Back Fill Optimization and Innovation—Red Lake Gold Mine's Success Story

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ABSTRACT

Backfill production can be challenging in a mining environment in which multiple mining methods are in use (longhole, overhand & underhand cut and fill). It becomes even more complex when there are multiple headframes, two processing facilities, and associated pastefilling facilities, and where many small, high grade stopes take priority over all others. The complexity of this type of operation in a mine that is mature and where the stoping areas are widely spaced and deep, can present many obstacles to maintaining the ideal inventory of stopes ready to fill and the reticulation to support.

Numerous associated obstacles over time led to a backlog of 80,000 tons of unfilled stopes. Such a deficit is very difficult to overcome when the pressure to meet targeted ounce production can lead to short term decisions which eventually create long term pain.

This paper describes the actions that were taken to completely overhaul the backfill process, eliminate the backlog and implement a sustainable system that will ensure the future success of the mine.

Through innovative improvements, via a structured team approach, with a focus on design flexibility, improved processes, optimization, and a simple mantra "do every task as soon as you can do it," significant step changes in backfill management were achieved.

Changes to organizational structure, planning, scheduling, and coordination, along with optimized preparation, transportation, and distribution, were achieved through the introduction of a philosophy where through team work, collective awareness, understanding, and ownership successful outcomes are achievable.

INTRODUCTION

The Red Lake Mine is located in a historic Red Lake gold camp of northwestern Ontario. Red Lake Gold Mines is located approximately 450 kilometres northeast of Winnipeg, Manitoba, in Ontario's western boundary region. Figure 1 shows the location of Red Lake gold mines. Gold was first mined in the area in 1930 and, out of the 18 gold producers, only one is operating today by Goldcorp, Red Lake Gold Mines through the two properties at Campbell and Red Lake Mine [1].

All mining is carried out through underground operations, utilizing overhand cut and fill, underhand cut and fill, and long-hole mining methods. Underground operation active areas are shown in Figure 2. Active mining operation covers approximately 2,335 hectares, with 3 active headframes and multiple mining zones. The operation is supported by two milling complexes: Red Lake (RL), and Campbell (CC) [2].

Figure 1. Location of Red Lake Gold Mines

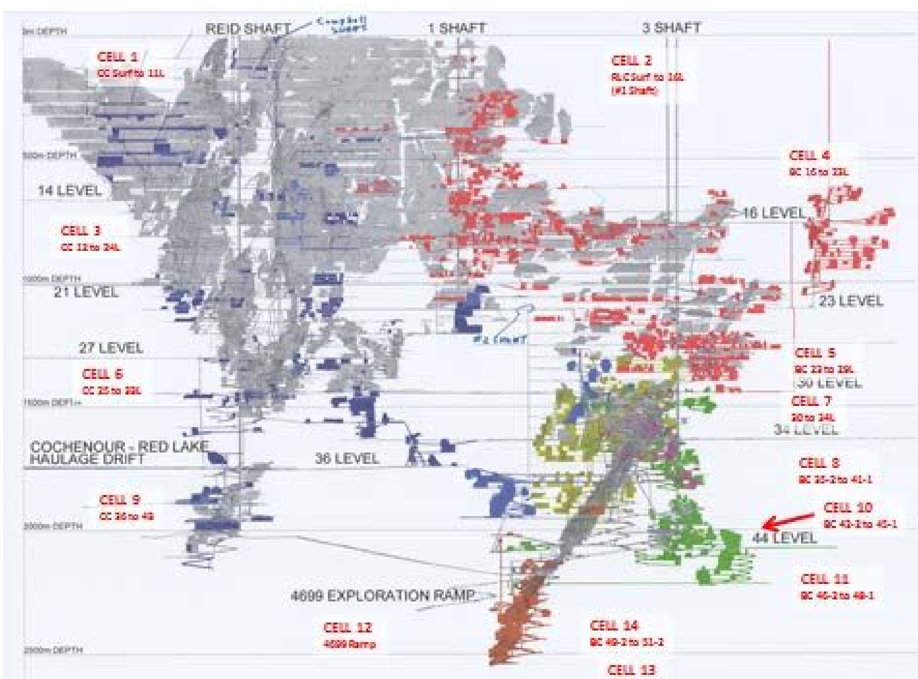


Figure 2. Underground operations

This paper discusses operational aspects and field performance of the paste fill operations at both Campbell and Red Lake facilities. It explains key improvements made to the paste fill plants, surface infrastructure, and to underground reticulation services. It also presents an overview of the paste fill plants at the Red Lake camp and describes the unique challenges that paste fill operations have faced over the last few years. Also described is the plan that was executed to continuously improve the paste fill operations and progress toward efficient operation.

