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The evolution of co-disposal stopes at Newmont Tanami Operations

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Abstract

As underground operations mine at greater depths, the haulage of waste rock to the surface becomes a constraint on efficient operation. By keeping waste rock underground, more trucks are available to haul ore to the surface. Additionally, the increasing cost of transporting cement to remote mine sites, and paste production costs in general require continuous optimisation. This is the case at Newmont's Tanami Operations, where there is a focus on keeping waste underground, and optimising cement usage. An outcome of this is the development of co-disposal, that is, depositing waste rock in what would traditionally be a fully paste filled stope, and encapsulating the waste rock in paste to allow safe mining of adjacent stopes. To achieve this, consideration is given to stope geometry, a suitable rock tipping location, stope exposures and filling rates, all assessed against total expenditure and mine scheduling. Modelling of the fill scenario is completed in Deswik, and Flac3D is used to confirm paste strength requirements to achieve the required Factor of Safety, and for optimised binder contents. By depositing waste rock in paste filled stopes, cost-savings are generated by displacing paste, and by reducing waste haulage costs. The development and fine-tuning of the co-disposal fill methodology to date has kept 325,000 tonne of waste rock underground, generating cost-savings exceeding $2.5 million, compared to fully paste filled stopes. This paper presents the evolution and optimisation of co-disposal stopes at Tanami since 2020, including the challenges experienced, the cost-savings, and value added to the operation.

Keywords: *mine fill, paste fill, rockfill, co-disposal, paste waste, waste management, fill optimisation*

1 Introduction

The Dead Bullock Soak Mine (DBS) at Newmont Tanami Operations (NTO) is a longhole open stoping mine, using a primary secondary mine extraction sequence and cemented paste backfill to fill voids to safely mine adjacent stopes. NTO historically has filled voids with 100% paste, 100% rockfill, or a combination of the two in a paste plug or paste cap configuration. Challenging stope geometries including multiple stope exposures, increased waste generation, and ongoing mine fill optimisation, has initiated more creative methods of stope filling. In particular, the careful deposition of waste rock within a paste filled stope, whilst maintaining a sufficient paste pillar around the waste rock 'core' to ensure stability once exposed. This allows waste to be deposited in what would traditionally be a fully paste filled stope. This fill methodology has been termed 'co-disposal', and is based on the 'Christmas tree' fill concept used at Mt Isa in the 1980s, with alternating stages of cemented hydraulic fill and aggregate to fill stopes, summarised by Grice (1989). Co-disposal has presented both benefits and challenges, but overall has generated cost-savings, and added value to NTO. The benefits have included displacing paste thereby reducing overall paste production costs and keeping more waste underground. This then reduces waste haulage distance and liberates trucks to move ore instead of waste, which has been of particular value whilst NTO is executing expansion projects that have generated increased waste. Not all stopes are suitable for co-disposal, and careful consideration and assessment is required for co-disposal to be successful, particularly design and scheduling compliance. The below sections outline the design approach, including implementation, review, and the continuous evolution of co-disposal at NTO.

2 Co-disposal design process

Depositing waste in paste filled stopes has been evolving at NTO for several years, and the original design and implementation as presented by Veenstra & Grobler (2021) has evolved from continuous rock tipping and paste filling, to a staged filling approach. Today, co-disposal refers to the alternating deposition of specific volumes of waste rock and paste, carefully managed to encapsulate the waste rock cone with paste to maintain a paste pillar that remains stable when exposed. The volume of rock is determined by the offset to exposures, and the staged tipping approach means that maximum targets are achieved. Once the rock target has been met, paste filling can commence to partially encapsulate the rock cone. When the paste target is met, rock tipping resumes, and so on, until the stope is filled. Survey control is required during filling to confirm design compliance, particularly in the early stages to ensure the rock is being deposited as expected. The co-disposal configuration and fill approach is simplified in Figure 1. A number of conditions need to be met for a stope to be suitable for co-disposal, as outlined below.

2.1 Initial suitability assessment

The critical parameters for co-disposal are the availability of a suitable rock tipping location, consideration of future exposures and stope geometry. Challenges with these parameters may eliminate co-disposal potential. Waste rock placement needs to be carefully controlled to maintain offsets to adjacent future stopes, and therefore a suitable rock tipping location on the level above is required. Consideration should be given to existing development, future use, and length of rock chute to determine if rock can be tipped from the level above. This is best conducted early and with consultation with the long-term planning team so any additional development is scheduled to align with the greater mine plan. Early identification of co-disposal stopes may also mean that development can be used for multiple stopes, reducing overall development costs.

Co-disposal can occur in stopes with multiple exposures however the design and more importantly, compliance to design, become more critical with more exposures. The Mt Isa Christmas tree concept, on which NTO’s co-disposal is based, demonstrated the importance of understanding the distribution of fill within the stope to ensure the stable placement of aggregate within the cemented hydraulic fill mass, as presented by Bloss et al. (1993). To ensure the stable placement of rockfill in co-disposal stopes, strict compliance is required to control the rock cone and ensure adequate paste encapsulation is achieved. Higher strength paste will likely be needed which should also be considered.

