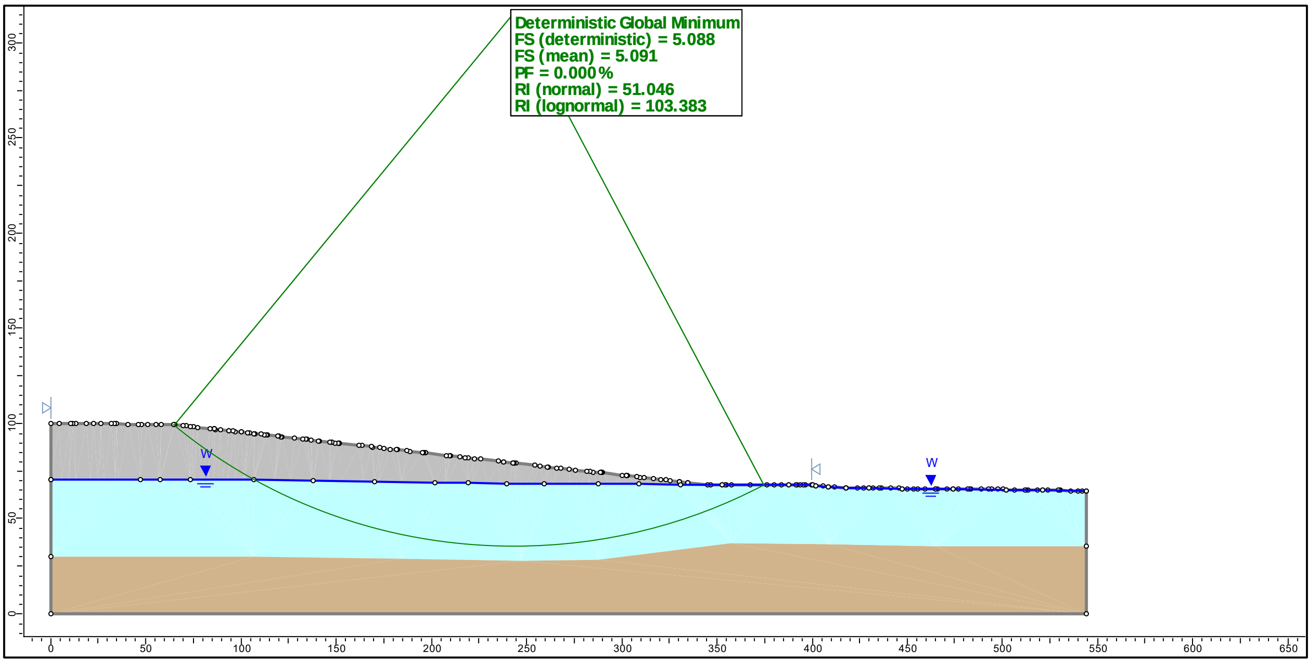

Figure 21: Section C-C long-term static condition (with drained parameters)

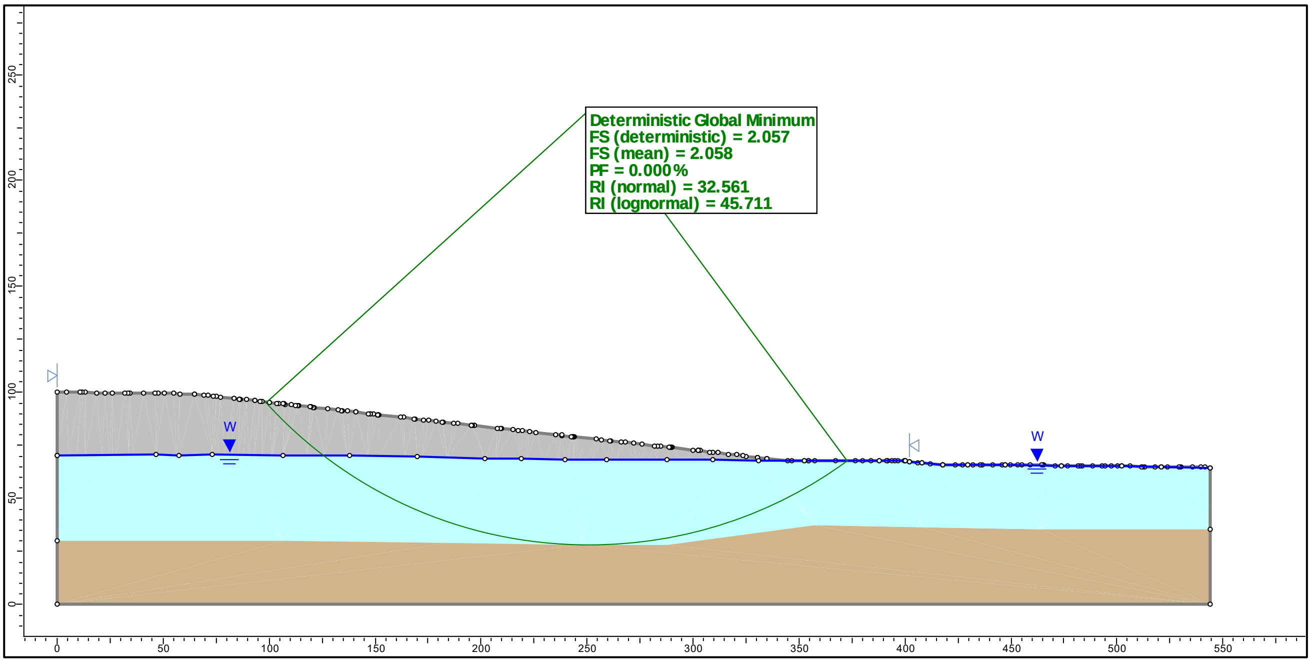

Figure 22: Section C-C short-term static condition

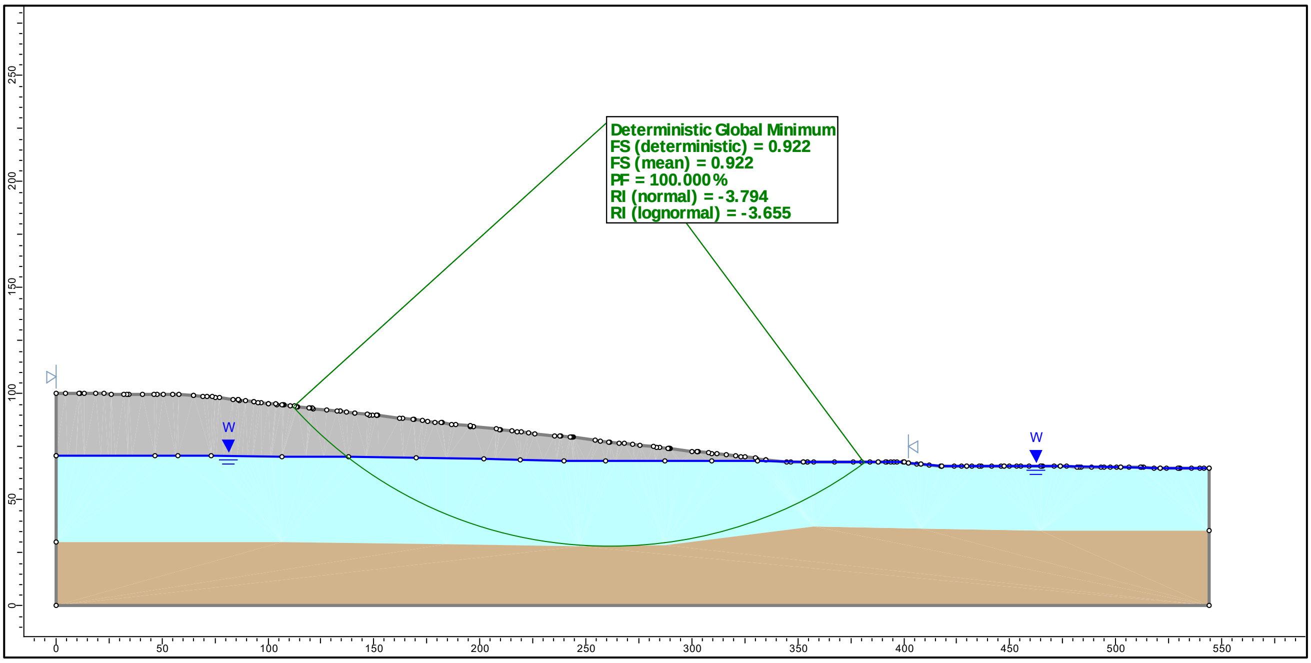

Figure 23: Section C-C post-seismic condition (with a post-seismic strength ratio of 0.1)

