Oversize Reduction Project at the Iron Ore Company of Canada

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Abstract

The IOC Mining and Operations Departments expressed an interest in reducing the amount of oversize material (>1.0 m x 1.0 m x 1.0 m; 39 inches x 39 inches x 39 inches) being produced and its subsequent downstream effects including in-pit sorting and reduction, damage to mobile equipment, and significant delays in the loading pockets and the primary crushers. To achieve this goal an oversize reduction project was undertaken by the mine and to date has significantly improved upon baseline measures.

One key approach used to reduce the amount of oversize was the implementation of thicker emulsion. The introduction of a thicker emulsion provided more resistance to the forces created by dynamic water and reduces the infiltration of the emulsion into the cracks and fissures of the rockmass. Reduced amounts of oversize and more consistent fragmentation throughout the muckpiles has been a result. Additionally, a significant reduction in nitrates leached into the mine water discharge has been realized.

To determine the effectiveness of the oversize reduction project, IOC used a of first-of-kind technology to assess fragmentation presented to the shovel at the digging face. A Digital Vision System (DVS) was installed on one of the shovels to capture images that were stamped with GPS locations. A large population of digital images were analysed to produce a robust fragmentation distribution baseline that was used as one of the mine key performance indicators (KPI). Changes to blasting practice were subsequently measured against the baseline KPI to assess effectiveness.

Introduction

The Iron Ore Company of Canada (IOC) is the largest manufacturer of iron ore pellets in Canada and its customer base covers North American, European and Asian steel producers. The Company operates a mine, concentrator and a pelletizing plant in Labrador City, Newfoundland and Labrador, as well as port facilities located in Sept-Îles, Quebec. It also operates a 418-kilometre railroad that links the mine to the port. IOC has approximately 1,900 employees. Its shareholders are Mitsubishi Corporation (26.18%),

Labrador Iron Ore Royalty Income Fund (15.10%) and the international mining group Rio Tinto, which is its major shareholder (58.72%) and operator, with activities in more than 40 countries throughout the world.

The Iron Ore Company of Canada (IOC) was incorporated in 1949 and by 1954 had completed the Quebec North Shore and Labrador (QNS&L) rail line. IOC began mining in Schefferville, Quebec by 1954 and closed those operations down in 1982. In 1962, IOC commissioned the present day Carol Project consisting of mining, concentration and pelletizing facilities in Labrador City, Newfoundland. In 2004, IOC shipped its one-billionth tonne of ore on the QNS&L Railway. In 2005, IOC celebrated 50 years of mining history.

Geology

The Labrador West Mines are located within the highly metamorphosed Grenville Province of the Canadian Shield. IOC's Carol Lake Operations are situated at the southern end of the 'Labrador Through', a 1200 km (745 miles) long sinuous belt of metasedimentary and metavolcanic rocks. The deposit is located within the Wabush Iron formation is composed of ferruginous sediments that have been regionally metamorphosed. Two episodes of structural deformation have occurred in the mine area, resulting in a series of isoclinal syncline structures that generally plunge 10º to either the north or south. The fold limbs typically dip 40 to 45º eastward. The Middle Iron Formation of the Wabush Iron Formation is the principle ore bearing formation with thicknesses ranging from 50 to 100 m (164 to 328 feet) and is comprised of quartz-magnetite, quartz-specularite-magnetite-carbonate and quartz-specularite. Unixial Compressive Tests results from several samples ranged of 170 to 240 MPa (25,000 to 35,000 psi). A highly altered zone of limonite to the west is very soft in comparison to the rest of the orebody. A cross section of the 8800N section of the Luce Deposit is shown below in Figure 1.

