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Review of mechanization within Lonmin

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In 2004 Lonmin embarked on an aggressive strategy to achieve 50% of reef production using mechanized mining methods. At the end of 2008, a decision was made not to 'bet the farm' on mechanization but prove the concept on a smaller scale before rolling out the technology to the applicable operations.

In this regard, Hossy shaft at the Marikana operations was chosen to be the pilot site for the 'proof of concept' using XLP mining. This paper examines the lessons learnt from the implementation of XLP mining at Hossy shaft and the potential way forward for the application of mechanization within the hard rock narrow reef environment at Lonmin.

Introduction

The narrow tabular hard rock reef environment has proven to provide multiple challenges to the successful application of mechanized mining methods. This paper reviews the lessons learnt to date on the implementation of mechanized mining at Lonmin and discusses the future plans for piloting XLP mining at Hossy shaft.

Strategic drivers for mechanization

The potential drivers for the use of mechanization mining systems compared to conventional mining systems are:

- Improved safety due to reduced exposure of employees on the face
- Improved productivity (oz/man)
- Reduced exposure to labour cost increases
- Increased skills development of labour force
- Change in workforce demographic assisting in tackling some social issues and reducing the effect of HIV/AIDS

In essence the drive is towards safe, cost-effective production. The critical success factors that can make mechanization work are:

- Reliability and availability of the mechanized equipment
- A mining layout and design that promotes maximum utilization of mechanized equipment
- Potential of reducing unit costs through continuous improvement drives
- Suitable orebody, i.e., reef not undulating excessively.

History of mechanization at Lonmin

Lonmin and Sandvik's relationship started in early 2001 with the development and trial of the Voest Alpine ARM 1 100 rock cutter.

Following this a series of project meetings were held with the first taking place in Lyon on 4 and 5 October 2001 (Pickering and Moxham, 2007) where Project 1,1 (XLP project) was born. Some of the key discussion points around the development of extra low profile (XLP) mining equipment revolved around:

- The need for a lower cost per ton (similar to LP room and pillar mining) which can offset the increased dilution of the ore resulting in a cost per platinum ounce similar to conventional mining
- The suite of equipment required an XLP face drill rig, roofbolter and a loader
- The preferred method for initial implementation of mechanization was room and pillar mining
- The development of a suitable roofbolt support design was considered critical as the mechanized stoping could not be integrated with the use of stick support or hydraulic props.

The subsequent meetings in January 2002, April 2002 and July 2002 revolved around the development of a suitable suite of equipment for XLP mining (Pickering and Moxham, 2007).

Lonmin representatives visited EJC in Burlington and Lyon in September 2002 to view the prototype equipment (Pickering and Moxham, 2007).

Underground trials started at Karee 1 B shaft employing a room and pillar layout. Some of the key learnings from these initial trials were as follows:

- The performance of the face rig required very little further development.
- The roofbolter body was fine but the drill feed needed further development.
- The extra low profile LHD was very problematic leading to the development of the dozer.
- Shortage of skilled labour both on the maintenance and operating sides.
- The lack of a free breaking face in the room and pillar method caused poor face advances.
- Relatively short face lengths in room and pillar resulted in time wastage due to tramming of machines between the rooms.
- The mining method was then changed to the mechanized breast layout with on reef access development.
- Original panel faces were designed to be as long as possible to ensure a high extraction ratio.

Table I
Mechanization build up plan

Phase 0	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Phase 5**
2001	**2006**	**2007**	**2008**	**2010**	**2010+**
Conventional hand-held mining methods	**Develop mechanized machines and equipment**	**Off-the-shelf machines and equipment**	**Mechanized mining**	**Full cycle mechanized mining**	**Robotics—intelligent and continuous mining**
% of tonnes from mechanization					
0%	10%	20%	30%	50%	70%
% of metres from mechanization					
0%	10%	30%	50%	100%	

- It was considered imperative that the cyclical operation be maintained to maximize the utilization of the equipment.
- Each fleet was accommodated with 3–5 panels for cycle mining.

