

Review of drawpoint management



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Abstract

The NSW Resources Regulator conducted a series of assessments at every NSW underground metalliferous mining operation throughout 2016 and 2017 to determine how effectively the principal mining hazard of 'ground and strata control' was being managed. A key part of the assessment was to assess how operations manage the risks associated with drawpoints. This report covers findings from the first six mines assessed.

In 2015 there were three fatalities in and around drawpoints that occurred in Australian underground metalliferous mines. The assessment revealed a number of common failings in managing the risks drawpoints pose to workers. It also revealed some innovative practices that were adopted by some operations following serious incidents in and around drawpoints, however these practices had not been passed on to other mines.

The assessment found that the management of drawpoints needs to be considered from the pre-feasibility stage of a mining project, through to a back filled stope. By reducing the size of drawpoints, using down holes and adopting remote systems of work, many of the risks associated with drawpoints can be greatly reduced.

The aim of this report is to share the outcome of the Resource Regulator's assessment program and highlight the good practices and common failings that exist with the control the risks drawpoints pose to worker safety.

Introduction

Across an international spectrum of underground metalliferous mining publications, there appeared to be a lack of formal guidelines and standards for management of drawpoints. This has invariably resulted in a significant variation in how effectively each mining operation assesses and deals with these risks.

Despite the considerable advances made in the use of remotely operated machinery, some of the risks associated with drawpoints remains stubbornly high and has resulted in repeated fatalities. This report identifies a number of common failings and provides information as to what could be considered 'good practice'.

The design of drawpoints will be influenced according to the mining method, the geotechnical environment, fragmentation of material and the geometry of a stope or cave. The production cycle must contend with factors such as stopes hanging up, stope sequencing, backfilling, maintaining hanging wall strength and the management of open holes.

Despite the dynamic production environment, many of the practices in and around drawpoints can be standardised and still offer the flexibility that operations with differing mining methods require. To ensure the operation of drawpoints is effectively managed, factors to be considered should include:

- with reference to the hierarchy of controls, elimination of the risk posed by drawpoints represents the most effective method of managing drawpoints. By adopting remote systems of work through improving remote drilling, remote charging, remote hydroscaling and remote surveying operations, operations move closer to eliminating the risks drawpoints pose to workers.
- assessment of the adequacy of risk controls and any systems to manage erosion of those controls.
- standardised bunding procedures that all workers who interact with bunds are appropriately trained in. The assessment found a number of contradictory standards across similar systems of work even within the same mining operation.

- establishing minimum bunding heights relative to the backs rather than the floor, where mines have experienced significant overbreak in development.
- developing minimum bunding standards taking into consideration the size distribution and moisture content of material contained within the bund, height of backs, height required between backs and floor, and rill angles.
- drawpoint design considered from the outset of the mine planning process to promote better stability and reduces worker exposure. For example, favouring production downholes over upholes, considering drive height, ring spacing, stope sequencing and equipment selection.
- strict control of overbreak. Workers to be aware that ore drives will one day be a brow and overbreak unnecessarily increases the size of the brow.
- where no bunding is implemented (such as watering down a drawpoint post firing) clear wall markings to determine a safe stand-off distance beyond which operators must not pass.
- for seismically active mines, a robust trigger action response plan (TARP) to manage seismic activity. The system should be supported by an appropriate risk assessment. By capturing and interpreting seismic data, appropriate standoff times, pillar size, stope size and blast design can be determined.
- while bunds are a critical control measure, they are not generally constructed to a strict engineered design therefore should not be considered a true engineered control under the hierarchy of controls.
- where spiling is implemented (e.g. to create a false brow and hold up the rill from a drawpoint), a risk assessment should determine the depth of fibrecrete required, the height from the true brow fibrecrete is to be applied and any bolting requirements. The review found that operations who engaged in spiling had no written procedures despite the risk to workers if the spiling failed and material rilled from a drawpoint.