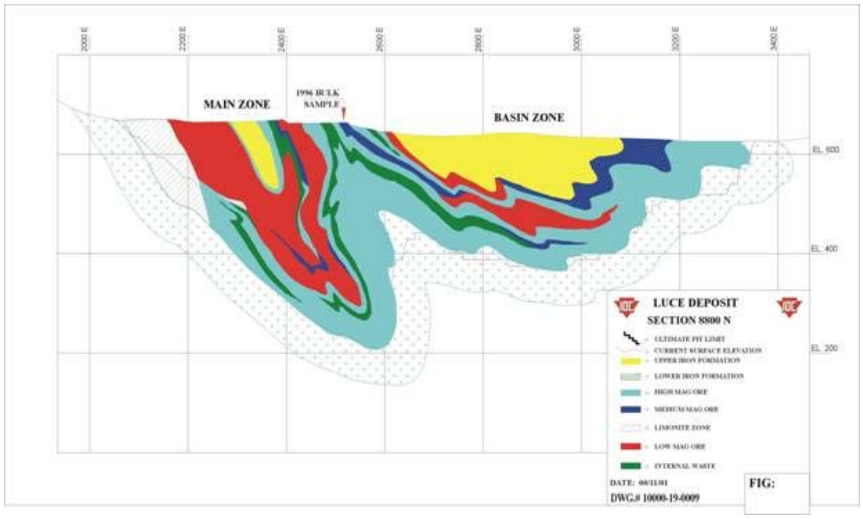


Figure 1: Luce Deposit

Expansion Program

The expansion program that was originally approved in March 2008 and later suspended that same year due to the global financial crisis that severely impacted markets worldwide, has now resumed. This expansion will grow IOC's ore crushing, delivery and grinding capacity and increase its annual concentrate capacity by 4 million tonnes (4.4 million tons) to 22 million tonnes (24.3 million tons) by the year 2012.

The first phase of the expansion project involves the acquisition of new drilling, loading and hauling equipment at the mine, the construction of an in-pit crusher, the construction of a new overland conveyor linking the crusher to the concentrator, the installation of an additional autogenous grinding AG mill at the concentrator as well as upgrades to the power supply to the plant and acquisition of new railway locomotives and ore cars.

The drill fleet at IOC has been expanded and now consists of three BE 49RH rotary drills and four new P&H120A/320XPC rotary drills. Both drill fleets currently drill 381 mm (15-inch) diameter blast holes to a maximum depth of 17.0 m (55.8 ft). Typical blast pattern parameters are 7.6 m x 7.6 m (24.9 ft x 24.9 ft) square patterns. Bench heights are 13.7 m (44.9 ft) with an average blasthole depth of 15.2 m (49.9 ft). Monthly drilling totals average approximately 40,000 m (131,000 ft).

The expanded loading fleet is made up of four P&H 2800 (26 m^3 - 34yd^3) rope shovels, one LeTourneau 1800 (15 m^3 – 20yd^3) front-end loader and one LeTourneau 1850 (17 m^3 - 22 yd^3) front-end loader. The two new P&H 2800 rope shovels have replaced two older BE 295 14m^3 (18 yd^3).

The haulage fleet at IOC had been expanded to twenty-seven Komatsu 830E haulage trucks with a 217 tonne (239 ton) payload and four Komatsu 930E haulage trucks with a 270 tonne (297 ton) payload. Daily material movement averages 120,000 tonnes (132,200 tons) of ore and 60,000 tonnes (66,100 tons) of waste.

The construction of the in-pit crusher and the PODS (Parallel Ore Delivery Service) has begun in earnest and is approximately 30% complete at time of writing. The Concentrator will have its grinding capacity increase to 8,400 tonne/hr (9,260 ton/hr) with the addition of a fourth AG (autogenous grinding) mill.

Currently, the mine plan is to modify the pit configuration and transform the three pits, Luce Main, Luce South and Luce Basin all into one larger pit called Luce Pit. The Humphrey West pit has been reactivated with a new layback and the new Sherwood pit has recently begun production. A plan view is shown below in Figure 2.