In 2004, a decision was made to mechanize all the new shaft projects at Lonmin. The original targets set for the phased implementation plan for mechanization is shown in Table I.

This build-up plan did not progress as expected (see Figure 1). In 2008, the following lessons were learnt from the application of XLP mining:

- The XLP equipment delivered lower efficiencies than expected.
- There was a shortage and high turnover rate of labour (both artisans and operators).
- The XLP equipment could not effectively deal with geological anomalies, especially on the western side of Lonmin's operations.
- The XLP fleet required a large amount of face length
- The interdependency of machines in an XLP cycle meant reliability issues were compounded.
- The excessive on reef development caused high dilution to the head grade. Larger development ends were blasted to accommodate the mechanized equipment. Excessive stoping widths were caused by the inability of the XLP equipment to deal with rolls in the reef.
- There was a lack of mechanized culture at all levels of the organization.
- There was a lack of experienced mechanized supervisors.
- The stay in business replacement capital for XLP equipment is higher than conventional.

This underperformance in production combined with the economic downturn subsequently resulted in a change in approach. The strategy was changed in that the concept of mechanized XLP mining needed to be proved on a much smaller scale before it being rolled out to the rest of Lonmin's operations.

Health and safety within the mechanized operations has performed relatively well when compared to the conventional areas. No fatal accidents have been recorded in the last four years on the mechanized shafts and the LTIFR (lost time injury free rate) rates have outperformed conventional areas (Figure 2). Hossy XLP site has achieved a year to date LTIFR of 2.31. No LTIs have been recorded in the stoping or development environment for the year to date.

Maximum noise exposure levels have been reduced to below 100 dB in mechanized areas with no new NIHL cases been recorded since 2008.

Hossy shaft

As mentioned earlier, Hossy shaft was selected as the pilot site for XLP mining at Lonmin due the mineable UG2 chromitite seam having a relatively thick channel width (1.25 m) consistent dip and relatively less geological structures. Hossy shaft was sunk to a depth of 765 metres and currently consists of four production levels from where the UG2 ore is extracted. The deepening of Hossy incline is ongoing and will eventually extend to seven production levels. At Hossy both stoping and development operations are done using mechanized trackless machines on a breast mining layout. The UG2 chromitite seam dips in a north south direction at an inclination of 10 degrees.

Method/equipment selection

As a result of the depth, channel width and relative flat inclination of the UG2 chromitite seam, the equipment and methodology described in this report were selected.