Background detail and discussion

Effective management of drawpoints should encompass every phase of the mining life-cycle. In addition to supervisors and workers, all technical disciplines should be made aware that ore drives will eventually become drawpoints and that poor mining practices will increase risks around the drawpoints. While a number of practical measures can be introduced to mitigate the risks posed by drawpoints, better pre-planning and design is essential to eliminate or reduce risks So Far As Reasonably Practicable (SFARP).

Feasibility stage

Drawpoint management begins at the project feasibility stage and through better planning, many of the risks associated with drawpoints can be reduced by:

- avoiding uphole stoping wherever possible to reduce exposure to brows
- where appropriate, using smaller equipment and having smaller drives to provide a smaller drawpoint
- developing drill and blast standards that provide for the largest possible distance between a designed brow and the next ring. This includes using strategies like dumping rings, uncharged collars on the final ring of each firing, electronic detonators and maximising ring burdens and powder factors.
- sequence stoping and backfilling to allow the best possible hanging wall stability and reduce the risk of material rilling from the stope

- conducting the appropriate level of geotechnical analysis to provide for a stable hanging wall, improve stope stability and reduce the risk of material rilling from the stope
- avoiding placing ore drives on geology control to control drive width.

The hierarchy of controls shows that by using downholes, worker exposure to drawpoints is reduced or eliminated. Whilst downhole drilling can have some negative production implications, this should always be balanced against the significant reduction in workers' exposure to risk. Where possible, downhole stoping methods should be used.

Where uphole stoping is the only feasible option, a cable bolting support plan should be established, with brow cables appropriately scheduled according to planned intermediate and final brow positions. When developing geotechnical designs, attention should be paid to the management of overbreak and that the systems of work proposed at the feasibility stage should aim to minimise potential overbreak.

The design of equipment used around drawpoints continues to improve in capability and should allow operators to eliminate or minimise exposure to drawpoint risks. The latest advances in remote drilling, hydroscaling, charging and cavity monitoring should be investigated and budgeted for at the feasibility stage. Whilst cost is a factor in any risk assessment this must be balanced against the foreseeable risk of injury including fatalities which can occur in proximity to drawpoints. Good examples of how this technology can be applied are the remotely operated hydroscalers, drilling, charging and surveying systems used at Newcrest's Cadia Valley operations. A review of literature found some Canadian mass mining operations where also employing various remote technologies to limit worker exposure to drawpoints.

Risk assessments

Risk assessment is at the heart of how the industry should discharge its legal obligations under the NSW Work Health and Safety Act 2011 therefore it was disappointing to report that a key finding of the assessment was that Risk Assessments regarding the risks drawpoints pose were often poorly drafted or sometimes non-existent.

The most significant risk posed to workers from drawpoints is material rilling from the stope. This is controlled via a bund placed before the stope brow. Bunds are a critical control but in only one example reviewed by inspectors was the required bunding height and position (relative to the brow), properly addressed in the risk assessment.

When developing a risk assessment for systems of work around drawpoints, a systematic approach should be taken.

- What is the critical control that protects a worker from being hit by rilling stope material?
- What are the erosion factors for that critical control?
- Adapt systems of work to suit the critical control.
- Develop systems to manage all erosion factors.
- Always reference the hierarchy of controls.

A critical control is '*a control that is crucial to preventing the event or mitigating the consequence of the event. The absence or failure of a critical control would significantly increase the risk despite the existence of other controls*'. (International Council of Mining & Metals: *Health and safety critical control management/ Good practice guide*)

Erosion factors

A common issue identified during the review was the improper adaptation of risk controls to suit a particular situation. For example, where a risk assessment had identified a minimum bund height design of 2 m, this would be reduced to 1.5m in order to accommodate a cavity monitoring survey (CMS) which involves a surveyor placing a laser scanner attached to a long fibre-glass pole over the bund. The risk of a fall-of-ground remains the same but the controls have been arbitrarily eroded to suit the circumstances. The better decision would be to employ a safer method of horizontally inserting the scanner above the 2m bund rather than reducing the critical control.

