GLENCORE

Dragline Spoils Design Process Optimization at GCSA

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Acknowledgements

- GCSA Management for permission to conduct this study and subsequent presentation at this forum.
- Sandor Pethö – GCSA Manager Rock Engineering, for mentorship and review.
- Danny Barnard – GCSA Group Mining Engineer, for sharing personal experiences on the dragline operation.
- Maemu Mariba – GCSA Strata Control Officer, for assisting with data collection and preparation.

Excluded from this presentation

- Rockfall analysis conducted to determine the in-pit spoil bench effectiveness.
- RS2 modelling results.
- Back analysis of the localised slumping failures on the oversteepened portion of the in-pit spoils.
- Empirical runout distance analysis in the case of failure.
- Dragline spoil surcharge loading.

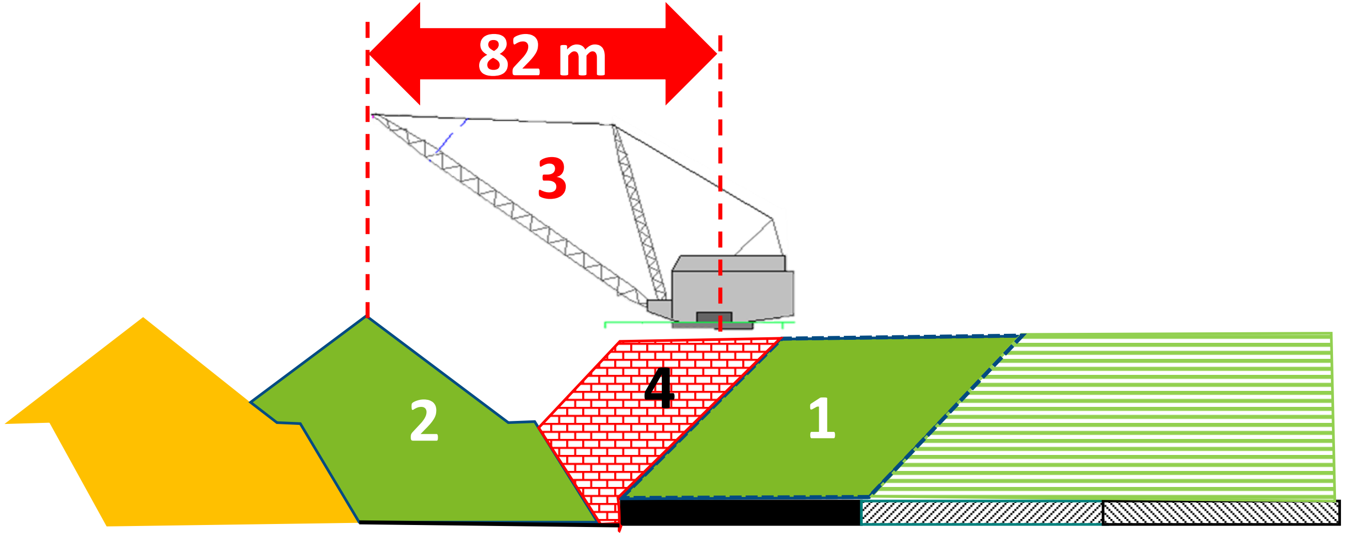
Introduction

- Dragline spoiling and the design thereof forms a critical and integral part of exposing the economic and mineable coal seams for subsequent mining, where mining is conducted using a dragline.
- It is also so for the safety of the subsequent mining activities being conducted below the in-pit spoils, where these are not properly designed and implemented.
- The coal strip mine design has traditionally been a function of optimizing resource exploitation by maximizing the reserve extraction and minimizing waste rehandle, in some instances by trial and error, and have generally been regarded as a low risk mining method.
- However, with the increasing depth of mining and the shift away from extracting virgin coal seams to extracting old underground coal pillars, geotechnical factors assume an increasing level of importance in the design and operation of coal strip mines.
- As part of catastrophic hazard management at GCSA, a group wide Strata Failure bowtie risk assessment was conducted to determine the potential failure modes and the critical controls in line with the International Council of Mining and Metals (ICMM) guideline.
- Due to their heights and potential large runouts relative to the cut widths, dragline spoils were identified as a potential catastrophic hazard exposure, which necessitates a formal design approach with geotechnical input, and the subsequent compliance monitoring thereof.
- In addition, there was a need for integrating the operational design process and the geotechnical design process, in order to optimize the overall mine design process.

DRAGLINE OPERATIONAL DESIGN

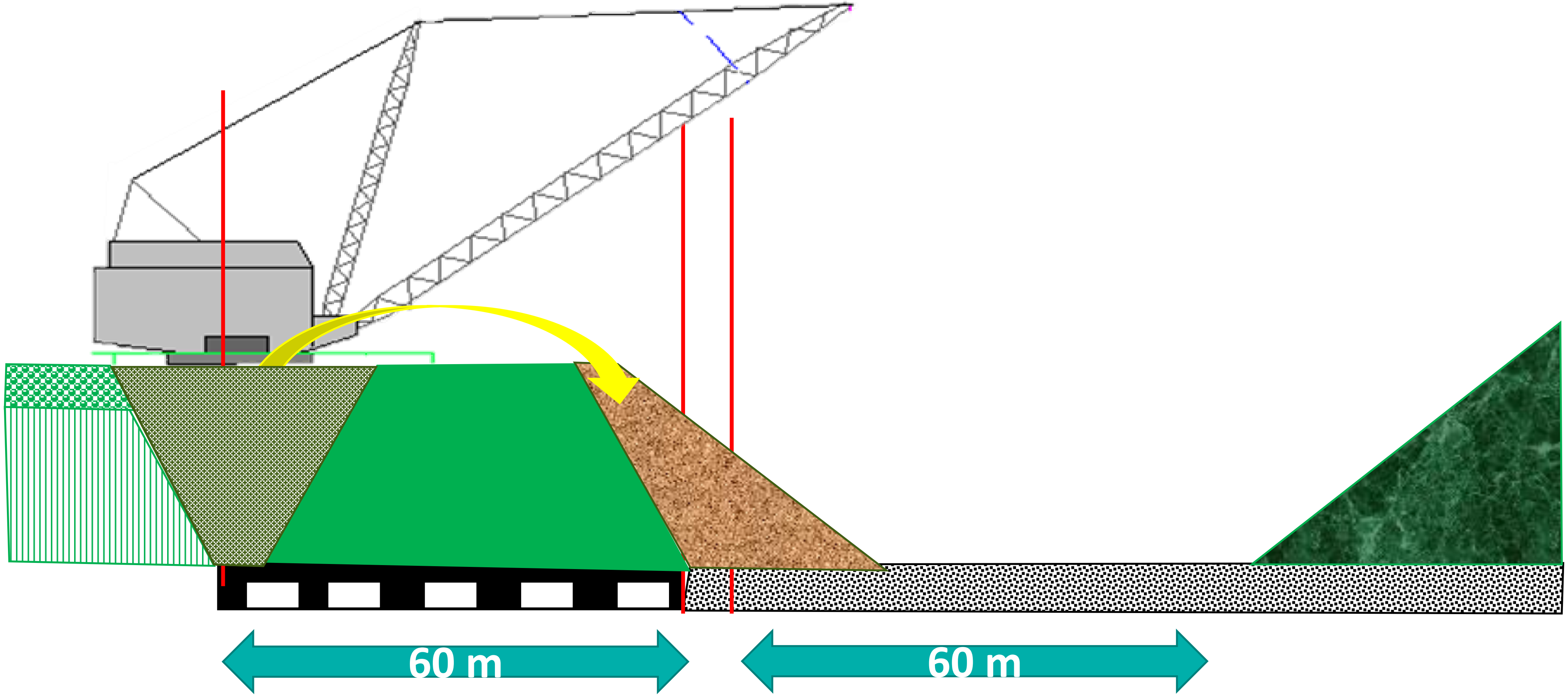
Design process

- The fundamental benefit of a dragline is its ability to reach far and also to reach high with a significant bucket size.
- When planning dragline operations, we want to make use of the full boom length and the available dumping height.
- The dragline position is thus determined by the reach of the boom in relation to the top of the in-pit spoil pile.
- The in-pit spoil height is determined by the available void size and the volume of material to be moved. As the bench height reduces, so the in-pit spoil size will also reduce.
- The optimal dragline position is then located as close to the highwall as practicably possible, thereby minimizing any losses from positioning time.
- When we use the full boom length, we effectively reduce the rehandle caused by excessive pad building.

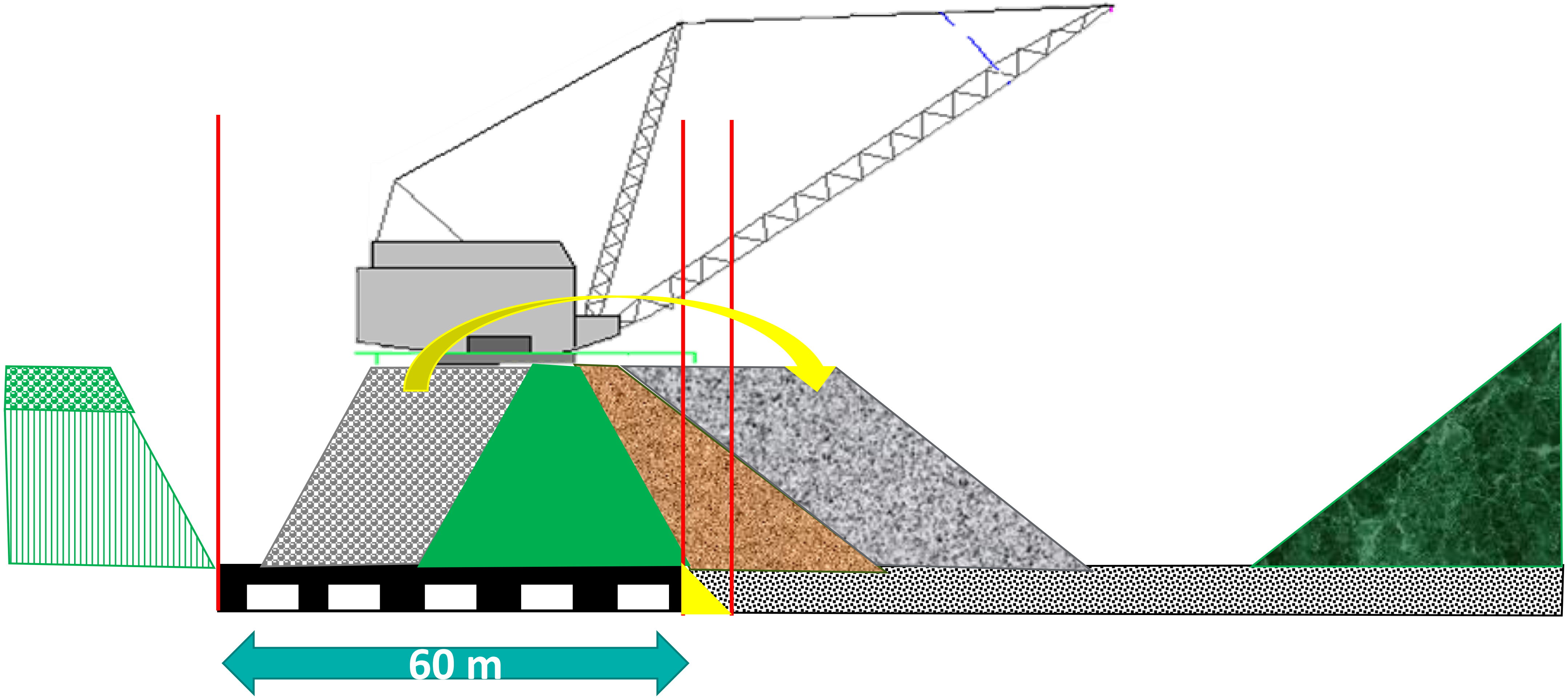


1. Start with the “As is” of the cut, with the previous in-pit spoil, the void and the cut to be mined.
2. Volumetrically transfer the cut to be mined to the void, using the material’s angle of repose.
3. Determine the dragline position from the top of the in-pit spoil pile.
4. Determine the required bench to be built to position the dragline safely. The bench is the rehandle material.