Stope geometry may impact the suitability for co-disposal, such as stope footprint and inclined walls. Vertical walls are preferred as there will be little interaction with the rock tipping, which will assist with rock tipping compliance. The presence of inclined walls below the rock tip may result in waste rock hitting the wall and being trajected in an uncontrolled manner within the stope, and possibly encroach on exposures. Pouring paste to a level above the inclined wall to limit interaction, or reducing rock tipping volumes, has been effective in managing this at NTO.

An example from NTO is shown in Figure 2, where the 139C stope has been assessed for co-disposal, and will be exposed to the north and east, by 139B and 142E, respectfully. The waste rock cone needs to have a minimum of 5 m offset to the north and east stope boundaries, and the inclined southern wall of 139C results in smaller waste rock stages to achieve the offset.

Stopes with larger footprints are generally more suitable for co-disposal as this allows for greater volumes of rock to be placed and usually results in more efficient filling. It is important to note that at this stage, the stope shape is a long-term estimate, and may change and be optimised when transitioned to the short-term space.

Providing the stope being assessed has appropriate geometry, manageable exposures and a suitable rock tipping location, the co-disposal filling methodology is acceptable and design and fill assumptions can be built into the mine plan, such as development for rock tips, and waste and paste estimates.

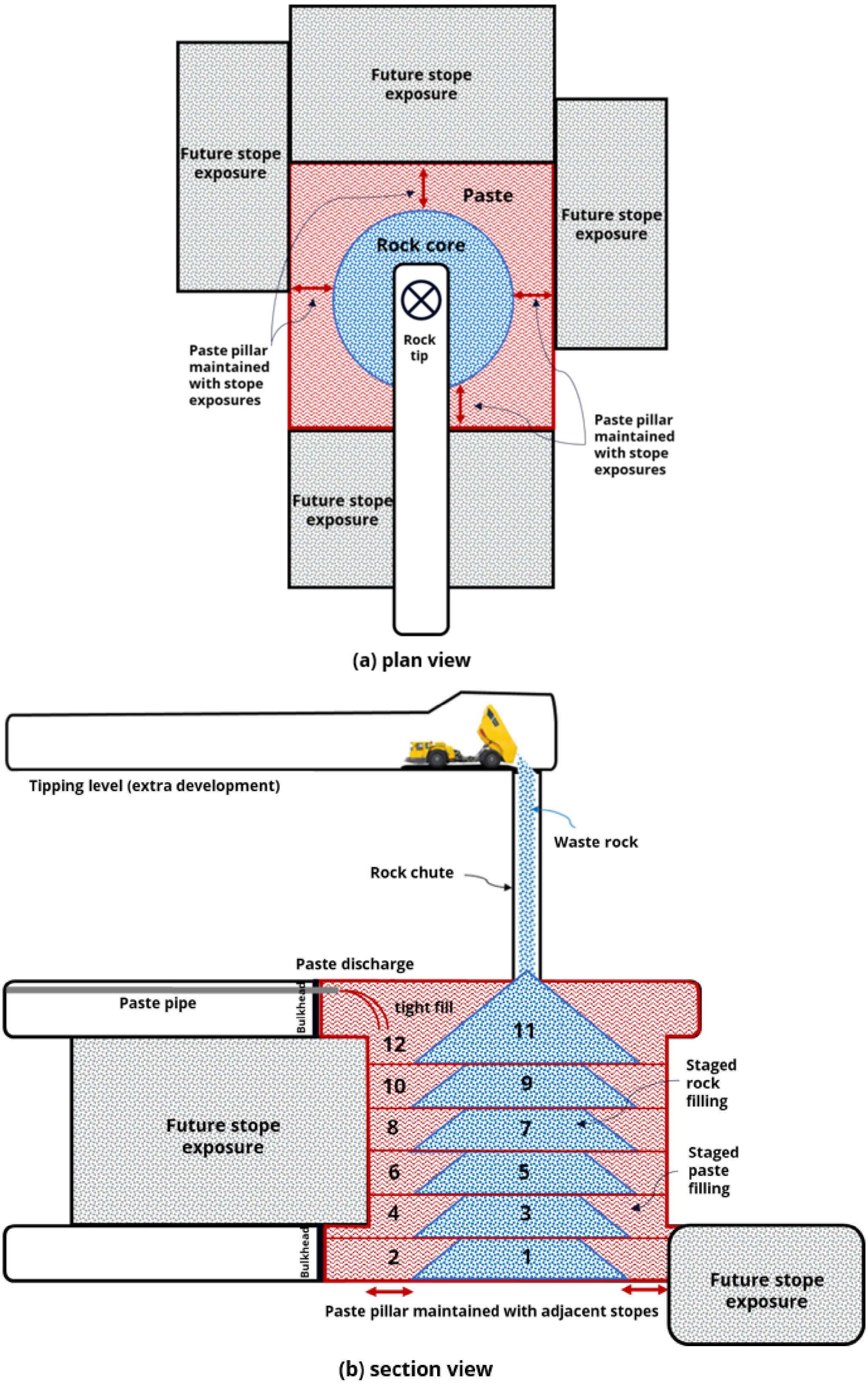
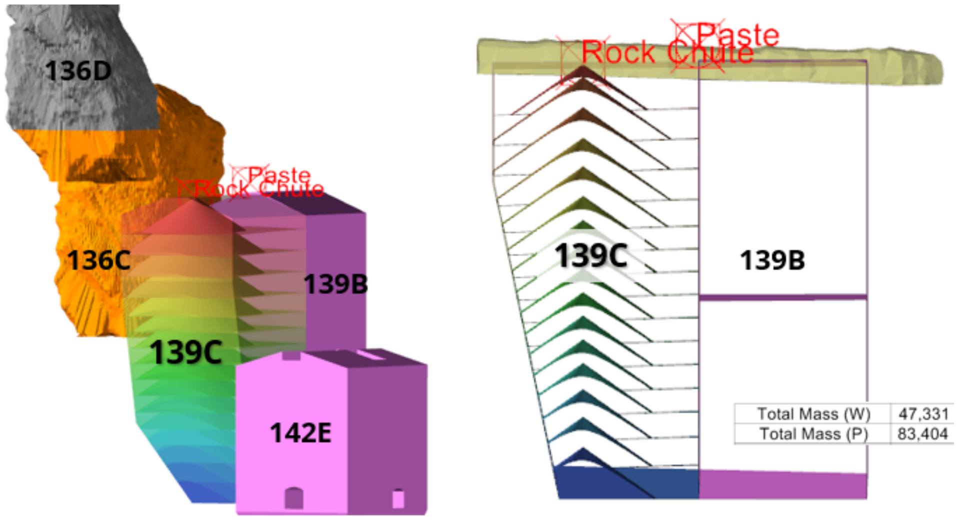