PASTE FILL PLANT OPERATIONS

Red Lake Facility

At the Red Lake facility, slurry from the flotation tails reports to the paste fill thickener. The slurry is then thickened to a solid content of 65% to 68% and then is transferred to a storage tank. The overflow from the thickener is transferred to the tailings pond. On an as-needed basis, the thickened slurry is vacuum filtered and the filtered solids (cake) are stored in a hopper that has a number of auger screws located below it (Live Bottom Feeder). As required, the auger screws dump the filter cake onto a conveyor. A weightometer measures out the proper amount of cake material which is then added to the backfill mixer. The Live Bottom Feeder system allows the filter process to run continuously yet can be stopped after reaching a 60% capacity level in the feeder.

A set of parameters are entered into the process system to achieve the desired material characteristics required by underground operations. Water (initial), cake, and binder quantities are entered while mix times are set. A target power draw for the mixer is set and is based on predetermined process information to achieve the desired fill "slump". Operators physically test the fill slump during the mixing process and adjust the power draw accordingly to either thicken or thin the paste fill material.

Campbell Facility

At the Campbell Complex, tailings are transferred to the 6.1 m thickener and thickened to 65% to 68% solids content. This thickener is large enough to allow operations to maintain a decent amount of solids as storage. The overflow from the thickener is treated by the Waste Treatment Plant before being transferred to the tailings pond. Underflow slurry is fed from the thickener to disk filters and is dewatered. The disc filters' overflow reports back to Detox tails. Cake falls to a conveyor belt which feeds a dual shaft mixer. The tonnage of the cake is fed back to the binder rotary valves/weightometers to control the addition of binder to the mixer. Water is continuously added to achieve a target amperage which will produce the desired slump after the binder is added. Binders are fed to separate conveyors for weighing, which then feeds them to a common auger to transfer them to the mixer. The paste from the mixer feeds into a Schwing pump hopper and is pumped underground or to the load-out area to fill trucks. The Schwing pump provides the Campbell facility with more flexibility on the underground distribution system as it isn't purely reliant on gravity to pull the material to the required pour points. This also offers the operation another option for pumping into paste fill transport trucks.

PROCESS IMPROVEMENTS

A number of plant improvements were made to increase plant uptime and throughput. In 2015 the paste plants were on line over 67% for RL and 49% of the time for CC, up from about 54% for RL and 33% for CC in 2014. Increased operating efficiencies continued with optimization and RL is currently on line at 78% operating efficiency and CC is at 78%.

Binder based mix times were further optimized and supported reduction in mixing times. Increasing the speed at which the binder was added to the mixer also decreased the overall mixing times. The mix time also depends on the % binder in the paste pour. For a 15% pour, the mix time is 90 seconds and for <12% pour the mix time is 70 seconds. Another improvement was the removal of the fly ash (bin) knife gate and replacement by a straight pipe. A plant program and batch cycle time improvement process flow map is shown in Figure 3 to illustrate recent plant improvements that have been made.