Once a critical control is established, erosion factors should be considered and measures put in place to control them. The assessment carried out by the NSW Resource Regulator found that 60% of the operations assessed, failed to meet their own bunding standards.

Size distribution of stope material

The assessment of caving operations found that risk assessments had determined that material in excess of 50% fines could perform like a fluid. Whilst the mechanics of fine particles is an evolving field of study and not developed within report, it is essential that these factors are considered as part of the critical control at drawpoints.

As caves mature and more comminution takes place, a greater percentage of fines will develop within the cave. Such material can have very low angles of rill and have been found to push away bunds as they apply a hydraulic force due to performing more like a fluid than a solid material ([Investigation report into the death of Lee Peters at Ridgeway Mine.](#)) This reduces the effectiveness of bunds and particularly for these cases, remote systems of work should be developed.

Newcrest's Ridgeway operation introduced remotely operated hydroscalers following a fatality in September 2015. A hydroscaler operator died after material rilled from the block cave drawpoint, pushing the rig backwards and crushing the operator between the hydroscaler and the wall. Investigations found similar inundation events had occurred at Ridgeway where bunds could not contain the rill of fine material. ([Investigation report into the death of Lee Peters at Ridgeway Mine.](#))

Drawpoint controls

Bunding

The most common method for managing the uncontrolled riling of stope material is a bund, however within the hierarchy of controls, bunding represents a low level engineering control. Whilst it is apparent that bunding can be effective at managing stope rill, so long as the strength of the bund is unknown, it can only be attributed a low-level control. At the time of writing, no study on the strength of bunds used in drawpoints has been completed.

Despite the resistance properties of a bund being untested, a bund provides a physical barrier between the worker and the rill. For a bund to be effective, its height should be relative to the backs within a drive rather than the floor. This is a key finding of the assessment. By making bund heights relative to the backs rather than the floor, the consequences of overbreak when developing a drive are better managed.

The review found overbreak in ore drives to be an issue in all six operations. The lowest level of overbreak found was 14% greater than design, the average overbreak in ore drives was found to exceed 25%.

With higher backs, material has further to rill, so bund heights should be raised to account for this. Only one operation actively managed bund heights according to the height of the backs.

All bunds should be 'patted down' (consolidated) at the crest. This is to reduce the risk posed by material rilling from the bund itself. The need to pat down the bund, means the bund height is constrained by the size of the loader bucket and the lift-height of the loader. There should also be enough room for production holes to be charged. The assessment found a distance of 1.8 m – 2.0 m from the backs to be the practicable maximum height a bund could reach.

For empty, partially bogged out or hung up stopes, bunds should be as close to the brow as possible so the next row of holes can be charged. For the bund to be effective, the bund apex should be at the brow as a minimum.

The sole operation found to have conducted a risk assessment around bunding standards, and to have bunding heights derived relative to the backs, had determined that production charge-up requires a 1.8 m gap between the bund apex and the backs. Please refer to Figure 1.

Stope geometry is also an important consideration in determining the risk of material rilling from stopes. A narrow stope while empty, poses a greater risk than wider stopes because there is less void available to contain any material that could fall into the stope from the hanging wall or backs.

For stopes with a hang-up or a suspected hang-up, there are additional considerations. Bunds should be constructed as high as possible, although the height will depend on the equipment required to manage the hang-up.

The risk assessment should consider the maximum practicable bund height. Once determined, a conservative angle of rill should be developed so that the required distance between the brow and the bund can be calculated. A safety factor should be determined which takes full account of the excess height of the bund, beyond which material will rill to. Figure 2 describes the variables.

Within a risk assessment model, the key variables to be determined include:

- maximum practicable bund height relative to the backs
- for processes such as watering down a drawpoint post firing (where there is no bund) the same risk assessment process should be followed including a horizontal safety factor.
- rill angles.