Figure 1 Co-disposal filling methodology schematic. (a) Plan view showing rock chute placement considering exposures; (b) Section view with sequencing of waste rock and paste stages to maximise waste rock placement, maintain a suitable offset to the exposures, and a paste pillar to encapsulate the rock mass to ensure stability on exposure. Not to scale



(a) (b)

Figure 2 Initial suitability assessment for 139C. (a) Oblique view (looking northwest) showing exposures; (b) Section (looking west) through stope showing the Deswik design rock cones from ideal rock chute location and suitable rock offset to future 139B stope exposure to the north

2.2 First pass co-disposal design and financial assessment

The stope note design process triggers the first pass co-disposal design, which involves running an initial fill model, identifying optimum rock tipping location, review of rock offsets to exposures, initial waste rock and paste volume estimates, as well as a financial assessment. These assessments are all made on the design shape, which has usually been refined from the long-term shape to account for grade variations and geotechnical advice.

The Deswik 'Backfill Planning and Reconciliation' tool (Deswik 2020) is used to simulate the co-disposal model, to assist in determining the rock tip location, manage offsets to exposures, and to provide estimates of waste rock and paste volume estimates.

Perhaps more critical, is the financial assessment of the co-disposal stope. Additional development and rock chute mining for rock tipping is an added expense that needs to be considered in the overall economic assessment of the stope. Furthermore, co-disposal stopes also require increased cement as higher strength paste is used to ensure no mobilisation of the fill mass upon exposure. The additional development and cement costs need to be assessed against the cost-savings achieved by co-disposal. These cost-savings are twofold: the displacement of paste fill, and the reduced waste rock haulage costs. In summary, if the expense of co-disposal is not recovered by the cost-savings, then co-disposal is not economically viable, and paste fill should be used.

NTO has created a co-disposal financial calculator which compares the overall cost of co-disposal, including development and paste production costs, and the haulage savings (based on the estimated cost of hauling waste to the rock tip instead of to the surface), against the cost of fully paste filling the stope. This is shown in Figure 3. This tool allows the backfill engineer to find the minimum quantity of waste rock required to offset the additional costs incurred by co-disposal set up. Assumptions are made for cement content, however this has been fairly well understood with experience, and the indicative fill volume estimates from the first pass Deswik co-disposal model are applied. All fill design parameters are input into the calculator, and this generates an overall fill cost for each scenario (paste fill or co-disposal). If there are acceptable cost-savings from co-disposal, then the design is considered economically viable, and can proceed to more detailed design.

OPTION A: 100% paste	
Inputs	
Stope Name:	139C
Truck Backfill Level:	
Total Stope Capacity (T):	135,500
% Pastefill	100%
Average Binder %	2.5%
Development Required (m)	
Rock Chute Depth (m)	
Total Rockfill Capacity (T)	-
Total Paste Capacity (T):	135,500

Costs		
Paste	Cost of Paste ($/T):	
	Total Paste Cost:	
Development	Cost of Development	$ -
	Cost of Chute	$ -
Tip Setup		
TOTAL COST		$ -

Savings		
Waste Trucking to surface	Backfill level to Surface (km)	0.00
	TKM's	0.00
	Cost of Trucking	$ -
TOTAL SAVINGS		$ -

Paste %:	100%
GRAND TOTAL	$ -

OPTION B: Co-disposal	
Inputs	
Stope Name:	139C
Truck Backfill Level:	260
Total Stope Capacity (T):	135,500
% Pastefill	65%
Average Binder %	3.4%
Development Required (m)	35
Rock Chute Depth (m)	40
Total Rockfill Capacity (T)	47,600
Total Paste Capacity (T):	87,900