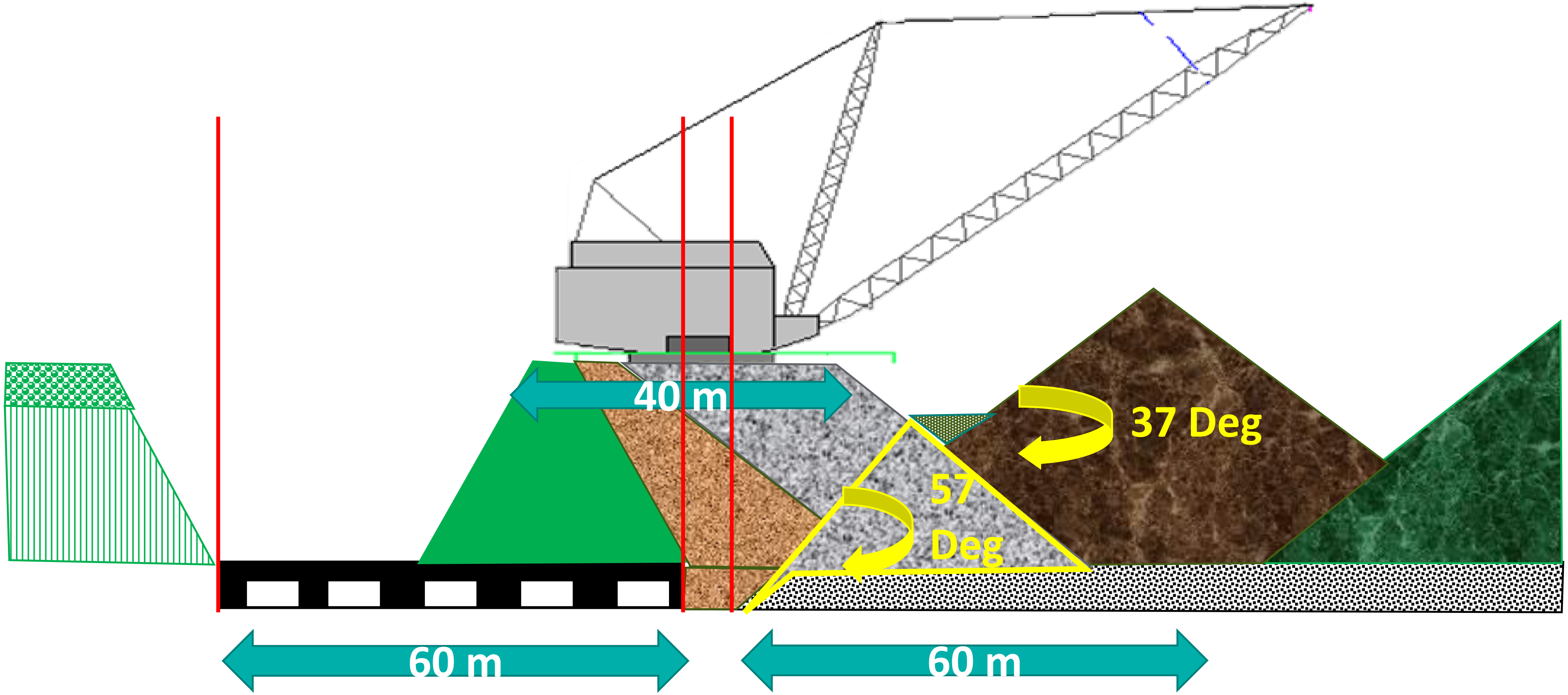
Current method with the extended bench - Step 1



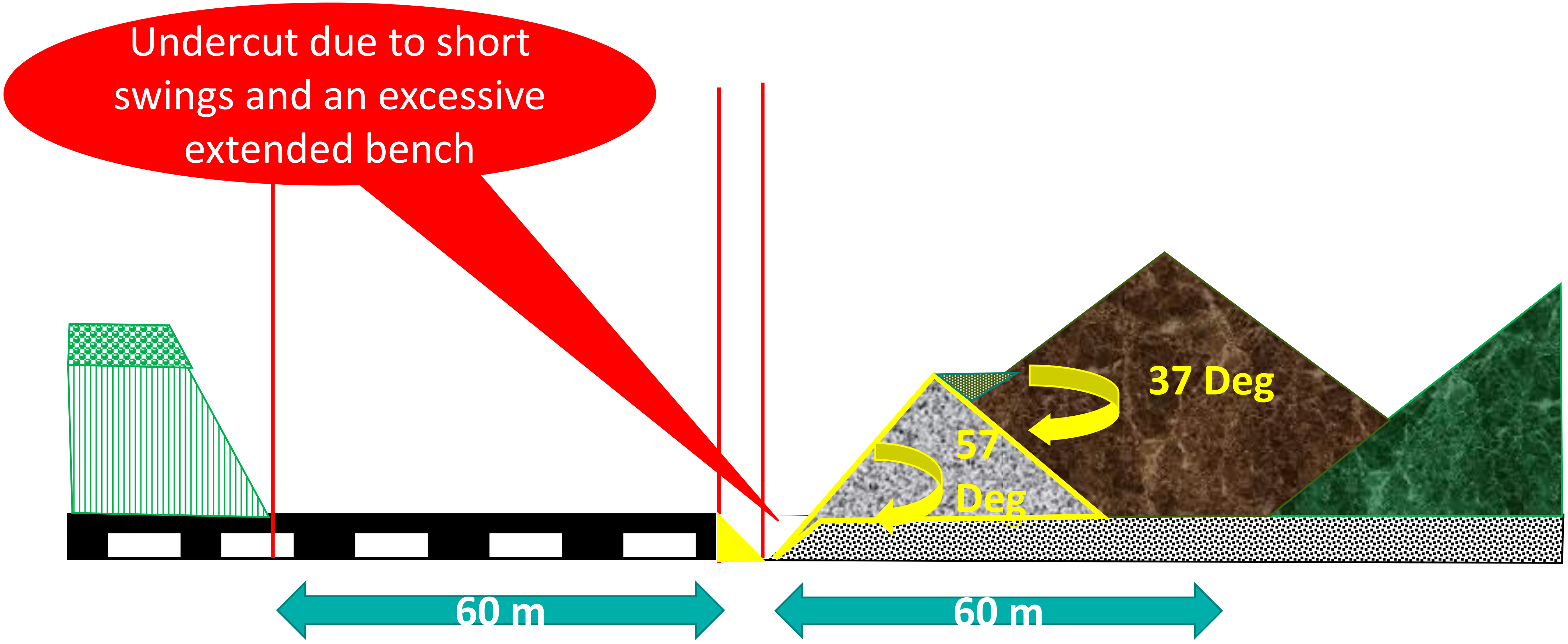
Current method with the extended bench - Step 2



Current method with the extended bench - Step 3



Current method with the extended bench - Step 4



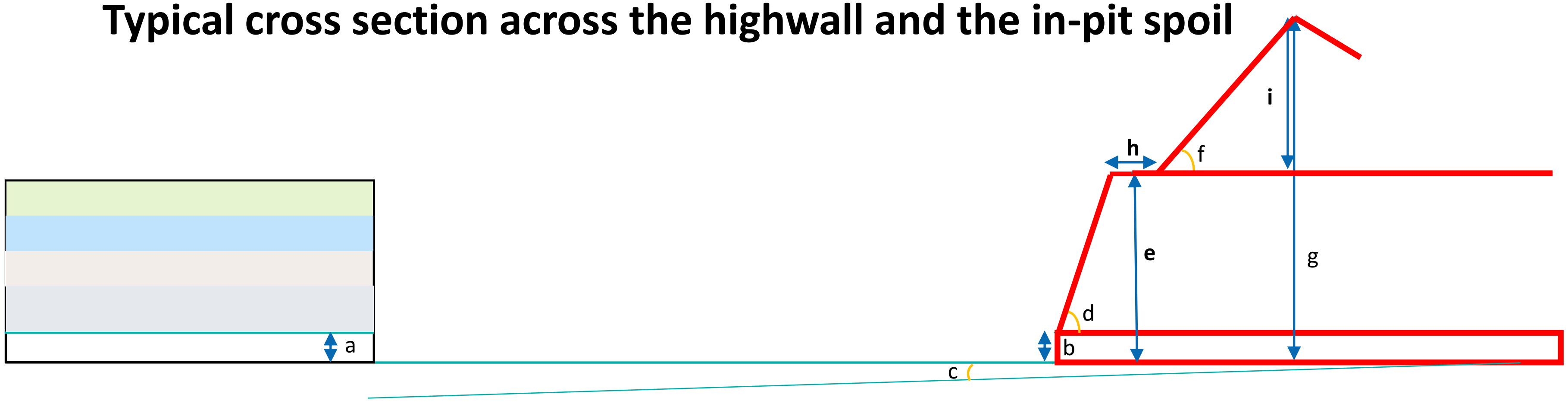
Undercut due to short swings and an excessive extended bench

In-pit spoil geometrical mine design parameters

Legend

a - coal seam thickness [m]
b - discard thickness (height) [m]
c - coal seam floor gradient (dip) [°]
d - over-steepened angle [°]
e - **over-steepened height** (**OH**) [m]
f - angle of repose for the in-pit spoils [°]
h - **in-pit spoil bench width** [m]
g - total height [m]
i - **spoil height** (**SH**) [m]

Typical cross section across the highwall and the in-pit spoil



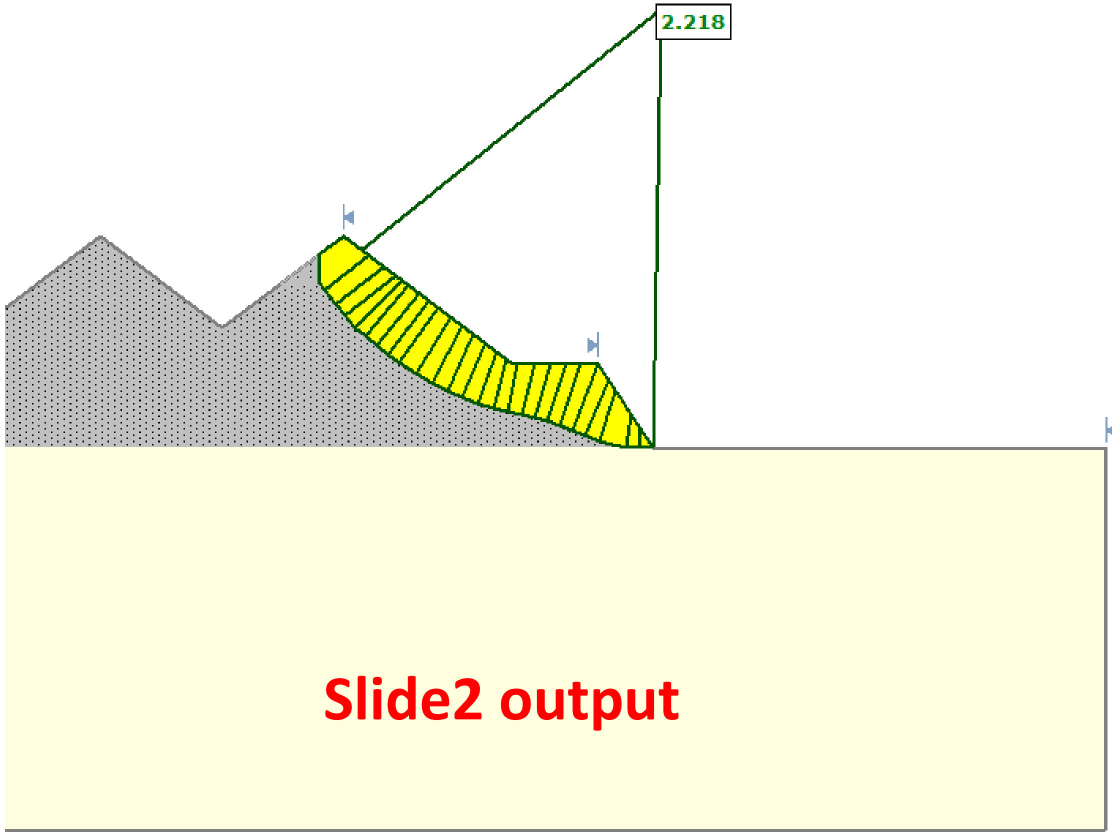
GEOTECHNICAL ASSESSMENT APPROACH

Geotechnical assessment approach

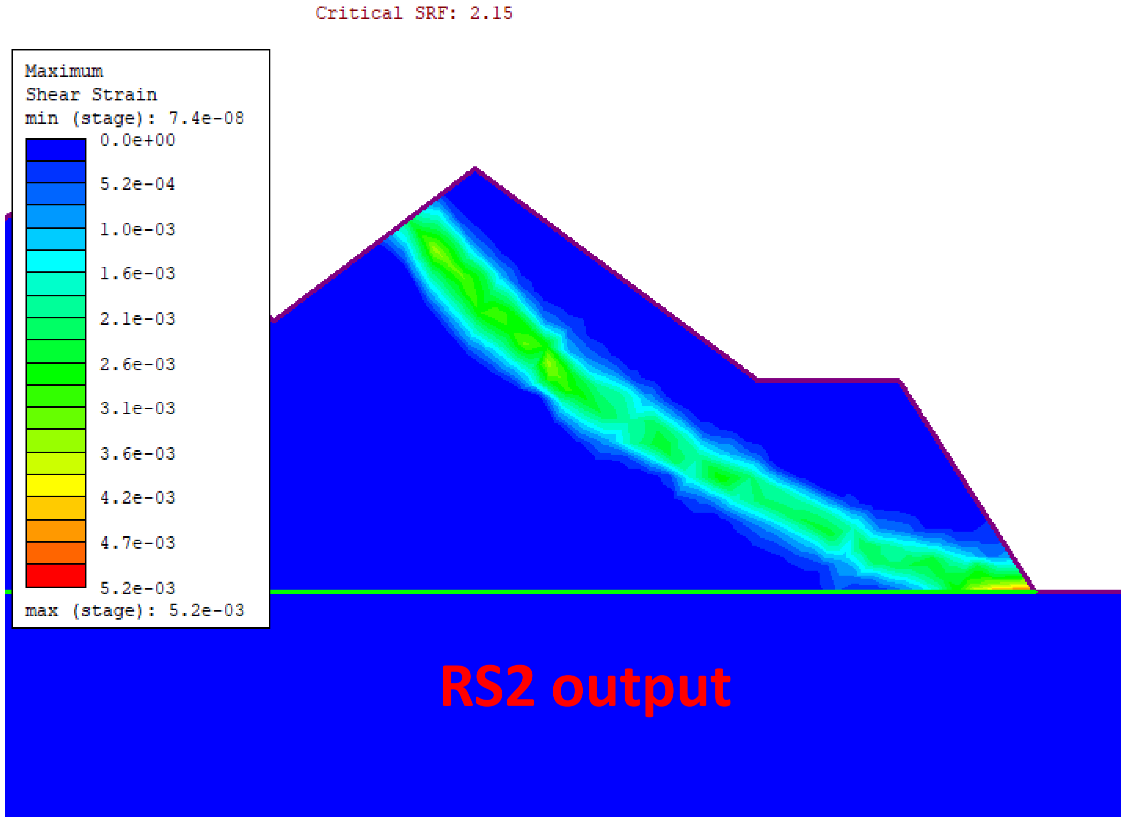
- Numerical modelling was used for the stability assessment of the dragline in-pit spoils using a combination of geometrical parameters.
- The primary base case slope design methodology at GCSA is a 2D Limit Equilibrium (LE) analysis using the *Slide2* Rocscience numerical modelling software package.
- Other numerical methods e.g., FEM, 3D LE are used as secondary analysis methods, and may also be used as the primary slope stability assessment technique, where specific circumstances require this.
- In compliance with the **5.3.2 (c) of the Fatal Hazard Protocols**, both *Slide2* (as a primary tool) and *RS2* (secondary tool) numerical modelling software packages were used in the assessment.
- The results however presented herein are those obtained from the *Slide2* analysis.
- Three scenarios were assessed viz. Spoil material comprising of freshly blasted material; with coal discard material on the foundation and softs material on the lower batter (oversteepened portion of the in-pit spoils).