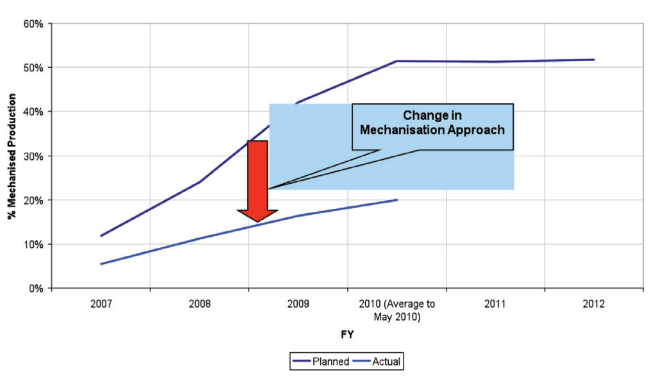

Figure 1. Planned mechanization build-up against actual build up

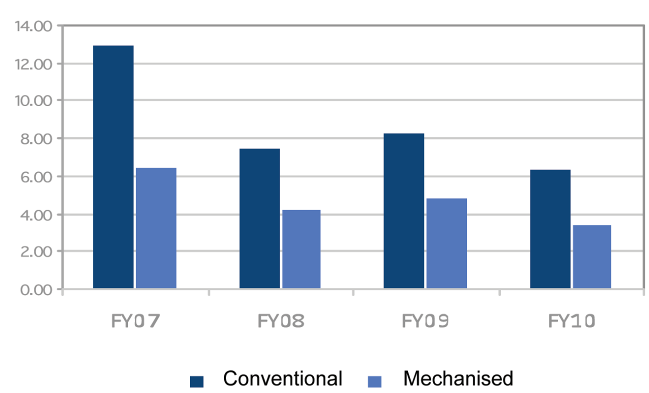

Figure 2. LTIFR comparison

Stoping

In order to extract the UG2 chromitite seam efficiently, dilution had to be kept to the minimum. Therefore the decision was made that stoping would be done with a fleet of extra low profile (XLP) equipment with a planned stoping width of 1.45 m.

For the purpose of free tramming of the XLP machines along the stope face, support in the form of roof bolts and grout packs are used. Grout packs used have a diameter of 1.2 m and are installed on spacing of 3 m on dip and 4 m on strike (skin to skin) with a maximum distance of 8 m from the advancing face after the blast. A later section of this report describes the breast mining layout used at Hossy shaft in greater detail.

XLP bolter

The XLP bolter (Figure 3) utilizes a single boom to drill and install 1.6 m split resin bolts. Roof bolts are installed on a spacing of 1 m (dip) by 1.5 m (strike).

As shown in Table II, the XLP bolter has a total cycle time, taking account of 45 minutes for tramming and set-up, of 5 hours and 20 minutes. Thus the XLP bolter can complete the support of a 26.5 m panel length (installing 32 resin bolts) in less than a shift. The bolter's cycle time of 5 hours 20 minutes currently represents the longest cycle time in the fleet of equipment, and options of separating the drilling of support holes and installation of roof bolts are under investigation. Separating the drilling activity from the installation of roof bolts would cause a drop in the bolter's cycle time of 1 hour 40 minutes, lending more flexibility to the total fleet operation.

Figure 3. XLP bolter on the stope face

Figure 4. XLP face rig drilling the stope face

XLP face rig

After supporting the panel with the XLP bolter the face is drilled with the XLP face rig (Figure 4). The XLP face rig utilizes two booms for the drilling of the face compared with the single boom for the bolter. The face is drilled with a 1.8 m drill steel providing an effective hole length of 1.6 m; however, the option is available for the drilling of a 2.1 m drill steel for an effective hole length of 1.9 m depending on ground conditions and support distances.

The cycle time as indicated in Table II shows that the XLP face rig can complete the 26.5 m panel in a shift with at least 54 minutes to spare.

XLP Shark dozer

The broken rock from the stoping panel is removed using the track mounted XLP Shark dozer (Figure 5 highlights a XLP Shark dozer in action). Blasted ore is removed from the panel by throw blasting (30%) and the remainder by dozing it down the face of the panel to the ASD (advanced strike drive or gulley). Once dozed into the ASD the ore is loaded, hauled and dumped onto a vibrating feeder, feeding a conveyor belt, by means of an EJC 777 LHD.

At a rate of 44 tonnes per hour, the XLP Shark dozer is able to clean the blasted stope face in 3 hours 20 minutes, which leaves additional time for sweepings or cleaning of another stope panel. In panels with poor ground conditions the dozer is required to removed barred rock after the bolting cycle has been completed in order for the face rig to travel down the panel face.

Development

The development is done ahead of the stoping in order to create independent development and stoping phases as well as to provide additional stoping face length. Advanced strike drives (ASD) are developed at 35.5 m centres creating a grid of five ASDs per section. All five ASDs are intersected by a series of raises developed at an angle of 60 degrees to the ASD. These raises are spaced at 174 m centres creating blocks of 26.5 m by 170 m for stoping. At the bottom of each section a belt drive is developed where a conveyor belt is installed keeping LHD tramming distances within efficient limits.

