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Optimisation of Overburden Blasts at Glencore Ulan Surface Coal Operations

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OPTIMISATION OF OVERBURDEN BLASTS AT GLENCORE ULAN SURFACE COAL OPERATIONS

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ABSTRACT: This paper presents the outcomes of a joint project carried out by Glencore Ulan Surface Operations and Orica, to reduce total mine cost by optimising overburden blasts. Typical overburden blasts are 60 m wide and 1000 m long with the blasts designed to cast. Ulan Surface operations has a Marion 8050 dragline operating using the traditional Key-Low wall combinations, High Wall Chopping and Extended Bench according with spoil profile balance with a dragline production rate of 2000 bcm/hr.The objectives of the project were to: optimise post blast muckpile profile to improve dragline advance; improve cast percentage (%); reduce coal roof damage and edge loss; and control blast emissions and their impact on neighbours. The aim of these objectives is to reduce the total cost of mining. The use of Orica's advanced blast modelling software, Distinct Motion Code (DMC), was essential in this as it allowed the analysis of alternative blast designs using the results from previous blasts in Strip 5 as the baseline. The results of the modelling indicated that there was scope to improve the cast % from a baseline of 23% to a range of 25-35% to final. In addition, the coal model was validated using touch coal and gamma logging data for each strip. From this information the blastholes were designed to stand-off from the coal seam and QA/QC approaches in the backfill and redrill tolerances were implemented. This paper also presents outcomes of this validation work.

INTRODUCTION

Ulan Coal Mines Limited (UCML) is one of the most established coal mining operations in the Western Coal Fields of NSW. The mine is located 40km north of Mudgee in the state's central west region with operations only 3 km from the village of Ulan (Figure 1). The complex consists of two approved underground mining operations (Ulan No.3 and Ulan West) and an Open Cut coal reserve. There has been a rich history of open cut mining at Ulan dating back to the early 1980s with the current dragline in operation since that time. The operation has changed ownership several times over these years but most recently it was purchased by Xstrata to run in conjunction with the two underground operations. Ulan open Cut was brought to life in early 2012.

The Ulan Open Cut is set up as a 24x7 strip mine operation in which overburden is mined primarily using a dragline. Where possible the dragline removes all of the overburden material to ensure lower operating costs. Based around dragline techniques and efficiency, the blasting practices are to cast-blast an entire strip with several subsequent coal blasts as coal is uncovered and required (Figure 2). Currently the open cut produces approximately 2.0 Mtpa of coal with the flexibility to vary this significantly. Current life of mine plans extends out to 2019. This paper presents the outcomes of the joint project carried out by Glencore Ulan Surface Operations and Orica to reduce total mine cost by optimising overburden blasts. The paper also discusses the optimisation approach, enabling tools/softwares, Quality Assurance/ Quality Control (QA/QC), coal loss and blast emission controls to manage vibration, overpressure and fume.

GEOLOGY

Borehole R834 was chosen to detail the geology of strip 6 which was being mined as of November 2013. The details of the geological description and core logs are given in Appendix 1. The overburden consists of interbedded, weathered sandstone and siltstone in the top 12 m above the base of weathering. The base of weathering is at around 12 m. Below the base of weathering is approximately 6 m of moderately soft, quartz lithic, fresh sandstone, light grey in colour. From 25 m to coal (30.83 m) is a moderately hard, lithic to quartz lithic, light grey sandstone.

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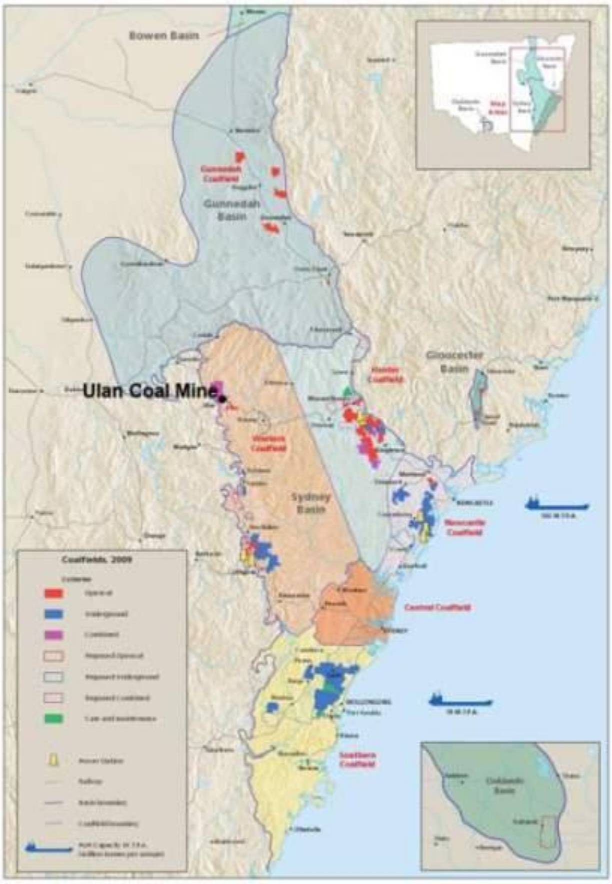