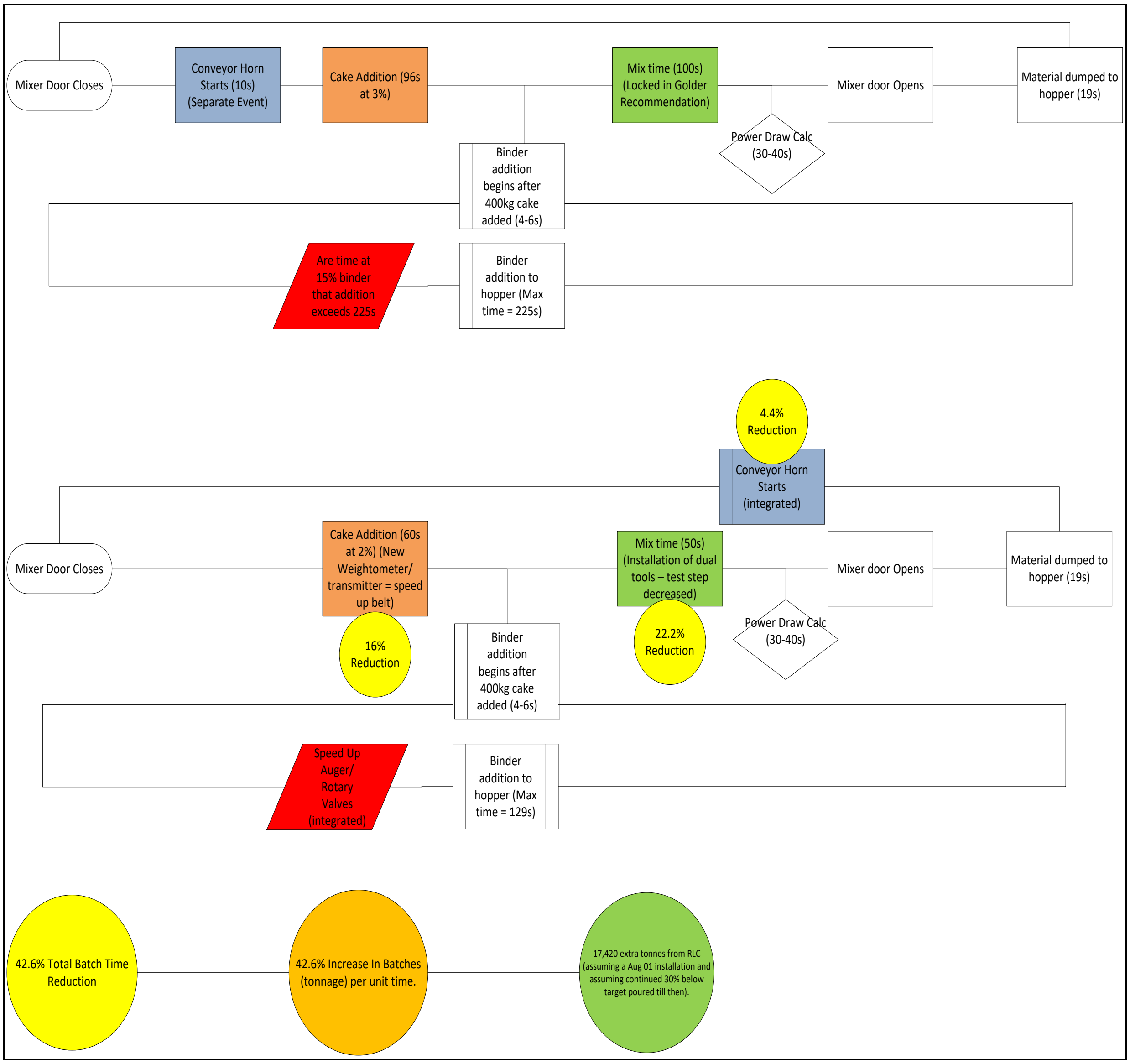


Figure 3. Plant program and batch cycle time improvement process flow map

Availability of adequate tails to support continued plant operations was a constant constraint. When underground operations could not provide ore and subsequent tailings the paste plants were shut down because of no other sources of tailings. Efforts were made to evaluate tailings storage options, but it was later determined that if paste needs were considered when mill run rates were to be set, then the tailings feeds to the paste plants would only meet production needs if they were managed properly.

Paste plant operation and maintenance were historically viewed as a secondary priority to processing facilities. Rigorous efforts went into increasing visibility of the critical importance that paste fill production plays in achieving overall site operating targets. Operations and maintenance "good practices" training, adoption of improved checklists, use of standardized reporting, and performance tracking procedures were established. Maintenance procedures and scheduled maintenance programs were better defined. Adoption of original equipment manual (OEM) maintenance recommendations and procurement /installation of critical spare equipment were implemented. Weekly combined operations and maintenance planning processes were also enhanced. All of these efforts supported improved plant availability and utilization.

Another improvement was made through the installation of the Red Lake 2 (RL2) hopper. This allowed the utilization of the Campbell paste to fill voids that would normally be filled by Red Lake paste plant product, thus allowing dual filling of Balmer Complex stopes. Secondary line utilization required the installation of additional lines underground to twin sections of reticulation. The new RL2 hopper was tied into the existing borehole pit and both were connected to plant water and air supply.

Fluidizers were also installed in the CC paste fill plant. The system is a continuous mix process, and the stream of binder feed needed improved control. Fly ash addition was always sporadic. This was due to a combination of bridging in the silo as well as binding and plugging of the rotary feed valve. It was very difficult to maintain a constant binder flow which affected consistent paste fill quality when higher binder content was required. Laboratory test work is currently on-going to determine the optimum binder dosing rate based on tonnage. An overview of RLGM's surface infrastructure and (paste plant) operations, as of 2015, are shown in Figure 4.

