Engineering People Out of Harm's Way

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1.0 Introduction

Behaviours at Moranbah North Mine (MNM) have traditionally been the leading cause for incidents and injury with manual handling activities and the work environment exacerbating the nature and frequency of incidents. The mine has focused on a cultural shift to pursue engineering / elimination type controls to reduce manual handling and remove personnel from the potentially more hazardous areas throughout the mine. Examples include shotcrete support for difficult to reach areas of the mine, an automated real-time roof monitoring system and the elimination of the need for the routine use of standing support in tailgate (TG) roadways.

It was recognised that the routine installation of standing support in the tailgate, in particular, involved significant manual handling, both in the installation of the support and in the restriction of access, resulting in the need to transport replacement parts from the maingate or between the standing supports. Heavy spare parts such as rams posed particularly higher risk due to their size and the frequency of the task.

The routine use of standing support also created compliance problems. A minimum buffer of 100m of installed support outbye of the face was stipulated. The buffer was difficult to maintain due to high gas in the roadway and could at times be counter intuitive to safe mining, forcing the longwall (LW) to stop in poor conditions. Encroachment on the buffer required reprioritisation of resources and written approval / justification from the Mine Manager. The operation was still forced to encroach on the standing support buffer on several occasions during the retreat of LW109. Stone dusting with standing support in the roadway impacted on its effectiveness with frequent failures recorded in TG109.

2.0 Geology

MNM is a large scale underground mine extracting hard coking coal from the Goonyella Middle (GM) seam by longwall. The GM is one of 11 coal seams that make up the Moranbah Coal Measures. The mine is situated in the Bowen Basin of Central Queensland, approximately 180km from the coastal port at Mackay.

The seam ranges in thickness from approximately 5m to 6m and is overlain by ~2m of weak carbonaceous material above which are interbedded sandstone and siltstone units. The depth of the GM seam varies up to 400m.

The immediate floor consists of siltstone, grading down into sandstones ranging in strength from 10MPa to 30MPa. A thin seam, about 0.5m thick, occurs approximately 2m to 4m from the base of the GM.

3.0 Geotechnical Environment

The GM seam roof at MNM is considered to be a low strength environment. The seam itself is estimated to have a UCS of 8MPa. In contrast to this, the immediate roof of the seam is a laminated carbonaceous siltstone and mudstone with a measured strength of around 5MPa. In order to maintain roof stability, a roof beam with a minimum of 1m of coal is left in the immediate roof in both longwall and development.

A strong contributing factor to the low strength roof environment is the presence of the Ryder seam (GMR) which overlies the GM working seam at varying parting distances and comes within several metres of the GM roof in the inbye end of the 100 series longwall panels. The interburden between the two seams is characterised by very low strength sediments and the zone where this interburden thickness is between 1m and 2m is typically where the longwall experiences poor roof conditions and reduced production rates. Cavities form easily along the longwall face in these split zones and the TG roadways experience high levels of movement and deterioration due to the weak nature of the roof material. The nature of the immediate roof means that goaf caving is typically rapid on retreat and controlling the goaf edge adequately to prevent it from running outbye along the tailgate has been challenging.

Overlying the immediate weaker roof conditions, and further north of the seam split zone in the 100 series panels, the sediments increase in strength and are composed of thicker, more competent beds and channel sandstones which vary in strength and thickness. The thickness and distance above the seam of these sandstone units impacts on the roof behaviour during mining.

4.0 Research Project Concept and Methodology

At the outset of the project, MNM was installing 1.0m Link'n'Locks in a single row on a 3m spacing in headings and a 2m spacing through intersections. An ALTS (2009) analysis (Colwell, 2009) indicated that a 4.5m spacing would be appropriate. However, this analysis was carried out using what was assessed to be inadequate data and so, given Anglo American's low risk approach to geotechnical design, it was considered necessary to develop a greater knowledge of TG roof and support behaviour by means of an intensive monitoring trial before an increase in spacing could be contemplated.