Figure 1 - Location of Glencore Ulan surface coal operations

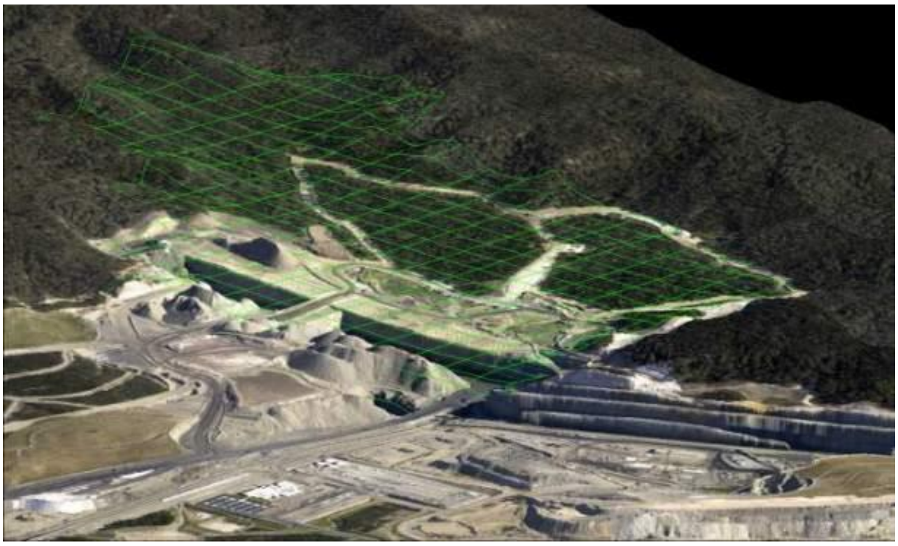


Figure 2 - Pit layout for the strip mining

As shown in Appendix 1, there are two coal seams in the strips. The top seam is called the UAA Rider band which is approximately 0.58 m thick, of poor quality therefore not mined. The rock between the rider band and the main coal seam (ULA) is carbonaceous siltstone and the thickness of this band is 1.06 m. The Ulan Seam working section is 6.53 m thick.

Gamma logging was also carried out at Strip 6 to validate the top of coal seam obtained from driller's logs and the coal model. This would be discussed in detail in later section. Figure 3 shows the gamma log results of blasthole B11, Strip 6 showing both Rider band and Ulan main seam and is representative of the coal seams in this region.

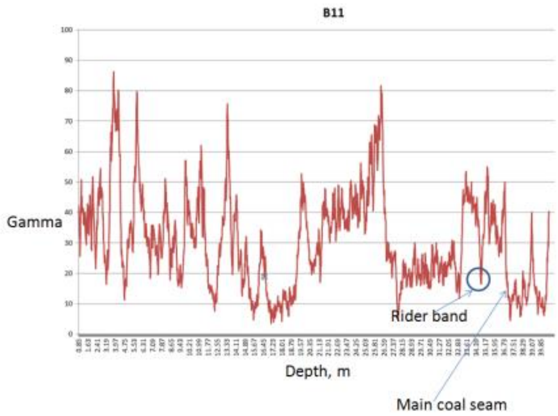


Figure 3 - Gamma log result for hole #B11

STRIP MINING METHOD

Ulan Open Cut is a dragline open cut pit that recommenced mining in March 2012 with an estimate life of mine until 2019 at 2.0 Mt of ROM coal per year. It is a single coal seam operation (thermal – high ash) where coal seam is 7.5 m thick with a relatively flat floor. Overburden thickness varies from 28 up to 65 m. Pre-stripping operations are required to guarantee a blasting bench of not more than 50 m height.

The mine has got the following equipment: 1xMarion 8050 dragline, 1xHitachi EX3500 hydraulic excavator, 1xKomatsu WA1200 Loader, 5xCaterpillar 789 trucks and 7xCaterpillar D11T dozers.

Dragline dig methods used at Ulan Open Cut vary from traditional key-low wall combinations, high wall chopping and extended bench according with spoil profile balance and a planned dragline productivity of 2,000 bcm/h. Figure 4 shows the key-cut method used at the mine.

Figure 4 - Key-cut method used at Ulan Mine

OVERBURDEN CAST BLASTING OPTIMISATION

Cast blast design parameters

Ulan surface operations commenced mining the first strip by firing Strip#1 on March 15th 2012. Currently Strip 6 is being mined out and Strip 7 is being drilled (Figure 5).

After the initial box cut each of the strips has essentially been blasted as a single cast blast with similar characteristics and blast parameters. In general the strips are 60 m wide, 30-50 m high and 800-1100 m long. The strip width is optimised for dragline efficiency. The pit profile is generally 30m from surface to top of coal in the middle and upwards of 50m on each end of the strip.

Previous strips used a variety of similar burdens and spacing with minor product variations in initiation systems (Exel™) and bulk products (Fortan™ 12) with a process of optimising the application of bulk products being applied for blast in Strips 2 to 4. For Strip 1 a spacing of 12 m was used with multiple decks to comply with site Maximum instantaneous charge (MIC) limits that resulted in a lower powder factor. The subsequent 4 strips used 14 m spacing with small variations in burden.

Strip 6 used a reduced spacing of 13 m and optimised burdens to aid an improved muckpile profile and optimised cast. Strip 6 had the following cast blast design parameters:

- 60 m wide
- 1 040 m long
- 644 holes, Depth: Average = 36 m, Min = 31 m, Max = 51 m.
- Hole diameter: 251 mm
- 13 m spacing, 6 m face burden, 6.5 m for the next row and 7.4m for remaining rows.
- 0.5 kg/m3 design powder factor
- Blast volume: approximately 2.2 Mbcm
- 5 m stemming length
- 1800 kg/hole
- Initiation system: i-kon™ electronic blasting system
- Bulk explosives: Fortan™ Coal 12, Fortis™ Coal, Aquacharge™ Coal

Figure 5 shows the mine plan for Strip 6 and upcoming strips. To minimise coal edge loss the coal seam is buffered using imported coal rejects from the wash plant. Figure 6 shows Strip 6 buffering in process.