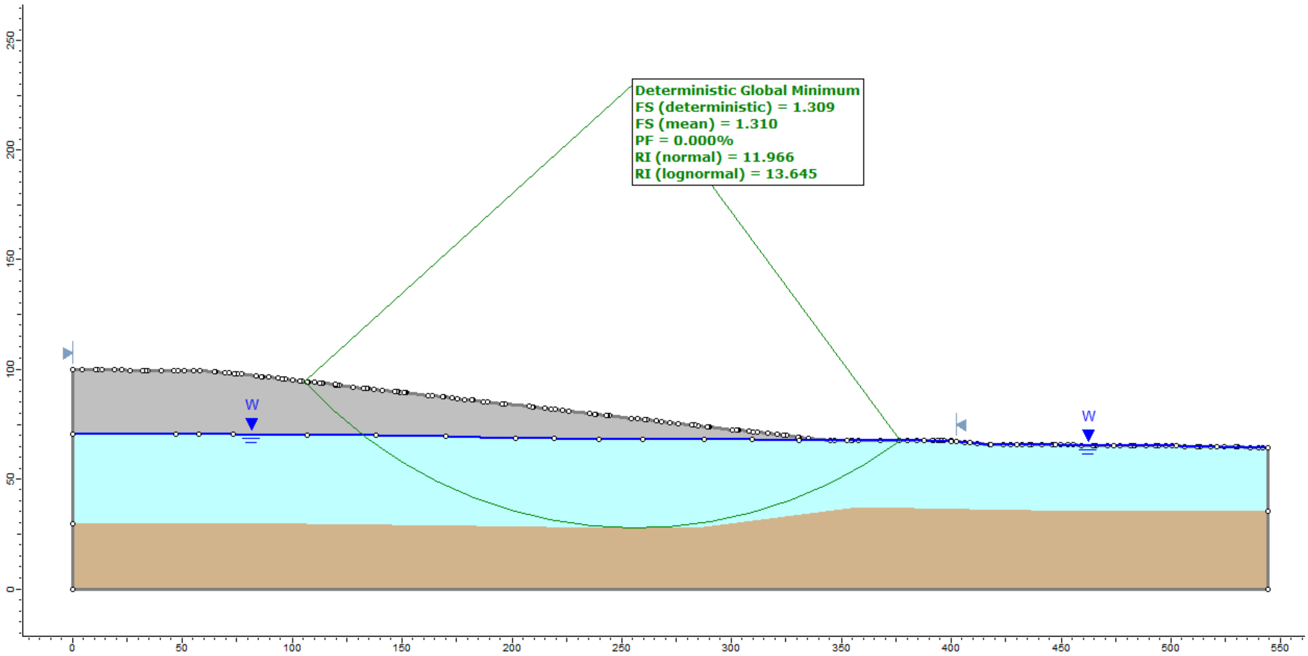

Figure 24: Section C-C post-seismic condition (with a post-peak strength ratio of 0.15)

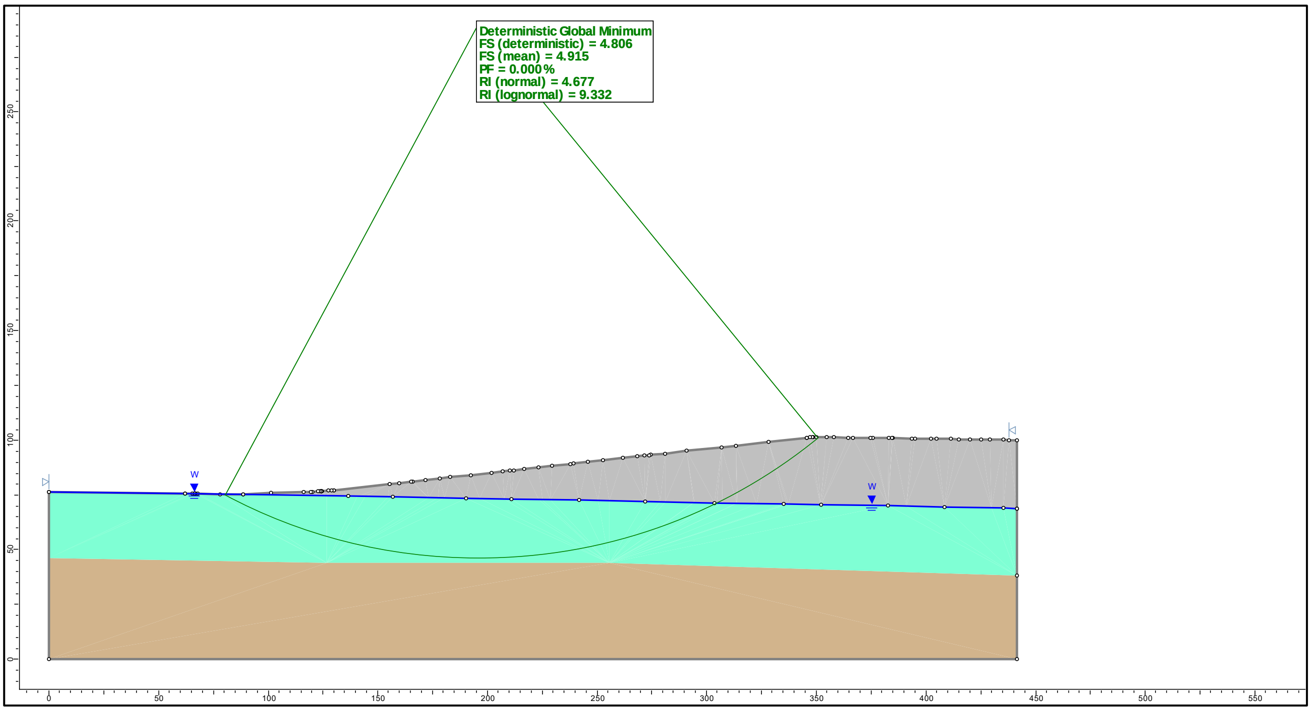

Figure 25: Section D-D long-term static condition (with drained parameters)