All ASDs and raises are developed to an average height of 2.2 m and a width of 4 m to allow for clearance between moving machinery and services. Each belt drive is developed at an average height of 2.2 m and width of 5.0 m for the installation of the conveyor belt.

Figure 5. XLP Shark dozer cleaning blasted ore from the stope face

Table II
XLP Performance KPIs

LP face rig						
	Panel length	**Holes**	**Drilling cycle time**	**Holes per hour**	**Travelling and set-up time**	**Total cycle time**
KPIs	26.5 m	156	4.3 h	36	45 min	5.1 h
XLP Bolter						
	Panel length	**Bolts**	**Bolting cycle time**	**Bolts per hour**	**Travelling and set-up time**	**Total cycle time**
KPIs (resin bolts)	26.5 m	32	4.5 h	7	45 min	5.3 h
KPIs (hydro bolts)	26.5 m	32	2.9 h	11	45 min	3.7 h
XLP dozer						
	Panel length	**Tonnes for dozer cleaning**	**Cleaning cycle time**	**Tonnes per hour**	**Travelling and set-up time**	**Total cycle time**
KPIs	26.5 m	122.4	2.8	44	30 min	3.3 h

The support standard in all development working places incorporate a grid of 1.8 m resin bolts spaced at 1 m by 1 m. At all intersections of roadways cable anchors are installed.

LP Axess rig

The LP Axess rig is used for the drilling of support and face holes in all ASDs, raises and belt drives. With a total cycle time of 3.5 hours per face the Axess rig is capable of supporting and drilling two development ends per shift.

The LP Axess rig is also used for the drilling and installation of all back area support and the drilling of support holes for the installation of cable anchors at the roadway intersections (as mentioned).

EJC 777 LHD

The EJC 777 LHD is used for the cleaning of all development ends and the loading of stoping ore extracted into the ASD by the dozer. With a load carrying capacity of 7.484 tonnes and a 3 m³ bucket, the 777 LHD hauls a load in excess of 5.5 tonnes to the tipping point.

Layout

Figure 6 demonstrates the five panel layout currently in use at Hossy shaft. The development is blasted ahead of the stoping faces by the fleet of LP equipment creating a predeveloped stoping environment. This assists the short-term planning where major geological anomalies are understood prior to the stoping operations. The stoping panels with an average panel length of 26.5 m are then mined by means of a fleet of XLP equipment.

The layout used for XLP mining is of great importance as it determines the tramming distances of all trackless machines and therefore the productivity of these machines. In the layout presented in Figure 8, the main roadways for LP equipment are blasted on an apparent dip of 8 degrees. These relatively flat roadways create the opportunity of fast and easy LHD cleaning. The maximum average LHD tramming distance is 155 m from the face to the tip which allows efficient cleaning.

Even though the raise development is done on an apparent dip of 8 degrees, the stope panels are mined on true dip ensuring maximum throw blasting and easy dozer cleaning. Ventilation holings blasted in the strike pillars double as tramming routes for XLP equipment enabling quick access to the panel (Figure 7).

Challenges

The implementation of XLP mining at Hossy shaft provided management with various challenging situations. Some of these challenges were addressed in a short time interval whereas others have not yet been adequately addressed.