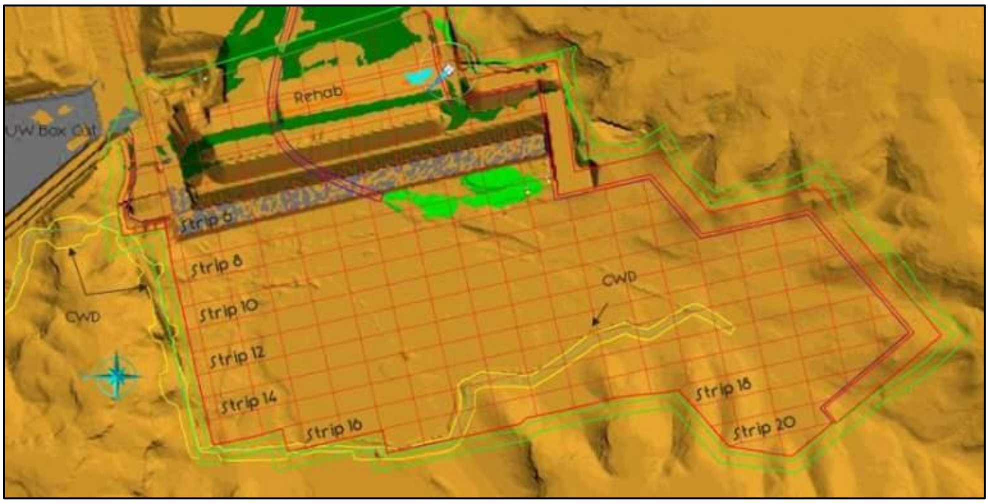


Figure 5 - Strip 6 and other strips to be mined at Ulan surface operations

Muckpile shaping for optimised dragline productivity

A review of the drill and blast design was implemented after the firing of Strip 5 with final aim to reduce the overall cost of the dragline operation with the following key requirements:

- The post blast muckpile profile is required to have an optimum height of ~28 m to optimise the dragline performance by reducing rehandle and improving advance along strip;
- Optimise cast %;
- Identify the coal loss and implement methods to reduce coal loss; and
- Implement changes to drill and blast process with a continuous improvement imperative.

Figure 6 - Coal edge buffering process in Strip 6

Muckpile profile optimisation using blast modelling tools

In the modelling process to meet the required muckpile profile the blast profile, blast parameter data from Strip 5 formed the base case. From this base case, alternative blast designs were modelled using Orica's advanced blast model, Distinct Motion Code (DMC). The base case and alternative blast designs are summarised in Table 1. The results of the alternative designs are detailed in Appendix 2.

Table 1 - Base case and alternative cases for blast modelling

	basecase	c1	c2	c3	c4
Row 1	7.1	6	6	6	5.5
Row 2	7.5	5.5	6	6	5.5
Row 3	7.5	7.5	6.5	6.5	5.5
Row 4	7.5	7.5	7	7	6
Row 5	7.5	7.5	7.5	7.5	6
Row 6	7.5	7.5	7.5	7.5	6.5
Row 7	6.7	7.5	8	8	7
Row 8	5.2	7.5	8	8	7
Row 9					7.5
Spacing	14	13	13	12	11
Burden(average)	7.1	7.1	7.1	7.1	6.3
PF (kg/m^3)	0.49	0.53	0.53	0.57	0.7

The base case (Strip 5) delivered an actual cast of 23.1% and the modelled cast result for Case 1 was 25.5%. Using a step by step approach the team implemented the blast parameters as detailed in Case 1 for Strip 6.

To ensure optimum timing and the required emission control i-kon™ electronic blasting systems were implemented. Strip 6 loading required the use Aquacharge™ Coal due to rain events in the weeks prior to the loading making a large percentage of holes damp or having wet sides. This is discussed in more detail in Section 5.

The actual cast for Strip 6 was calculated to be 25.1%. The modelled prediction was 25.5%. Figure 5 shows the cast profiles before and after the optimisation work. As mentioned earlier prior to the start of the muckpile optimisation work the mine was using non-electric initiation and Fortan™ Coal 12. The use of these systems and associated blast parameters resulted in a cast of 21.1%. By the implementation of the muckpile profile project where the type of bulk product used was optimised, i-kon™ electronics blasting system implemented, blast patterns adjusted via DMC modelling and environmental emissions managed the team delivered an increased cast of 4% and an improved muckpile profile to reduce rehandle and improve the dragline rate of advance.

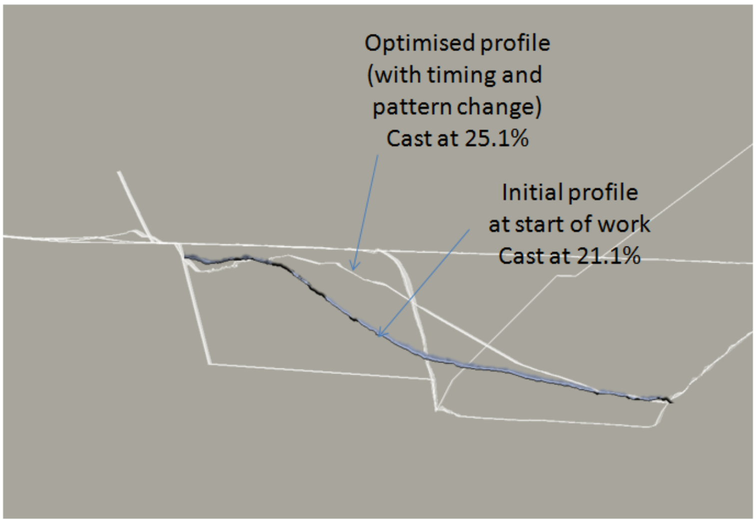


Figure 7 - Comparison of the muckpile profiles

Table 2 lists the cast % achieved in the last six strips. It is shown that cast % was gradually increased with the use of the continuous improvement process in the application of bulk products and the change to electronic detonators.

Table 3 shows the dragline productivity for October 2013 for Strip 6 and the productivity summary for Strip 5 for a similar time period. As can be seen the dragline productivity rates (bcm/h) are similar, swing angle has been reduced from 113 to 95 degrees and the cycle times reduced from 77 to 69 seconds. The combination of these factors indicates that the dragline advance along strip has improved.