Strain was selected as the most suitable monitoring measurement as it allows large numbers of readings to be gathered comparatively easily. By contrast, stress measurement is complex and relatively expensive, requiring purpose constructed stress cells, and would yield only a small number of results. The number of results is important in an environment such as a coal mine TG where there are a large number of uncertainties which could make analysis difficult if only a small number of measurements are taken. Among these are:

i) Quality of construction of standing support

ii) Variability of the nature and structure of roof and floor strata

iii) Amount of waste material on the floor

iv) Nature and moisture content of the timber

v) Location of the standing support relative to cut-throughs

vi) Location of the standing support relative to the rib

vii) Any variations in parameters such as roof support installation and roadway width

As these confounding factors may be regarded as largely random (with the exception of location), they will be expected to cancel each other out with a sufficiently large sample size. Hence, the study was designed to generate a large number of results for each of the locations and the spacings.

Readings were taken on the inbye and outbye sides of the Link'n'Locks by a simple and easily installed measurement arrangement as shown in Figure 1.

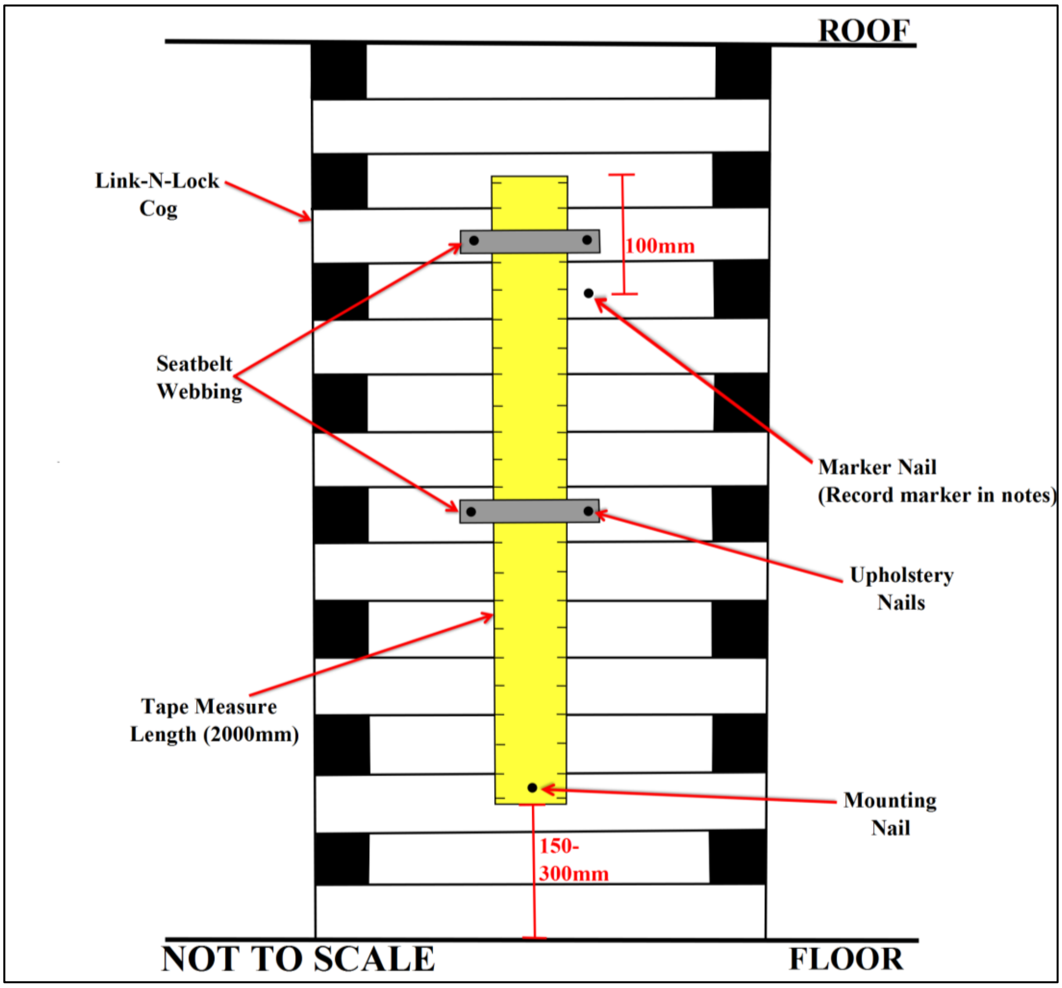


Figure 1 Arrangement for Link'n'Lock Strain Measurements

Once a large volume of data had been gathered for the original Link'n'Lock configuration, the Link'n'Lock spacing in the headings was increased to 4.5m and intensively monitored. Following a review of the data obtained during this stage of the project, the spacing through intersections was also opened up to 4.5m.