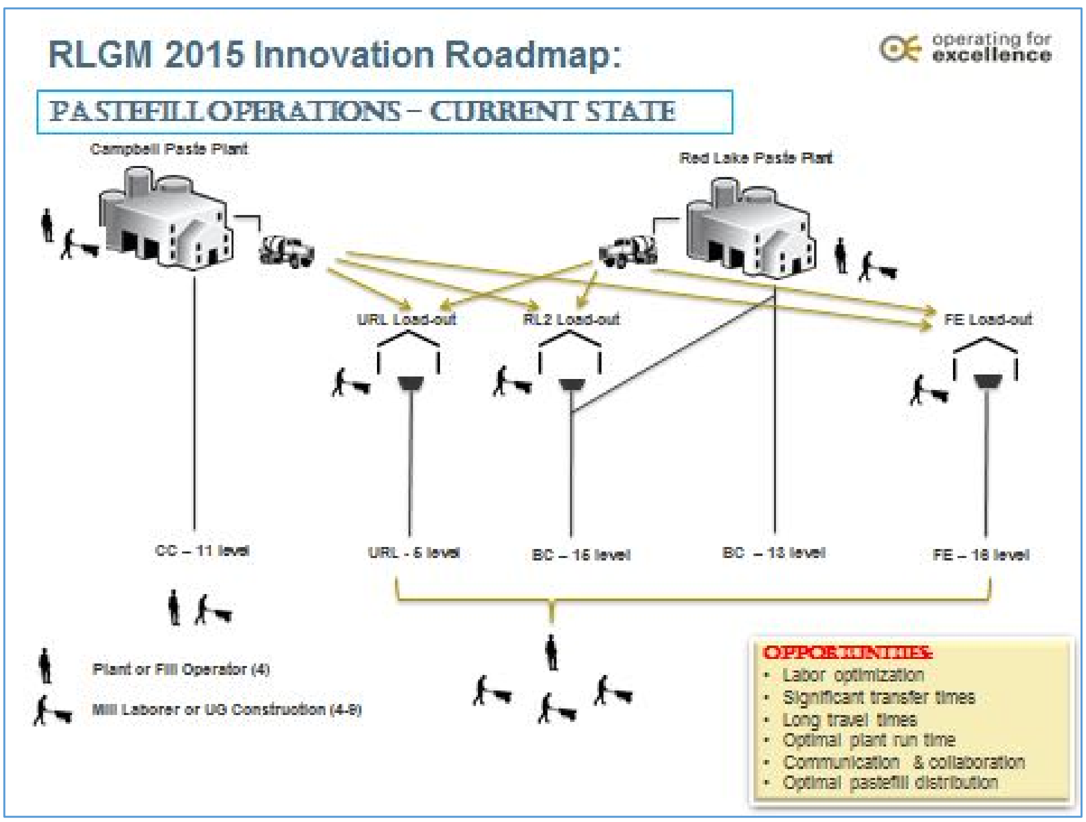


Figure 4. 2015 Surface infrastructure and operation

FUTURE PLANT IMPROVEMENTS

Future improvements to the plant infrastructure and operations will include installation of fluidizers at the Red Lake complex (RLC) for both binders to enhance silo flow and to prevent minor bridging. This will lead to and allow rotary valves to provide better control of binder addition. Further improvement will be automation of the RL2 hopper. The instrumentation and air supply are already hooked up. Electrical work is planned for operating the knife gate in “automatic mode” allowing operation to be fully automated. This will optimize resources and allow operators to spend more time operating the system safely. Additional improvements will include replacing the feedwell for the paste fill thickener and optimizing flocculant additions.

At the Campbell Complex paste fill plant, construction of a load-out system was completed to optimize its paste production capability. The Far East/ upper Red lake (FE/URL) underground zones, were to be filled using RLC paste however this meant that the RLC could not also pour sufficient fill quantities to high grade stopes. A line was connected from the Schwing pump to the outside of the pastefill thickener to allow for the filling of trucks. This allowed additional placement flexibility of paste fill plant operations. Automation of this system is currently on going. The control system is in place and tying the knife gates into the system and gate commissioning is underway. Currently the knife gate system is manually operated to alternate and line filling. Figure 5 shows the Campbell Complex truck load-out. Figure 6 shows future planned surface infrastructure and operation features.

Figure 5. Campbell Complex load (out-prior to winterizing facility)