Table 2 - Cast % in strips mined to date

Strip	Cast %
1	21.4
2	21.1
3	23.5
4	23.7
5	23.1
6	25.1

Quality Assurance/Quality Control

Common practice at most coal mines is for drillers to be instructed to drill to coal every 5 to 10 holes and adjust the remainder of blastholes drilled to achieve the required standoff. This is primarily due to the variation between the modelled coal seam and the actual seam location. At Ulan the drillers used the rider coal band as the stand off line for blastholes that were not drilled to the main coal seam as a practical guide for drillers. For Strip 6 a change was implemented with every blasthole drilled to touch coal to ensure a consistency for all drillers and a QA/QC process implemented. This process required each drill hole to be measured and backfilled to achieve the required stand off and the depths recorded. The stand off used in Strip 5 was 3 m for the front row and 2 m for the remainder of the blastholes. When the holes were dipped it was found that majority of holes already had a backfill with cuttings of approximately 1-1.5 m due to a variety of factors such as drilling practice where air is turned off before hole has been completed, wind and rain. From the drill logs an actual coal surface was generated and backfills applied during loading using drill cuttings. All blastholes that did not meet the required tolerance were redrilled. The implementation of this QA/QC process ensured improved control of blasthole depths and associated stand off from coal. Appendix 1 details an analysis of the blasthole depths and associated deviation.

Table 3 - Dragline productivity analysis

	Strip 5	Strip 6 (October report)
Cast %	23.1	25.1
Dragline bcm per operating hour	2113	2140
total cycles per cycling hour	47	52
Average Swing Angle (deg)	113	95
Average Cycle Time (secs)	77	69
Average Fill Time (secs)	15	15
Average Bucket Load (BCM's)	52.1	45.9
Total bcm/month	932,468	1,111,216

A review of the coal model and the actual coal surface from drill logs showed that the coal model was deeper by approximately 0.4 m with a 0.8 m standard deviation. The coal roof model when compared to the survey coal roof showed a standard deviation of 0.7 m (see Appendix 3).

When hole depths are compared for the strip 6's front row calculated from strip 5's survey coal data and touch coal data, it was shown that touch coal data was approximately 0.9 m shorter. This calculation was done for the front row as the coal seam dips slightly (-1.9^{o}). There was limited survey coal information for Strip 6.

In addition to this analysis, five blastholes were gamma logged in Strip 6 to compare the coal surfaces obtained by touch coal, design coal and gamma log results. Table 4 summarises the results.

Table 4 - Coal depths from design, touch coal and gamma logging

Hole ID	Design coal depth, m	Touch Coal data_driller, m	Gamma Coal, m	Gamma vs design depths, m
B6	36.86	39.2	40.4	-3.5
B11	34.91	41.1	36.9	-2.0
D11	35.12	41	37.3	-2.2
E18	34.3	37.7	36.2	-1.9
G11	34.26	41.3	37.2	-2.9
average				-2.51

The following can be drawn from Table 4:

- Design depths are 2.5 m shorter when compared to the gamma coal depths for the zone that was logged.
- Design depths are shorter than Touch Coal (TC) depth by 0.8 m.
- When TC data is compared with the strip 5's last row's survey coal data, it was found that TC data is about 0.9 m shorter than actual survey coal.

Coal loss

A post blast visual examination of the top of coal surface post dragline excavation showed, in general, minimal damage to the coal roof. It was noted that a 0.5 m shale band was left above coal roof after dragline excavation and the coal roof had limited to no damage. The second type of coal loss to be evaluated is edge loss which is relevant in cast blasts as at Ulan Coal Mine. An analysis of edge loss showed a loss of approximately 2 m for the top 1.5 m of coal which is consistent with the model (See Appendix 2) and observations (Figure 8).

A review of these results has led to changes for Strip 7 blast loading design with extra standoff and the use gravel for backfill in the front rows to minimise the coal edge. It is the opinion of the team that the use of gravel for backfill in the front rows will assist in minimising the coal edge loss. By implementing this change the team is ensuring that all factors are evaluated before other options such as 'baby decking' are considered for future blast improvements.

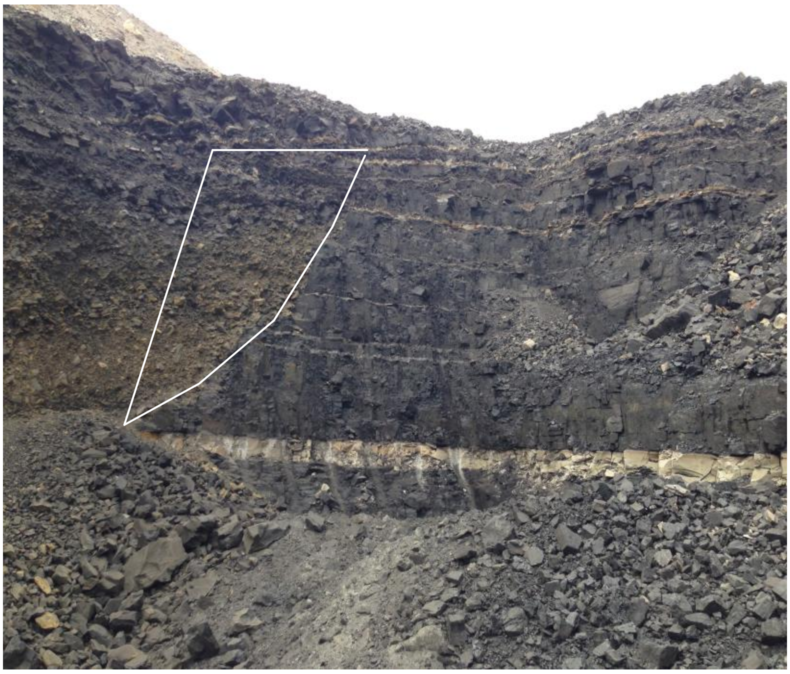


Figure 8 - Coal edge loss

BLAST EMISSIONS

Blast vibration and airblast

Despite its reasonably remote location, Ulan mine is faced with a number of blast emission constraints that restrict some blasting practices. As per project approval, Ulan mine is obligated to comply with the following:

- < 115 dBs and < 5 mm/s at closest neighbour (~2.5 km)
- < 115 dBs and < 5 mm/s at Ulan Public School (~3 km)
- < 100mm/s at archaeological sites
- 3000 kg MIC limit at site.
- Fume generation
- Fly rock

The 5 mm/s vibration limit is not an issue for the site at the current time as the blasts to date resulted in vibration values well below the limit (See Table 5).