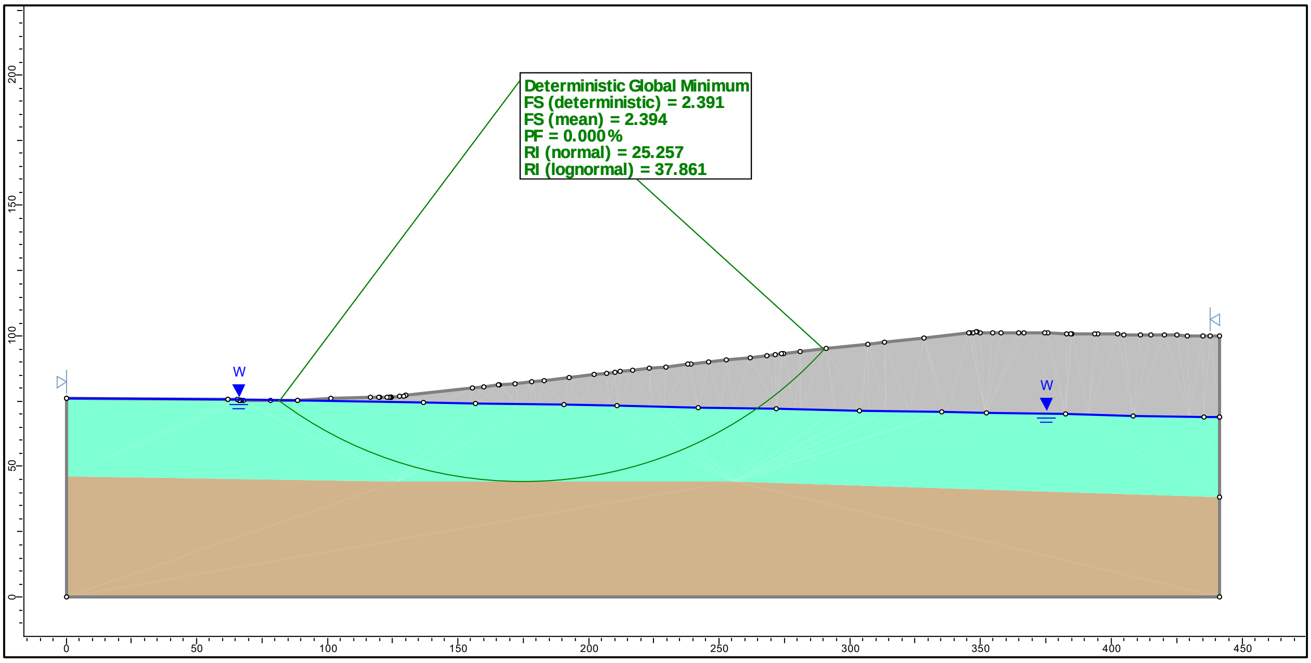

Figure 26: Section D-D short-term static condition

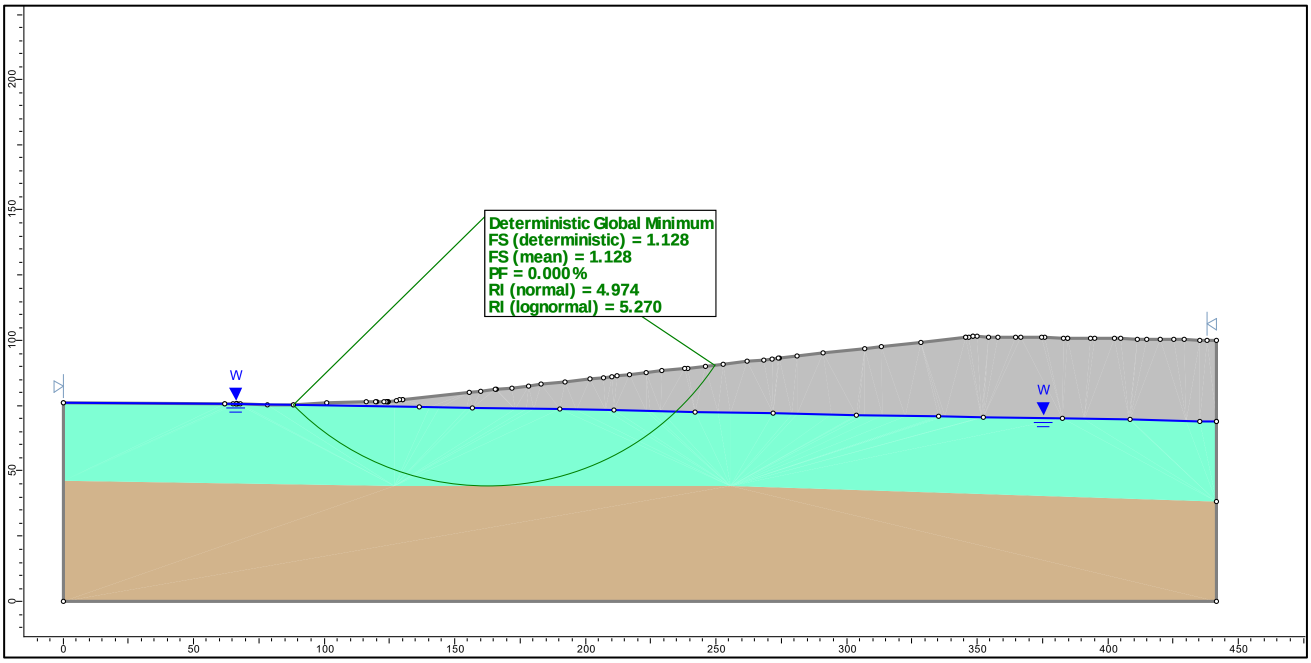

Figure 27: Section D-D post-seismic condition (with a post-seismic strength ratio of 0.1)

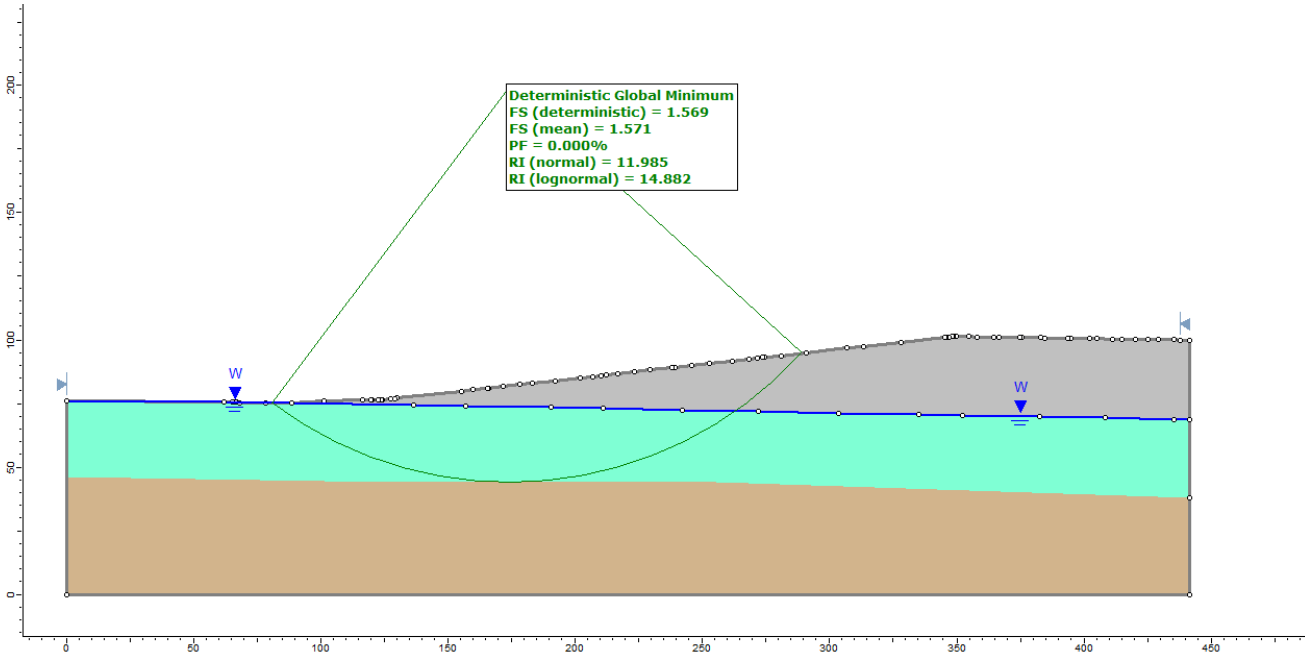

Figure 28: Section D-D post-seismic condition (with a post-peak strength ratio of 0.15)

4.7.5 Discussion of results

The resultant safety factors for the static analyses were consistently greater than the minimum requirement of 1.5. Based on the conditions analysed in this assessment, the stability of the discard dump is considered to be safe under both short-term and long-term conditions. The key reason for the high FoS under both short-term and long-term conditions are based on the flat outer slopes that were selected.

For the post-seismic condition, the factor of safety will not be maintained above the acceptable target value of 1.1 on the western, northern, and eastern sections assessed with the assumed phreatic surface and post-seismic undrained strength ratio. In addition to the post-seismic analysis, a sensitivity analysis was conducted to understand what the FoS might be with a post-peak strength of 0.15 as opposed to the assumed 0.1. The results obtained from the sensitivity analysis show that all sections obtained an acceptable factor of safety with a post-peak strength ratio of 0.15. A full stress-deformation analysis is recommended to comply with the Anglo-American Corporate Standards (2016) and to confirm the post-peak strength ratio that can be utilised for the post-seismic loading conditions.

4.7.6 Conclusion

The discard facility has been assessed for four sections on each side of the facility for both static and post-seismic loading conditions. An acceptable factor of safety have been achieved under long and short-term static aforementioned loading conditions, thereby deeming the facility safe for short and long-term static loading conditions. However, further analysis is required for seismic conditions. It should also be noted that the compaction of the discard surface impacts the stability of the facility since shallow localised failures may occur with a low FoS.