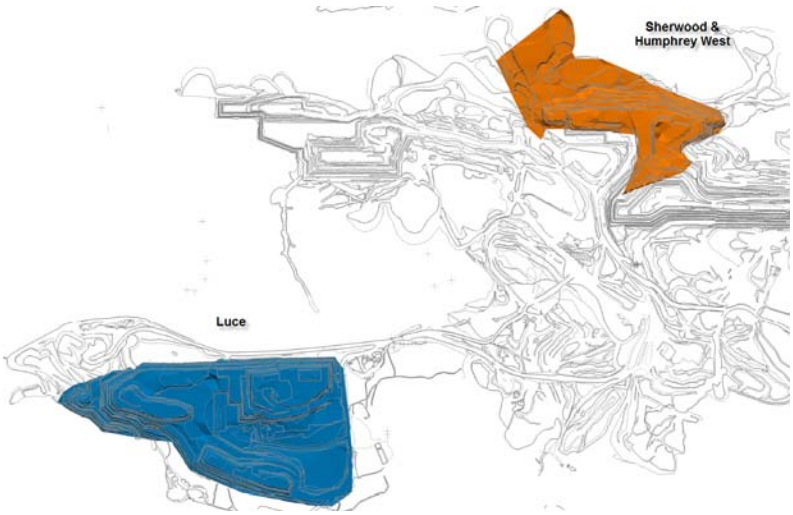


Figure 2: Luce Pit Expansion

Definition of the Issue

The IOC Mining and Operations Departments expressed an interest in reducing the amount of oversize material (>1.0m x 1.0m x 1.0 m; 39 inches x 39 inches x 39 inches) being produced and minimize the negative downstream effects including in-pit sorting and reduction, damage to mobile equipment, and significant delays in the loading pockets and the primary crushers. An in-house study by IOC's Six-Sigma® & Lean Project Leader showed that the revenue lost due to primary crusher downtime was estimated to be Cn $1.85 million. An extensive baseline fragmentation assessment of the mine fragmentation distribution has been obtained and the resulting amount of oversize material was found to be equal to 2.1% of the total tonnage.

A three-pronged approach is being used to reduce the amount of oversize material. 1) Top and bottom primer placement in the explosive column. 2) Implementation of a thicker emulsion, and 3) Introduction of crushed stone for stemming.

Top and bottom priming with electronic detonators by other large-scale iron ore and copper operations have been noted to reduce the oversize generation.

The introduction of a thicker emulsion that is more resistant to the forces created by dynamic water will reduce the infiltration of the emulsion into the cracks and fissures of the rockmass. It is anticipated that this will produce more consistent fragmentation throughout the muckpiles. A reduction to nitrates leached into the mine water discharge may also be realized. The fragmentation obtained from these changes will be measured against the baseline value of 2.1% of oversize material.

Introduction of crushed stone as stemming material will improve the effective use of available energy by increasing the gas retention times during the detonation process. Improvements to total muckpile fragmentation and reduction in the quantity or oversize originating from the stemming area are expected.

Top and Bottom Priming

Since June 2005, initiation at IOC has been performed with the i-kon™ electronic blasting system. Electronic initiation has allowed the mine to easily implement top and bottom priming using the collision of shock waves to improve fragmentation and reduce oversize material. Computer blast modeling indicates that fragmentation can be improved in the body of the blast by placing one primer near the bottom of the hole and another primer near the top of the explosive column. In concept, by employing precision timing, a zone of amplified shock waves can be generated within a blast hole that in turn results in improved rock fragmentation. Confirming statement by others (Koski, 2009) shows that this principle works in practice.

Thickened Emulsion

There are three deep water wells currently pumping groundwater to help lower the water table ahead of the mining plan. As well there are two in-pit sumps at the north and south end of the Luce Main to enhance the dewatering capabilities. The bedrock aquifer is interpreted to drain north along the syncline axis and discharge into Luce Lake. Copious amounts of groundwater have made for challenging mining conditions.

