Cave management and secondary breaking practices at Palabora Mining Company

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Synopsis

Palabora Mining Company operates a low grade underground copper mine situated in the Limpopo Province, South Africa. Full production was first reached in May 2005 after a successful transition from an open pit operation to an underground block cave operation.

The operation faces a number of technical and operational challenges, not the least being fragmentation of a competent rock mass and external dilution. The cave is subdivided into three main sectors being the east, the west and the central sectors. Caving was initiated from the weaker central sector, which has the majority of its drawpoints located directly under the open pit bottom currently filled with about 130 million tons of waste material from the pit wall failure incurred in 2004. About 48% of the ore reserve has to be extracted from the western sector, which has a much courser fragmentation compared to the other two sectors and only 25% from the central sector with the finest fragmentation.

The main constraint during the ramp-up stage has been secondary breaking of drawpoint blockages. Ground-breaking secondary breaking and cave management initiatives and practices have made it possible for Palabora to realize and sustain high production rates.

Background

The Palabora block cave is serviced by two shafts with a herringbone layout consisting of 166 draw bells. Tonnage is currently drawn from 314 drawpoints with an average availability of about 50%. These drawpoints make up 19 cross-cuts from which ore is loaded and tipped in the four 750 t/h jaw crushers. The footprint covers approximately 100 000 m^2.

The original footprint consisted of 332 drawpoints (166 draw bells) and 20 cross-cuts. In 2004 cross-cut 11 collapsed, sterilizing about 7 million tonnes. None of the 18 drawpoints in the cross-cut currently accessible (see Figure 1.).

The current production level lies at a depth of about 1 200 m below surface. Column height ranges between 397 m directly below open floor and 760 m on the furthest columns in the western sector. This remains the highest lift ever to be caved. The original reserves totalled in excess of 220 million tons at a copper grade of 0.69%. Feasibility study results indicated that a production rate of 30 000 tons per day will ensure financial viability for the project.

During the ramp-up period not enough attention was paid to cave management measures, amongst others being the draw control factor and draw compliance, until full production was reached. The first 32 kt average week was achieved in May 2005, and since then more emphasis was put on proper draw control and proactive secondary breaking activities to sustain production rates. Subsequent to the 2004 open pit wall failure, increased control has become critical to prevent further ore reserve losses.

Pit wall failure effect on ore reserves

Seismic monitoring data indicates that the crown pillar failed in April 2004 with the cave breaking through to the open pit. Subsequent to this was a major open pit wall failure that occurred in September 2004. Approximately 130 million tons of waste filled the north- west corner and the floor of the open pit. (see Figure 2.)

A physical model was constructed in 2005 and Rebop (particle flow simulation software) was acquired in order to quantify the impact of waste material on the ore reserves. Results indicated that there will be approximately 30% ore reserve loss.

Cave performance

The cave consists of three geological zones; however, it has since been divided to four zones for management purposes. Each sector consists of five cross-cuts with cross-cuts 1–5 forming part of sector 1. Figure 3 illustrates the variable sectorial drawpoint availability. During the 24-hour period the average cave

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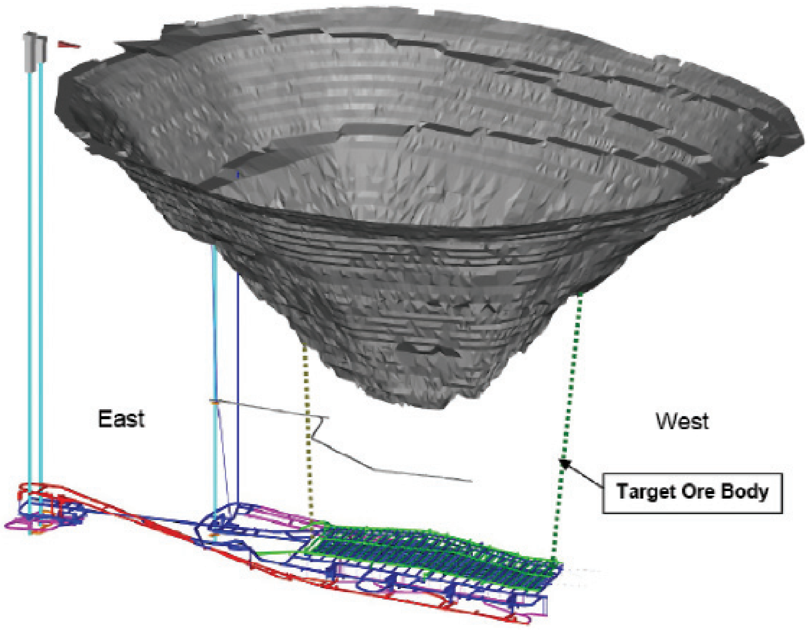