Geotechnical assessment approach

Examples of the output generated from the two different numerical modelling approaches, using the Rocscience packages.



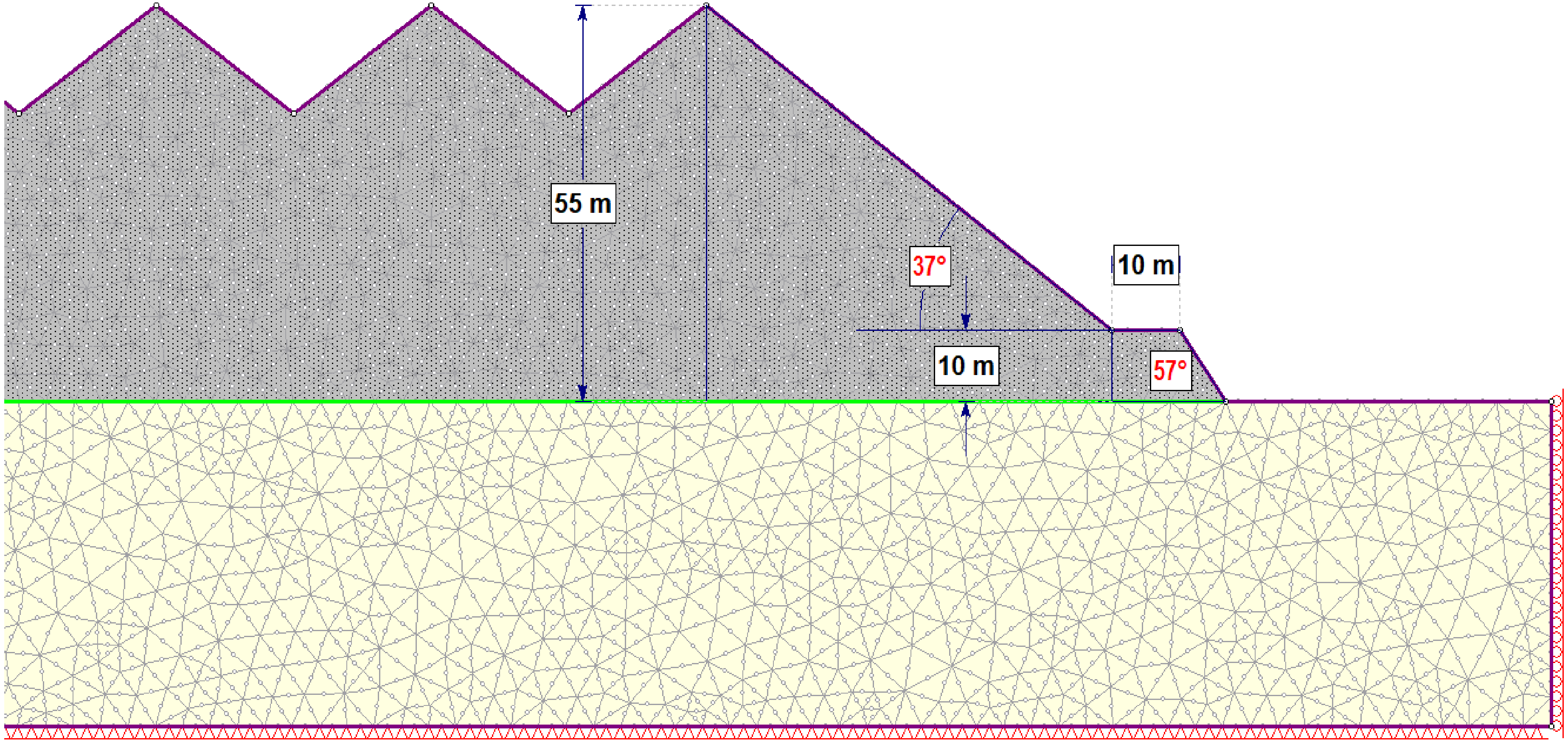
Slide2 output



RS2 output

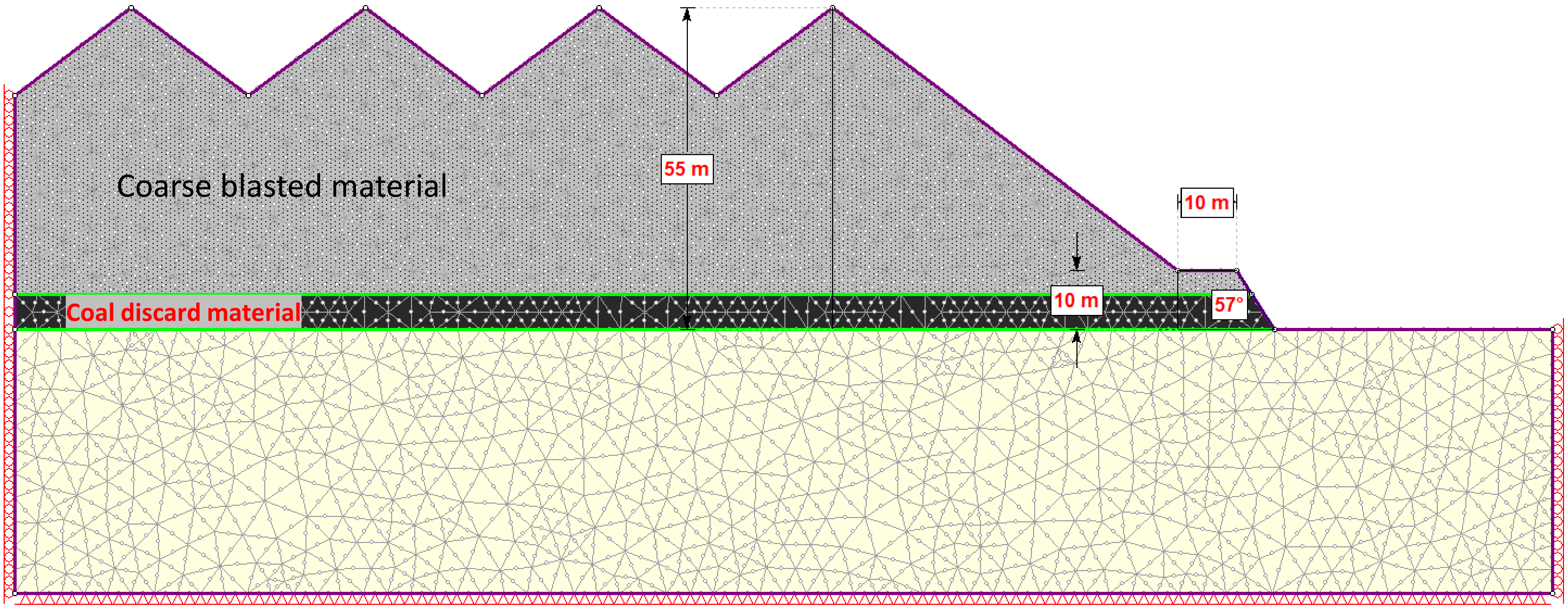
Modelled Scenario 1 - Fresh Blasted Material

- The in-pit spoil comprises only of coarse material from the blasted midburden / interburden.



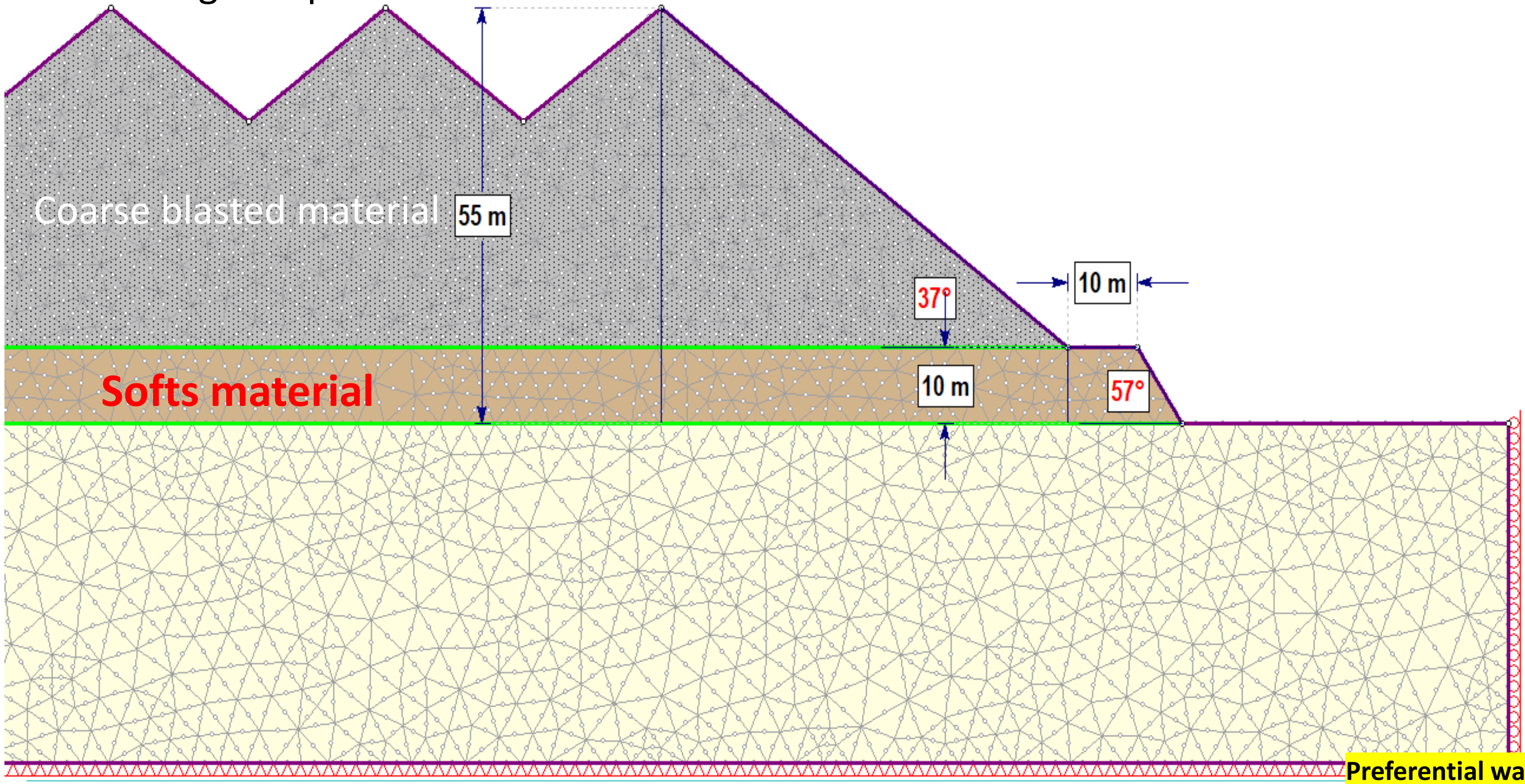
Modelled Scenario 2 – Layer of Coal discard material

- The in-pit spoil comprises of coarse material from the blasted midburden / interburden together with a 6m coal discard layer on the foundation.



Modelled Scenario 3 – With softs material

- The in-pit spoil comprises of coarse material from the blasted midburden / interburden together with softs material from the highwall cladding or sand dressing for SponCom control.