5.0 Research Project Outcomes

The results from the intensive monitoring of the various stages of the project are shown in Figure 2.

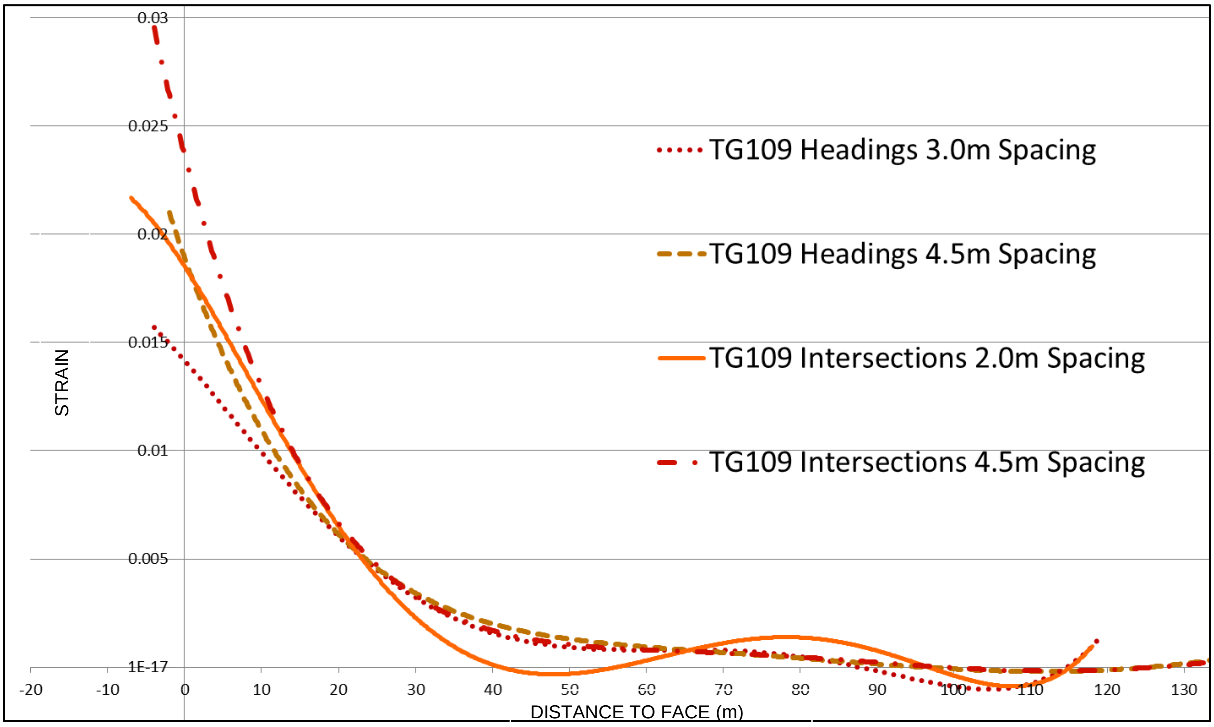


Figure 2 Research Project Outcomes for TG109

The results suggest an increase in strain at the face of the order of 0.005 for the increases in spacings (headings 0.014 to 0.019 and intersections 0.019 to 0.024). The results also suggest a difference in strain due to location (intersections relative to headings) of about 0.005. For a 3.4m high Link'n'Lock, a strain of 0.020 represents a total compression of 68mm.

Strain measured on the Link'n'Locks has potentially three components:

i) Strain due to the roof beam sagging as a result of rib spall and horizontal stresses. The load generated in the Link'n'Locks by this strain assists the roof bolts and long tendons to control the TG roof.

ii) Strain due to pillar compression as a result of increased vertical stresses. This displacement cannot be resisted and the load generated in the Link'n'Locks as a consequence does not contribute to TG strata control. As the roof comes down uniformly, pillar compression does not load the roof bolts and tendons.

iii) Strain due to floor heave, if occurring, will compress Link'n'Locks and the loads generated will resist beam deflection.