The design was thus benchmarked against the international standards of Anglo American for mine waste facilities. It should be noted that this is a dry waste facility, and that the facility risks are less than a wet tailings facility. The aspect of possible liquefaction was considered, and it was indicated that Anglo standards may require the design process to address the possible liquefaction of underlying spoils. Such a worst case scenario may occur in the event of a rapid rise in the water table within the spoils despite the decant point being managed and controlled with excess water being pumped to the treatment plant or re-used in the coal wash plant. On-going monitoring during the operations, would be essential.

4.7.7 Recommendations

The following recommendations are proposed for consideration to be executed prior to implementation, during the operations and prior to closure):

- Performing a veneer stability analysis to estimate the resistance of the cover material to sliding. It is proposed that this analysis be done as part of the closure design of the facility.
- Performing a full stress-deformation analysis is required to comply with the Anglo-American Corporate Standards (2016) and to better understand the post-peak undrained stress behaviour of the spoils.
- Installation of standpipe or vibrating wire piezometers to measure the phreatic surface within the facility.
- Performing a liquefaction assessment on the spoil material to better understand the liquefaction potential and undrained behaviour.

4.8 Settlement of discard material

Differential settlement of the dragline spoils may be caused by the following factors:

- Since the coal discard material will be deposited on uncontrolled compacted dragline spoils causing non-uniform stiffness throughout the spoils.
- The thickness of the dragline spoils is expected to vary between 30 to 50 m (with an average of 40 m) based on the MASW survey.
- Variability of the spoil material being placed inside the open pit will also create differential settlement.

The differential settlement caused by these factors can pose a negative impact on the operation of the discard dump and may impact the production of the coal discard placement.

4.8.1 Estimation approach

It was assumed that any immediate settlement that might occur due the placement of the coal discard, will take place during construction and therefore not taken into account in the settlement calculations. It was further assumed that the coal discard will not be fully saturated during construction and therefore no consolidation settlement due to excess pore pressure generation was taken into account. The consolidation settlement was estimated for the spoils alone due to the placement of coal discard. The coefficient of volume compressibility (m_v) and coefficient of consolidation (c_v) values were derived from available laboratory test data conducted on the spoils.

A schematic of the proposed cross-section is presented in Figure 29.

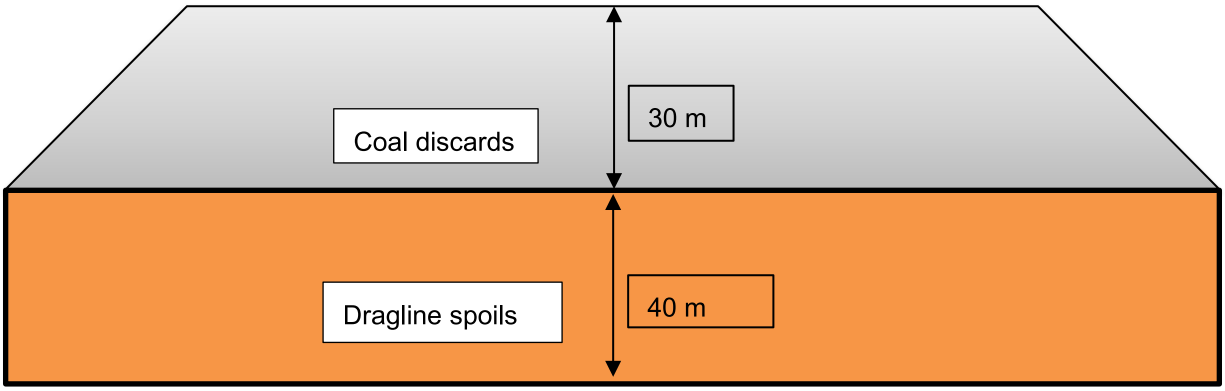

Figure 29: Cross-sectional area schematic of discard facility

4.8.2 Estimation inputs

Oedometer tests were undertaken for three samples of the spoils (as shown in Figure 30) and interpreted for the estimation of the m_v values. The samples were compacted to 93% of their Standard Proctor maximum dry density and indicated inconsistencies. This is expected from highly variable material. However, the coarse fraction samples were removed to accommodate the particle sizes required for the oedometer apparatus, which also affects the stiffnesses and the results.

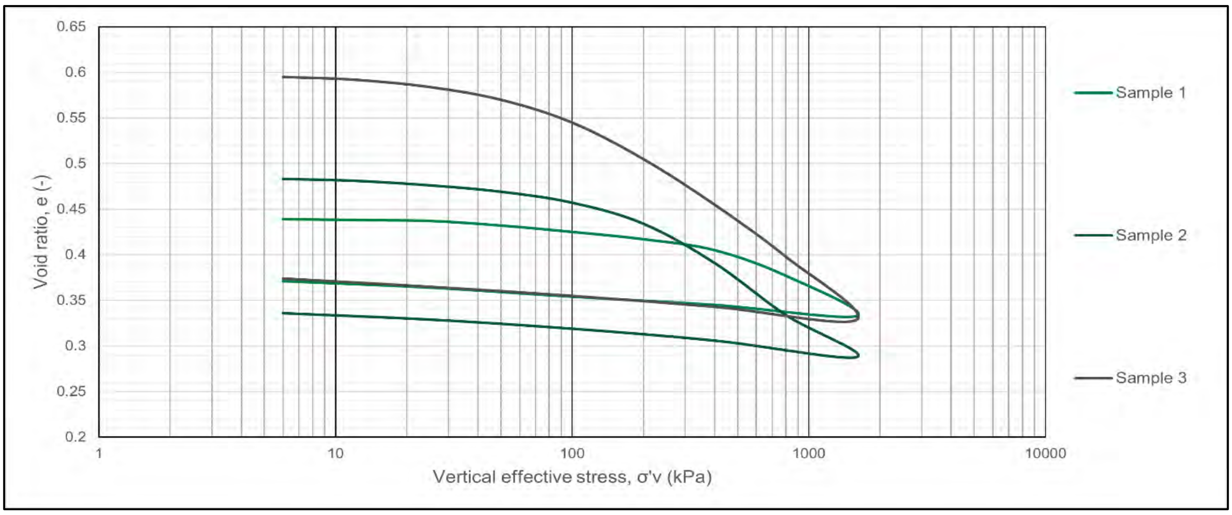

Figure 30: Oedometer tests undertaken on sampled spoils

The average m_v was used for the estimation of the settlement of the spoils. For each stage in construction, the function presented in Figure 31 was used to estimate the m_v values of the spoils in relation to the applied vertical stress (pressure) within each layer for every 5 m lift.

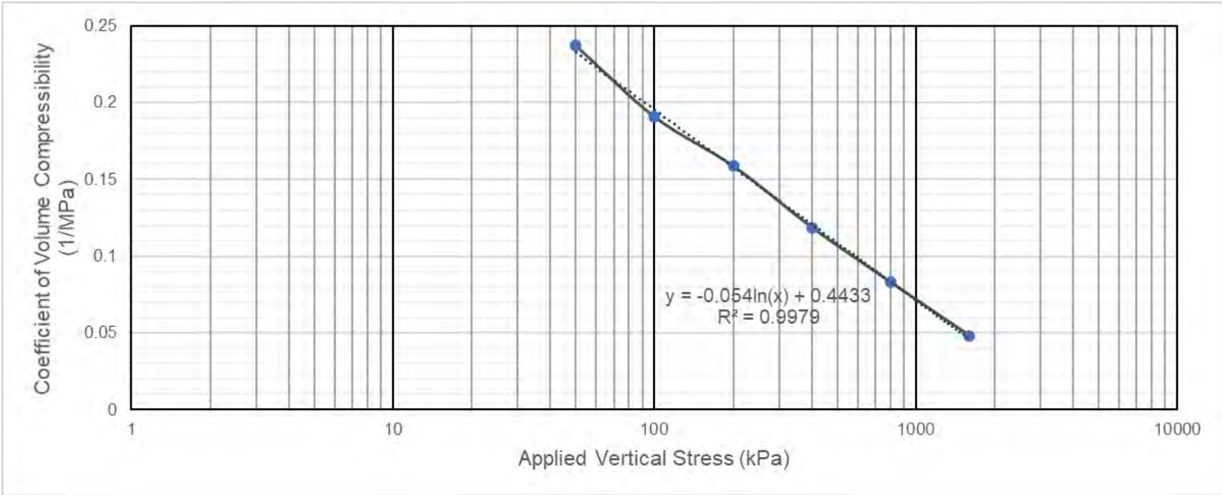

Figure 31: Relationship of vertical stress and m_v from oedometer tests undertaken on sampled spoils

The density of the discard material was assumed to be 1,755 kg/m^3 (17.2 kN/m^3), resulting in a load of 516.5 kPa for a total height of 30 m (assumed to be implemented in 5 m lifts resulting in a load of 86 kPa per lift). A width of 20 m per 5 m lift was assumed for the estimation of the consolidation settlement in the spoil material.