Preferential water flow and perched saturation within the softs material

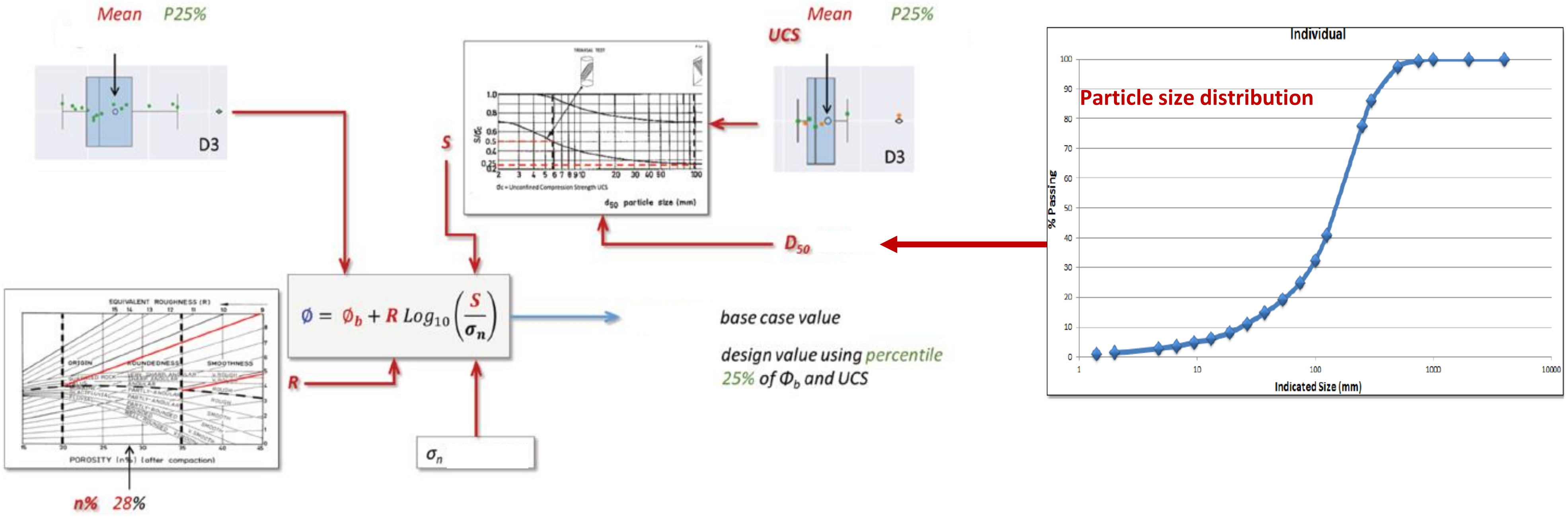
Design acceptance criteria

Consequence[1,3]	Confidence[2,3]	Static analysis		Pseudo-static analysis	Maximum allowable strain[5]
		Minimum FoS	Maximum PoF[4]	Minimum FoS	
Low	Low	1.3 - 1.4	10% - 15%	1.05 - 1.1	≤ 1%
	Moderate	1.2 - 1.3	15% - 25%	1.0 - 1.05	≤ 1.5%
	High	1.1 - 1.2	25% - 40%	1.0	≤ 2%
Moderate	Low	1.4 - 1.5	2.5% - 5%	1.1 - 1.15	≤ 0.75%
	Moderate	1.3 - 1.4	5% - 10%	1.05 - 1.1	≤ 1%
	High	1.2 - 1.3	10% - 15%	1.0 - 1.05	≤ 1.5%
High	Low	≥ 1.5	≤ 1%	1.15	≤ 0.5%
	Moderate	1.4 - 1.5	1% - 2.5%	1.1 - 1.15	≤ 0.75%
	High	1.3 - 1.4	2.5% - 5%	1.05 - 1.1	≤ 1%

[1,2,3,4,5] ***Hawley, M, and Read, J; 2017**, 'Guidelines for Mine Waste Dump and Stockpile Design. CSIRO Publishing CRC Press.*

Input waste dump design parameters

- For the waste rock dump material characterization, the blasting fragmentation analysis conducted as part of the AEL bi-annual audit report was used to ascertain the d_{50} size from the particle size distribution.
- The Barton & Kjaernsli (1981) nonlinear method was then utilized to estimate the shear strength envelope. This method utilizes the insitu Uniaxial Compressive Strength (UCS), d_{50} particle size, degree of particle roundness (R), porosity (n), equivalent strength, (S) and the base friction angle (ϕ_b).
- The result is then used as input in the numerical modelling software package.



Adapted from S Linero-Molina, etal.; (2021)

Input parameters_Coal discard material

Parameter	Coal discard material[2]
Density (kN/m³)	16
Friction angle (°)	37
Cohesion (kPa)	4

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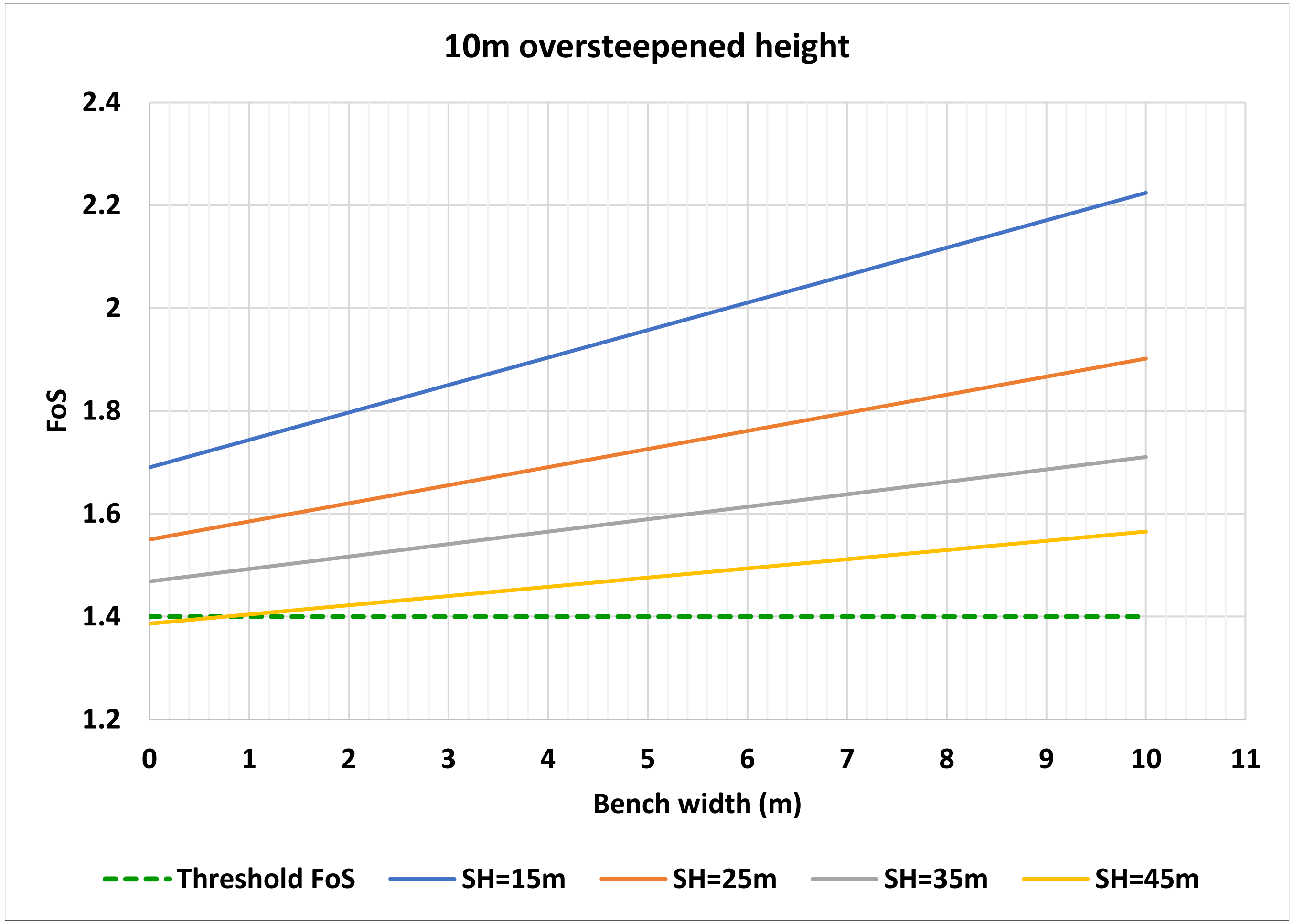
[2] ***Jones & Wagner**, ‘Various TSF technical and inspection reports.*

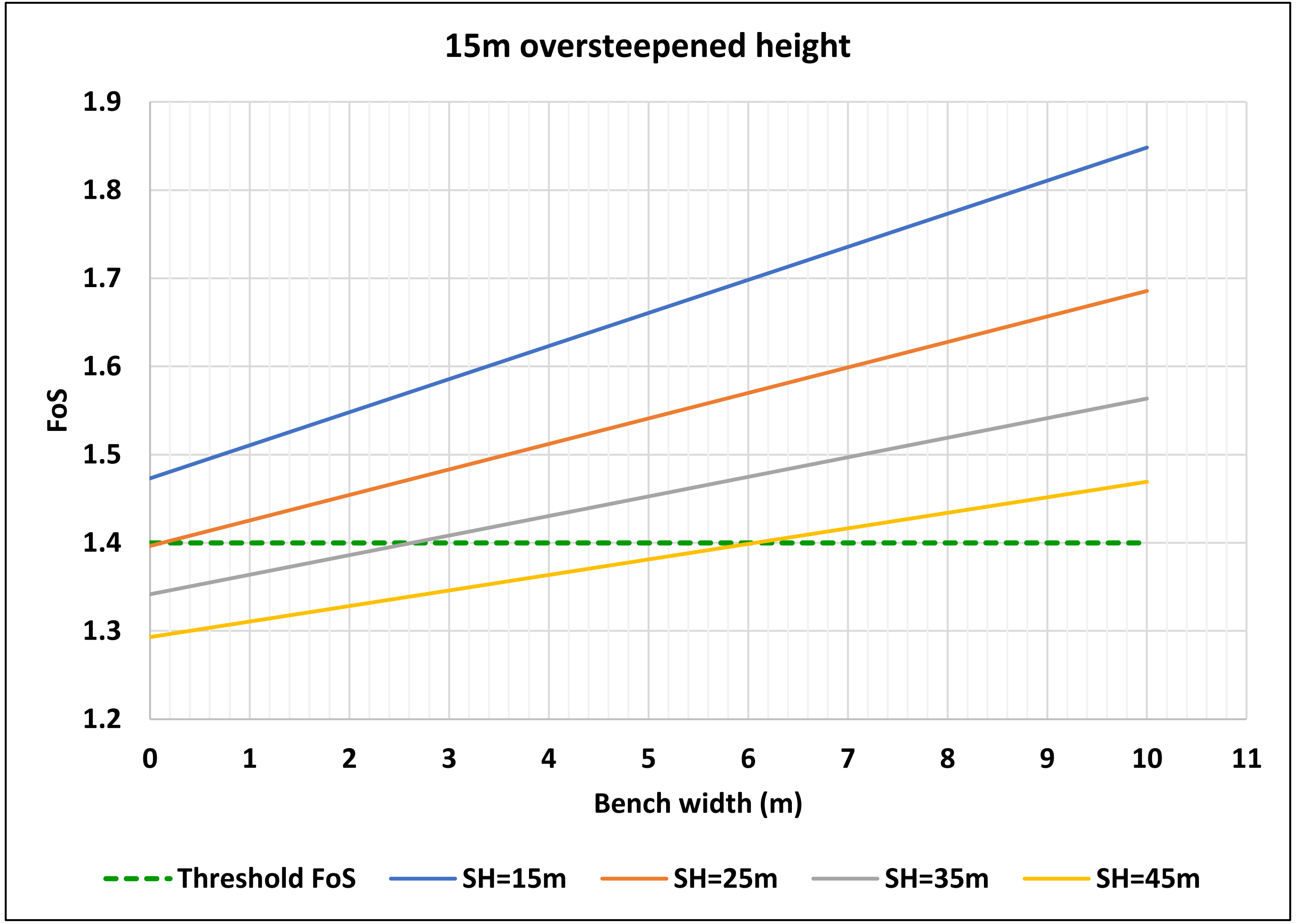
MODELLING RESULTS FOR FRESHLY BLASTED MATERIAL