Costs		
Paste	Cost of Paste ($/T):	
	Total Paste Cost:	
Development	Cost of Development	
	Cost of Chute	
Tip Setup		
TOTAL COST		$ -

Savings		
Waste Trucking to surface	Backfill level to Surface (km)	
	TKM's	
	Cost of Trucking	
TOTAL SAVINGS		$ -

Paste %:	65%
GRAND TOTAL	$ -

Total Savings by Co-Disposing stope:	$ -
Total Savings by Co-Disposing stope:	

Figure 3 NTO co-disposal calculator tool to understand total expenditure of co-disposal against paste fill, and to assess fill costs for each methodology

2.3 Detailed design and numerical analysis

The detailed design is completed upon close out of the stope, and when the 'as mined' stope shape is available for co-disposal review. The final stope shape is critical to re-run the first pass model on, as any overbreak or underbreak will impact the waste rock placement. There may be the opportunity for additional waste rock in the case of overbreak, and conversely, waste rock may need to be reduced if underbreak occurs.

Additional to the final stope performance, is the performance of the rock chute. The rock chute may be mined before or after the stope is mined, depending on mine schedule or geotechnical advice, however it is essential that the chute is carefully managed. Rock chute deviation may impact the placement of waste rock, and will need to be assessed prior to final design. The waste rock volumes may need to be reassessed if the rock chute deviates towards a critical exposure.

The detailed Deswik model is run with the final stope and rock chute shapes, with the waste rock stages adjusted according to the final stope walls and rock chute. From here, meshes of the stope and waste rock cone are created for stability modelling that is completed using Itasca's Flac3D software (Itasca Consulting Group, Inc. 2019). Detailed explanation of the Flac3D numerical analyses for both paste and co-disposal modelling is presented by Veenstra & Grobler (2020, 2021), however is beyond the scope of this paper. In summary, the Flac3D modelling simulates the filling of the stope, with the waste rock and paste mass assigned shear strength parameters acquired from laboratory testing. The 'transition' zone between the paste and rock cone where there is mingling of paste and waste has been assigned 'transitional' shear strength parameters in an effort to recognise what is occurring within the stope. The cement content reduces with height within the stope and is based on uniaxial compressive strengths (UCS) acquired through site laboratory testing, and historic performance. The stope filling is sequenced and aged with anticipated fill rates, with curing stoppages around bulkheads included. When the final paste stage has achieved 28-day curing, the model exposes the fill mass with the adjacent stopes to the correct mining sequence. These stope exposures have been positioned to simulate reasonable anticipated overbreak into the fill mass to model 'worst case' performance. A Factor of Safety analysis is completed on each exposure, demonstrating the anticipated failure plane and critical stope exposure. The model is re-run with revised cement contents until an acceptable Factor of Safety is achieved. Or conversely, if an excessive Factor of Safety is achieved, the model is re-run with reduced cement contents to optimise cement usage and costs. Model iterations are useful in understanding what waste rock offset or paste pillar is required to maintain stability, and look for opportunities for fill optimisation.

When waste rock and paste volumes are determined, estimated fill duration and scheduling is provided to the mine schedulers to allocate fill rates and manage interactions. This is based on known fill rates for paste fill, and assumed waste rock trucking and tipping rates. Often, the scheduling interactions and fill duration have a major influence on the success of co-disposal, so needs to be well managed between the backfill engineers, schedulers and mine control.

The detailed design package, including all the above modelling considerations, is communicated to all relevant parties for comment, and accepted as the final co-disposal fill design to be executed.

3 Implementation

The success of co-disposal is determined by compliance to design. This requires effective communication from the backfill engineering team to all stakeholders, including mine scheduling, survey, paste plant operators, and mine control. Backfill engineers are required to communicate daily with all parties to update fill status and confirm upcoming targets.

Mine schedulers and mine control must understand waste rock stages and the timing of these to plan and allocate waste. If waste is not readily available, rock tipping stages can extend across many shifts, and therefore extend overall fill duration. It may be necessary to provide mine control time limits to meet waste tipping targets to manage overall fill rates. Mine control is responsible for allocating the correct number of trucks to the co-disposal stope, and providing confirmation for when a waste rock stage is complete. This then triggers the paste plant to resume paste filling, so effective communication is required.

Regular surveying is required to ensure the stope is filling to design. This is particularly important in the early stages, to confirm the waste rock is being placed as intended, and that offsets to the stope boundaries are being achieved. This is completed using Cavity Monitoring System (CMS) or C-ALS (Cavity Auto-scanning Laser System) scans and assessing against the Deswik model. If there are any concerns with the waste rock placement.

Additional paste may be required, waste rock targets reduced, or the opportunity to add waste rock. As the stope fills and if filling as expected, the survey frequency can be reduced. Figure 4 shows the 139C co-disposal tracking during filling, with a comparison between the Deswik design model and the CMS scans, clearly showing the waste rock cones. The scans provide verification that the rock cone is performing as expected, and that the paste pillar to the adjacent 139B stope is achieved. As the 139C was the second stope filled using staged co-disposal, CMS scans were completed very regularly, however confidence infill execution has reduced scan frequency, assisting infill efficiency.