Triaxial results conducted on the spoil material were used to derive the average c_v values for the spoil material. Due to the variability of the spoil material, the c_v values might vary between a minimum of 11.15 m^2/yr and maximum of 44.63 m^2/yr with an average c_v value taken as 27.9 m^2/yr.

4.8.3 Estimated magnitude and duration of settlements

The estimated consolidation settlement of the spoils material due to the placement of 6 lifts of 5 m coal discards was found to be approximately 1,400 mm based on the assumptions above.

Based on an average c_v value of 27.9 m^2/yr, it is expected that the total consolidation settlement would occur over a period of 55 years from the start of construction. However, the results from the settlement calculations further indicate that 68% of the consolidation settlement will occur during construction. Therefore, it is expected that only about 450 mm of settlement will occur after the final placement of the 6th lift over a post closure period of about 42 years.

Based on the maximum of 44.63 m^2/yr and minimum of 11.15 m^2/yr c_v values, the total settlement expected after construction could vary between 315 mm for over 26 years and 730 mm for over 106 years. Therefore, the maximum differential settlement is expected to be about 415 mm that might prevent the facility from free draining if deformations are not rectified. Refer to the second recommendation of Section 4.8.5.

From a closure point of view, even the average expected settlement of 450 mm after construction for over 42 years might cause issues with the capping layer. Thus, some mitigation measures are recommended in Section 4.8.5 to cater for this.

4.8.4 Conclusion

A total of 1.4 m of consolidation settlement of the spoils has been estimated over the life cycle of the facility. It should be noted that the estimated settlement is only indicative of potential situations that could occur on site since the nature of the spoils is shown to be highly variable in addition to the limitations in testing of coarse materials. Settlements are expected to be more within thicker layers of spoils.

4.8.5 Recommendations

The following recommendations are proposed for consideration:

- A slurry consolidometer tests is recommended for the next phase of the discard dump design to better define the consolidation parameters (m_v and c_v) of the coal discard and dragline spoils.
- An observation method should be carried out during construction in order to update our consolidation model and for future preloading planning of the coal discard after placement to increase the rate of the settlement if necessary.
- An observational approach beyond closure should also be followed to monitor the settlement and cover movements.
- Installation of standpipe or vibrating wire piezometers to determine the excess pore pressure dissipation during placement of coal discard and to calibrate the consolidation model during construction.
- Since the mine has a shortage of topsoil and a topsoil cover of approximate 600 mm (as specified within Section 4.5) is required, topsoil material should be borrowed from other available sources (such as, commercial sources or neighbouring mines). Topsoil stockpiles should be made readily available for any additional topsoil that may be required for the cover remediation to accommodate any possible consolidation settlement that may occur after construction. Any excessive settlements should not impact the free draining of the facility and promote ponding.
- A detailed consolidation model should be conducted during the detailed design phase of the project to predict the magnitude of the settlement and durations thereof to a higher degree of accuracy.
- The mine should monitor and maintain the facility for a minimum of 30 years beyond closure.

5.0 RISK-BASED APPROACH TO GUIDE DESIGN

5.1 Background

The management of mine residues (stockpiles and waste deposits) is governed by regulations under the National Environmental Management: Waste Act (Act 59 of 2008): *Regulations regarding the planning and management of residue stockpiles and residue deposits from a prospecting, mining, exploration, or production operation* (GN R632 of 2015), which allows for the characterisation of mine residues (all forms of mine waste and stockpiles) as the basis for a risk assessment.

When promulgated, GN R632 of 2015 also provided that the pollution control barrier system be driven by the Waste Classification and Management Regulations (GN R634-636 of 2013), based upon the leachable and total concentrations of specified constituents of concern. GN R632 of 2015 was, however, amended on 21 September 2018, removing the reference to the Waste Classification and Management Regulations, and instead, requiring that the pollution control barrier system be driven by a risk assessment based upon the geochemical hazard and toxicology of the waste material and the risk of the water resource and other receptors.

In addition to the waste licence application, the disposal or stockpiling of mining residues typically requires a water use licence (WUL) in terms of Section 21(g) of the National Water Act (Act 36 of 1998). The *regulations on use of water for mining and* related *activities, aimed at the protection of water resources* (GN R704 of 1999) provide for the protection of the water resource in the context of mining and related activities, notably:

- Regulation 7(a) which requires the prevention of water containing waste or any substance which is likely to cause pollution from entering a water resource.

- Regulation 7(e) which requires that residue deposits and stockpiles be designed with suitable barriers that prevent the leaching of materials from the residue into the water resource.

The standard that is applied by the Department of Water and Sanitation (DWS) in considering the acceptability of a pollution control barrier system, in this regulatory context, is either:

- A ‘compliant design’, which the DWS bases on the Waste Classification and Management Regulations (GN R634-636 of 2013), notwithstanding these regulations no longer being applicable in terms of the amended GN R632 of 2015; or
- A ‘risk-based approach’ to pollution control barrier design, per the exchange of memoranda between the DWS and the Minerals Council (ref. WULA/1/2016 and EPC/60/16, respectively).

If the risk assessment required for the purpose of compliance with GN R632 of 2015 demonstrates that a proposed pollution control barrier provides an acceptable outcome in terms of environmental impact, then it is likely that DWS may also accept the proposed pollution control barrier as a risk-based design.

5.2 Approach

From the outset of the project, emphasis was placed on the development and motivation of a pragmatic and alternative risk-based solution as opposed to that of the rule-based ‘compliant’ approach comprising of a costly synthetic geomembrane material to rehabilitate the facility. This approach was based on the premise that the additional waste load from the facility through seepage could be intercepted and managed without unacceptable risk to the environment through the post-closure pit water regime.

Although a Class C barrier design is required to contain a Type 3 waste in terms of a compliant design, it is proposed to demonstrate that a similar level of protection of the resource can be achieved with the application of alternative intervention measures and design features. Refer to Golder (2021c) for a discussion on the waste classification risk assessment. There is likely to be a reasonable degree of settlement of the discard above the backfilled spoils which renders the site unsuitable for lining with a geomembrane. Furthermore, the presence of a geomembrane is likely to lower the FoS of the facility due to the introduction of a weak slip plane above which the phreatic surface could build up. An added consideration is the possibility of spontaneous combustion (or “sponcom”) which would destroy a geomembrane.

The water pumped from the pit will be treated at the eMalahleni Water Treatment Plant, refer Golder (2021d) for the Source-Receptor-Pathway modelling. These measures include decreasing the volume of dirty water by use of a cover, and interception of dirty water by means of proactively pumping groundwater, which prevents decant from the pit.

6.0 CONCLUSIONS

The following conclusions have been made:

- The discard facility is located above the dragline spoils within the pit thereby preventing extension of the facility onto undisturbed land. The discard dump and final void will be able to accommodate the required volume of 26 Mm^3.
- The facility will be developed in a staged approach, with vertical lifts of 5 metres.
- A 519 mm soil cover system is recommended to reduce possible leachate from entering into the water resource from the facility.
- The stormwater management system for the discard facility is compliant with the NWA GN 704 regulations in which the clean and dirty water systems are separated and the water routing structures have been designed to contain the 1:50 year, 24-hour storm event.
- The discard facility satisfies long, and short-term conditions of the stability assessments investigated.
- Based on the conditions analysed in this assessment, the stability of the discard dump is considered to be safe under both short-term and long-term conditions.
- A 1.4 m of consolidation settlement has been estimated for the spoil material over the life cycle of the facility.
- From a closure point of view, the average expected settlement after construction beyond closure may be problematic for the capping layer. Thus, mitigation measures are essential to cater to the issues that may arise (refer to in Section 7.0).
- Compaction of the discard and spoil material is crucial in minimising the settlement within the material layers, in addition to improving the stability of the facility.