Modelling result_10m oversteepened height



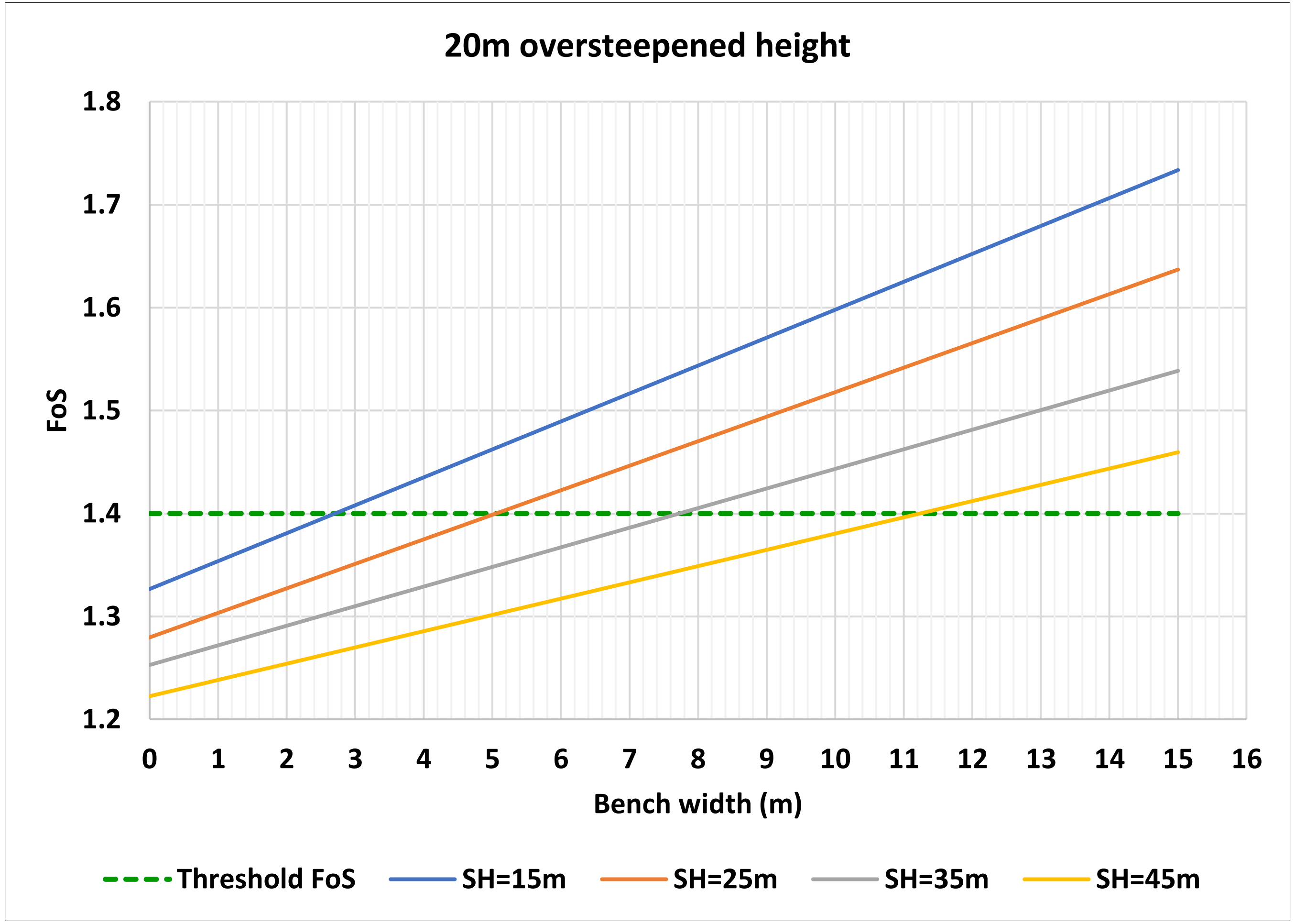
Spoil height (SH) (m)	Required bench width (m)
15	0
25	0
35	0
45	1

Modelling results _15m oversteepened height



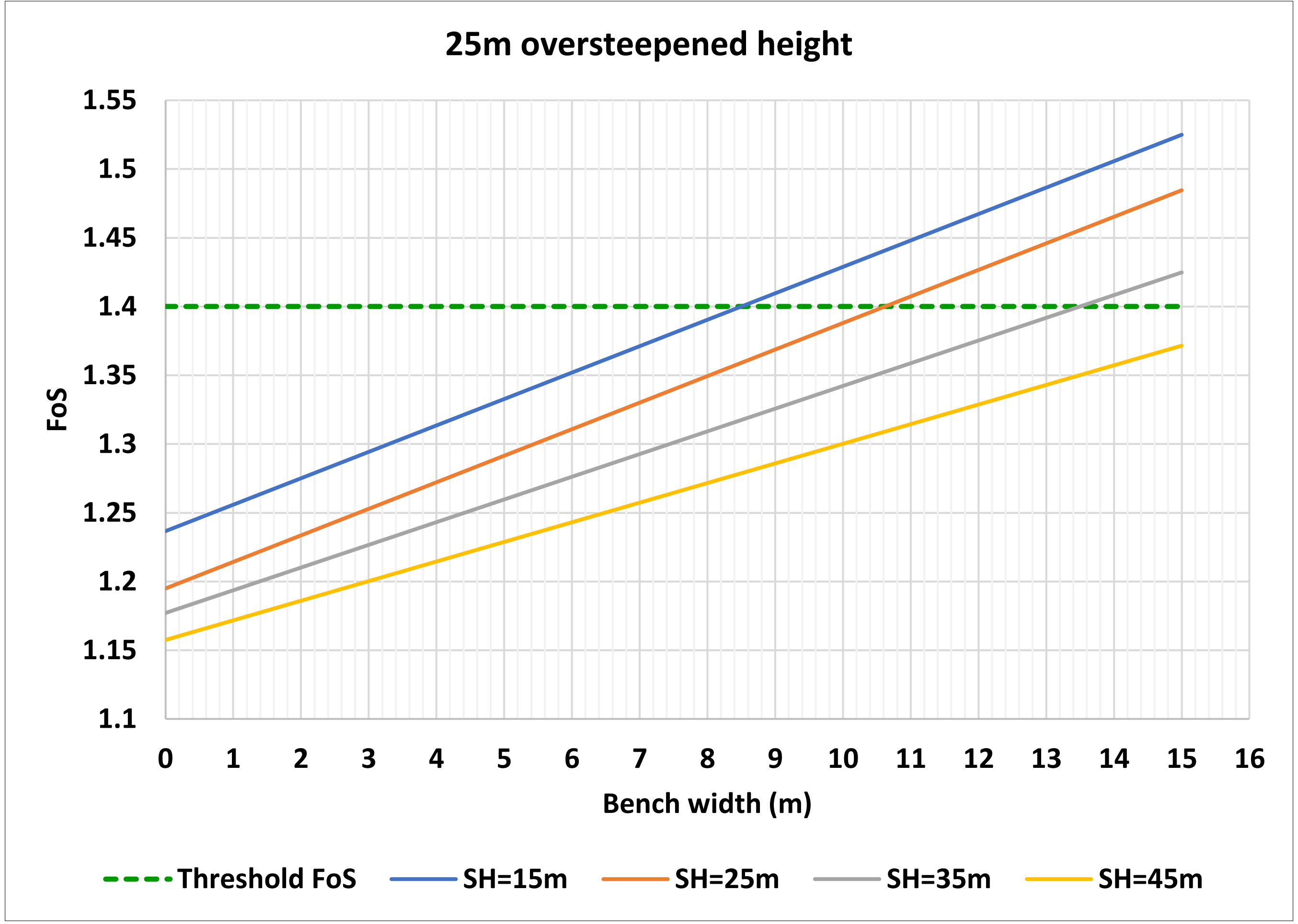
Spoil height (SH) (m)	Required bench width (m)
15	0
25	0.2
35	2.6
45	6

Modelling results _20m oversteepened height



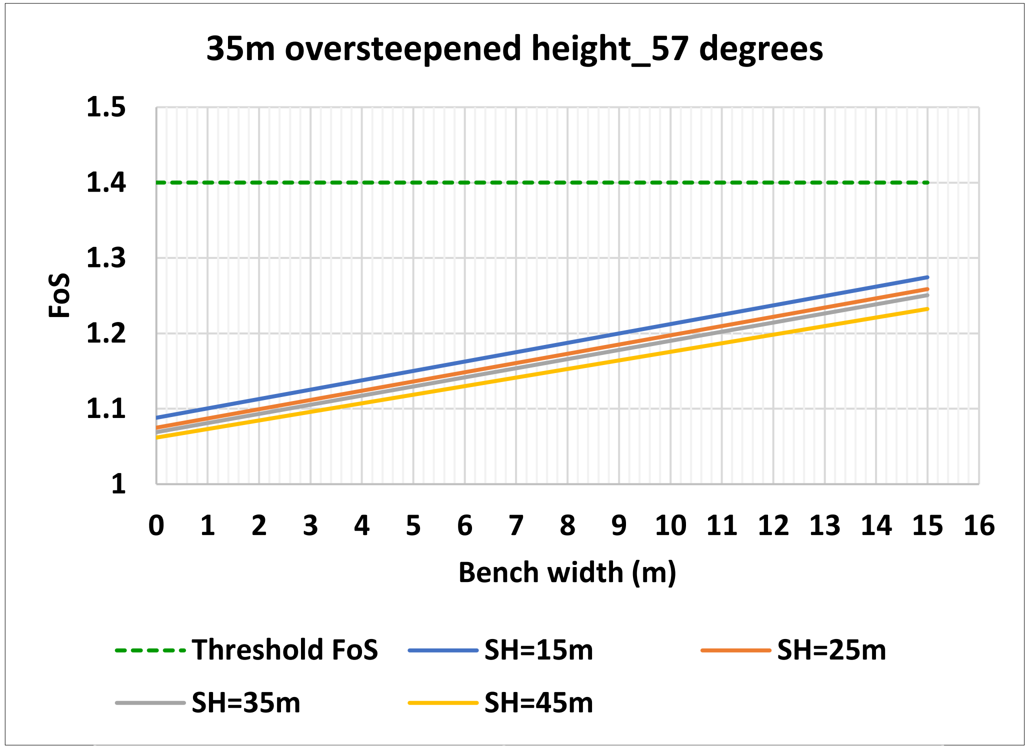
Spoil height (SH) (m)	Required bench width (m)
15	2.8
25	5.0
35	7.6
45	11.2

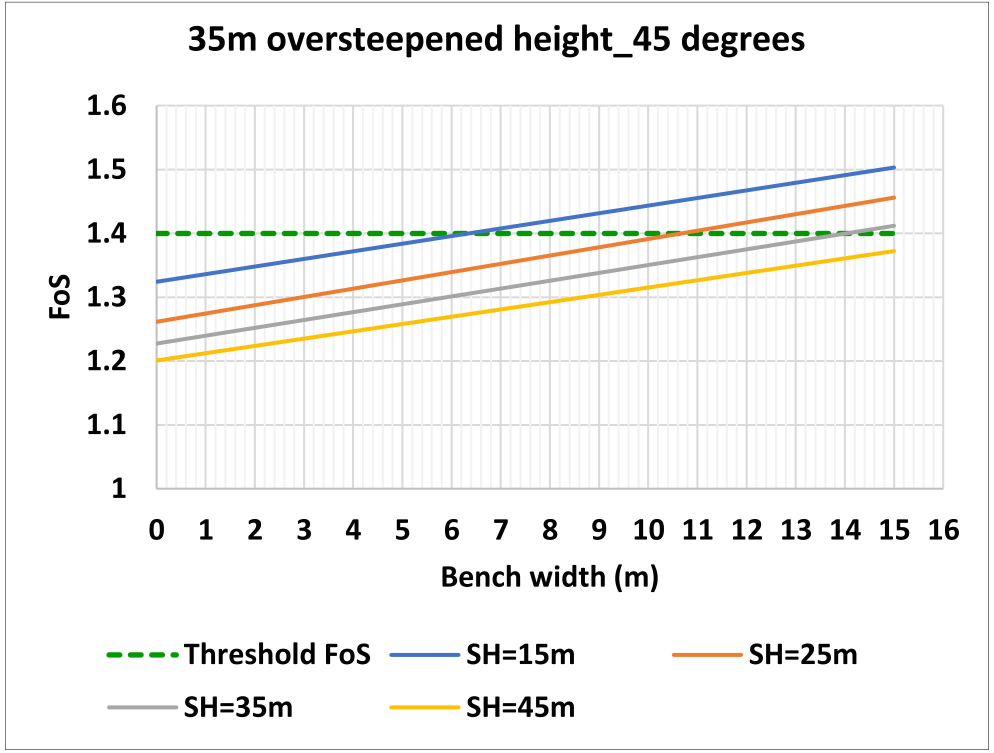
Modelling results _25m oversteepened height