Considering these variables will assist in determining appropriate stand-off distances and bunding construction standards.

Determining a safety factor

The required safety factor for bund height is largely determined by rock fragmentation. The bund safety factor should be derived by considering the largest rock that is likely to fall down the rill and then designing enough bund height to stop the rock passing the bund. The safety factor also should consider excessive fines. This is a particular issue for caving operations where a high percentage of fines material causes the caved material to perform more like a fluid than a solid. ([Investigation report into the death of Lee Peters at Ridgeway Mine.](#))

Determining rill angle

Rill angle is determined by fragmentation and the percentage of water within the ore. Rill angles from existing drawpoints are relatively straightforward to measure via survey pick up. By using existing drawpoints to predict rill angles, operations can have a degree of confidence in the angle chosen. Rill angles can alter over a project's life as fragmentation and moisture content varies. Mine operators should be alert to an increase in fines as this will reduce rill angles and may ultimately see rill material perform more like a fluid.

Remote systems of work

Technological advances has resulted in reducing workers' exposure to drawpoints and in the case of Newcrest's Cadia Valley operations, exposure has been eliminated. The Cadia Valley operation is able to eliminate worker exposure, thanks to the static nature of block cave drawpoints where no production drilling and charging is required.

Remote drilling technologies continue to improve and drones are becoming increasingly advanced allowing for stope inspections and in the near future, cavity monitoring. Operators should keep up to date with improvements in remote technologies and apply them where practicable to their existing systems to remove workers from drawpoints.

Brow integrity

False brows can cause significant problems. In common with the management of drawpoints, the integrity of brows is partly determined at the feasibility study stage of a project. The stability of brows needs to be given appropriate consideration at this early design stage to ensure the maximum practicable distance between a brow and the first ring is established. By maximising the spacing between the brow and the nearest ring, exposure is minimised for charge-up operators. If necessary, support cables should be preinstalled and ring-firing conducted to fit in with pre-installed support in order to maintain brow stability.

Brow integrity is usually determined by certain job categories. For drives whose direction is being determined by geologists, they should be trained in how drawpoints work and the necessity to keep the drives as small as possible. Geologists should be empowered to use sludge holes if they are unsure of what structure to follow in an ore drive, rather than be forced to come back at a later date and to strip a drive, increasing the size of a future brow.

Jumbo operators and their supervisors should carefully monitor for overbreak and should adjust accordingly when overbreak is occurring. Overbreak does not simply increase the size of a drawpoint and the possible amount of material that could rill, it also impinges on pillar distances, which than may increase the likelihood of overbreak within the eventual stope.

The assessment carried out by the NSW Resource Regulator revealed overbreak to be a problem at every operation inspected. Operations should have robust systems in place to manage overbreak which should be measured and accounted for. In each of the operations assessed, there were a variety of methods used to calculate overbreak.

One of the most common issues identified during the assessment was that designed drive volumes assumed in the overbreak calculation, were based on a square drive shape (i.e: 5 m x 5 m) yet the drives were designed with an arched profile. An arched profile has a lower cross sectional area than a square profile, so this over-

simplification of the calculation often results in designed volumes being over estimated, masking the true extent of the overbreak.

Overbreak should be calculated monthly and reviewed by management. Measures such as lower density explosives, tighter perimeter hole spacings, drilling accuracy, shorter development rounds and close supervision of Jumbo operators should be used to manage excessive overbreak.

Mine operators also should clearly define where the brow actually is. For all operations reviewed, it was deemed to be at the last row of ground support. However other operators may determine this to be too aggressive and establish the brow position beyond the second-last row of installed ground support. Whatever measure is employed, it is preferable that the standard implemented corresponds to that used to define unsupported ground in development drives for consistency.