7.0 RECOMMENDATIONS

A site geotechnical reconnaissance has been conducted for the facility footprint area; however, further confirmatory testing and analysis will be required. It is recommended that the following be implemented to refine the design:

- Perform a materials balance to quantify a higher level of certainty pertaining to potential borrow areas and soil characterisation for capping materials.
- Perform a veneer stability analysis to estimate the resistance of the cover material to sliding.
- Perform a full stress-deformation analysis to comply with the Anglo-American Corporate Standards (2016).
- Install standpipe or vibrating wire piezometers to measure the phreatic surface within the facility and monitor the excess pore pressure within the dragline spoils during construction.
- Perform a liquefaction assessment on the spoil material to better understand the liquefaction potential and undrained behaviour.
- Perform a more quantified evaluation of the geotechnical behaviour of the underlying spoil material through appropriate studies/ investigations to estimate the short and long-term settlement.
- Perform a slurry consolidometer tests for the next phase of the discard dump design to better define the consolidation parameters (m_v and c_v) of the coal discard and dragline spoils.

- Perform a detailed consolidation model during the detailed design phase of the project to predict the settlement magnitude and durations to a higher degree of accuracy.
- Perform an observation method during construction and beyond closure in order to update our consolidation model and monitor the settlement and cover movements in addition to future preloading planning of the discard after placement to increase the rate of the settlement.
- Ensure topsoil stockpiles are made readily available for any additional topsoil that may be required for the cover to accommodate any possible and significant consolidation/ settlement that may occur. Any excessive settlements should not impact the free draining on the facility and promote ponding. Topsoil material should be borrowed from other available sources (such as, commercial sources or neighbouring mines) when there is a shortage thereof.
- Monitor and maintain the facility for a minimum of 30 years beyond closure.

8.0 REFERENCES

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Signature Page

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https://golderassociates.sharepoint.com/sites/104294/project files/6 deliverables/19117180-338899-17 tech design report/19117180-338899-17_zibulo_technical_design_rev01_12apr21.docx

APPENDIX A

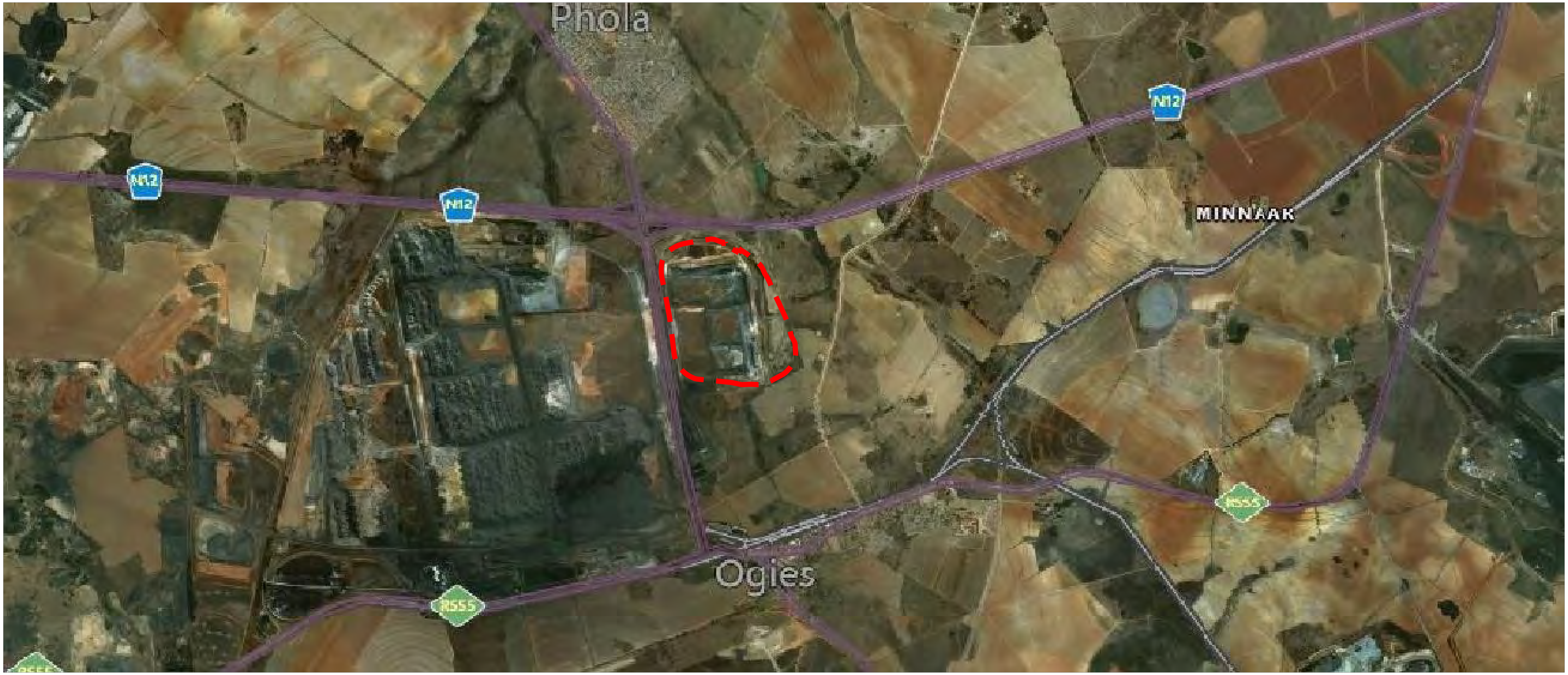
Zibulo Discard Facility Design Drawings

CLIENT:
ANGLO AMERICAN

CONSULTANT:
GOLDER

ZIBULO COLLIERY DISCARD FACILITY

BOOK OF DRAWINGS
MARCH 2021



LIST OF DRAWINGS

PLAN NUMBER	DESCRIPTION	ORIGINAL PLAN SIZE
19117180 - KP - 001	LOCALITY MAP	A1
19117180 - GA - 002	DISCARD FACILITY GENERAL ARRANGEMENT	A1
19117180 - LP - 003	DISCARD FACILITY LAYOUT PLAN AND SECTIONS	A1
19117180 - LM - 004	PROPOSED FACILITY LANDFORM PREPARATION PRIOR TO DISCARD DUMP DEVELOPMENT	A1
19117180 - EL - 005	DISCARD FACILITY ELEVATION PLAN	A1
19117180 - DR - 006	DISCARD FACILITY DRAINAGE LAYOUT	A1
19117180 - DR - 007	DISCARD FACILITY SECTIONS	A1
19117180 - TP - 008	DISCARD FACILITY TYPICAL DRAINAGE SECTIONS	A1
19117180 - LD - 009	DISCARD FACILITY STAGED APPROACH	A1
19117180 - TP - 010	DISCARD FACILITY TYPICAL SECTION OF REHABILITATED SIDE SLOPE	A1

ISSUED FOR

INFORMATION

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	SIGNED
0	2021-01-22	ISSUED FOR INFORMATION	JA	JA	FM	FM - 830215	F.J. Marais

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PROJECT
Zibulo Colliery Discard Facility