These difficult dynamic water conditions present at the mine have made it easier for emulsion product to migrate into cracks and crevices. Typical open pit emulsions are diesel fuel based and are more susceptible to leaching in poor ground conditions such as the aggressive water inflows in the Luce pits, more particularly during the spring run-off season. Development work was conducted to formulate an emulsion with significantly higher viscosities to help withstand these dynamic water forces. Laboratory testing was performed with various formulations and viscosities were measured. 70% EP / 30% AN samples were created for penetrometer resistance testing, stability testing, shear testing and gassing rate testing.

The data showed that the new emulsion formulation has significantly higher viscosities than the original formulation. The new emulsion formulation also exhibited superior storage capabilities and was less susceptible to shear induced crystallization as compared to the original formulation. Reduced wear on pump stator rotors was also expected.

Stemming

The introduction of crushed stone has been delayed due to cash conservation efforts and has not yet been implemented for this project.

Bulk Evaluation

A thicker emulsion was manufactured at the Carol Lake plant for a bulk evaluation. A total of 16 truck loads or 268 tons (243 tonnes) of the reformulated M-1171 product were pumped into separate blast areas in the mine as well as the regular daily deliveries to a neighboring mine.

Truck loading rates ranged from 992 to 1102 lb/min (450 to 500 kg/min) and pumping pressures on the truck were in the range of 758 to 965 kPa (110 to 140 psi). The product gassed very well within 15 minutes to a cup density of 1.13 g/cc. The product looked much thicker and had higher measured viscosities as shown in Figure 3 below.

Velocity of detonation (VOD) probes were inserted into three holes on the Luce Main 29-42 pattern. Holes #36, 72 and 108 were monitored. Hole #108 recorded trace produced a VOD of 17,241 ft/s (5,255 m/s).

Figure 3: Thickened Emulsion

The successful evaluation of the thickened product assured its introduction into full production for all areas of mining at IOC. Over time, a drastic reduction of 75% of the nitrate levels has been measured in the mine water discharge.

Baseline Fragmentation Assessment - Key Performance Indicator

Orica has provided IOC with first-of-kind technology to assess fragmentation presented to the shovel at the dig face. The Orica Digital Vision System (DVS) installed on 96 Shovel (Figures 4 and 5 below) captures images at the rate of 300 images per day. A set number of images per day were analyzed over a period of six months in Luce Basin. The images were separated using GPS location technology and converted to mine coordinates. A total fragmentation distribution was generated for each blast and grouped into three Contractor Blasts and seven Mine Blasts. The Contractor Blasts showed an Oversize value (>1.0m) of 2.9% for 1 million tonnes analyzed. The Mine Blasts showed an Oversize value (>1.0m) of 2.1% for 4.3 million tonnes analyzed. The analysis presented below provides a robust fragmentation baseline and was used as a Mine Key Performance Indicator.

Figure 4: Side View of 96 Shovel

Figure 5: Camera atop Operator's Cabin

Figure 6 below shows the GPS image locations of where the shovel was digging on 28 Bench for three separate blasts. The GPS transmitter is located directly above the shovel operator and the technology makes it possible to separate the bulk of the images on a blast by blast basis. Figure 7 below displays the location of the images that were selected for analysis as compared to the original sample. Of the roughly 300 daily images, approximately 20 images per day are selected and analyzed using Orica's PowerSieve™ Fragmentation Analysis program. These 20 images per day are selected throughout the whole day's sample to ensure that the analyzed images are evenly spread out over the entire blasted area and that no clumping of data occurs.