Managing seismicity

Mining-induced seismicity presents a risk at many underground metalliferous operations across Australia. The review found some operations had a poor understanding of seismicity and how a seismic event could affect an active stope. For mines that are seismically active, a comprehensive risk assessment of the hazards associated with seismicity should be undertaken. This risk assessment should be used to develop a seismicity management plan. Through the appropriate number and location of geophones with appropriate data capture and analysis, operations can adequately assess the risks posed by seismicity in active stopes and how to best manage them.

Management of seismicity encompasses a number of factors. The prevailing geology should be well understood by geotechnical and mine planning engineers to ensure mining orientations are optimised to reduce seismicity. Omori analysis of seismic data allows for the calculation of stand-off times and determining ground support standards. Seismicity is managed by blast design, stope sequences, ground support standards and mining orientation.

Any seismicity management plan should be dynamic in nature. Plans should be updated regularly as new conditions are discovered and more data is collected. The management plan should also be accompanied by a comprehensive TARP to inform workers at the mine what actions are required after pre-determined seismic events.

Erosion of controls

Bund dimensions

The assessment found that at five mine sites there was confusion among workers and supervisors as to an agreed bunding standard and observations underground confirmed that one or more bunds failed to meet the mine's own standard.

While all mine sites had bunding standards, the enforcement of those standards was unsatisfactory, with standards eroding at all but one operation. The single operation where bunds were found to consistently meet site standards, achieved this level of control by photographing every bund. The stope name was sprayed on the bund and a survey staff held in each photo to provide a reference for height. The images were downloaded at the end of shift and filed. One of the images can be seen in Figure 3.

For bunds to be fully effective, their heights should be relative to the backs. The assessment found overbreak to be so common as to be normalised in all six operations. Traditional markers like grade lines are not effective for measuring height relative to the backs. By taking a photo with a survey staff, bund height relative to the backs can be audited.

Another option to improve compliance is using handheld laser distance measuring tools which allow the user to pick up the top of the bund, and the backs, and then calculate the height difference. From this observation a formal sign-off can be undertaken.

Yet another option could be for survey to paint a line on the walls to show minimum bunding height when completing ring markups. This provides a simple visual check for supervisors to ensure compliance.

If mines can satisfy themselves that they can effectively manage overbreak, then the use of a grade line may be appropriate.

Defining a choked brow

A 'choked brow' is a drawpoint with no hang ups and full of stope material. A choked brow always contains the risk that a false brow has formed, holding up rilled material that could suddenly let go. To manage the risks posed by false brows, standoff distances and bunding standards should be developed with distances based on the position of the last fired ring. What this means in effect is that the brow position should be set back from the last ring of fired holes, not where it may appear to be if the last row of holes did not fire correctly.

The fragmentation of material also should be considered in defining a choked brow. Large rocks can hang up above the brow and leave a slight gap, yet operations still consider the brow to be choked (please refer to figure 2). For operations with larger fragmentation, this should be considered when determining the standoff distance between any worker and the base of a rill. There is a risk of these larger rocks moving and forcing material to fall down the rill and onto a worker.

Stand off distance for choked brows

To comply with stand off-distances, operations can consider measures such as wall mark-ups and issuing shift supervisors with electronic distance measuring devices to mark-up stand off distances pre-blast for systems of work that do not have a bund, such as watering down. Some Australian operators install a bund at the stand off location before firing a stope. This ensures there is a bund present before anyone enters the heading.

The tragic death of a boggler operator who was watering down a drawpoint in Western Australia in June 2015 highlighted the need for caution when developing stand-off distances or factors of safety. The drawpoint was hung up and the operator began watering down at the base of the rill. A 700 kg rock came down the rill and struck the operator, killing him. ([Department of Mines and Petroleum – Resources Safety Government of Western Australia, 11th June 2015](#)).

Stand off distances should be clearly labelled and measured relative to the brow, so that workers have a reference point from which they know they cannot pass. This point can be updated before each ring firing.