The 115 dbover pressure limit is of concern due to the relatively close location of monitors, the large amounts of explosives detonated in a single blast event and the preferred firing direction to deliver the required blast profile is toward the monitors. To reduce the risk of an event Orica used its ShotPlus™ 5 Professional design program to determine the number of holes arriving at monitoring locations in a given time window, with this as a base a variety of timing options were evaluated whilst delivering the optimum blast profile.

The 3 tonne MIC is perhaps the most restricting of constraints as a single blast hole of a hole depth of 35 m contains 1.8 t alone. The constraint basically means that every hole needs to be fired within its own 4 ms window. This had an effect on options available for face row timings and variable burden timings, it proved quite difficult to achieve a face row faster than 4.2 ms/m without negative effects at monitors.

After the recent blast there has been a big effort to have the MIC limit lifted or removed. A late change was made to the timing in the northern end of the shot in an attempt to move the dirt in a more desirable position for the dragline which meant that precise timing was required to meet the blast emissions criteria. This would have been impossible without the use of electronic detonators.

Table 5 - Blast vibration and airblast data from overburden blasts

Shot ID	Distance		Actual Air Blast (dBL)		Actual Vibration (mm/s)	
	Ulan School	Cope Road	Ulan School	Cope Road	Ulan School	Cope Road
S6_Overburden	3314	2899	101.0	106.0	0.80	1.20
S5_Overburden	3306	2983	108.9	115.5	0.93	0.64
S4_Overburden	3485	3086	102.9	100.4	0.97	1.63
S4_Sth_Ext_OB	3217	2996	99.2	100.6	0.93	1.01
S3_Overburden	3496	3133	105.9	99.0	1.53	1.14
S3_Nth_Ext_OB	4204	3435	112.4	107.8	0.77	1.11
S2_Overburden	3820	3447	109.6	105.7	0.94	1.45
S2_Nth_Ext_OB	4262	3611	95.8	107.6	0.94	0.93
S1_Overburden_2	3630	3435	101.4	96.5	0.49	0.50
S1_Overburden	4007	3618	112.1	116.6	1.00	1.13

*Yellow cells are high overpressure readings.

In the previous twelve months two of the overburden blasts caused airblast issues (>115 db). Investigations into te two events showed that the causes were stemming ejection due to cratering below the designed stem zone as a result of the increased explosive amount and/or stemming bridging. Another common cause for airblast is the face burst. The risk of this has been reduced at Ulan with the use of face scans to ensure sufficient burden exists for the front row with adjustments to the standard loading as required.

Presplit blasts were stemmed at Ulan with 4 m length. Initially, each hole was separated by 25 ms delay using the detonating cord on surface. After the introduction of i-kon electronic blasting system there was a change with four blastholes fired in a group with the similar delay time between groups. The change improved the presplit efficiency between blastholes. This configuration has resulted in a continuation of overpressure measurements less than 115 db.

Fume

Typically the ground at Ulan is quite damp and varies from almost dry at the south to several meters of water at the north (the seam dips to the north east at ~2^{o}). Wet holes are loaded with Fortis Coal product. The middle third of the blast is essentially dry with damp clays on the walls of the holes, this area of strip was loaded with mostly dry product (Fortan™ Coal 12) and some degree of slumping was observed through this section which resulted in small amount of fume. In Strip 4, a change in bulk product to Aquacharge™ Coal product was implemented with an improved blast result with no fume in the Aquacharge™ section. In Strips 5 and 6, the Aquacharge™ use increased due to unusual rain events prior to loading. For strip 6, due to rain a larger section of the loading used Aquacharge™ with good (no fume) results. To adjust for the changing ground conditions strip 6 comprised 40% dry (Fortan™ Coal 12), 40% Aquacharge™ Coal and 20% wet (Fortis Coal) products. The fume level in Strips 4 and 5 were recorded as Level 2. For Strip 6 the fume level was recorded as zero which can be attributed to the use of appropriate bulk products (Fortan™ Coal 12, Aquacharge™ Coal and Fortis™ Coal) for the blasthole conditions encountered.
All bulk products are blended to the same density to maintain powder factor and consistency of energy. Additionally there has been a reduction in sleep times from3 weeks to 2 weeks with an improved team approach that has also reduced the risk of fume from extended sleep times. This approach has resulted in the blast in Strip 6 having a fume recorded as zero.

Flyrock

Cast blasts, such as that being applied at Ulan Coal Mine, may result in an increased risk of fly rock. During the analysis process, it was found that a design of 6 m face burden does not cause flyrock. The blast face is affected by a variety of factors such as over dig by the dragline and/or excavator, weather events such as rain that lead to geological failures and damage from previous presplit blast especially at the crest. As has already been mentioned to ensure the front row blastholes have the required face burdens and can contain the explosives being used the blast face is scanned. A profile is made for each blasthole and the loading is determined from this analysis. The analysis of Strip 6 has shown that there is a large amount of crest damage occurring that has required an increase in stem heights for the front to approximately 5.5 m. As part of the continuous improvement process this issue is assessed for improvement with changes to presplit loading for Strip 7 being implemented.