Spoil height (SH) (m)	Required bench width (m)
15	8.6
25	10.6
35	13.4
45	>15

Modelling results _35m oversteepened height



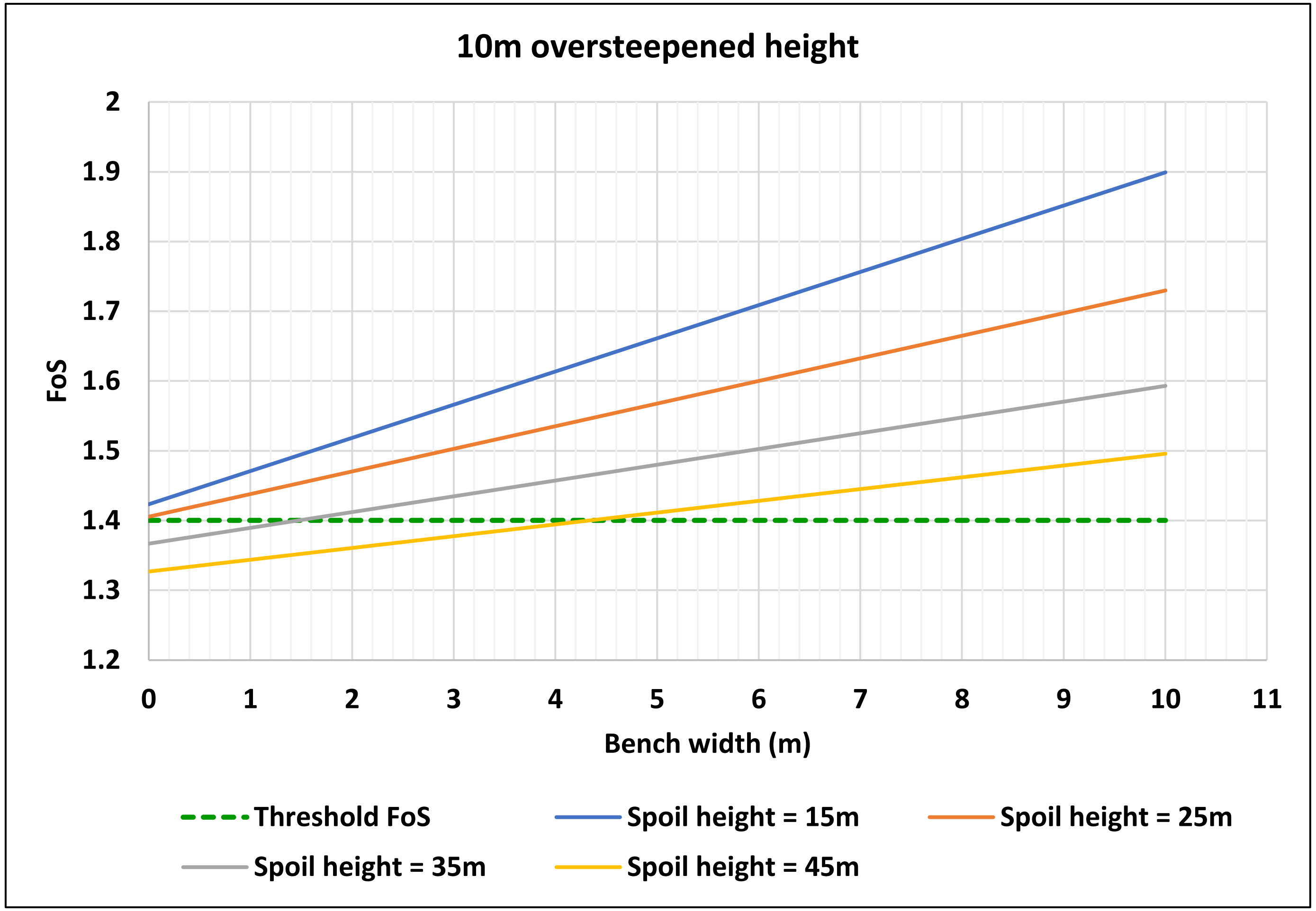


Spoil height (SH) (m)	Required bench width (m)
15	>15
25	>15
35	>15
45	>15

Spoil height (SH) (m)	Required bench width (m)
15	6.4
25	10.8
35	14
45	>15

MODELLING RESULTS WITH SOFTS MATERIAL ON THE FOUNDATION

Modelling results _10m oversteepened height



Spoil height (SH) (m)	Required bench width (m)
15	0
25	0
35	1.6
45	4.4

Modelling results _15m oversteepened height

Spoil height (SH) (m)	Required bench width (m)
15	3.2
25	3.8
35	5.6
45	8.6

Modelling results _20m oversteepened height

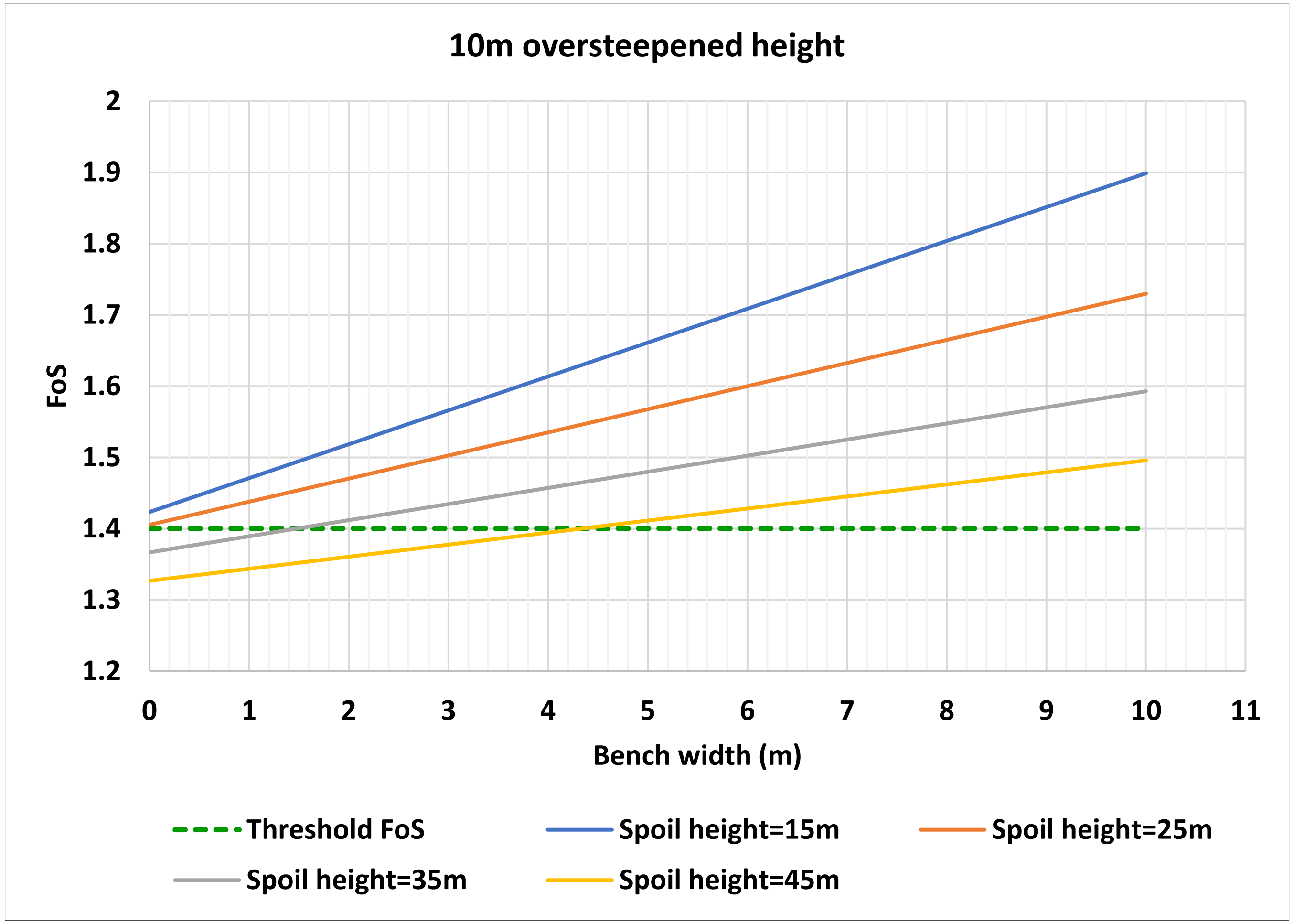
Spoil height (SH) (m)	Required bench width (m)
15	8
25	8.6
35	10.6
45	13.4