Figure 1—Palabora block cave mine layout

Figure 2—Palabora pit before and after failure

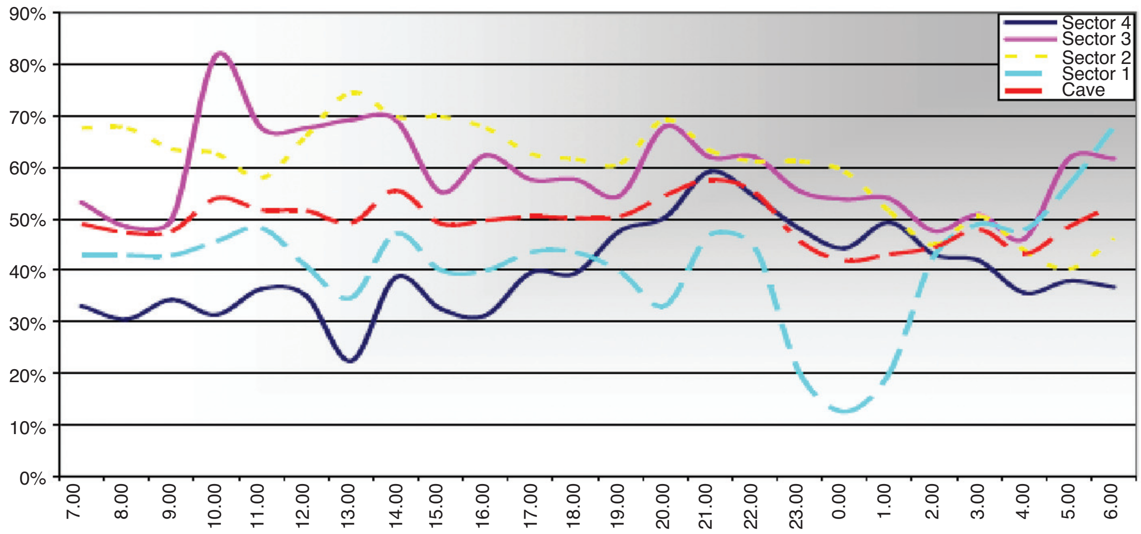

Figure 3—Cave availability (24hours)

availability equates to 50%, while there is a significant status change within the four sectors. As the drawpoint status changes during the loading process from ready to down, loaders will move systematically to the next available set. Cross-cuts with the highest number of down drawpoints are handed over to the secondary breaking unit for treatment. Between three and seven cross-cuts are treated per 8-hour shift.

Figure 3 represent the 17th of July 2007; however, similar patterns are expected for each day of the month. This erratic pattern is driven by the high production rates coupled with low yields in some drawpoints. Yield represents the average tonnage liberated per hang-up blasted. Low yield represents tons per hang up blasted below 310, high yield above 660 tons per blast, while intermediate represents tons per blast between 310 and 660.

Figure 4 is an illustration of the current footprint layout, with each cell representing a drawpoint. The majority of the lowest yield drawpoints form part of sectors 4 and 1. Sector 4 contributes 33% of the ore reserves and comprises the majority of low yield drawpoints. Sector 2 has an average of about 1 300 tons per hang-up yield and contributes only 24% to the ore reserves.

Cave management systems

The Palabora block cave was originally designed for 30 000 t/d mined from 20 cross-cuts. Current target tonnages range from 32 000 to 34 000 t/d. Originally, the mine used a daily draw order system developed by Robin Kear. This was replaced in 2004 with Gemcom s PC-BC and CMS systems, the latter being used for the daily draw order.

PCBC (Personal Computer Block Cave) runs on a Gemcom platform with its subsystem CMS (Cave Management System). Annual and monthly plans are generated with PCBC. With the centre of the cave being the weaker zone, it was therefore an obvious initiation point. The failure incurred in 2004 meant that draw has to be significantly reduced in the middle and increased in the poorly fragmented west while maintaining high production rates.