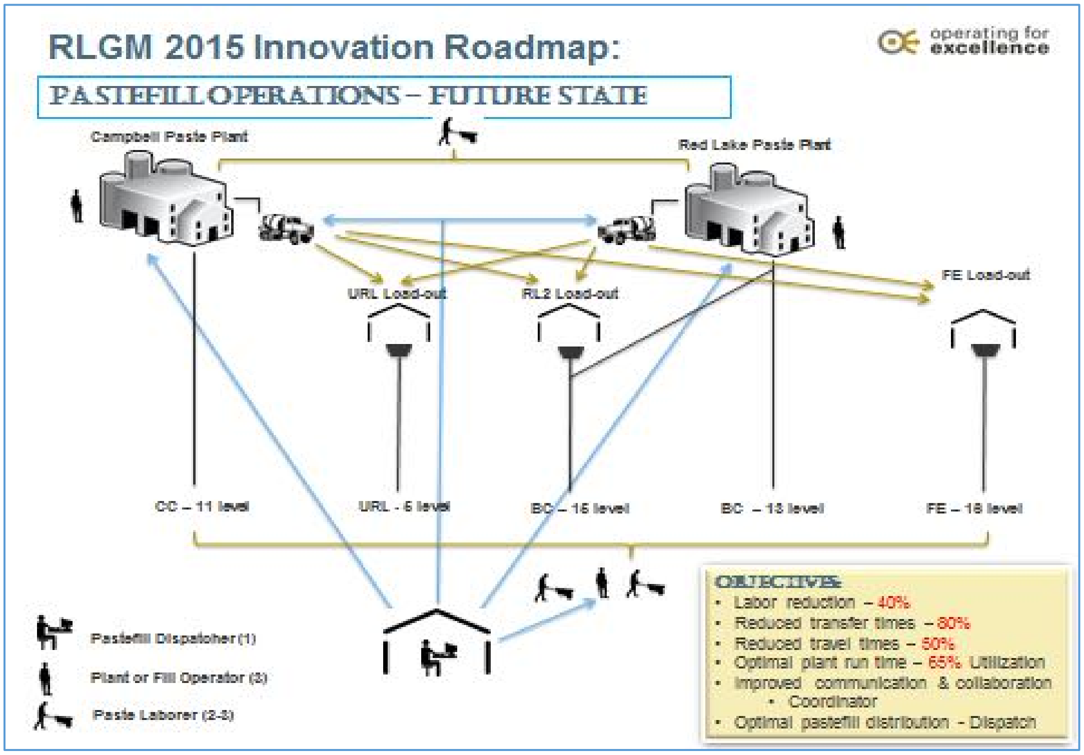


Figure 6. Future surface infrastructure and operation features

The installation of a new bidirectional tailings line in 2016 will allow and ensure that the RLC paste plant will have a tailings supply regardless of the functioning state of the RLC mill or RLC mill supply. The RLC plant is dedicated to filling the High Grade (HG) zone and so the plan is to ensure that it will have sufficient tailings for operating the Red Lake paste plant while running one mill. This will also allow operations to cycle or shut down the Red Lake Complex and not compromise the production of paste fill.

UNDERGROUND CHALLENGES

Backfill production for underhand or overhand cut and fill stopes within a small layout, high grade mining profile requires efficient processes and practices. The design of such stopes requires multiple Mob/Demob fill preparation (cleaning, fence building, piping, etc…) and very short fill cycles before operations can start again in the same heading. It becomes even more challenging with continuously increasing production and development requirements and multiple headings to manage simultaneously. Every part of the fill cycle takes planning, leadership, defined processes, understood procedures, and disciplined execution to ensure efficient operation and plans must stay on track. Off cycle processes can lead to catastrophic failure in the mining cycle, and it takes everyone involved to be part of the end goal for safe, successful process management.

Red Lake Gold Mines also initiated a serious shift in mining methodology and converting designs in underground areas to support bulk mining and longhole stoping. With the addition of more longhole mining, while being faced with multiple cut and fill headings to back fill and multiple locations to prepare at any given time, the mine faced additional backlogs as production profiles continued to grow. Having numerous shortcomings in filling processes and management practices, it was soon realized that a more structured support hierarchy was needed to provide a strategic supply of backfill to meet and exceed the production profile and close the gap on the backlog that was slowly growing. The backfill distribution process consists of a series of gravity fed underground distribution lines from the production plants, as shown in Figure 7.