The increase in strain due to increasing the spacing may reasonably be assumed to be the difference in contribution of the two different spacings to resisting roof beam sag. In the absence of discernible floor heave, the portions of the curves which are the same irrespective of the spacing, i.e. do not diverge, are likely to be primarily due to the constant parameter, pillar compression, rather than the variable parameter, roof beam sag, as the former is independent of support resistance. Hence, from the nature of the curves in Figure 2, it may be deduced that compression of the pillars is responsible for the greatest proportion of the strain on the Link'n'Locks. The results of compressing a Link'n'Lock in a laboratory suggest that the average increased load on the Link'n'Locks due to increasing the spacing to 4.5m is a maximum of 30 tonne compared to the capacity of a Link'n'Lock which is of the order of 240 tonne.

This suggests that, in designing secondary support for a cribless TG, it is not necessary for the additional roof bolts and tendons to fully replace either the capacity of the Link'n'Locks or the total loads measured on them.

6.0 Cribless Tailgate Design Approach

The outcomes of the Link'n'Lock monitoring project in TG109 gave the necessary confidence that cribless TG design was a viable option. However, in view of Anglo American's low risk approach to geotechnical design and the major nature of the change represented by the elimination of the routine use of standing support, it was decided that the initial secondary support designs for cribless TGs should fully replace the support capacity of the standing support with tendons. In addition, the monitoring was intensified such that there was a geotechnically competent geologist carrying out the monitoring on every shift. In addition to the Tell Tales, convergence monitoring was carried out every 10m. As the convergence readings were measuring roof to floor convergence, the resulting strain measurements could be directly compared with the Link'n'Lock strain measurements.

7.0 Cribless Tailgate Outcomes

The revised standing support strategy for Moranbah North has been in effect for only 7% of LW109 (no adjacent goaf), 82% of LW601 and all of LW204. The strategy is planned to continue in LW110, however, conditions are prescribing the use of standing support until such time that proper TG conditions are achieved (i.e. double goaf conditions adjacent to LW109). Statistics of retreat from panel to panel have shown substantial improvement in safety and productivity while TG roadway conditions have been excellent.

The measured convergence strains for TG109, TG601 and TG204 are shown in Figure 3. The reduced roadway deformation (even allowing for the lower depth of cover of TG601 and TG204 relative to TG109) and hanging back of the goaf in the TG suggest that the design methodology is conservative as was intended.