NTO has been evolving the co-disposal design process since late 2019, and has completed 13 co-disposal stopes to date. Not all of these have been successful, and have necessitated the continual critique and development of co-disposal design and execution, resulting in the fill approach described above. There have been many challenges, with some resulting in financial loss and fill delays, however overall, the co-disposal fill methodology has been successful in keeping waste underground and reducing paste filling costs. A number of case studies are presented below, demonstrating the evolution and continuous evolution of co-disposal at NTO.

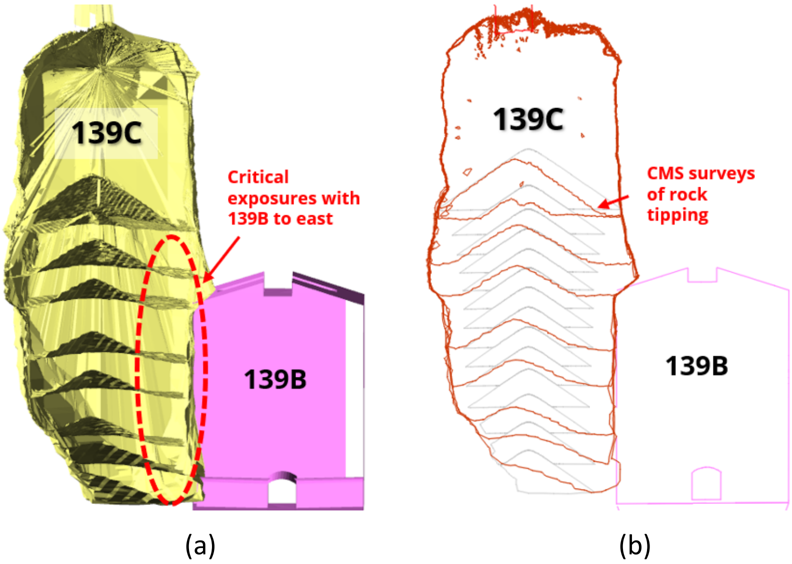


Figure 4 139C co-disposal fill tracking model. (a) Slice through stope showing scans of rock tipping stages and fill cone and offset compliance; (b) Section through stope showing scans (red lines) against the Deswik design rock cones

3.1 085A

Stope 085A was the first stope at NTO filled using a co-disposal approach and as such, a conservative design was used, including high strength paste and no specific waste rock targets. Instead of having set waste rock and paste targets, the 085A was filled using a 'simultaneous' filling approach, meaning that waste rock was tipped during paste filling, at a rate dictated by the backfill engineers. As the rate of truck tipping was not consistently achieved, the paste volume exceeded waste rock placement so full benefit of co-disposal was not achieved. 085A was a financial loss, with waste rock only comprising 6% of the total fill mass, and was the catalyst for the staged filling approach currently adopted.

3.2 100C

Stope 100C was the second attempt at co-disposal at NTO, with an attempt to increase waste rock content. The stope geometry proved challenging with a narrow stope footprint (26 m × 24 m) meaning waste rock stages were relatively small to maintain offsets to adjacent exposures to both the east and west. This fill approach was slightly more successful, with 11% of the fill mass comprising waste rock, however was still a financial loss as cement content was relatively high, and the waste rock content did not offset the overall cost. 100C did see good fill duration compliance, filling in just under two months. Figure 5 overlays the stope scans during filling to the Deswik design, showing small mounds indicating waste rock. This design indicated that with a larger stope footprint, waste rock targets could be increased.

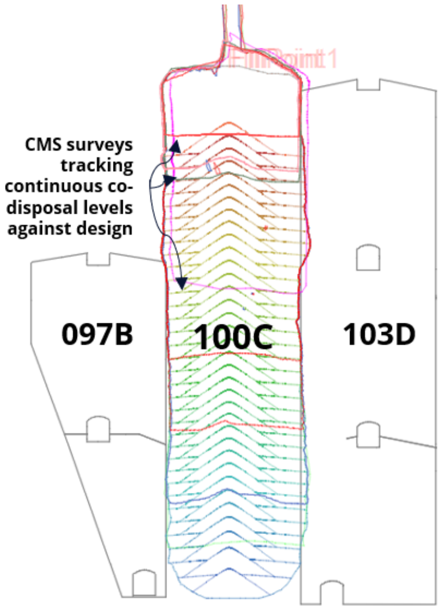


Figure 5 100C, section view looking north. CMS scans shown in red against design (small waste targets)

3.3 088A

Stope 088A was the first successful co-disposal stope at NTO, with an ideal geometry for co-disposal. 088A had one exposure, meaning only one offset to manage allowing large waste rock targets. This stope was the first ‘staged’ co-disposal stope, which allowed optimisation of waste rock targets, resulting in 51% of the stope being filled with waste. This resulted in an overall co-disposal cost-savings approaching $900,000. 088A had some initial challenges, with the first waste rock stage migrating to within 5 m of the adjacent stope, as the rock chute had deviated towards the exposure. Waste rock targets were reduced to manage this, however this was the motivation for scanning the rock chute prior to tipping in future stopes. 088A was also the first co-disposal stope with a full height vertical exposure with the mining of 088B, shown in Figure 6, and remained stable with no unexpected paste dilution, adding considerable confidence in the co-disposal filling methodology.