TITLE
LOCALITY MAP

PROJECT NO.	PLAN	REV.	01 of 10 No
19117180	KP	0	01

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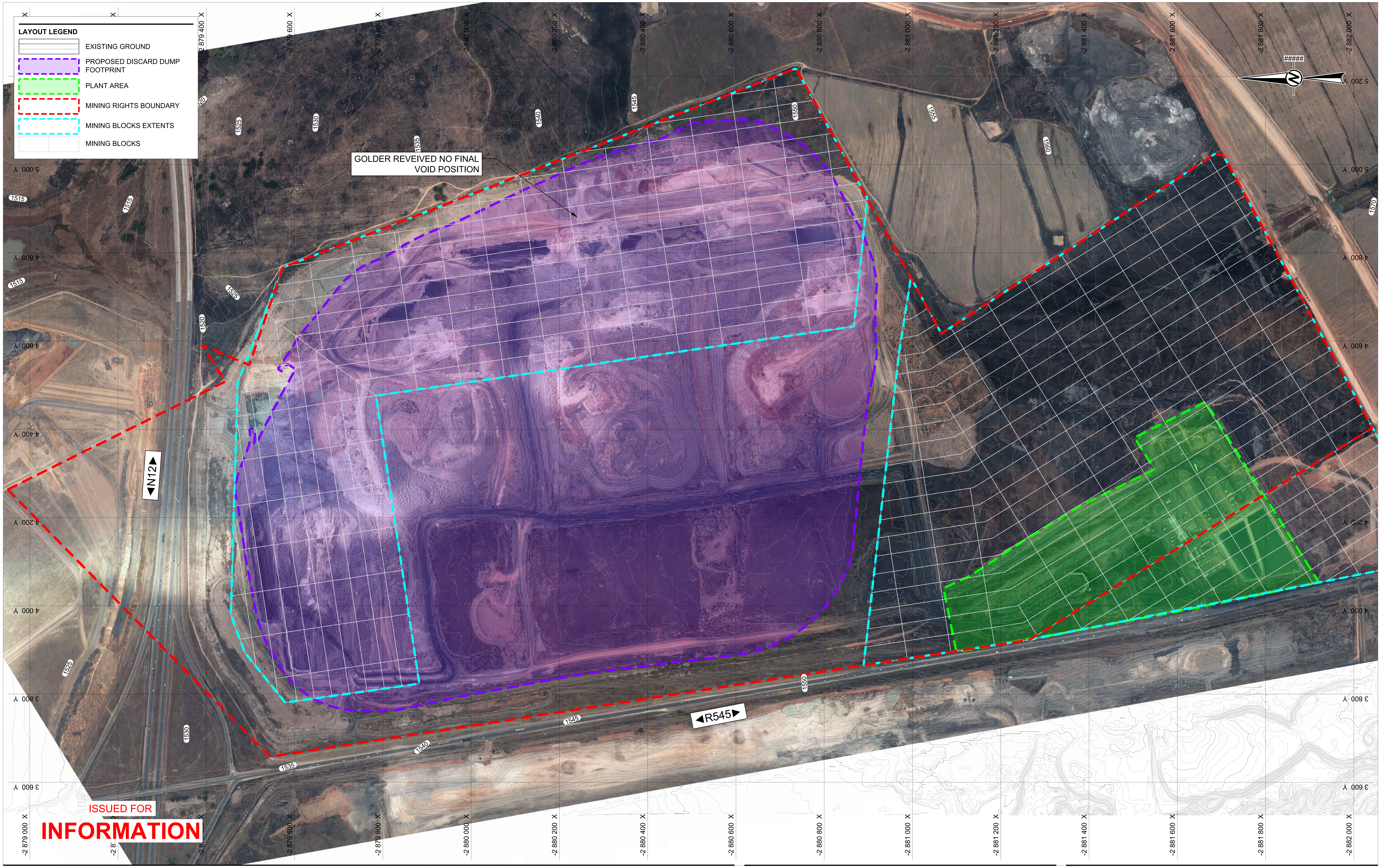

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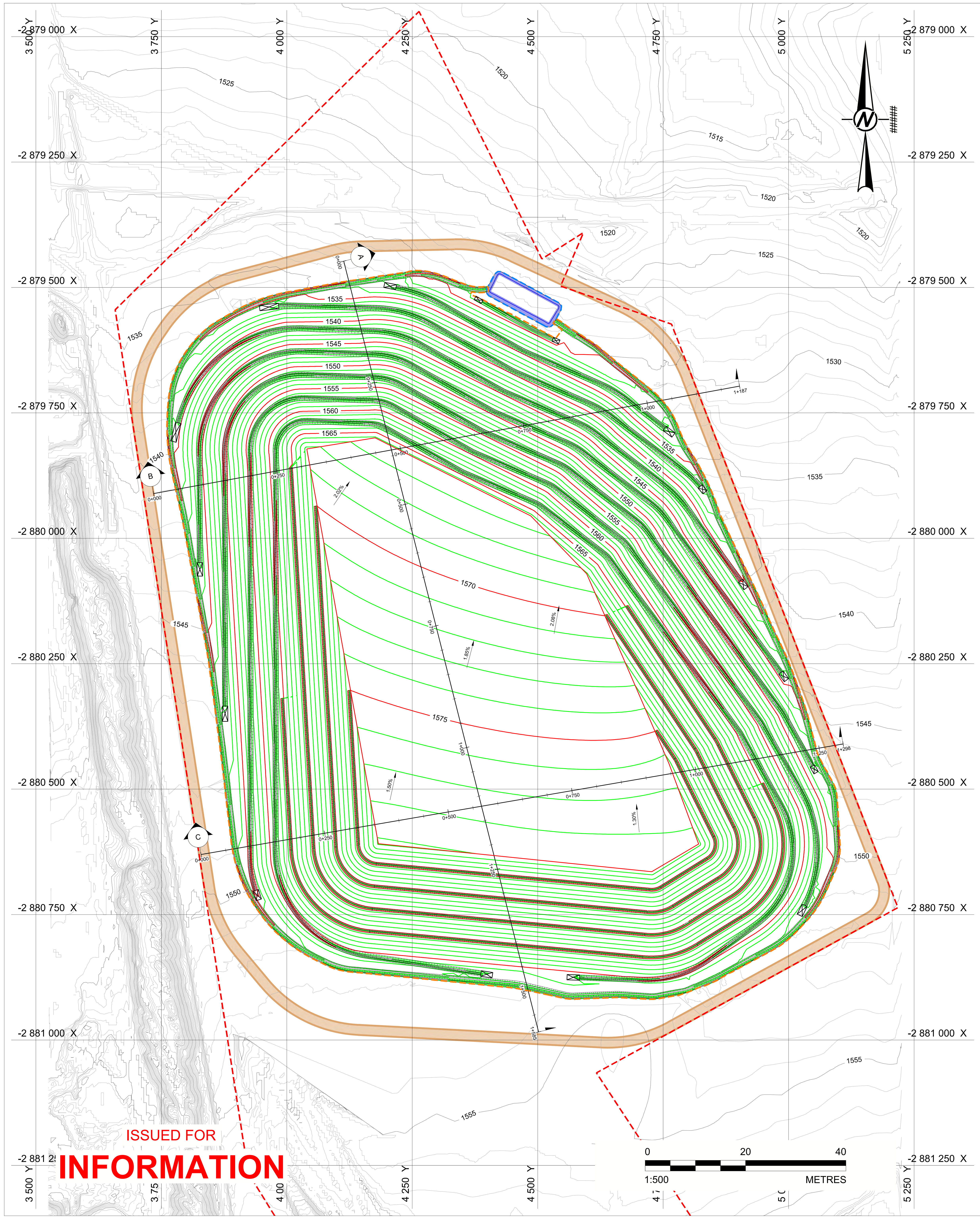
PROJECT
Zibulo Colliery Discard Facility