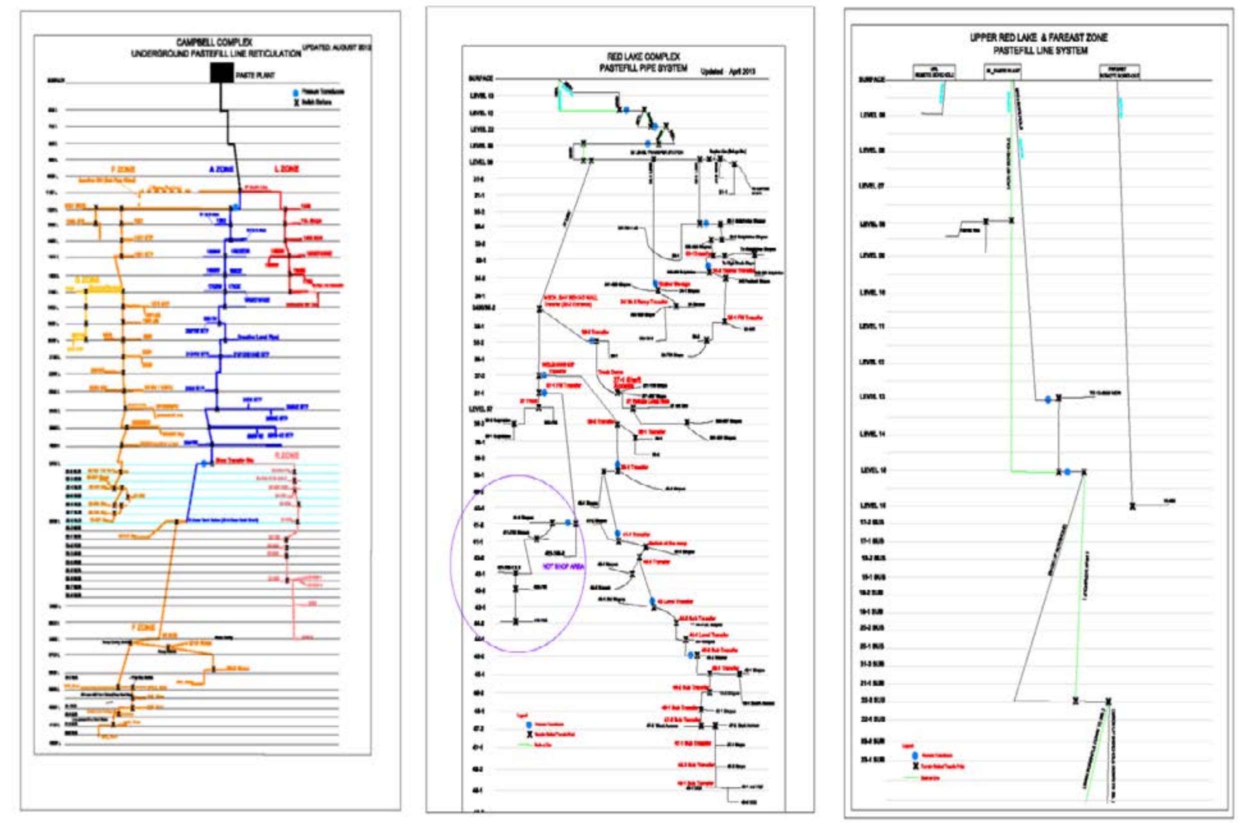


Figure 7. Underground paste fill reticulation

Most of the mine’s backfill requirements were for the lower part of the mine that was being fed by a single paste line. Additionally the operation was faced with a growing volume of backlog within the upper parts of the mine that was the holding back production needs. Production slowing down at the Campbell Complex, underground operations and subsequently Campbell’s paste plant while demand increased across the Red Lake / Balmer Complex; it was evident that RLGM needed a revised strategy to meet back fill needs in critical areas.

UNDERGROUND IMPROVEMENTS

In order to meet and exceed paste fill tonnage requirements, Red Lake Gold Mines paste fill teams needed to become much more efficient. Changes were needed in the way that the mine operation managed back fill processes. Change was required to allow operations to perform tasks proactively, and to gain time by improving plant reliability, plant utilization and paste placement to pour locations quicker.

Key areas of focus included:

- Reduced pours per stope through planning
- 24 hour per day operations (continuous pouring)
- Reduced time for switches (paste piping transfers & travel)
- Adoption of instrumentation & automation (monitoring & control)

An in depth review of paste fill delays yielded areas of opportunity and action planning to improve efficiencies. Figure 8 shows a survey of reasons for paste fill delays.

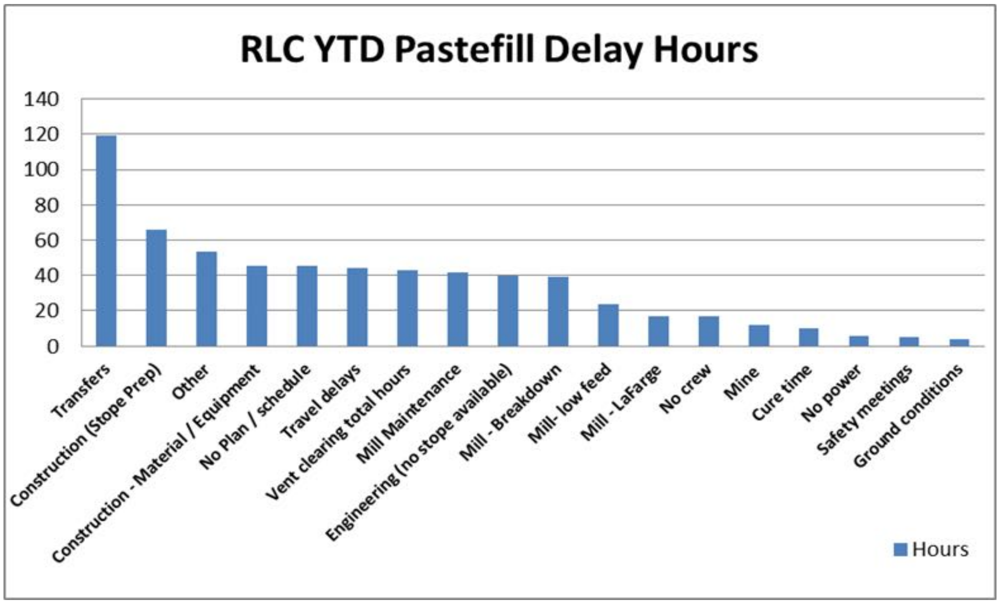


Figure 8. Paste fill delays

Significant improvements in transfer and travel times were made through better defined processes, improved procedures and communication between the plants and underground paste fill operators. Lock-out procedure changes made a significant reduction in travel delays. Infrastructure improvements were made that reduced transfer times, through the installation of mechanical transfer valves in key locations along with improved mounting of piping/transfer stations. Stope preparation procedures were also revised to improve efficiencies with pre-job kitting of materials and placement for easy access when needed.