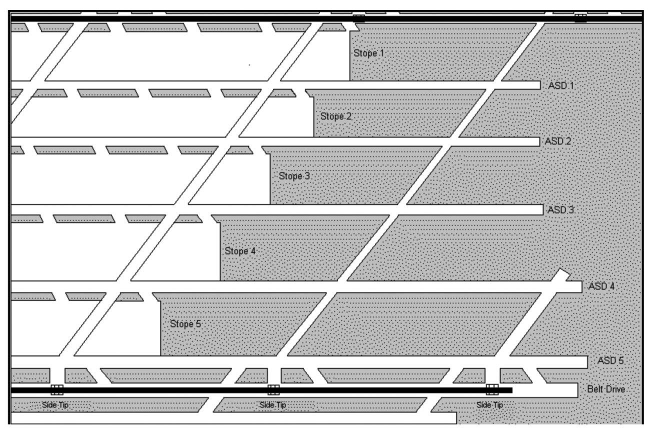

Figure 6. Typical section layout for Hossy shaft

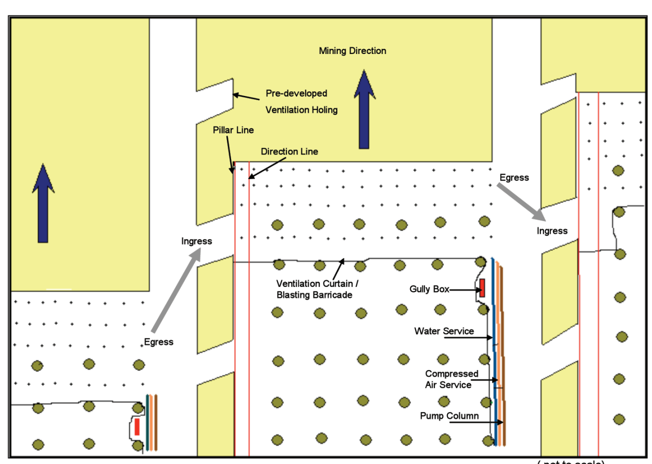

Figure 7. Plan view of stoping layout showing tramming route through panels

Figure 8. Grizzly-pecker arrangement with double pan vibrating feeder

Mechanized mining skills

It was found that the majority of supervisors at Hossy had very little if any mechanized mining experience. In conjunction with Sandvik and Trans4mine a mechanized training module was developed where supervisors were trained on specific XLP mechanization supervision points. This initiative was based on an on-the-job training scenario where supervisors were trained and assessed.

Due to the high cost of damages on mechanized machinery, focus was also turned to the mechanized machinery operators. In the past operators were trained only on the theoretical part of the mechanized machinery. On arrival at the shaft, the operator then had to use the specific piece of machinery for the first time in a production environment. For the purpose of reducing the cost due to damaged equipment, simulators were used for the practical training of the operators. This proved to have a positive effect on the reduction of damages to mechanized machinery and increased the skill levels of the operators significantly without incurring production losses.

Engineering skills

Practical skills of artisans and general knowledge of XLP equipment were found to be a concern for Lonmin as well as Sandvik. Sandvik then started a specialized training programme for all their supervisors and artisans working on the XLP equipment. This programme provides the following training to all artisans and maintenance supervisors:

- Electrical/hydraulics
- Schematics
- Schematic symbols
- General good practice
- Fault finding
- Component identification.

Ore handling

It was found that, with a single pan vibrating feeder, short LHD tramming distances and two LHDs tipping at the same tipping point, the vibrating feeder does not clean the grizzly fast enough not to delay the LHDs. Therefore, the tipping arrangement was changed according to Figure 10. Figure 8 illustrates that the current tipping arrangement incorporates two vibrating pan feeders situated as a side tip to the belt conveyor.

The side tip configuration also allows for uninterrupted belt extensions as the belt conveyor can be extended without rearranging the tipping point.

The side vibrating feeder (Figure 8) has a design capacity of 350 t/h, but is currently set to 40% of design capacity feeding the strike conveyor belt at 140 t/h. The reduced feed rate of the vibrating feeder allows more than one vibrating feeder to be operational simultaneously to the one strike conveyor belt with a capacity of 350 t/h.

Breakdown attendance

Due to the large areas covered by the breakdown crew for each section and the often cumbersome equipment needed to be transported to the machine on breakdown, the 'scavenger' was developed in partnership with a local manufacturer (Figure 9). The 'scavenger' is a compact transport vehicle equipped with accessories required for the quick and effective treatment of breakdowns.