Modelling results _25m oversteepened height

Spoil height (SH) (m)	Required bench width (m)
15	14.6
25	>15
35	>15
45	>15

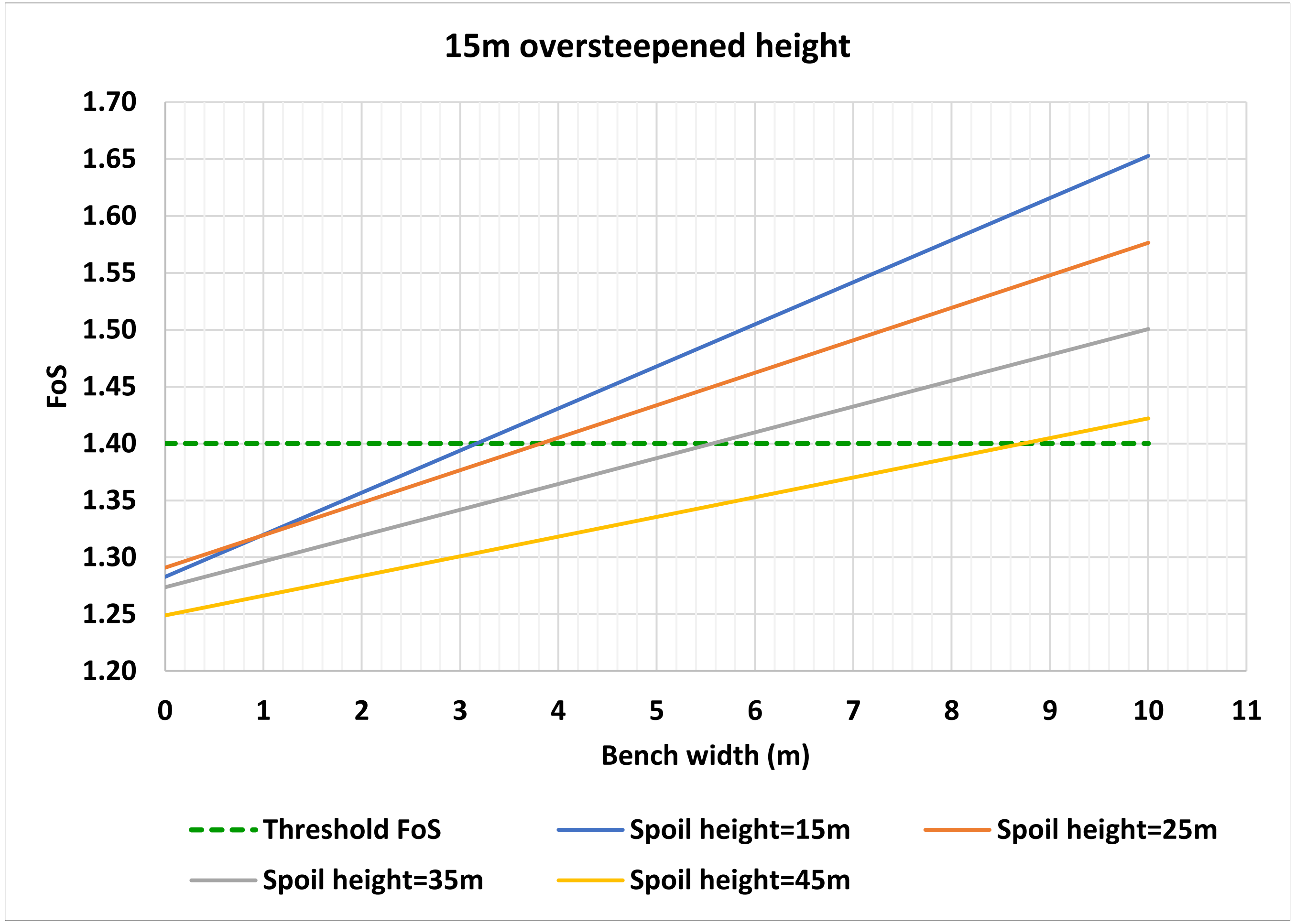
MODELLING RESULTS, WITH COAL DISCARD MATERIAL ON THE FOUNDATION

Modelling results _10m oversteepened height



Spoil height (SH) (m)	Required bench width (m)
15	0
25	0
35	1.5
45	4.2

Modelling results _15m oversteepened height

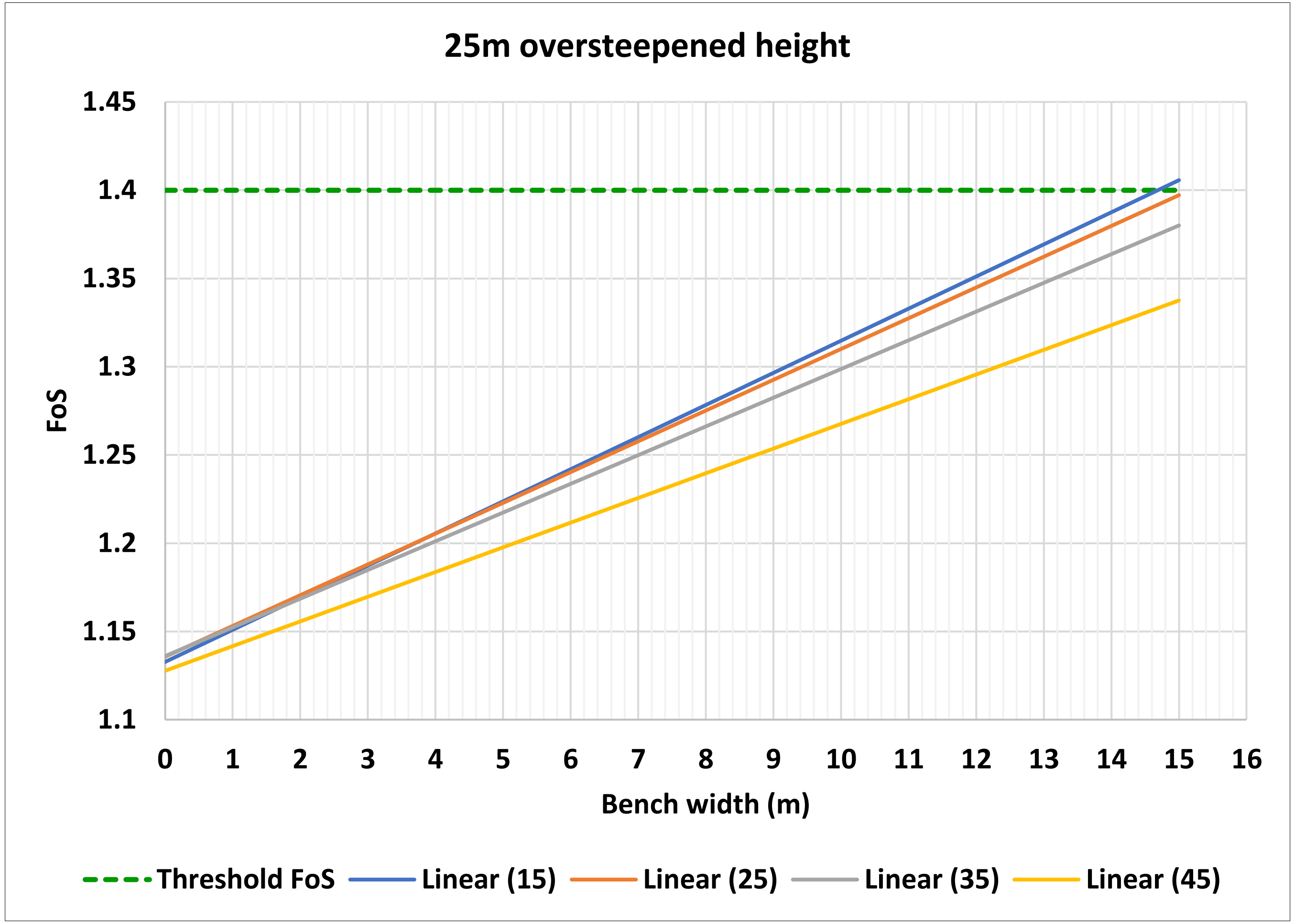


Spoil height (SH) (m)	Required bench width (m)
15	3.2
25	3.8
35	5.6
45	8.8

Modelling results 20m oversteepened height

Spoil height (SH) (m)	Required bench width (m)
15	8
25	8.4
35	10.4
45	13.4

Modelling results _25m oversteepened height



Spoil height (SH) (m)	Required bench width (m)
15	14.6
25	>15
35	>15
45	>15

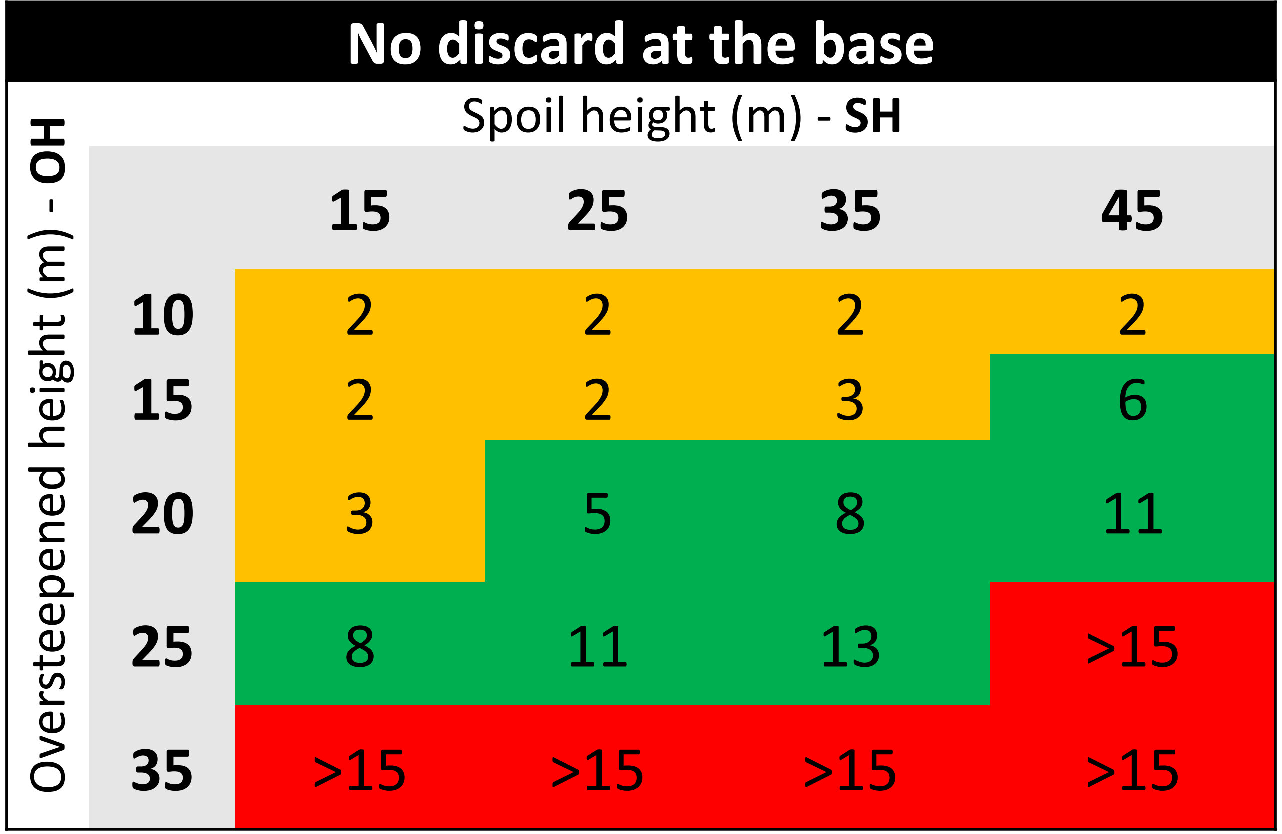
DESIGN MATRICES

Integrated planning tool

Boundaries within which the design matrices were derived

- Oversteepened (dragline extended bench remnant) batter angle was kept constant at 57° throughout all of the scenarios considered.
- Floor gradient assumed to be flat.
- Discard material thickness kept constant at 6m.
- Softs thickness assumed to cover the entire oversteepened height being modelled.
- The maximum remnant extended bench width of 15m was used.
- The calculated bench widths numbers were rounded up for simplicity.

Matrix 1: Freshly blasted material



No discard at the base

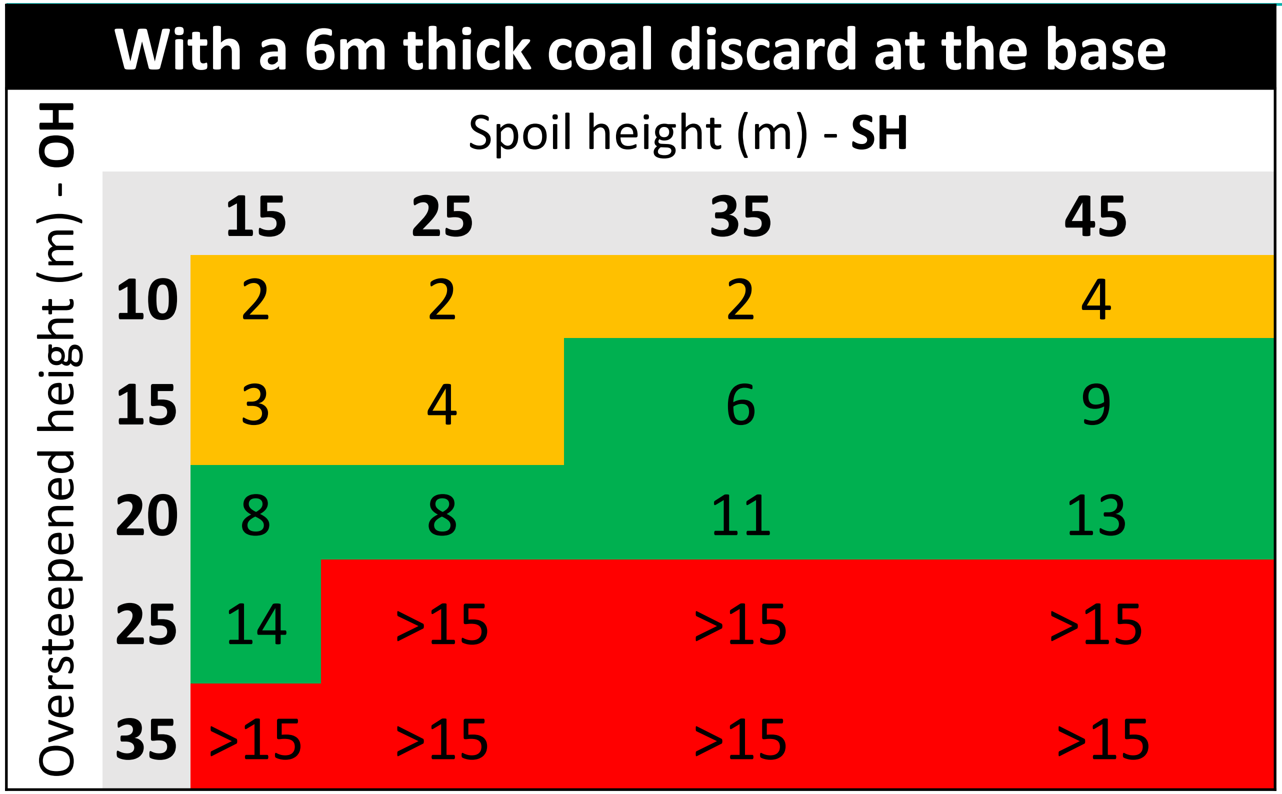
Oversteepened height (m) - **OH**	Spoil height (m) - **SH** 15	25	35	45
10	2	2	2	2
15	2	2	3	6
20	3	5	8	11
25	8	11	13	>15
35	>15	>15	>15	>15

🟨
- **Overall safety factor and stability achieved.**
- **Further analysis required to determine the bench effectiveness for rockfall and localized fall containment.**
- **May consider further geotechnical assessment for the influence of the floor gradient, seismicity where applicable, excessive pore pressure, etc.**

🟩
- **Overall safety factor and stability achieved.**
- **Bench considered effective for rockfall and localized fall containment.**
- **May consider further geotechnical assessment for the influence of the floor gradient, seismicity where applicable, excessive pore pressure, etc.**
- **Ensure that the bench width complies with the rockfall effectiveness requirements.**

🟥
- **Overall safety factor and stability not achieved.**
- **Review the oversteepened angles and related mine design parameters.**

Matrix 2: With a 6m thick coal discard material



With a 6m thick coal discard at the base

Oversteepened height (m) - **OH**	Spoil height (m) - **SH**			
	15	**25**	**35**	**45**
10	2	2	2	4
15	3	4	6	9
20	8	8	11	13
25	14	>15	>15	>15
35	>15	>15	>15	>15

- **Overall safety factor and stability achieved.**
- **Further analysis required to determine the bench effectiveness for rockfall and localized fall containment.**
- **May consider further geotechnical assessment for the influence of the floor gradient, seismicity where applicable, excessive pore pressure, etc.**

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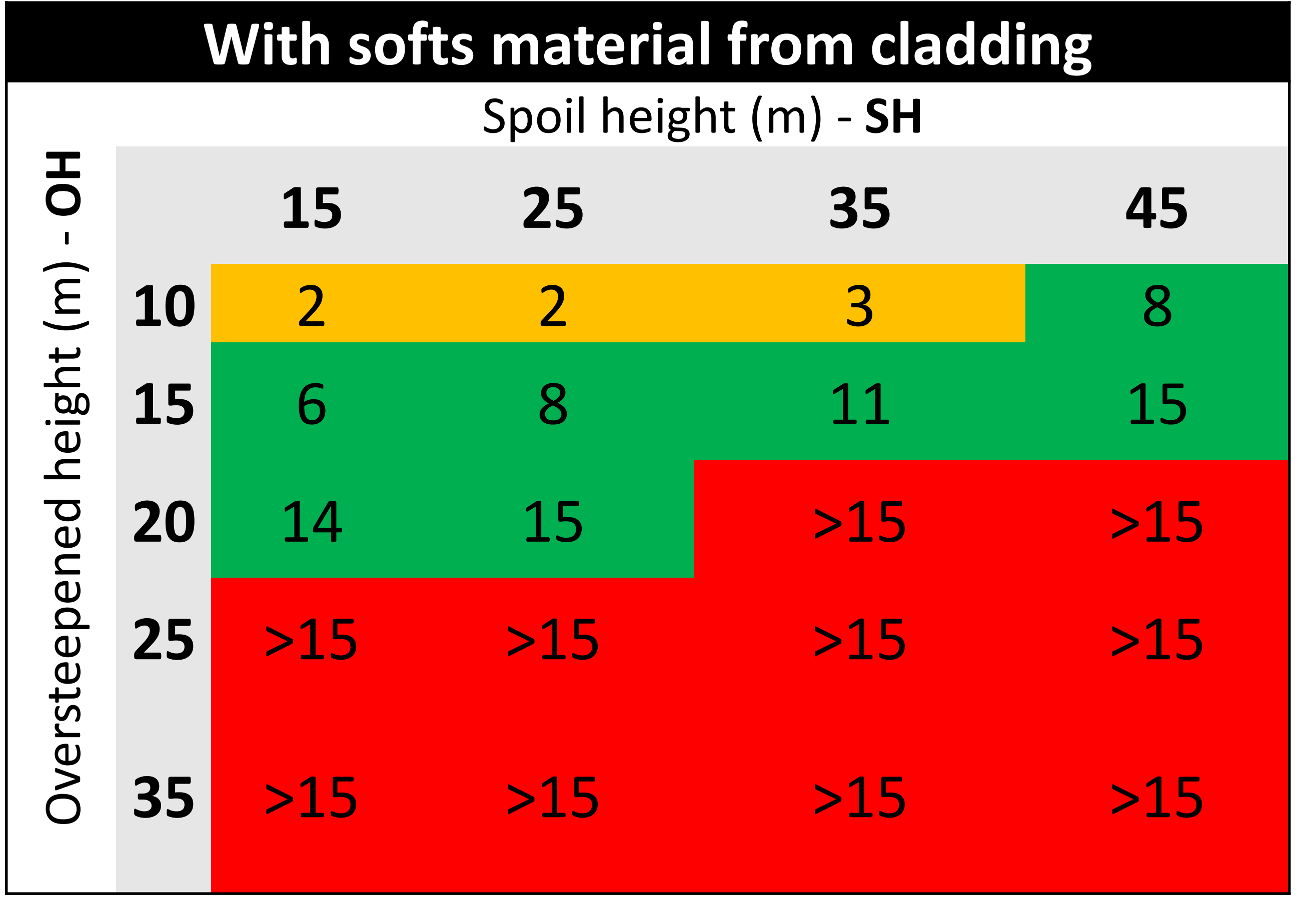
- **Overall safety factor and stability not achieved.**
- **Review the oversteepened angles and related mine design parameters.**