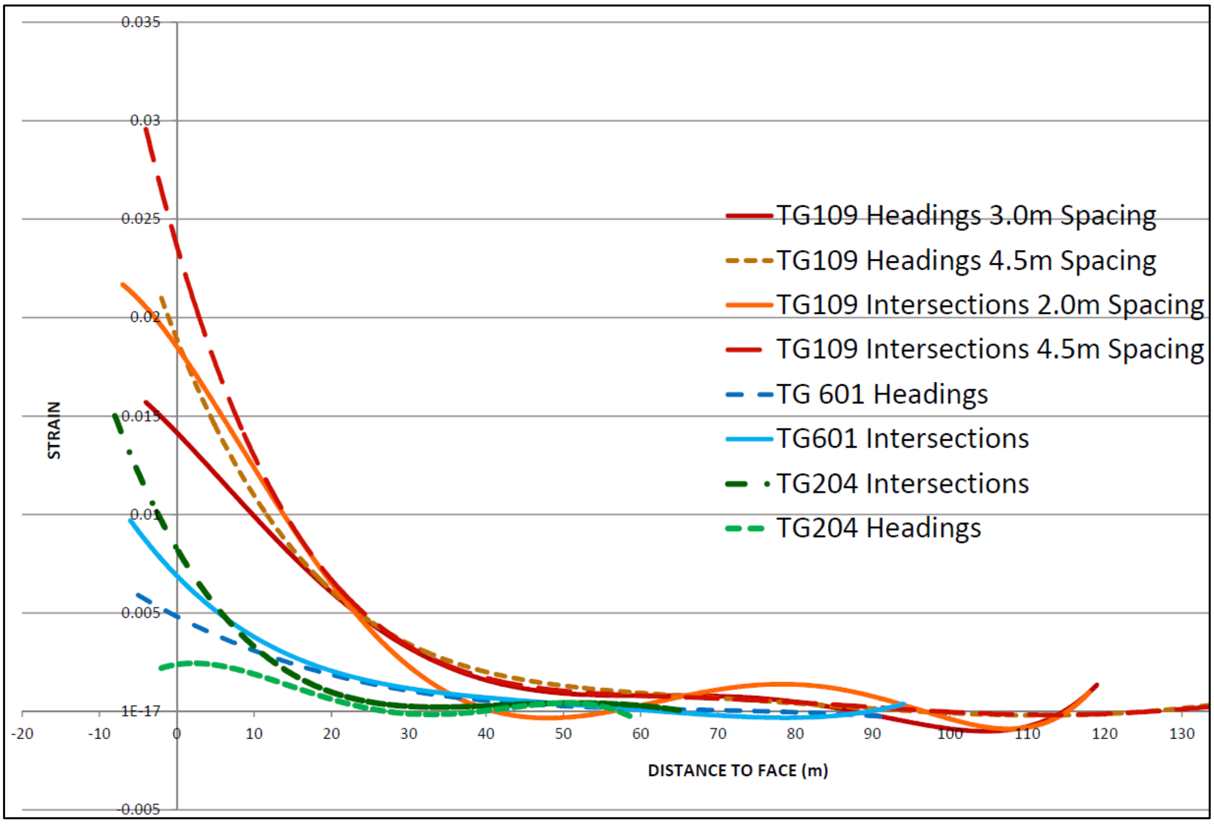
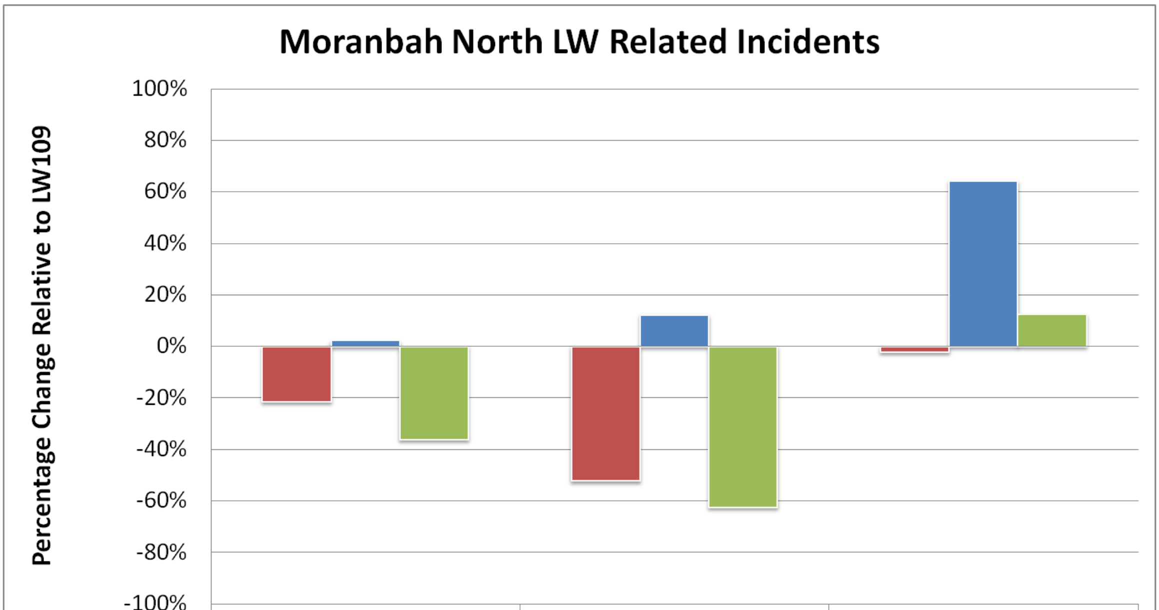


Figure 3 Roadway Convergence Comparison for Project Phases

Although the project's initial scope identified expected safety benefits, it was not considered certain that these improvements would measurable. The outcomes of the project, however, are in stark contrast to these assumptions and the improvements in safety have significantly exceeded expectations. The two defining variables were the removal of 200 man-hours per week from the TG roadway and the face access provided by an open TG. It is estimated that 323 hours of manual handling activities in LW109 were due to standing support, most of these involved the transport of heavy spares over the bootend such as relay bars, flippers, rams, etc.