This vehicle having a width of 1.522 m and a height of 1.650 m can be driven into the cage taken down the mine and driven out again. It uses a 3 cylinder, air cooled diesel engine that requires minimum maintenance and is easy to operate.

Communication

For the purpose of interactive communication and quick response times, a proper communication system was needed. Supervisors were equipped with portable two-way radios and a 'biza khuluma' system was supplied to each tipping point. The radios and 'biza khuluma' provided effective communication to the control room from where the services are distributed to where needed.

Figure 9. Breakdown assist vehicle 'scavenger'

Figure 10. 'Biza khuluma' communication system

Figure 10 shows the 'biza khuluma' communication sytem installed at tipping points in each section.

Diesel distribution

In the past the shaft experienced problems with the refueling of LHDs with diesel as only three diesel refueling bays were available to LHDs. Therefore a diesel distribution system was designed where diesel is pumped from surface to a centralized underground distribution point. From the centralized distribution point, the diesel is pumped to the satellite diesel bay located in each section.

These satellite diesel bays reduced the time of refueling the LHDs significantly and therefore increased the utilization of the LHDs. Figure 11 illustrates the distribution of diesel from surface to the satellite diesel bays located in each section.

Workshops

When using mechanization, the importance of workshops cannot be overlooked. Due to the XLP fleets reduced mobility Hossy shaft required satellite workshops to be