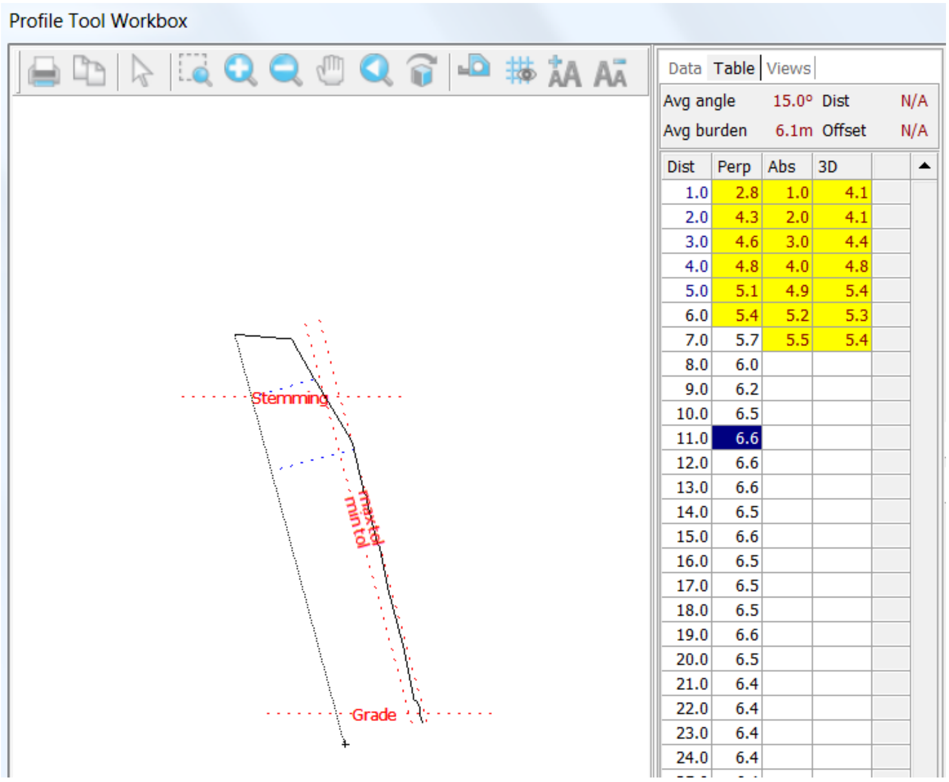


Figure 9 - One of the face row's hole position with respect to face

CONCLUSIONS

The joint project carried out by Glencore-Xstrata at Ulan Surface Operations and Orica achieved the project objectives with a process for future continuous improvement using a team approach. The focus on QA/QC provided the means to analyse the changes being implemented, understanding the reasons for the results being achieved in coal damage, blast emissions and the final blast result. Orica's modelling programs, DMC and ShotPlus™ 5 Professional, were essential to analyse the variety of options to determine the optimum solution.

The achievements of this team were:

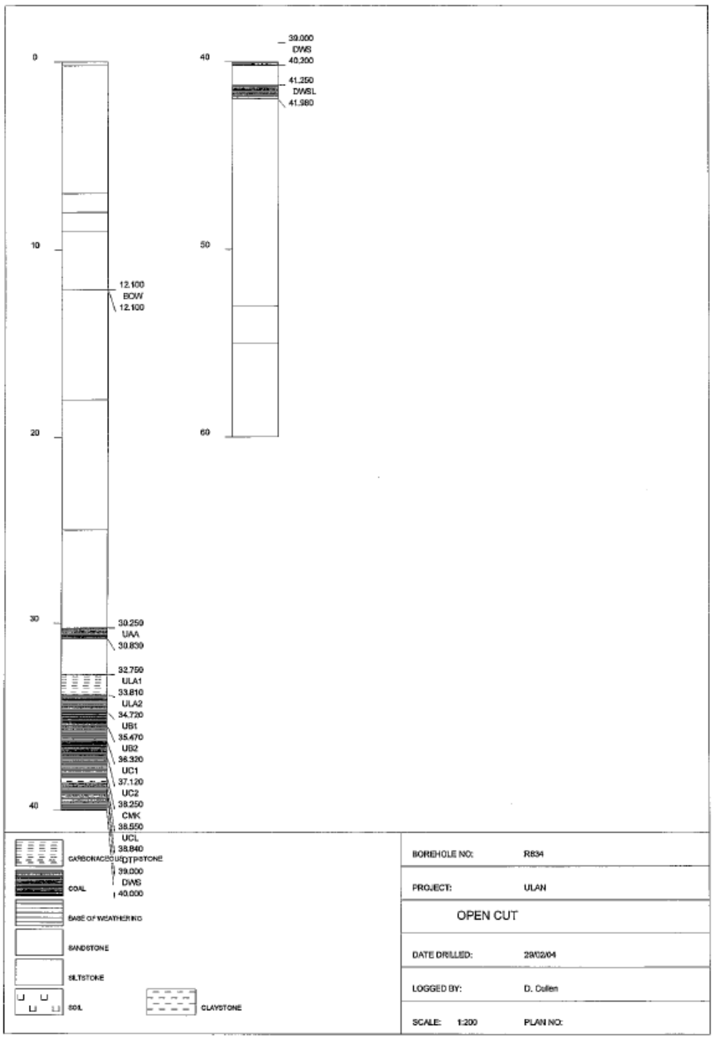
- The cast % increased from 21.1 to 25.1, which is 4% increase (19% improvement);
- Improved post blast profile improved the dragline's performance and operating method;
- Blast emissions managed;
- Fume managed by appropriate use of bulk product, blasthole determination and managing sleep time; and
- Coal loss has been reduced but coal edge loss is still an issue and options are being considered for implementation for Strip 7 to be fired in December 2013.