CMS is also being used at Freeport (where it was originally developed) and at the Finsch mine. At both these mines a daily draw order is generated. At Freeport (DOZ mine), the daily draw order is split into three equal shift orders. At Finsch, the daily draw order is fed into the Sandvik/Tamrock Automine system where it is converted into shift-based orders.

Palabora had been using a daily draw order in the initial start-up and up until early 2006. Ever since full production was reached, it was soon realized that the daily order was not appropriate for Palabora conditions. In early 2006 the scheduling engineers initiated and trialled shift specific draw orders.

The main driver for this was the desire for improved draw compliance and the ability to be more responsive to changing drawpoint status. With the high number of hang-up draw points and their rapid turnover, the daily draw order was found to be unrepresentative of these dynamic conditions and hence the implementation of shift schedules.

The mine currently uses Dispatch, a product of Modular Mining Systems Africa (MMSA) to send and receive loading and cave status information. Additional functionalities such as draw order complete warning were added to the system to improve operator draw order compliance. The entire secondary breaking unit fleet is now equipped with dispatch system to give operators access to real-time cave status. This information is then used by supervisors to prioritize drawpoints and cross-cuts that require immediate attention.

Compliance has for the past five weeks remained steadily around the 80% mark, regardless of the production rates. It is, however, early days before added value can be quantified from the life of mine plan simulations. It is expected that over time, good draw control will assist in delaying early dilution ingress and thus increase the current life of mine. (see Figure 5.)

Historic operational strategies

Tremendous production pressure to achieve an extremely optimistic production ramp-up schedule necessitated various improvement interventions. Four very distinct mining process strategies, developed over the course of 5 years, depict clearly how Palabora started in uncertain, unfamiliar territory and became a world expert in block cave secondary breaking.