Standing up a rill

For some operations, particularly sub level cave operations, there will be a requirement to stand-up the rill so that a drill rig can get closer to the brow. This is usually done through a process commonly referred to as

spiling; where fibrecrete or shotcrete is sprayed on the top 1-3 m of the rill. Split-sets may also be installed to further support the rill being held up. The rill below the spiling is then bogged out. The process is repeated in another one or two passes to hold up the rill at a more vertical angle.

This process effectively creates an artificial brow. However operations reviewed had no procedures in place for the practice of spiling and no accompanying risk assessment. If the fibrecrete was to fail, the artificial brow will fracture and material will rill out. To manage this risk, operations should determine an appropriate thickness of fibrecrete and length of split-set for standing up rill material and monitor for compliance.

In-cycle bunding

Building large bunds at the end of shift, when the next shift is simply going to continue tele-remote bogging a stope, may be assessed by some operators as unnecessary since no worker is going to enter the drawpoint. In such cases an intermediate bund size is used instead. The assessment identified that some operations had implemented a separate standard for these scenarios. If such practices are considered, the operator should have implemented robust access control measures such that no person will enter the drawpoint.

Worker training

Despite three recent fatal incidents at drawpoints, during this round of assessments by the Resource Regulator, it was determined that at all but one site, operators still displayed a poor understanding of their operation's bunding standards and procedures around drawpoints.

The review identified one operation that stipulated unique bunding standards for each system of work. This created confusion as to what the appropriate bunding standards were. For example, secondary blasting required a particular bunding standard, yet the geologist taking an assay from the stope material did not know if the installed bund was correct because they had not been trained in the secondary blasting procedure.

To reduce this inconsistency, it is suggested that bunding standards are captured in the one procedure and all operators who interact with drawpoints are trained in these procedure. By ensuring these workers also receive regular refresher training, the erosion of standards is more likely to be identified and prevented.

Future studies

Bunding is the critical control most underground mining operations use in order to manage the risk of the uncontrolled rilling of material from a stope. While a bund creates a physical barrier between the worker and the rill, it is a poorly defined engineered control since the bund's strength is poorly understood. Because bunds cannot meeting the true definition of an engineered control, industry has to continually seek ways of eliminating risk by stopping workers entering drawpoints.

Research should continue on the development of remote drilling, charging, hydroscaling and surveying technology to ultimately remove workers from drawpoints. Studies should also be conducted on developing an empirical measure of a bund's strength considering, its size, shape, material type, moisture content and size distribution of the material from which it is constructed. This would provide a greater degree of confidence in the use of bunds as an engineered control.

Conclusion

The review revealed confusion at all but one operation as to appropriate bunding standards. It also revealed operations were aware of just one of the three fatalities to of occurred in drawpoints the previous year. The risks associated with drawpoints are very real and through proper consideration and management of those risks, they can be greatly reduced.

The absence of adequate risk assessments was a major finding in the review of six mines despite all systems of work requiring comprehensive risk assessment under NSW Work Health and Safety legislation. Risks associated with drawpoints can be more effectively managed through:

- elimination of risk by adoption of more remote working practices.
- detailed risk assessment processes, outcomes including bunding standards for all systems of work. This report has proposed a range of measures to determine appropriate bund heights at various distances from the brow.
- having first risk assessed all elimination options, detailed procedures for any work that must occur in the vicinity of drawpoints, with the controls developed from the risk assessment process.
- robust monitoring of erosion factors, including overbreak, bund height and placement, and cable bolting of brows
- reviewing the risks associated with drawpoints from the outset of the mine planning process
- instilling better knowledge within all technical disciplines and workers of the dangers posed by drawpoints
- ensuring only fully trained workers are involved in work in the vicinity of drawpoints
- bunds providing a poor engineered control as their strength is unknown. Operations should keep abreast of developments in remote technologies and adopt these technologies SFARP to remove workers from drawpoints.