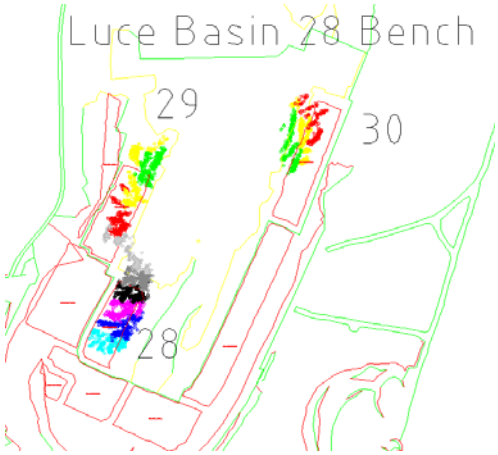


Figure 6: Total Images from 3 Blasts

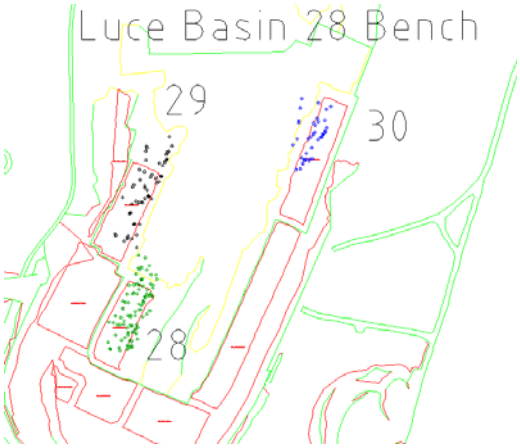


Figure 7: Analyzed Images from 3 Blasts

IOC Blasts					
Blast #	Images	80% Passing	> 1.0 m	> 1.0 m	Total
		m	%	tonnes	tonnes
LB28-28	92	0.2688	1.3	3,493	268,704
LB28-30	39	0.4235	3.4	12,362	363,574
LB28-32	234	0.3122	0.8	4,501	562,669
LB29-24	389	0.3512	3.4	35,628	1,047,884
LB29-25	229	0.3046	0.8	3,298	412,227
LB29-26	287	0.3258	2.5	19,223	768,905
LB29-27	482	0.3385	1.9	17,643	928,598
	1752	0.3324	2.1%	96,148	4,352,561
Contractor Blasts					
Blast #	Images	80% Passing	> 1.0 m	> 1.0 m	Total
		m	%	tonnes	tonnes
LB28-29	103	0.2821	1.7	5,502	323,639
LB29-22	255	0.3667	2.4	8,721	363,377
LB29-23	118	0.4603	5.1	13,097	256,811
	476	0.3632	2.9%	27,320	943,827

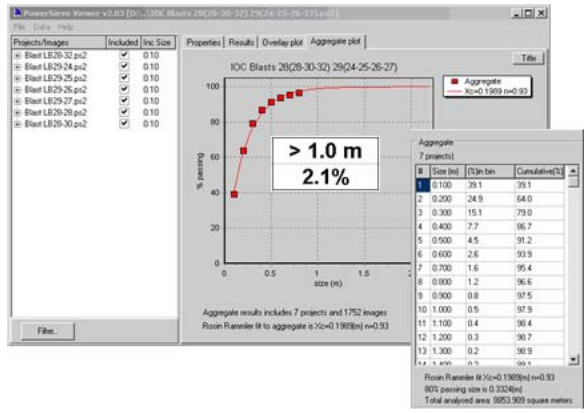


Table 1: Mine Blasts and Contractor Blasts Figure 8: Baseline Fragmentation Distribution

Table 1 above tabulates the results of both the Mine Blasts and the Contractor Blasts. Figure 8 above displays the aggregate fragmentation distribution plot of these seven Mine Blasts. The 80% passing size is 0.3324 m and the uniformity index is 0.93. The percentage of oversize (>1.0m x 1.0m x 1.0m; 39 inches x 39 inches x 39 inches) is equal to 2.1% and represents 96,148 tonnes (105,985 tons) of oversize material from a total of over 4.3 million tonnes (4.74 million tons). All of the initiation files indicate that the mine blasts were drilled and blasted on a 7.6m X 7.6 m square pattern. The files also show the V-cut initiation sequences used and holes being double primed at the bottom with electronic detonators.