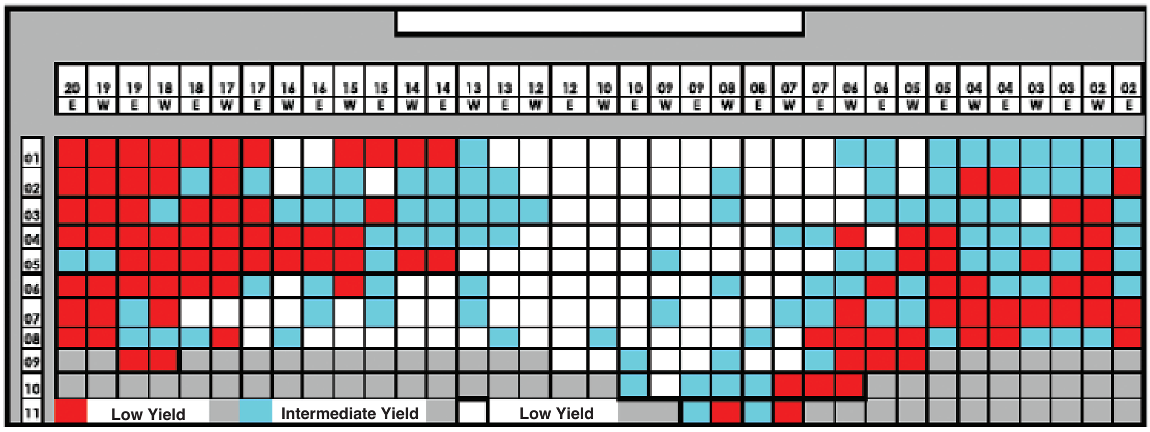

Figure 4—Drawpoint yield

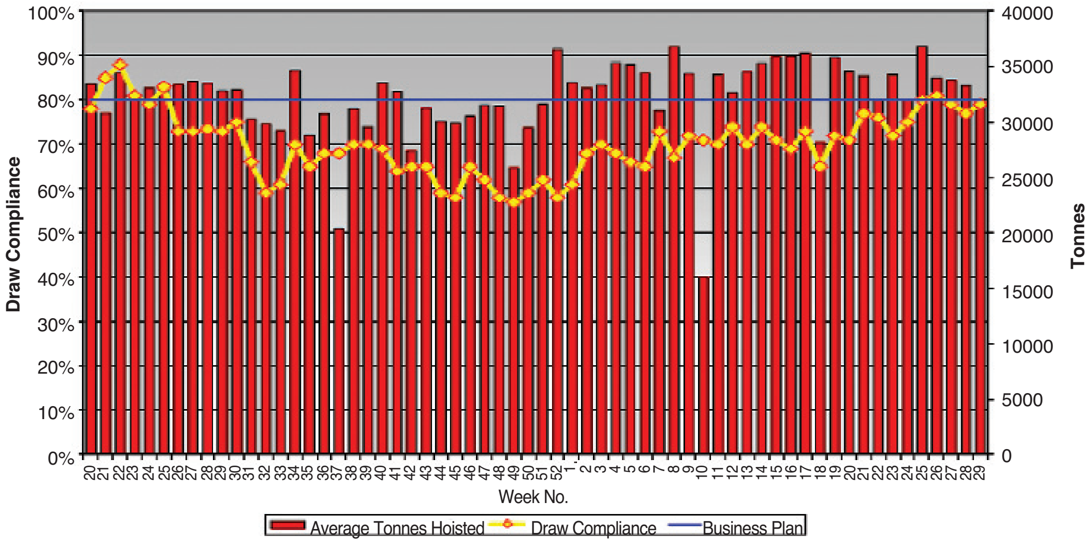

Figure 5—Draw compliance

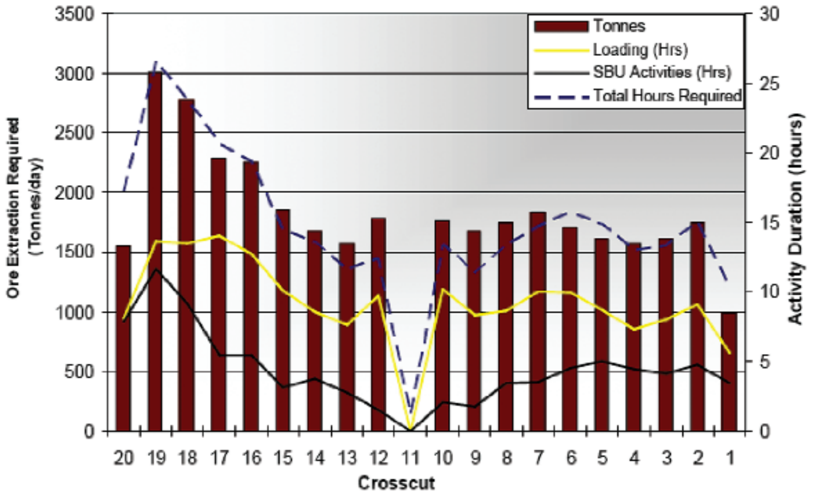

Figure 6—Cave utilization

From the outset in 2002, the approach was for each crew to break and load as much ore as possible from a partially developed cave and decisions based on very little information. With limited infrastructure and an inefficient mining process, the limitations were quickly apparent as production stagnated at 10 kt/day.

As a result of one of the first improvement intervention teams, a systematic but very rigid secondary breaking cycling process of cave sectors was introduced in June 2003. Adjacent cross-cuts with similar yield per blast results were grouped into 3 sectors in order to match the demand on resources. The cave management strategy at the time was even draw throughout the cave to maximize production and to achieve the stretched production plan.

Despite obvious improvement, the production remained below plan and further improvement intervention was required. In June 2004, the systematic, rigid, cycling process were simplified by combining secondary breaking steps and as a result, occupying fewer cross-cuts with secondary breaking activities. On-demand blasting was introduced, which improved crosscut utilization.

Towards the end of 2004 the open pit north wall failure above the block introduced 130 million tons of waste. It became desperately necessary to slow down ore extraction from the centre of the cave footprint located vertically below the bottom of the open pit and drastically improve draw control. At the end of 2005 the sector cycling process was abandoned and an on-demand secondary breaking process was adopted to increase cross-cut utilization and secondary breaking effectiveness. The basic approach is that the LHD in the cross-cut requiring the most secondary breaking activity gets reassigned and secondary breaking moves in.

Operational challenges

By suddenly changing the cave management approach from an even draw strategy to a strategy that will maximize ore extraction and prevent dilution entry required operational alignment. The east and the west sides of the cave had proportionally more ore to be extracted than the centre due to the pit excavation above. The challenge was even greater considering that the east and west are the lowest ore yielding areas per blast.