Longer pour times were achieved through shift / schedule alignment between the paste plant and underground operations and continuous pouring between shifts. Continuous pouring was achieved through the development of clear protocols that supported a safe-to-proceed procedure. Infrastructure improvements that included pressure monitoring, fill fence level indicators and cameras monitoring the pour along with improved collaboration and communication between paste plant and underground paste fill operations contributed to successful continuous pour operations where and when it was safe to do so.

A reinvigorated paste fill distribution system maintenance program also yielded improved run times by reducing failures, and aligning with plant scheduled maintenance downtimes to ensure optimal use of the time available for collective maintenance and optimal runtime.

Through revised paste pour planning, stope sequencing, and fence designs, RLGM was able to reduce the number of fill cycles on cut and fill stopes, reduce off-cycle impact, and increase diversified paste filling schedules that considered use of either paste plant to fill at both complexes. Paste trucking and plant schedules were designed to align with the backfill schedule. A typical paste fill scheduling board is shown in Figure 9. A simple, yet effective backfill scheduling “visual management tool” provides real-time twice weekly scheduling support performed by the cross-functional backfill coordination team. Highlights of the scheduling process include:

- Backfilling is on a 7 day rolling work schedule (not to be confused with the backfill plan)
- The Senior Mining Engineer, Senior Tactical Planner, and Operations Superintendent determine weekly priorities of where to fill
- The Backfill Engineer, Operations Backfill Coordinator, General Foreman , Operations Supervisor (logistics), Mill/Paste Plant General Foreman and Supervisor, and any other individuals as deemed necessary meet on Tuesdays and Fridays to review and revise the schedule as required
- The backfill scheduling board is used to help visually display the schedule and to help facilitate/communicate any changes to the schedule
- Use of a magnetic whiteboard to place magnetic labels to represent the various stages of the backfilling process (cleaning, fill prep, fencing, pouring, and curing) in the headings that we are filling over the following week.
- An electronic version of the board is also updated and released to all key stakeholders

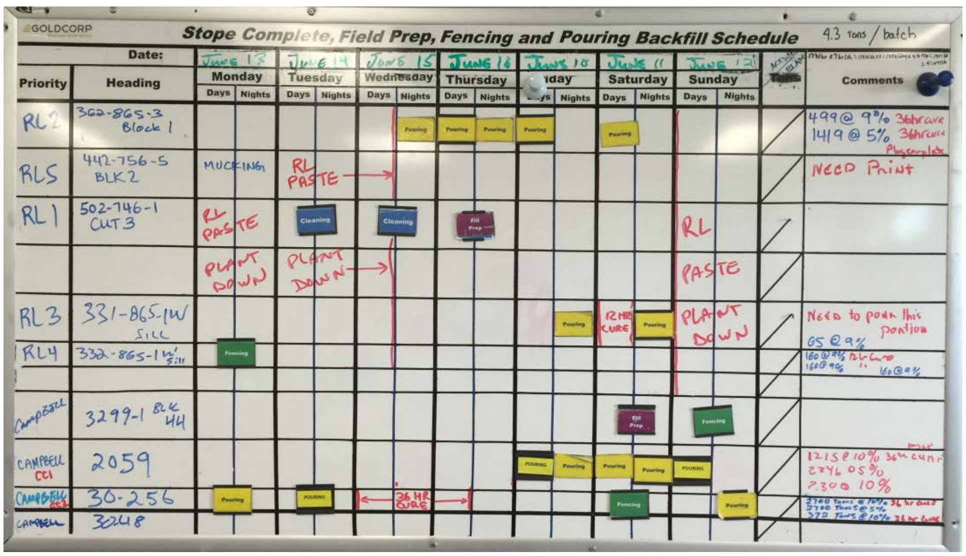


Figure 9. Paste fill scheduling board

As a result of the changes made to surface infrastructure and underground reticulation infrastructure, the site was able to pour simultaneously in multiple locations. More specifically, the plant could pour the High Grade Zone (UCF/OCF stopes) while simultaneously pouring the Far East Zone (Longhole). This effort provided much more ability to meet the varying demands that the mine plan placed on end-to-end backfill operations.

STEP CHANGE PROCESS

Following project management methodology and lean-sigma principles, a step change process was established and followed. A project charter was developed; project goals and objectives were established and team members were identified, as listed in the following:

Goal

To safely, efficiently, and consistently meet RLGM's paste fill demand requirements through life of mine (LOM) in a cost effective manner.