A practical way of measuring improvements to oversize is to compare year over year numbers of the delays incurred at Crushers No. 1 and 2 due to bridging. The figures are readily available and compiled daily. Figure 9 below shows the amount of crusher delays on a monthly basis for the 2008 calendar year. The total number of hours of downtime at the crushers amounted to 272 hours. This reality has a large impact on limiting full production at the mine.

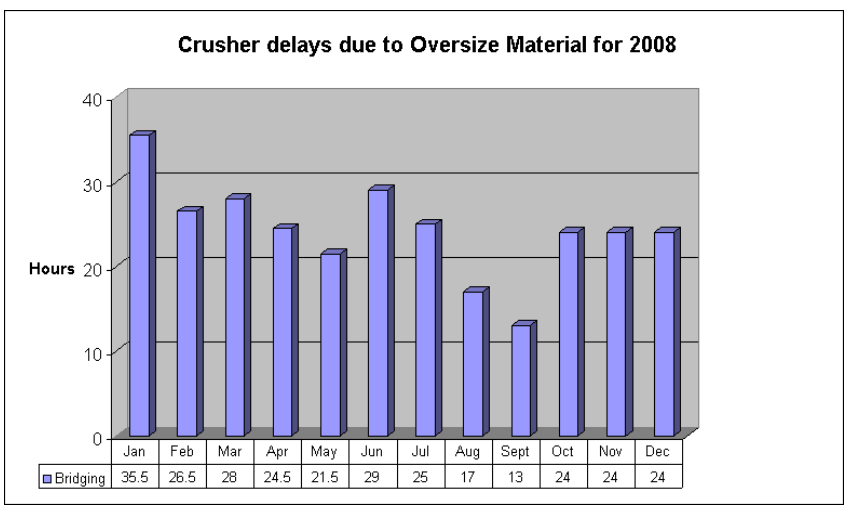
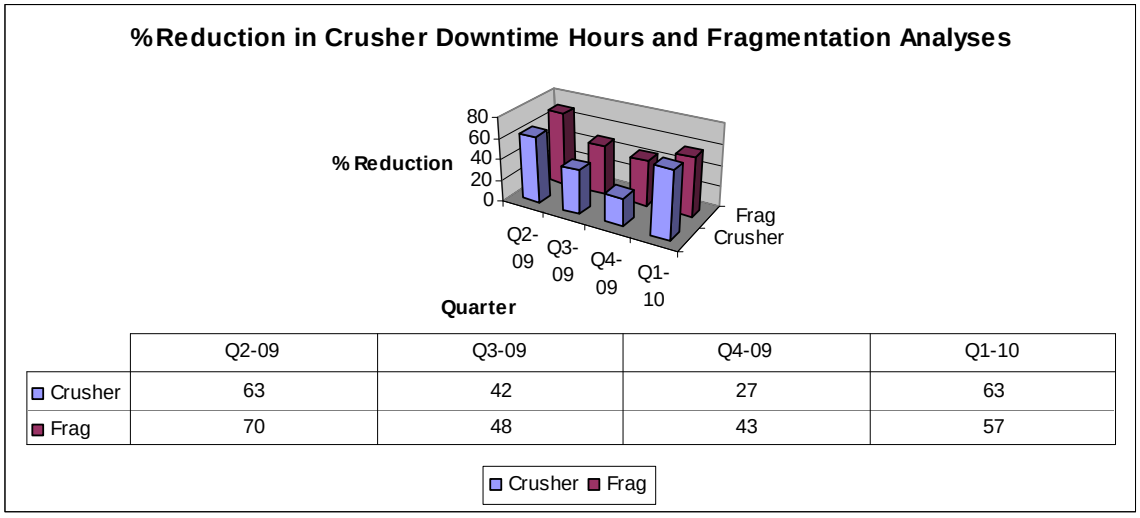


Figure 9: 2008 Crusher Delays

Since the implementation of the thickened emulsion at the end of the first quarter 2009, there has been a significant reduction in downtime hours due to bridging at the crusher. Quarterly reductions have varied from 27 to 63% when compared to the 2008 baseline year and average 49% as shown in Figure 10 below. Fragmentation analyses confirmed these reductions in all but one quarter.