More production from the east and west require more secondary breaking. Because secondary breaking and ore extraction are two mutually exclusive activities, the relationship implies that the more time is allocated to secondary breaking, the less time there is to extract ore.

Optimal utilization of cross-cuts in the west became essential as the realization dawned that with current equipment and processes there is not enough cross-cut time in a day to break the required amount of material and leave enough time to extract the required amount of ore to achieve optimal orebody extraction, as in Figure 6.

A few operational strategy changes to improve ore extraction from the west included:

- allocating best operators to western cross-cuts
- allocate equipment preferentially to the west
- allocate the maximum safe permissible amount of equipment in the western cross-cuts
- reassign resources to the west during voluntary overtime
- and since the introduction of the a mobile rock breaker to the fleet in middle 2006, parallel rock breaking while lashing in the same crosscut, significantly improved cross-cut utilization in the west (second rock breaker introduced in July 2007).

Since January 2007, draw compliance as a measure of cave management control received more operational focus, with a 1% increase per week in target compliance from 60% to 85%. It became essential to reduce the time to convert blocked drawpoints into drawpoints that can be lashed. A typical secondary breaking cycle rate through the cave is 24 hours using the systematic cycling secondary breaking process. The on-demand process improved and reduced the secondary breaking cycling time. The real draw compliance improvement was however, only realized when the mostly quality driven secondary breaking approach used from 2003 up till now was somewhat relaxed and a drive for cross-cut turn around time took preference during 2007. This slight lapse in quality, which bottomed out at 1.2 holes per hang-up is depicted in Figure 7 but the improvement in cross-cut turn round time is depicted by the number of cross-cuts blasted per day.

The reduction in quality has not negatively affected production output as depicted in Figure 8.