Objectives

- Improve paste plant utilization and production rates
- Establish a paste production and delivery process that optimizes use of both RL and CC paste plants
- Improve the paste planning/forecasting process
- Improve the paste filling process and cycle times

The cross-functional team included champions from the Mine, Planning, Engineering, Mill Operations / Paste Production, and Operating for Excellence (O4E) Departments supported by Corporate Backfill.

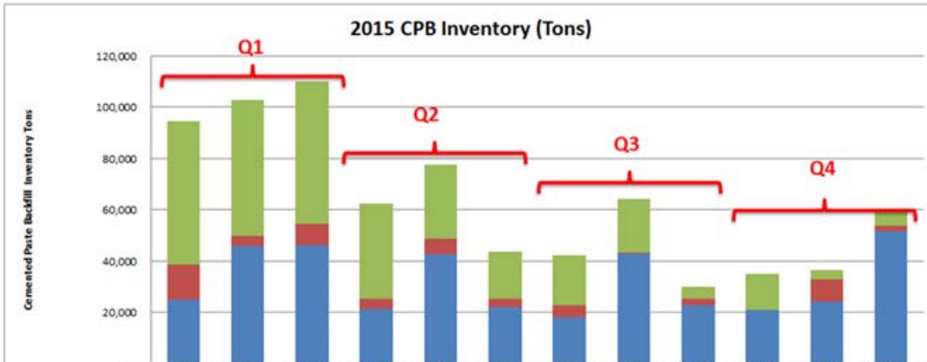
The team was formed under the title of Back Fill Optimization Team (BFOT). Each team member brought specific skills and understanding to the step change process. Planning provided a backfill engineer with intimate knowledge of quality control and assurance, paste fill placement, planning, scheduling, and the reticulation system. Mill operations appointed a paste fill champion who provided detailed knowledge of the production of the paste fill, plant operating practices / procedures, utilization and reliability. The O4E representative provided oversight, project management methodology, lean-sigma principles and delivered guidance in utilization and optimization strategies. The mine department provided members from the leadership and construction groups with firm understanding of the preparation, delivery, and proper placement of paste fill and provided day-to-day leadership in the step change process. The Corporate Director of Backfill provided guidance and oversight in paste fill best practices, and operating processes/procedures. His wealth of knowledge assisted in facilitation of backfill improvements and provided a number of technical considerations and a process flow to consider.

The team identified current paste fill production, transportation, and delivery limits, and constraints. It then determined what limits were required to meet and exceed required target limits (to meet mine demand). The team reviewed what the mine’s challenges and opportunities were and then established action plans to ensure a path to success.

Soon after forming the optimization team it was realized that certain parts of the process were working within the “Silo” effect. There was a need for a structured approach to gaining control of backfill inventory, future sustainability within backfill production, and placement to support the business needs.

The BFOT established an extensive list of opportunities and associated action items. Each action item was given an owner and delivery date and all action items were ranked for completion to ensure that critical items were addressed first, while ensuring personal time constraints yielded the best results. The team met weekly for an update on the status of their action items, to support each other when required and to brainstorm any items that arose over the previous week. As the program evolved, priorities were revisited and revised accordingly. Where material changes were made in management practices (processes, procedures, communication, reporting and the like an integration plan was established that included standard change management practices. Standard tracking and reporting of key performance indicators (KPI) were established and integrated into the regular business reporting structure.

At present the BFOT meets periodically to ensure sustained results and to discuss any opportunities to improve from the current state. When necessary the team will mobilize into action as it executes the planned "future actions". Figure 10 shows the 2015 Consolidated Paste Backlog (CSB) inventory in tons after the step changes process was implemented.



	January	February	March	April	May	June	July	August	September	October	November	December
Far East Pastefill Tons	55,636	52,753	55,486	37,235	28,750	18,569	19,815	21,128	4,406	13,970	3,430	5,747
CC Pastefill Tons	13,900	3,969	8,423	4,015	6,110	3,080	4,659	160	2,656	-	8,765	2,075
RLC/BC Pastefill Tons	24,770	45,834	46,036	21,164	42,546	22,086	17,878	42,928	22,713	20,901	24,112	51,476

Figure 10. 2015 CPB inventories in tons

CONCLUSIONS

As a result of following a structured step change process, RLGM was able to yield true step changes in throughput, quality, and management practices. RLGM revised its level of understanding and commitment towards backfill operations and the importance that it has towards overall site success. Backfill is "A critical link in the mining cycle chain". The site was able to increase backfilling "flexibility" required to meet the variable needs of the current and future mine plans.

ACKNOWLEDGMENTS

Everyone at the Red Lake Mine who contributed to this paper in one way or another deserves thanks. The Backfill Optimization Team (BFOT), and the operations teams on surface and underground are thanked for their input and support. The Corporate Director of Backfill requires honorable mention for his continued pursuit of backfill excellence across the Goldcorp organization.

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