Matrix 3: With softs material



With softs material from cladding

	Spoil height (m) - **SH**			
Oversteepened height (m) - **OH**	**15**	**25**	**35**	**45**
10	🟨 2	🟨 2	🟨 3	🟩 8
15	🟩 6	🟩 8	🟩 11	🟩 15
20	🟩 14	🟩 15	🟥 >15	🟥 >15
25	🟥 >15	🟥 >15	🟥 >15	🟥 >15
35	🟥 >15	🟥 >15	🟥 >15	🟥 >15

🟨
- **Overall safety factor and stability achieved.**
- **Further analysis required to determine the bench effectiveness for rockfall and localized fall containment.**
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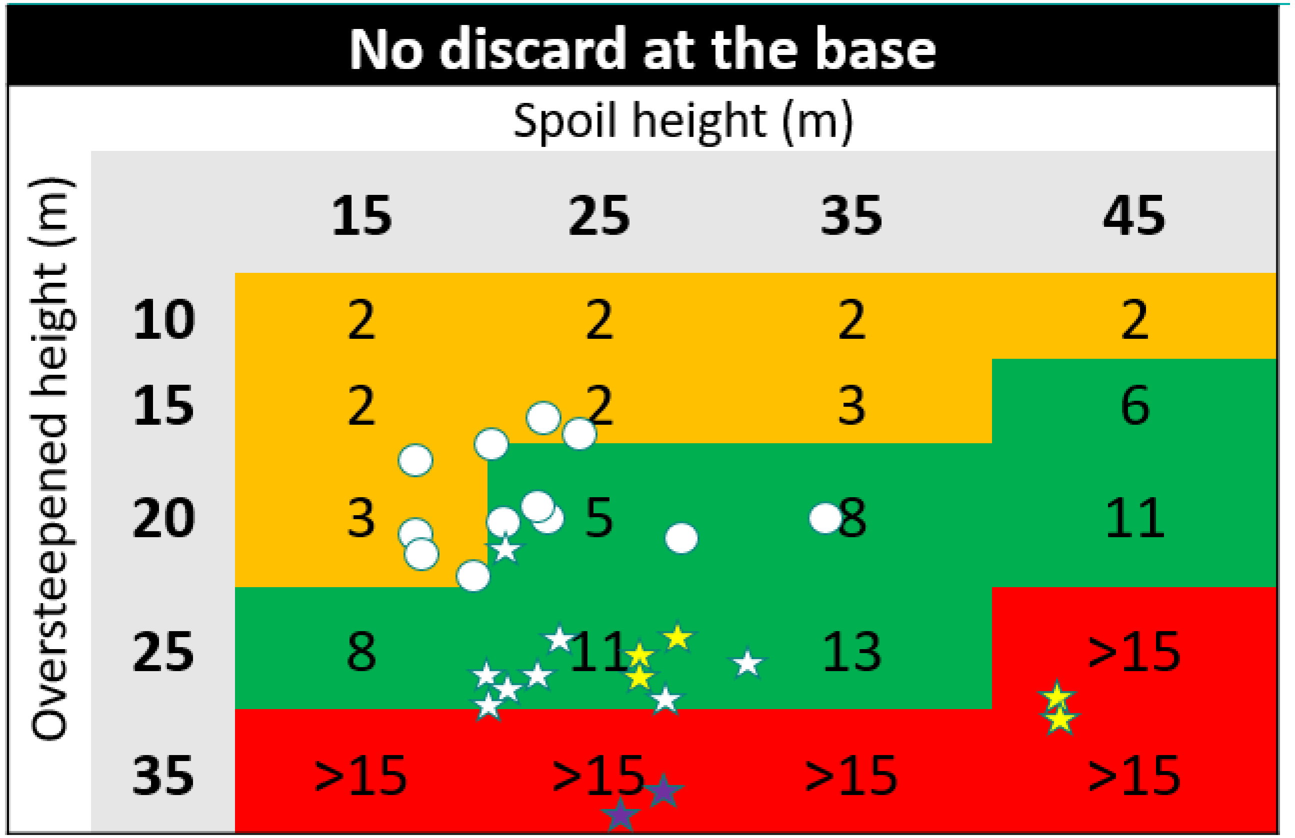
🟥
- **Overall safety factor and stability not achieved.**
- **Review the oversteepened angles and related mine design parameters.**

CASE STUDY EXAMPLES

Actual case studies

- Thirty-eight (38) sections of the actual dragline in-pit spoil geometries were obtained from the various complexes.
- Spoil heights (**SH**) were measured together with the oversteepened height (**OH**) and the bench width.
- These were then plotted on the relevant design matrix.

Site 1 - Case Study



No discard at the base

Oversteepened height (m)	Spoil height (m) 15	25	35	45
10	2	2	2	2
15	2	2	3	6
20	3	5	8	11
25	8	11	13	>15
35	>15	>15	>15	>15

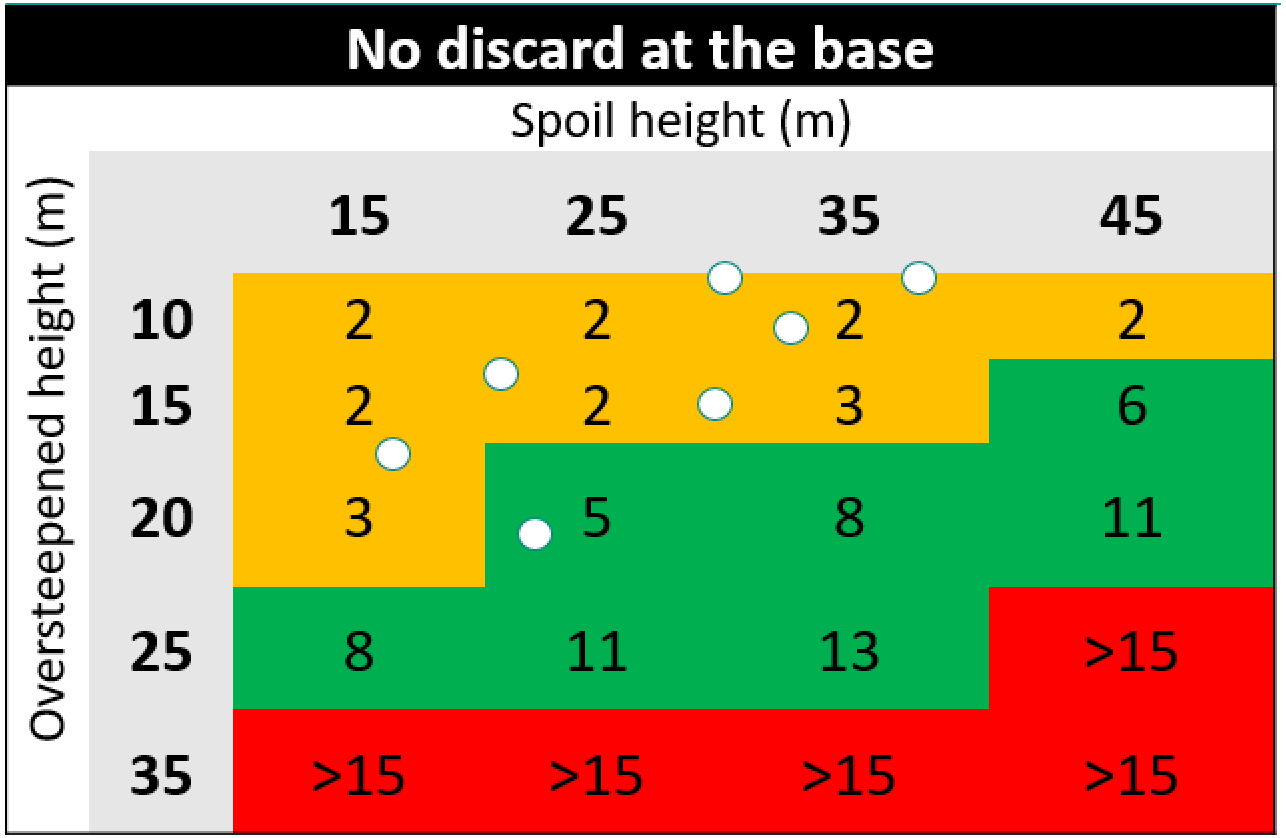
○ NW Pit

☆ RW Pit: Actual bench width is compliant

★ RW Pit: Actual bench width is non-compliant

★ RW Pit: Actual oversteepened height exceeds the range covered off in the assessment

Site 2 - Case Study

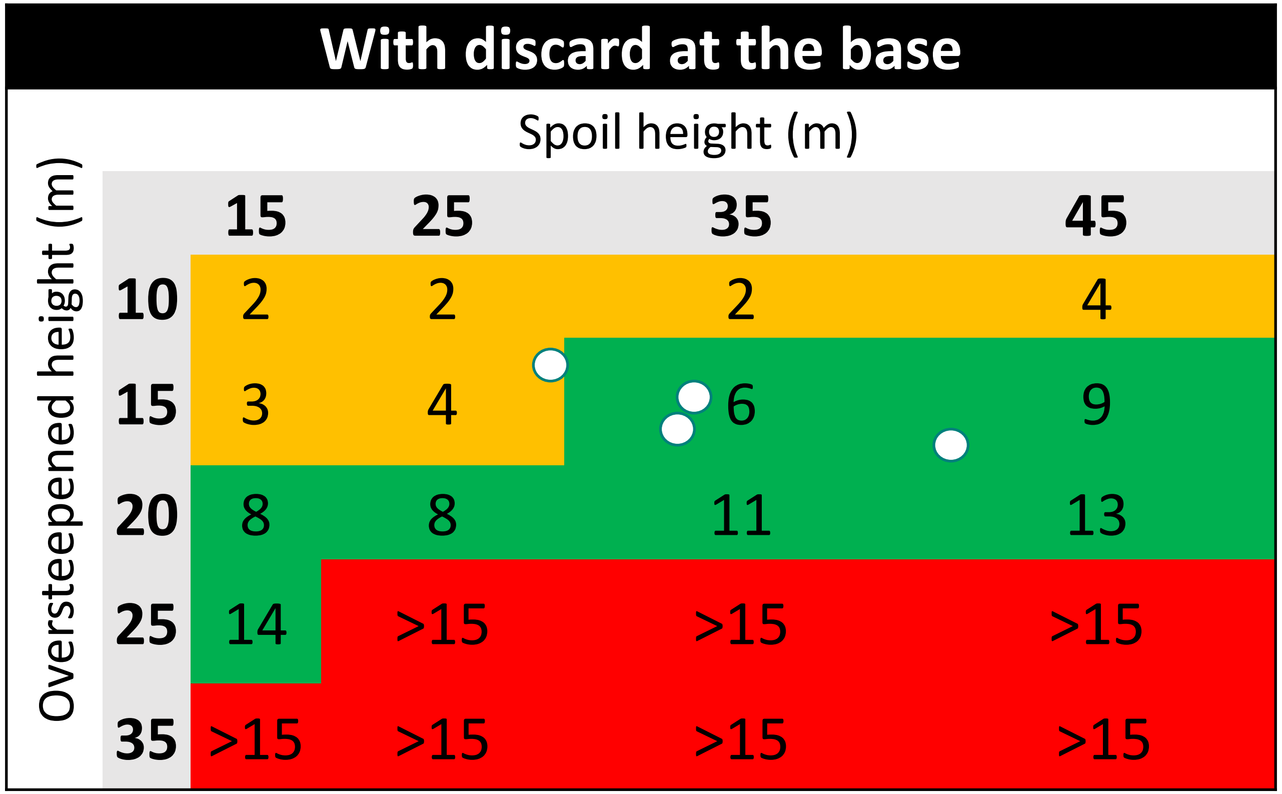


No discard at the base

Spoil height (m)

Oversteepened height (m)	15	25	35	45
10	2	2	2	2
15	2	2	3	6
20	3	5	8	11
25	8	11	13	>15
35	>15	>15	>15	>15

Site 3 - Case Study



With discard at the base

Oversteepened height (m)	Spoil height (m) 15	25	35	45
10	2	2	2	4
15	3	4	6	9
20	8	8	11	13
25	14	>15	>15	>15
35	>15	>15	>15	>15

Further work

- Large scale triaxial testing of the waste rock samples to verify assumed strengths obtained from the non-linear shear strength function for waste rock based on fragmentation analysis.
- Conduct further sensitivity analyses of the floor gradient and batter angle influence on the overall stability.
- Conduct further sensitivity analyses on the thickness of the discard material and softs material.

THANK YOU !!

End