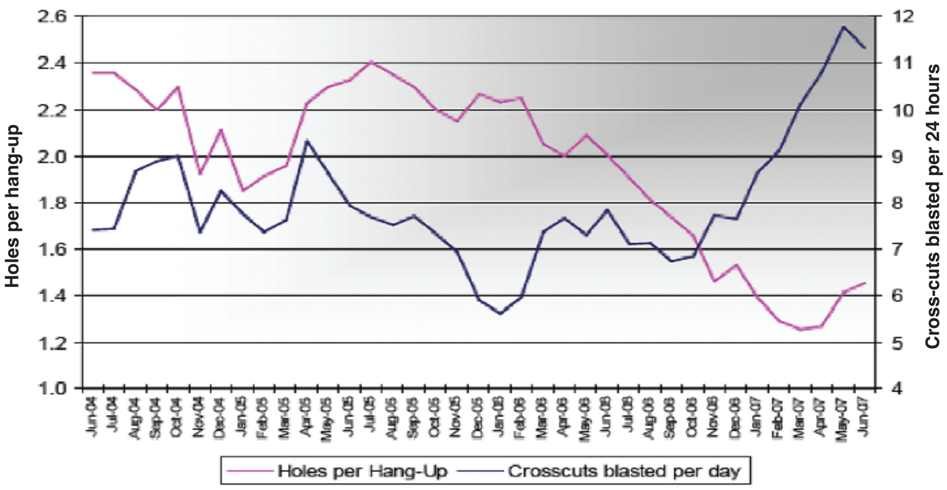

Figure 7—Quality and cycle rate

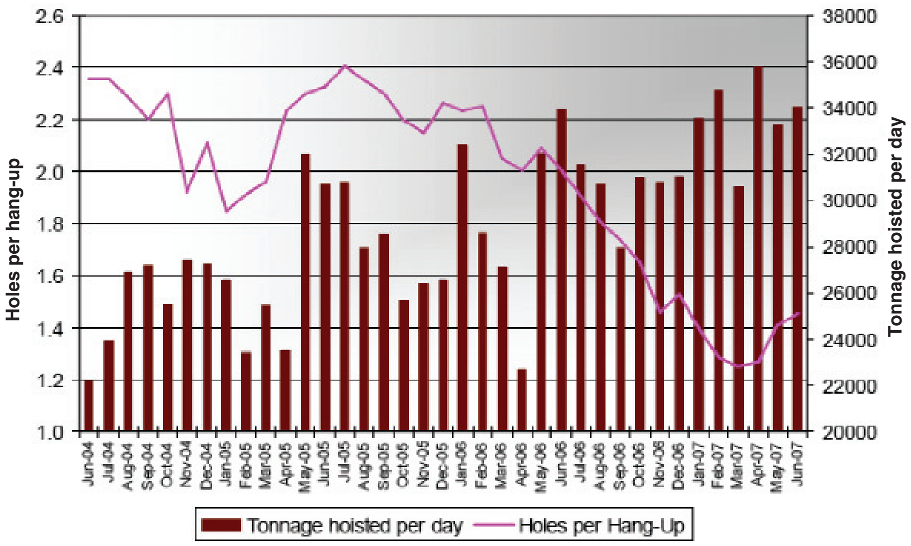

Figure 8—Quality and production output

The improvement in ore extraction from cross-cut 20 on the extreme west and the direct proportionality to the cross-cut 20 blasting frequency is depicted in Figure 9.

Figure 10 shows the production during the first half of 2007, which has been exceptional with five out of the six months being among the top six producing months ever. The cross-cut blasting frequency has also reached 12 blasts per day and is expected to still increase to close to 15 per day.

In Figure 11 the effect of the process change in November 2005 is very clear with the sudden drop in drawpoints blasted due to the reduction in blasting of unnecessary borderline blockages and small boulders in the muck pile. This behaviour of unnecessary blasting of small enough rocks and borderline blockages was mostly driven by the sector cycling in an attempt to match the different work rates demanded by cross-cuts in the same sector as well as by operational employees striving to meet the target hang-ups blasted per day used as a process driver at the time.

The yield per blast is determined by:

- fragmentation
- operator skill
- blasting practices.

The sudden step change in yield at the end of 2005 due to this cycle process changed to an on-demand secondary breaking process and stopped unnecessary overblasting. (Figure 12.)

Conclusion

In hindsight it is evident that the selection of the centre as the initiation point was not the best decision. The best initiation point would have been the western sector of the mine; however, production would have been slower at the beginning, leading to a longer tonnage build-up period. Cave management would have been simpler with waste ingress being the main challenge.

The changeover from Linux to PCBC and CMS has made it possible for Palabora to quantify the impact of external dilution and also to manage a fairly complex cave. Draw strategies should always be aligned with the operational