LW related safety incidents are categorized as hazards, loss/damage reports or injury/health. To account for varying longwall sizes, data are analysed as rate or incidents per 1000m of LW retreat. LW109 is considered as the baseline with information for subsequent panels presented as percentage change. The revised standing support strategy saw an reduction in the combined incidents of 19% for LW601 and 30% in LW204.

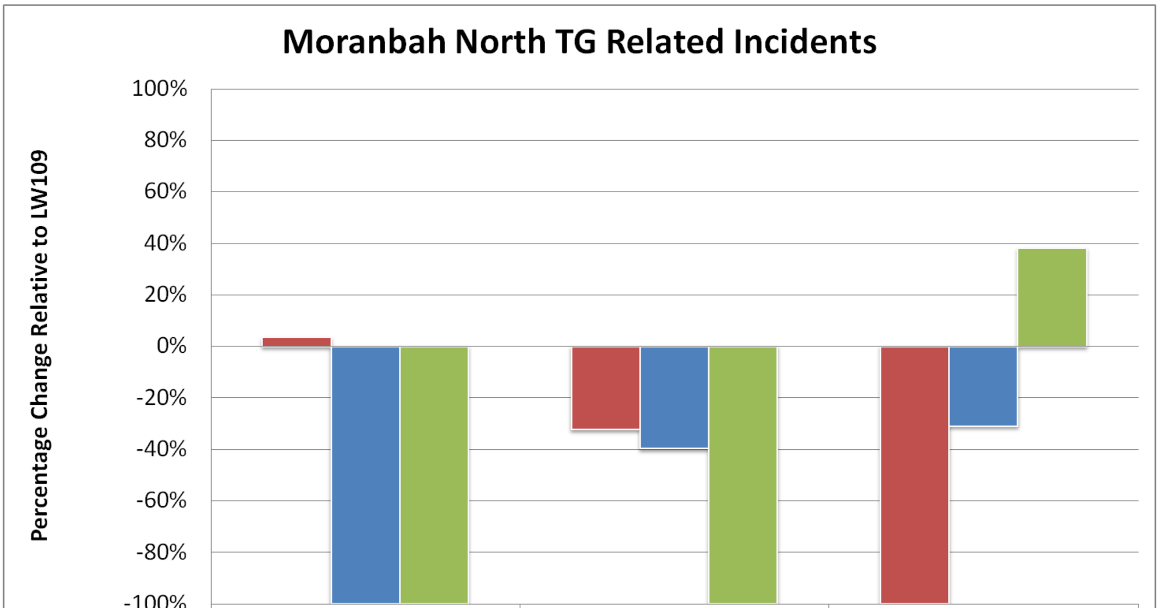
Injury/health related reports for general LW activity reduced by 36% in LW601 and 62% in LW204 (Figure 4).



	LW601	LW204	LW110
Loss/Damage	-22%	-52%	-2%
Hazards	2%	12%	64%
Injury / Health	-36%	-62%	12%

Figure 4 Safety Statistics Reported for General LW Activities

Although injuries directly related to TG activity in LW109 only represented 10% of reported injuries for LW109, no injuries were recorded for tasks directly related to TG activities in LW601 and LW204 (Figure 5). Significantly, the rates for general and TG specific activities increase substantially in LW110 where standing support has been a routine part of activities again.



	LW601	LW204	LW110
Loss/Damage	3%	-32%	-100%
Hazards	-100%	-40%	-31%
Injury / Health	-100%	-100%	38%

Figure 5 Safety Statistics Reported for TG Activities

The routine installation of standing support in TG109 cost a minimum of 20 hours per week in planned stoppages which was no longer required in the revised support strategy. LW601 saw an improvement in uptime hours of 24% and weekly retreat of 49%. LW204 experienced similar improvements with 32% in uptime hours and 64% in retreat metres (Figure 6). The statistics for LW110, currently utilising standing support, show a relapse in these numbers.