APPENDIX 1 - BOREHOLE R834 GEOLOGY

Geological strata description and core logging results for the borehole R834 in Strip 6 at Ulan Surface Operations

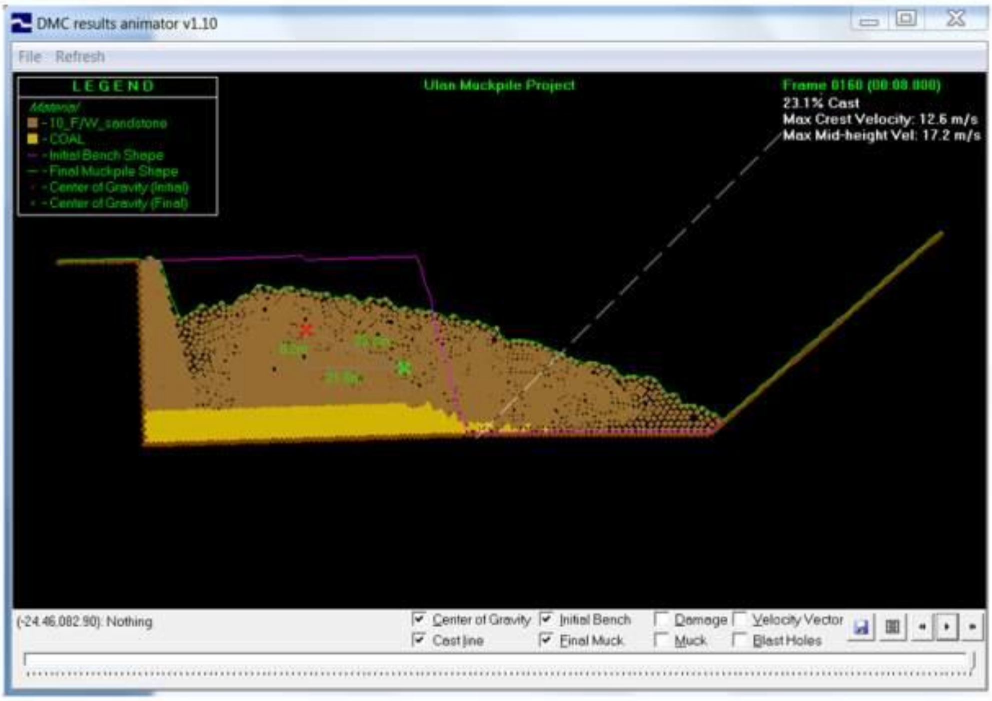
BORE NAME R834

DEPTH	THICKNESS	RECOVERED	GEOLOGICAL DESCRIPTION OF STRATA		SEAM
0.200	0.200	0.200	SOIL	brown.	
7.000	6.800	6.800	SILTSTONE	brown orange, weathered, soft.	
8.000	1.000	1.000	SANDSTONE	light brown, medium to coarse grained, lithic, weathered, moderately soft.	
9.000	1.000	1.000	SILTSTONE	grey, slightly weathered, moderately soft.	
12.100	3.100	3.100	SANDSTONE	orange brown, coarse grained to granule sized, quartz-lithic, weathered, moderately soft.	
12.100	0.000	0.000	BASE OF WEATHERING		BOW
18.000	5.900	5.900	SANDSTONE	light grey, coarse grained to granule sized, quartz-lithic, fresh, moderately soft.	
25.000	7.000	7.000	SANDSTONE	light grey, fine grained, lithic, moderately hard.	
30.250	5.250	5.250	SANDSTONE	light grey, medium to coarse grained, quartz-lithic, moderately hard.	
30.830	0.580	0.580	COAL		UAA
32.750	1.920	1.920	SILTSTONE	grey dark grey, moderately soft.	
33.810	1.060	1.060	CARBONACEOUS SILTSTONE		ULA1
34.720	0.910	0.910	COAL		ULA2
35.470	0.750	0.750	COAL		UB1
36.320	0.850	0.850	COAL		UB2
37.120	0.800	0.800	COAL		UC1
38.250	1.130	1.130	COAL		UC2
38.550	0.300	0.300	CLAYSTONE		CMK
38.840	0.290	0.290	COAL		UCL
39.000	0.160	0.160	COAL		DTP
40.200	1.200	1.200	COAL		DWS
41.250	1.050	1.050	SANDSTONE	light grey, coarse grained, lithic, moderately hard.	
41.980	0.730	0.730	COAL		DWSL
53.000	11.020	11.020	SANDSTONE	light grey, medium to coarse grained, quartz-lithic, moderately hard.	
55.000	2.000	2.000	SILTSTONE	grey, moderately soft.	
60.000	5.000	5.000	SANDSTONE	light grey, coarse grained to granule sized, quartz-lithic, moderately hard.	