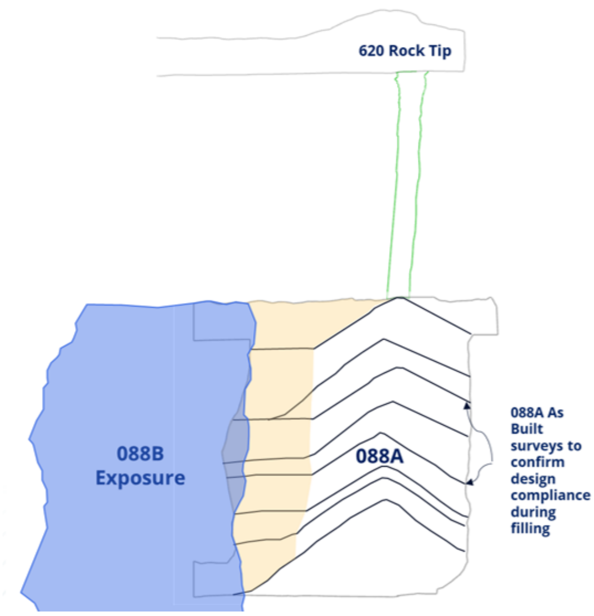


Figure 6 088A, section view looking east. As executed co-disposal, with waste rock scans shown, and 088B exposure

The concept of ‘cold joints’ in paste was assessed in 088A, as there is suggestion that cold joints can form between paste pours and act as planes of weakness upon exposure. This is more prevalent with co-disposal due to the frequent paste stoppages with staged filling. Similarly, the impact of tipping waste rock into uncured paste has been questioned, with the sudden impact simulating cyclic loading and causing liquefaction. To manage this, paste is cured to 100 kPa around bulkheads to minimise the liquefaction potential and sudden loading of paste walls. NTO typically exposes stopes vertically, with the occasional partial horizontal exposure (or undercut) and there is no evidence of liquefaction or cold joints impacting the stability of the fill mass. The successful vertical exposure of the 088A, and all other co-disposal stopes to date, indicate that cold joints and cyclic loading are not a cause for major concern at NTO.

088A was also the first stope that utilised the fill calculator, assessing all costs involved in co-disposal, from the paste production costs, to additional development, and offsetting this against paste displacement and haulage savings. It was identified through the shortfalls of 085A and 100C that a minimum waste rock content needed to be achieved to offset the total expenditure of co-disposal. This is a tool that is used for all co-disposal stopes to ensure the fill design is economically viable.

3.4 139C

Following the design and execution learnings from previous co-disposal stopes, stope 139C was successfully designed and executed, with 35% waste rock deposited in the fill mass. This stope also used a staged fill approach, allowing the full waste rock target to be reached, creating the most benefit in terms of waste kept underground and paste displacement. Figure 7 presents the tracking of filling 139C, showing good compliance to design. The main challenge experienced with 139C was scheduling compliance, as the total fill duration exceeded that scheduled, as rock tipping stages were not always completed efficiently.

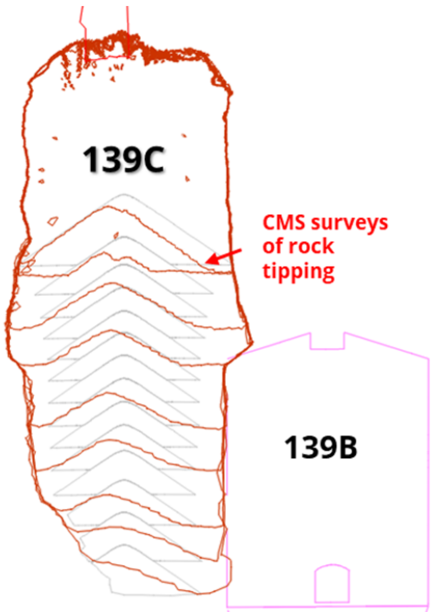


Figure 7 139C, section view looking east. CMS scans in red show excellent compliance in rock cones to Deswik design

3.5 145D

Stope 145D was a large stope, with a footprint of 30 m × 45 m. This allowed increased waste rock targets, and to achieve this, two rock chutes were utilised, with the first pass design shown in Figure 8. 145D experienced numerous challenges, including rock chute deviation and significant overbreak resulting in more paste than expected. As shown in Figure 9, one of the rock chutes deviated and so waste rock was deposited 6 m off design, towards the critical exposure, necessitating smaller waste rock targets. The 145D also experienced significant overbreak, and an unexpected paste plug due to unrecovered material left in the stope, requiring more paste than initially designed, increasing the overall filling costs. Another issue experienced was the type of material tipped into the stope, including raisebore fines (which perform differently to waste rock) and general underground waste, including ventilation bags. This unnecessarily complicates the filling and compromises fill mass stability and risks chute blockages. Effective communication to the underground crews and restrictions on acceptable waste material is required to manage this. Over 30,000 t of waste rock was deposited in the stope, however this was not sufficient to offset the overall filling costs, resulting in a financial loss. Managing the filling of 145D was significantly more onerous than a single rock chute and the fill duration was longer than scheduled. The value of co-disposing with two rock chutes will be reconsidered in the future.