	Q2-09	Q3-09	Q4-09	Q1-10
Crusher	63	42	27	63
Frag	70	48	43	57

Figure 10: Crusher Downtime Hours Reduction

Energy and Blast Patterns

Typical blast patterns are square and range from 7.6m x 7.6 m (24.9 ft x 24.9 ft). IOC blasters prime the blast holes, with supplier personnel manufacturing and pumping a blended 70% EP / 30% AN emulsion blend to a 4.0 m (13.1 ft) collar in ore and a 5.0 m (16.4 ft) collar in waste. A series of simulations were performed using SABReX software to help predict the fragmentation distribution in both ore and waste.

Using this data in combination with the grindability numbers shown in Figure 11 below, the mine has created blast pattern zones as shown in Figure 12 below. The area to the west of the pit or A-Zone is the soft limonitic ore zone and is drilled on either 7.8m x 7.8m (25.6 ft x 25.6 ft) or 8.0m x 8.0m (26.25 ft x 26.25 ft) pattern depending on the groundwater conditions present. The B-Zone immediately to the right is generally a waste band and is drilled on a 7.6m x 7.6m (24.9 ft x 24.9 ft) pattern. The C-Zone is the hardest material in the pit and is drilled on a 7.4m x 7.4m (24.25 ft x 24.25 ft) pattern. The easternmost blue line angled at 30 degrees from the north in the Basin pit separates two zones. The D-Zone is drilled on a 7.6m x 7.6m (24.9 ft x 24.9 ft) pattern while the E-Zone is drilled on the tighter 7.4m x 7.4m (24.25 ft x 24.25 ft) pattern. The introduction of the different blast patterns has ensured the production of minimal oversize creation and helped expand pattern in other areas.

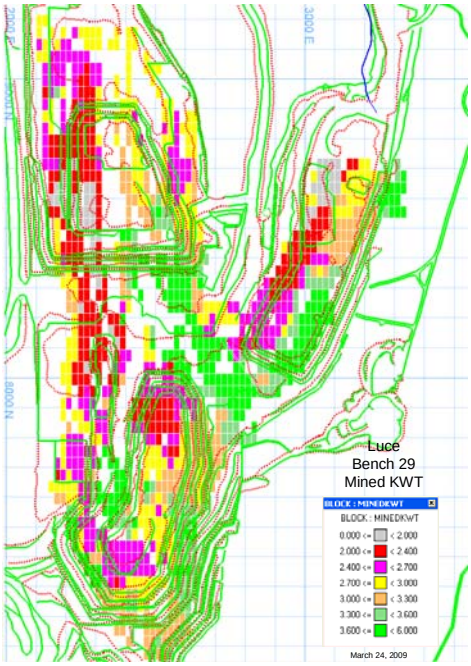


Figure 11: Grindability Areas

Figure 12: Blast Pattern Zones

Summary

A comprehensive baseline fragmentation analysis showed that the mine produced 2.1% of oversize material (>1.0m X 1.0m X 1.0m; 39 inches X 39 inches X 39 inches) and could be used as a Key Performance Indicator.

The implementation of both the top and bottom priming, the introduction of a thickened emulsion have helped reduced the amount of oversize generated at the mine by a factor of 49%. Fragmentation analyses taken from images on the shovel have confirmed this oversize reduction.

The thickened emulsion has provided a side benefit in greatly reducing the nitrate levels measured at the mine.

Acknowledgements

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