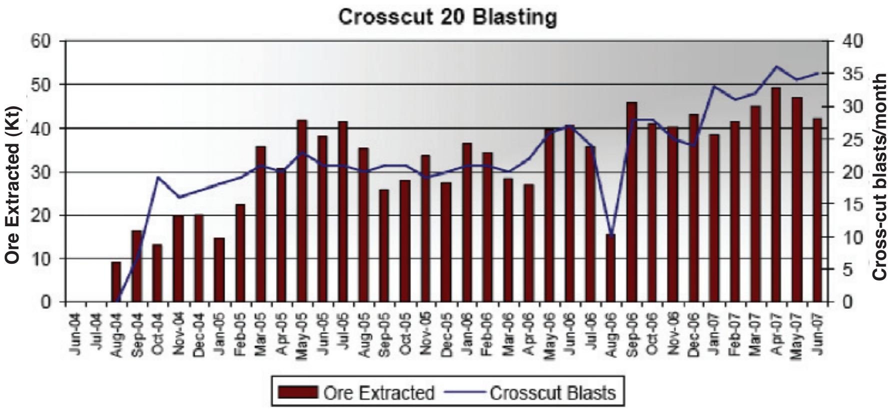

Figure 9—Cross-cut cycle rate and ore extraction

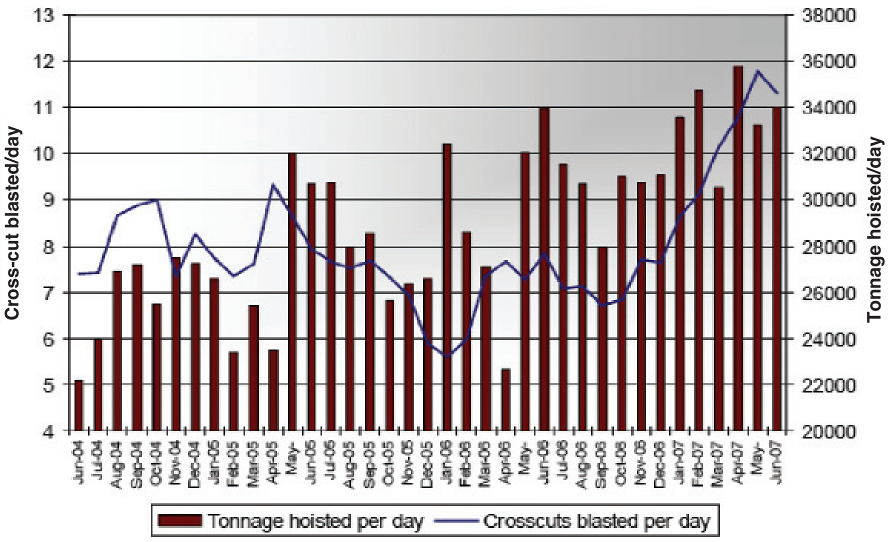

Figure 10—Overall production and cycle rate

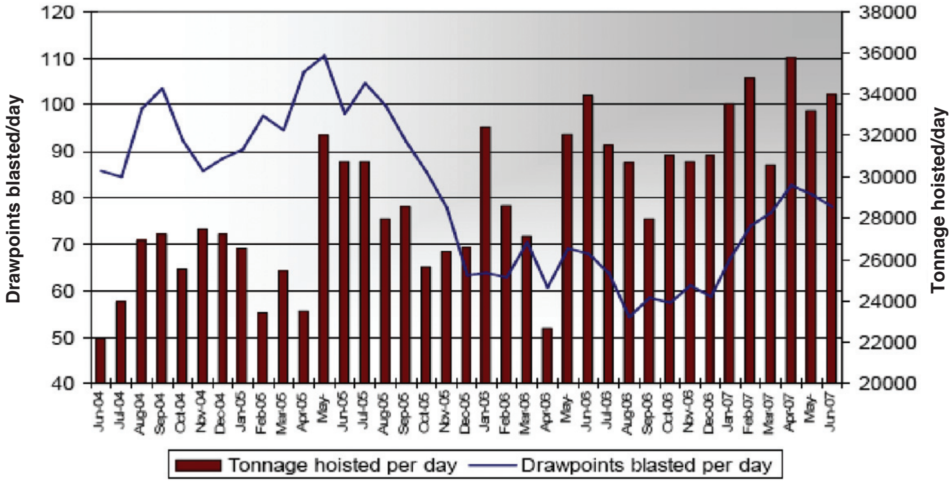

Figure 11—Quality and cycle rate

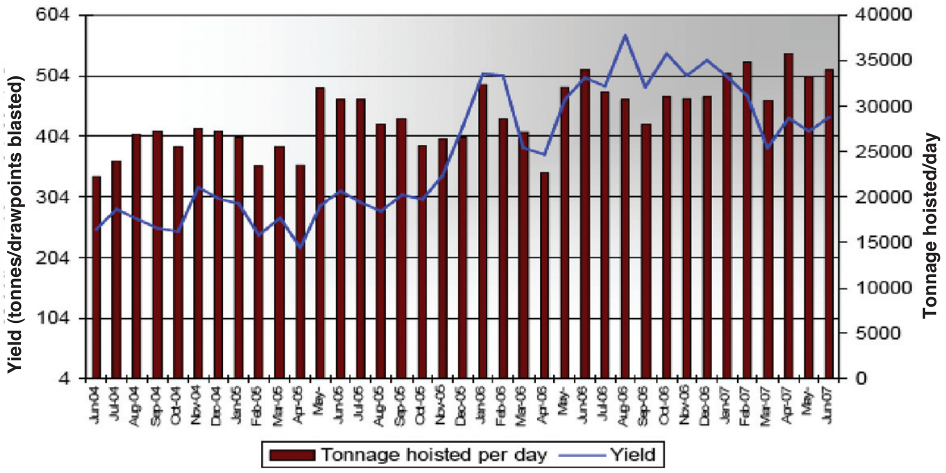

Figure 12—Quality and cycle rate

strategies and processes for better results. These should be reviewed regularly and changed when envisaged results are not realized.

Teamwork and the employment of flexible systems and processes between planning and operations are the underlying principles behind the accomplishments in Palabora Mining Company.

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