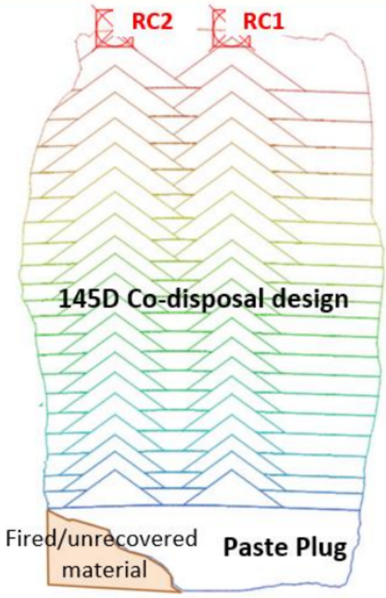


Figure 8 145D, section view looking east. Detailed design showing dual rock chutes and unrecovered material

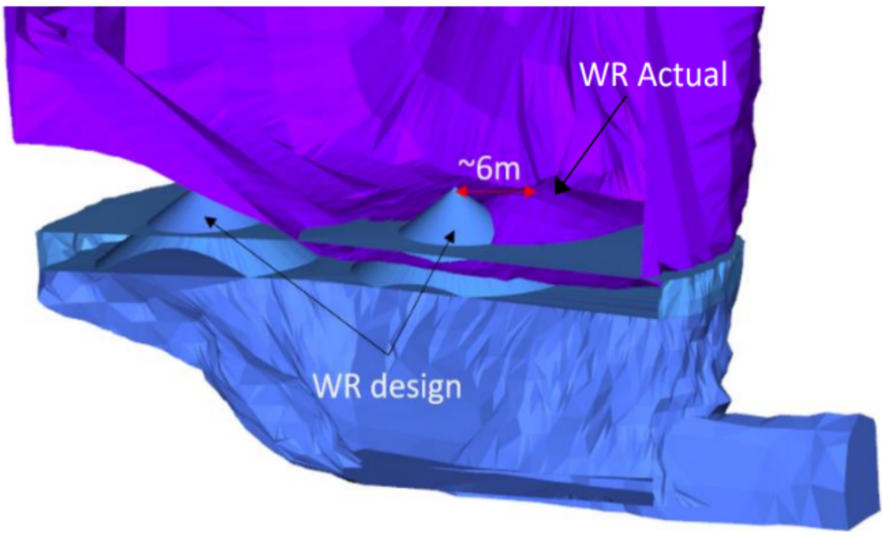


Figure 9 145D, oblique view showing first CMS scan of waste rock placement (purple) against design (blue). 6 m deviation of chute required reduced waste rock targets to manage offset and paste pillar to protect the exposure to the east

3.6 097A

Stope 097A was a successful co-disposal stope, achieving 41% waste rock content, generating significant cost-savings. This stope was similar in configuration to 088A, with only one paste exposure to manage, and the waste rock cap increased the waste rock content, as shown in Figure 10. The strategic placement of the rock chute in the northeastern corner of the stope allowed maximum waste rock targets. 097A also saw the benefit of optimised cement contents, reducing overall paste production costs. The challenge filling 097A was the extended fill duration, demonstrating the importance of scheduling appropriate filling rates to ensure that the mid-term schedule can accommodate slower filling of co-disposal stopes, and identify any problematic interactions this may present in other areas of the mining cycle.

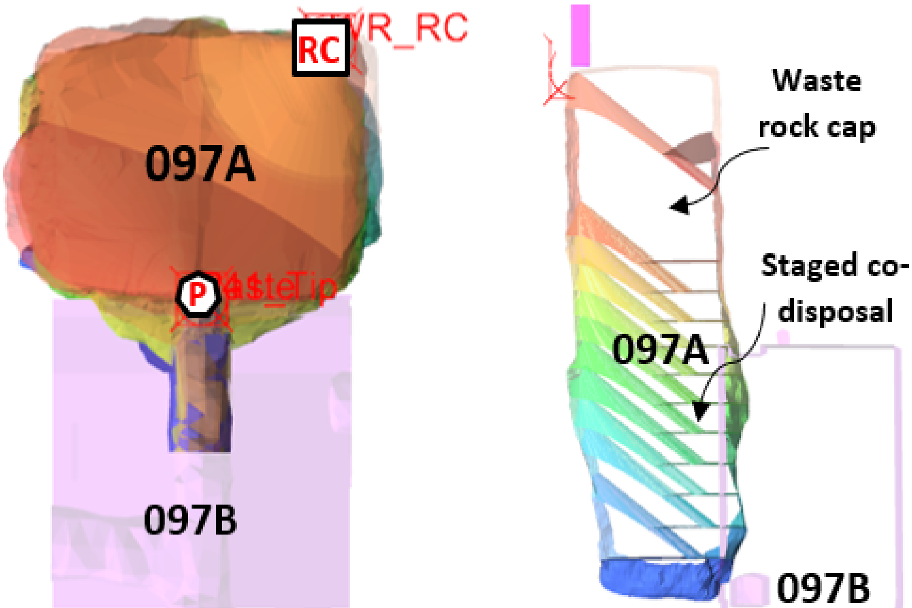


Figure 10 097A, plan and section view (looking east) showing rock chute (RC) placement targeting corner of stope to maximise waste rock. Successful co-disposal execution