APPENDIX 2 - MODELLING RESULTS

Base case

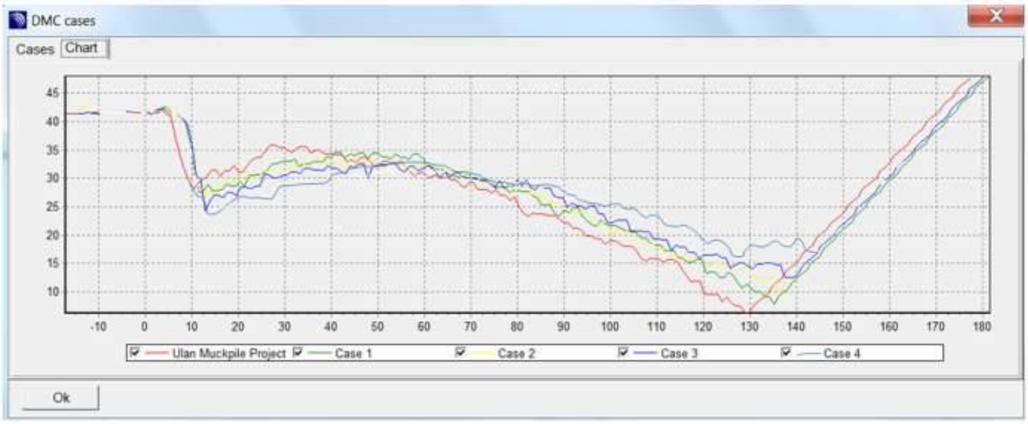


Summary

DMC cases

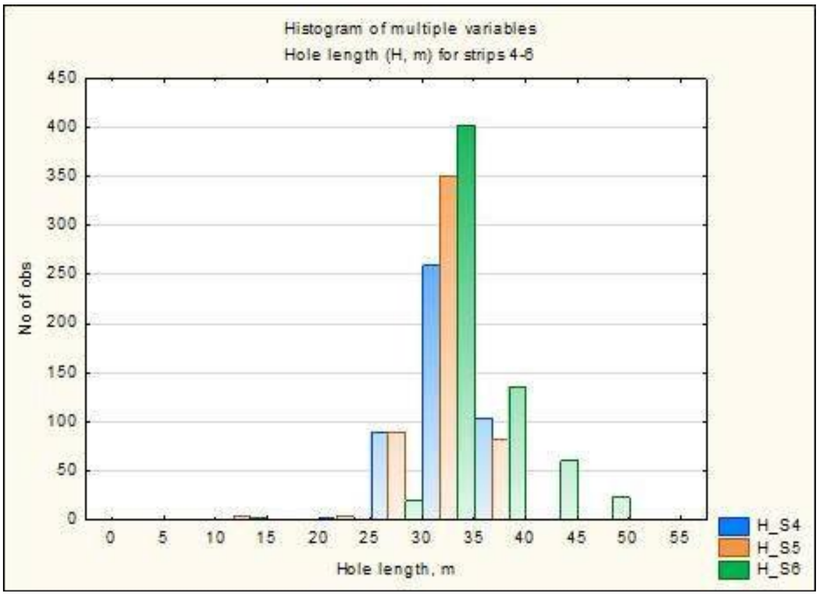
Cases Chart

#	Description	Results	%Cast	CG movement X(m)	CG movement Y(m)	Max Crest Vel X(m/s)	Max Crest Vel Y(m/s
1	Ulan Muckpile Project	Yes	23.1	21.6	-8.2	12.6	17.2
2	Case 1	Yes	25.5	24.6	-8.5	13.2	17
3	Case 2	Yes	27	26	-8.8	13.8	17.8
4	Case 3	Yes	29	28.4	-9	15.2	19.6
5	Case 4	Yes	34.7	34.5	-9.4	16.9	21.2



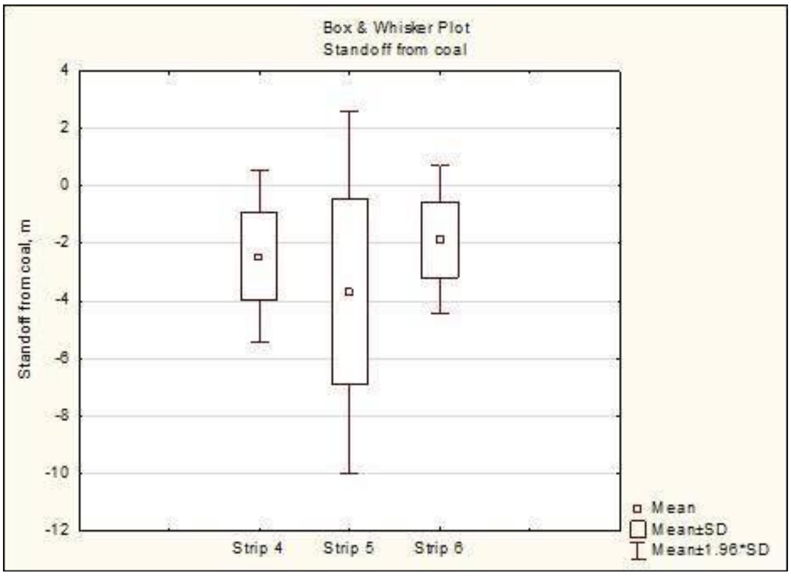
APPENDIX 3 - QA/QC

Hole depths at Strips 4,5,6:

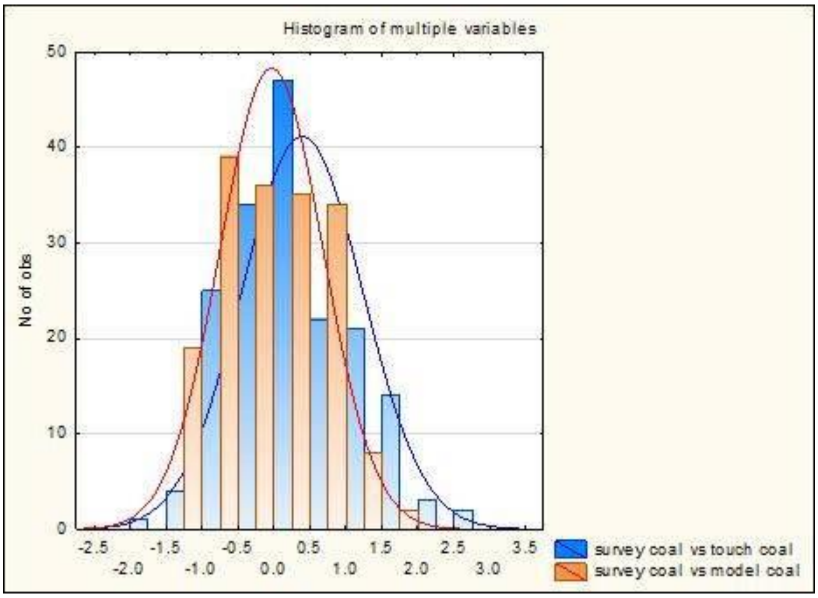


	Valid N	Mean	Minimum	Maximum	Std.Dev.
H_S4	454	32.9	25.0	42.0	3.0
H_S5	529	32.3	8.7	40.7	3.3
H_S6	644	34.7	10.0	49.3	4.6

Coal standoff at Strips 4-6 based on the coal model:



Comparison of standoffs - survey coal with touch coal and model:



	Valid N	Mean	Minimum	Maximum	Std.Dev.
survey coal vs touch coal	173	0.4	-1.7	3.0	0.8
survey coal vs model coal	173	0.0	-1.2	1.6	0.7