TITLE
DISCARD FACILITY GENERAL ARRANGEMENT

PROJECT NO.	PLAN	REV.	02 of 10	No
19117180	GA	0		02

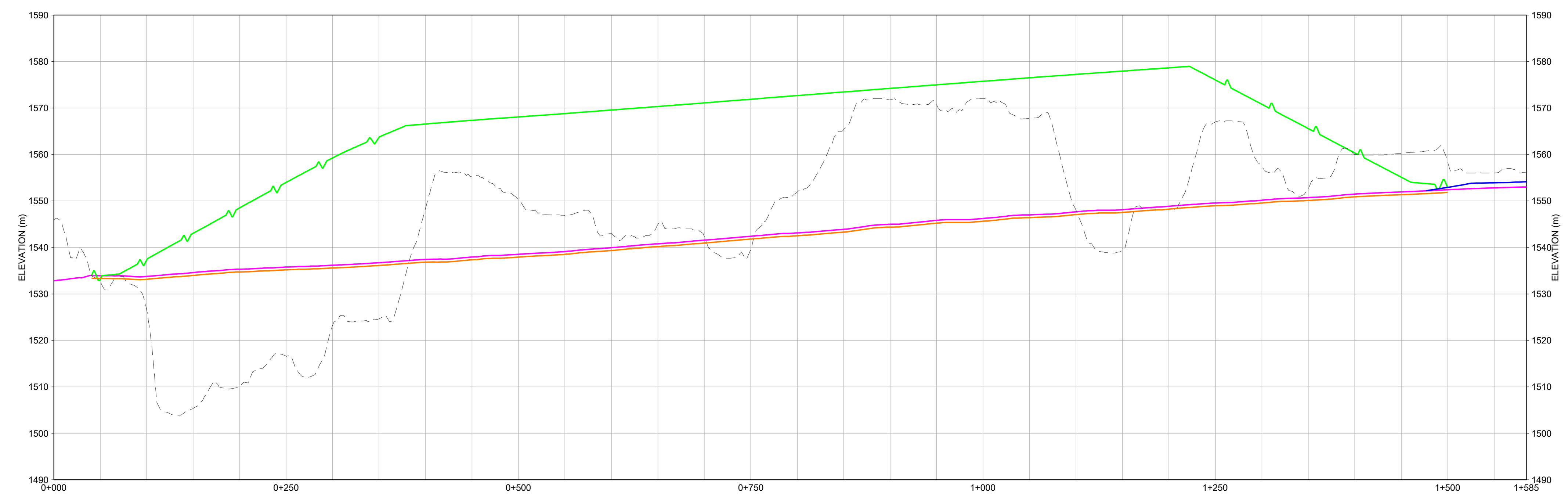


LAYOUT LEGEND

- EXISTING GROUND MARCH 2020
- DISCARD DUMP
- DISCARD DUMP AND PERIMETER CHANNEL EXTENTS
- PROPOSED INFILTRATION PIT
- MINING RIGHTS
- 20m WIDE VEHICLE MOVEMENT AREA
- INSTALL ENERGY DISSIPATOR AND TIE INTO PERIMETER CHANNEL AT 0.67%

SECTION LEGEND

- EXISTING GROUND MARCH 2020
- DISCARD DUMP
- RECEIVED LANDFORM
- 600mm TOPSOIL STRIPPING OFF RECEIVED LANDFORM
- LANDFORM CORRECTION



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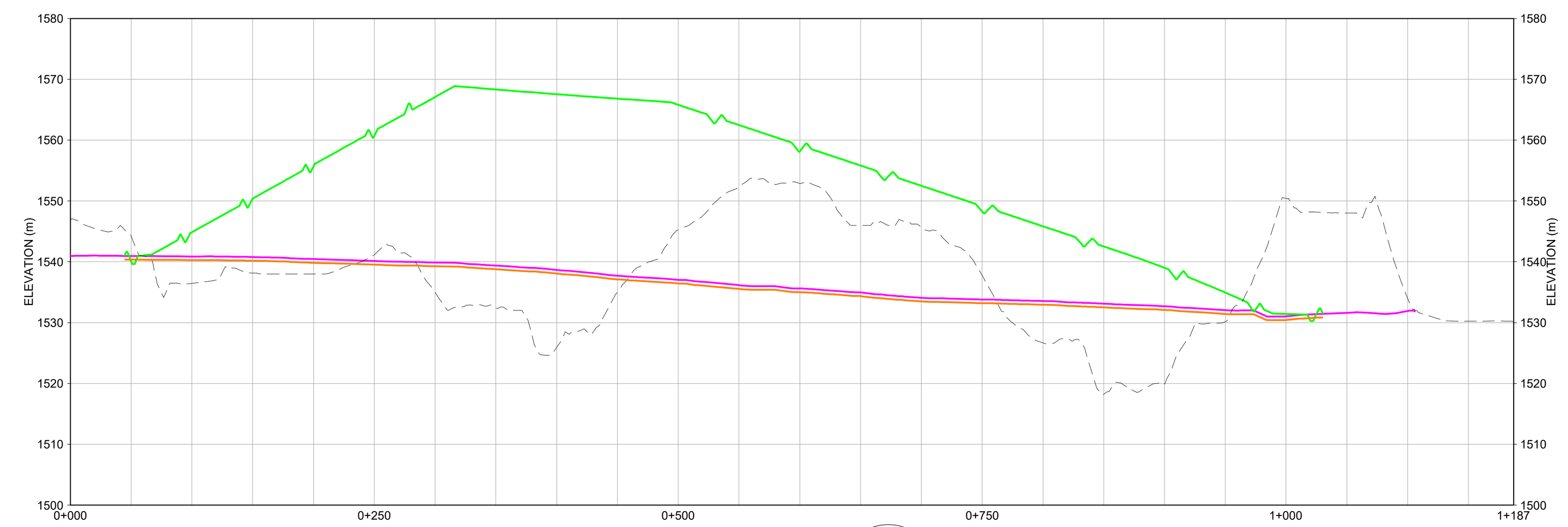

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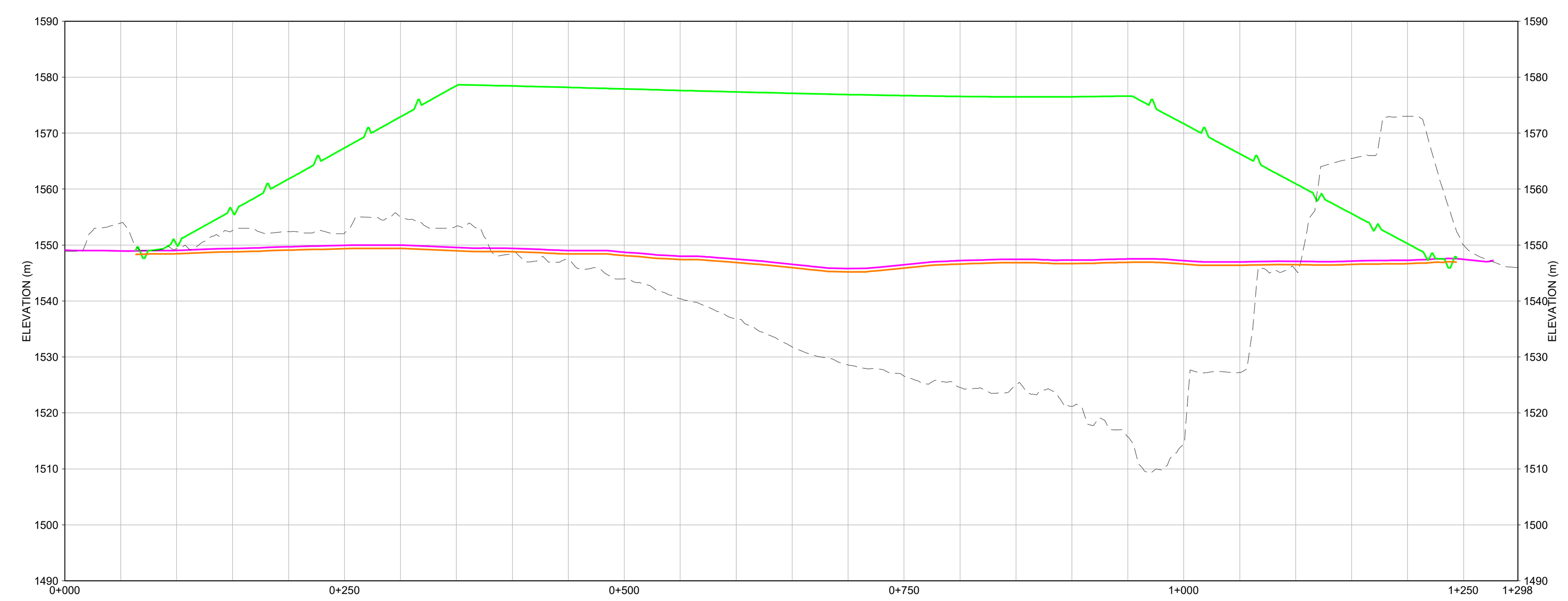

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REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	SIGNED
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PROJECT
Zibulo Colliery Discard Facility

TITLE
DISCARD FACILITY LAYOUT PLAN AND SECTIONS

PROJECT NO.	PLAN	REV.	03 of 10	No
19117180	LP	0		03

25 mm — IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A1