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Figures

Figure 1. The proposed bunding method for empty stopes in mines using an open stope mining method. Note the apex of the bund sits at the stope brow.

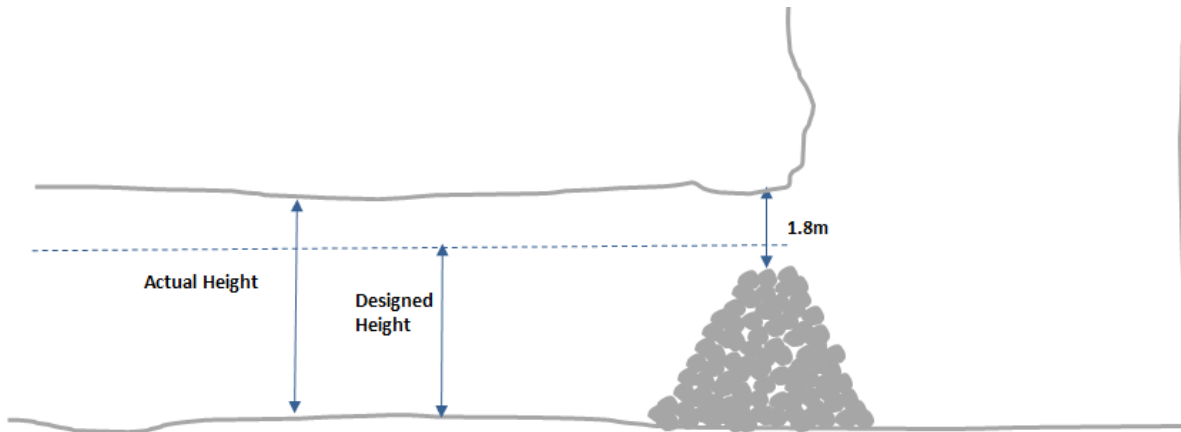


Figure 2 – Proposed bunding standard for empty stopes.

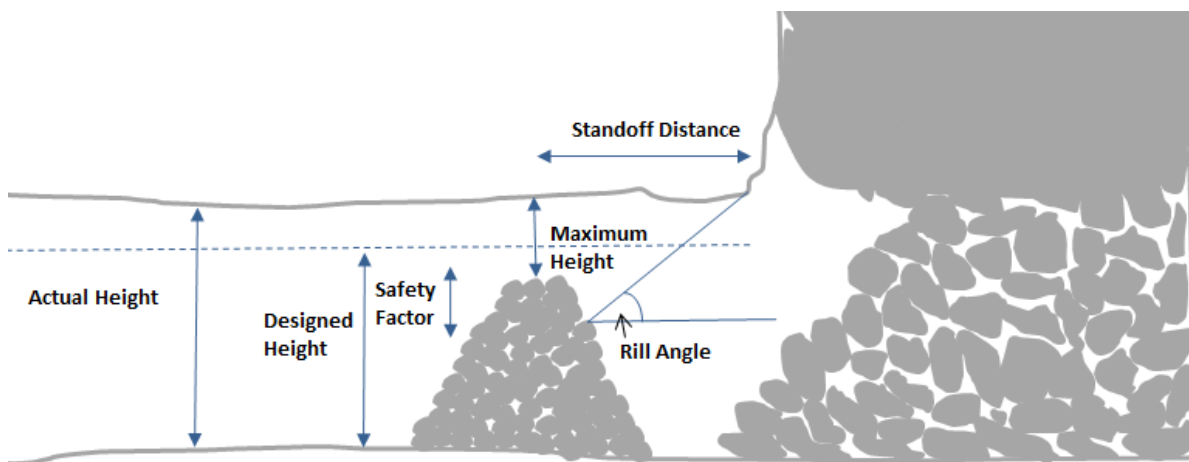


Figure 3 – Proposed method of controlling bund heights, courtesy of Perilya Ltd.