4 Simultaneous filling methodology

As mentioned, the main challenge experienced with co-disposal is the longer fill duration. Co-disposal has more variables than a fully paste filled stope, such as staged paste targets, cure stoppages, paste line changes, survey control, and waste rock truck cycles. In an effort to fill co-disposal stopes quicker, 'simultaneous' filling has been used to tip waste rock and pour paste simultaneously, at a rate determined by the backfill engineers. This sees less waste rock being deposited in the stope than staged co-disposal, so the financial impact of this needs to be considered in the overall fill cost. Consistent truck tipping cycles are required to achieve the desired fill rate (for example, two trucks per hour). If not achieved, more paste is poured than waste rock and the economics of the fill can change quickly and therefore reduce the benefit of simultaneous co-disposal.

This approach was used in the first co-disposal stopes somewhat unsuccessfully, however confidence in the co-disposal methodology, optimisation of cement content and a better understanding of minimum waste rock content allowed a more robust simultaneous filling approach. The main intent behind simultaneous filling is when mine scheduling has taken precedent over waste rock tipping, and slower co-disposal fill rates cannot be accommodated by the mine schedule. Figure 11 summarises the waste rock content and co-disposal cost-savings, and stopes that utilised simultaneous filling were 112L, 142E and 151A. Whilst these stopes still resulted in overall cost-savings, the waste rock contents were considerably less than would have been achieved with staged co-disposal. It is also worth noting that the 112L and 151A did not see significant time savings from simultaneous filling, however the 142E filled in the same duration as a fully paste filled stope, achieving 22% waste rock content, and so was a simultaneous filling success.

Figure 11 Waste rock totals and cost-savings from all co-disposal stopes to date, showing initial challenges but overall positive evolution of the fill approach

5 Summary

Co-disposal has the potential for significant cost-savings, however this is subject to the success of many parameters, presented in Table 1 and evident in the case studies detailed above. There are more variables at play and challenges to manage to successfully fill a stope using the co-disposal methodology, however if these are well managed and mostly compliant, the opportunities and value added to the operation outweigh the additional effort and resources. Figure 11 summarises the waste rock tonnages and cost-savings generated by co-disposal (compared to that of a fully paste filled stope), and even with the occasional financial losses, there is an overall major cost saving. When the stope does not fill as anticipated, NTO use this as a learning opportunity and motivation for improvement and so overall have been able to develop a general positive and impactful trajectory for the co-disposal fill methodology.

Table 1 Summary of opportunities and challenges experienced with co-disposal at NTO

Opportunities	Challenges
Reduced waste trucked to surface	Design compliance (RC, final stope shape)
Reduced strain on truck fleet	RC deviation and waste rock implications
Focus on ore movement	Fill duration compliance
Efficient filling if well scheduled	Truck/waste availability to meet waste targets
Safe rock tipping set ups	Challenging scheduling parameters
Significant overall cost-savings	Survey control and associated delays
Continuous learning and optimisation	Constant monitoring and tracking required
Reduced CO_2 generation with less haulage	Waste generation from rock tipping infrastructure
Displaced paste volumes and associated cost-savings	Consideration of cold joints/cyclic loading of paste
	Possible failure due to poor execution
	Reduced tailings needed for paste requires increased storage capacity on surface

6 Conclusion

The evolution of co-disposal at NTO has added value by reducing strain on the truck haulage fleet to move waste to the surface, and instead has been able to keep waste rock underground, freeing trucks to focus on ore movement. By placing waste rock in what would traditionally be a fully paste filled stope, paste volumes have been displaced by the waste rock, meaning overall paste production has also reduced. Whilst more cement is used in a co-disposal stope, the optimisation of cement and paste strength requirements have evolved, and providing minimum waste rock targets are achieved, the overall cost-savings with co-disposal can be significant. Since the inception of co-disposal at NTO in 2020, over 325,000 tonnes of waste rock remained underground, and overall cost-savings have exceeded $2.5 million, compared to fully paste filled stopes. The main challenge with co-disposal is the many moving parts that need to be managed to see the full benefit, and in a highly constrained mine requiring quick stope filling, co-disposal may not be suitable. Using new technology to assist in-stope filling is being investigated, including in-stope live fill monitoring to reduce reliance on survey, the benefits of haulage automation and improved truck cycling, as well as assessment of smaller offsets to exposures to further optimise waste rock and paste contents. There remains significant potential for the co-disposal fill approach to be further optimised to reduce overall filling costs, improve efficiencies and add further value to NTO.

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