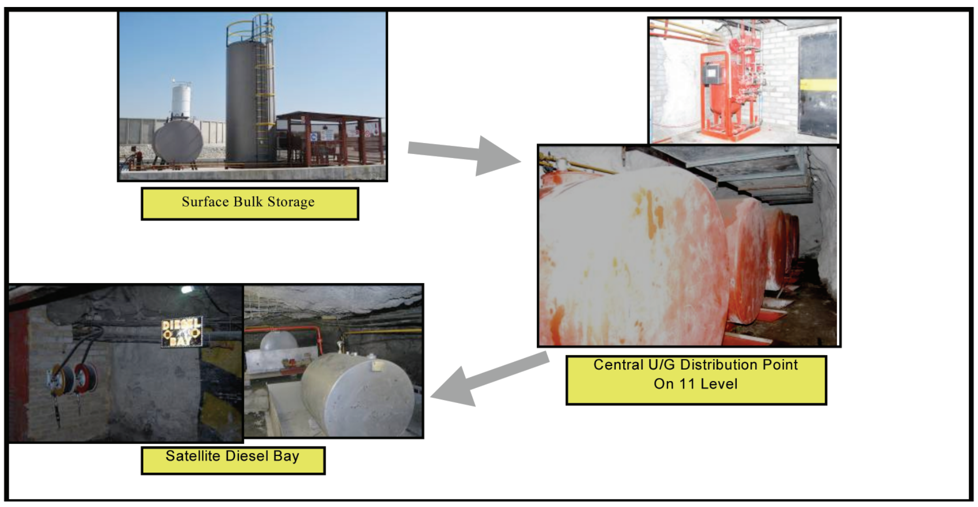

Figure 11. Diesel distribution from surface to underground satellite diesel bay

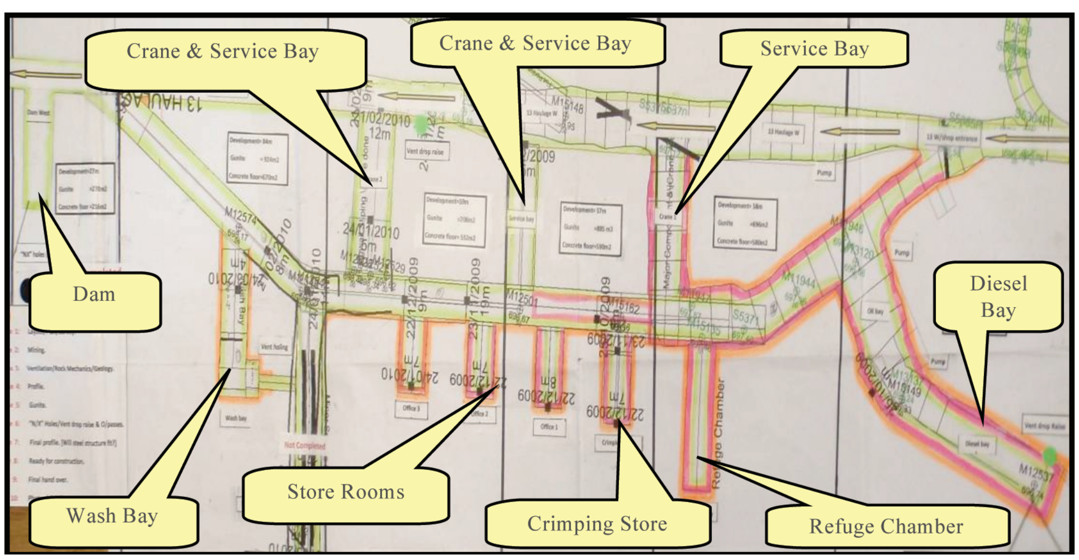

Figure 12. Main workshop

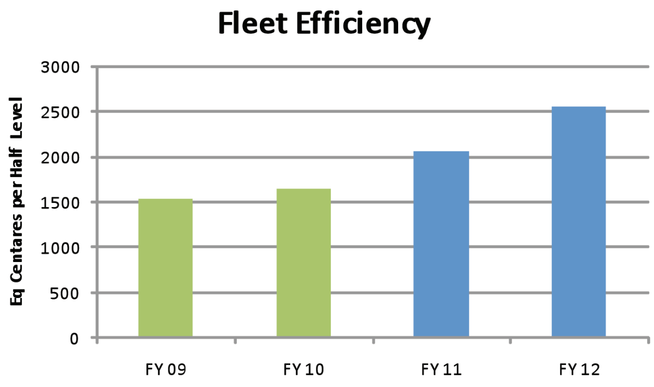

Figure 13. XLP Historical and planned fleet performance

established in each section. These satellite workshops are used for all maintenance needed on the XLP machines and are located as close as possible to the working panels.

On each level a main workshop was established for the maintenance needed on LP machines. These workshops are designed to be easily accessible and are equipped with cranes, inspection ramps, wash bay, diesel bay, crimping store, service bay and refuge chamber. Figure 12 indicates the layout of the main workshops established on each level.

Performance

Hossy shaft is currently producing 78 000 reef tonnes per month with 6 XLP fleets and aims for 90 000 reef tonnes by September 2011. The critical driver of quality production is centares per half level. The chart in Figure 13 highlights the historical and planned build-up of equivalent centares (including m^2 from the on reef development). This ramp-up in production will lead to a reduction in working cost resulting in a more competitive alternative to conventional mining.

Conclusion

The teething challenges with the implementation of XLP mining at Hossy shaft have been resolved and the planned ramp-up in production will lead to a reduction in working cost, resulting in a more competitive alternative to conventional mining. The safety achievements at Hossy have been also been exemplary compared to conventional mining.

Suitable areas will be identified for the application of mechanization within Lonmin once mechanization at Hossy shaft reaches its long-term goal of being a competitive alternative to conventional mining. However, a more systematic approach will be followed in the implementation of mechanization in the future planned areas.

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Grant Webber

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Grant has 22 years experience in the hard rock mining industry. His career began with JCI on Randfontein Estates in 1989. He has spent the last 11 years at Senior Operational Management level. Grant has managed both underground and open pit mining operations. His exposure to XLP Mechanised Mining began 2 years ago when he joined Lonmin Platinum where he was made responsible at Hossy Shaft for the optimisation of the mine design and the execution of the mining production plan. This responsibility includes the implementation of R&D and the capital investment programme and adherence to set safety and budget cost targets.