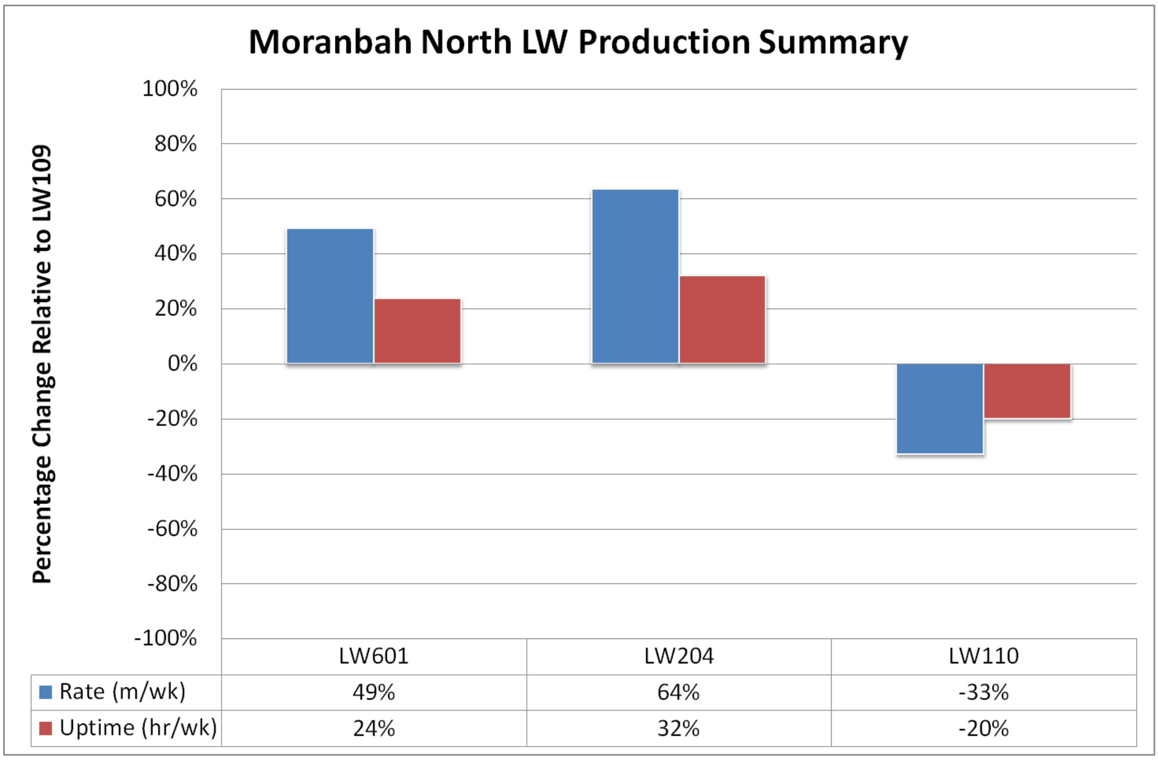


Figure 6 Summary of LW Production Rates and Uptime for Project

During the start-up of LW601, where standing support was initially utilised, a single incident resulted in 40 hours of delay and manual handling as the TG drive had to navigate through the pre-installed cans.

Cost Saving for the various stages of the project have also indicated positive results with an estimated cost saving in man-hours and material costs of 78% (~$75k per pillar) in LW601 and LW204. Even the intermediate stages of the project demonstrated 46% ($43k per pillar) cost saving just by increasing standing support spacing. A total cost saving of $5.5m is projected by the end of the project ($2.75m per year).

The removal of routine standing support meant that the mine no longer had to manage the support buffer or encroach on it. Stone dust coverage/compliance in TG601 also improved dramatically with 75% reduction in recorded failures.

8.0 Conclusion

The project has demonstrated the benefits that can be achieved by obtaining a good understanding of strata behaviour by collecting data in sufficient quantities that is relevant to the behaviour being investigated and cognisant of the circumstances and constraints of the data gathering process.

In this case, the data have resulted in there being confidence in the understanding of the manner in which standing support behaves in MNM TG roadways. This has enabled, through an engineered and managed process, the elimination of the routine installation of standing support in MNM TGs.

As has been demonstrated, the results in terms of safety, productivity and cost savings have been significant.

Due to the magnitude of the change, an appropriate level of conservatism was built into the project. The continued intensive monitoring has resulted in a good appreciation of the influence of this conservatism on the outcomes of the project. As a result, further optimisation of the TG secondary support design is possible in the future.

9.0 References

Colwell, M. G. (2009). Computational Aspects of ALTS. ALTS 2009 Resource Files, Colwell Geotechnical Services