Kemess underground: project update, production simulation, and quadrant crusher layout

J Fitzgerald Centerra Gold Inc, Canada

CJ Clark Centerra Gold Inc, Canada

PO Labrecque SRK Consulting, Canada

AM Kalviainen SRK Consulting, Canada

Abstract

Pre-construction activities at the Kemess Underground Project (located in Northern British Columbia, Canada) started in 2018. Activities to date include: purchase of the first lateral development fleet, preliminary earthworks, construction of a water discharge system to dewater the future tailings storage facility, and construction of a water treatment plant. The project has also undergone an economic update throughout 2019-2020 to advance engineering and improve economics ahead of a construction decision. A conceptual study was undertaken to determine the mine design changes required to increase the mining production rate to 35,000 tonnes per day versus the base case NI 43-101 Feasibility Study assumption of 25,000 tonnes per day. SRK's Sudbury Branch was contracted to conduct an extraction level simulation to evaluate the potential productivity of the mine design and production plan. The simulation concluded that larger production LHDs (17.3t payload) and a modified primary crusher layout is required to achieve 35,000 tonnes per day.

1 Kemess Underground Project – Summary

The Kemess Underground Project (KUG) is located in a mountainous area of north-central British Columbia, Canada, approximately 900 km north of Vancouver and 430 km northwest of Prince George.

Centerra Gold Inc. acquired KUG January 8, 2018, with the acquisition of AuRico Metals Inc. KUG is at an advanced stage – it has an approved Environmental Assessment certificate, all permits required to commence construction, and a completed NI 43-101 Feasibility Study. Pre-construction activities began in 2018 and continued through 2019.

The Kemess South (KS) open pit operation ceased production in 2011. Existing infrastructure on site includes a camp, administration buildings, a process plant, and a 380 kilometer power line from the nearest town of Mackenzie, BC. KUG is located approximately 6.5 kilometers to the north of the existing KS facilities.

KUG has a 4.5 year construction period leading up to cave production. Major project components include an 865m long Access Tunnel, three 3.25km long declines, and an 8 kilometre long conveyor from the underground mine to the existing KS processing plant. Figure 1 outlines some of the existing infrastructure, as well as planned surface and underground project components.

KUG is a gold-copper-silver porphyry deposit that hosts a probable Mineral Reserve of 107.3 Mt within a selected PCBC™ cave volume that has footprint dimensions of approximately 570 m east-west and 90 m to 300 m north-south. Mineralization extends from approximately 200 m to 550 m below surface. The head grade of the KUG Mineral reserve is 0.27% Cu and 0.54 g/t Au and 1.99 g/t Ag. The typical range of column heights and NSR values (in C$ per tonne) is shown in Figure 2.

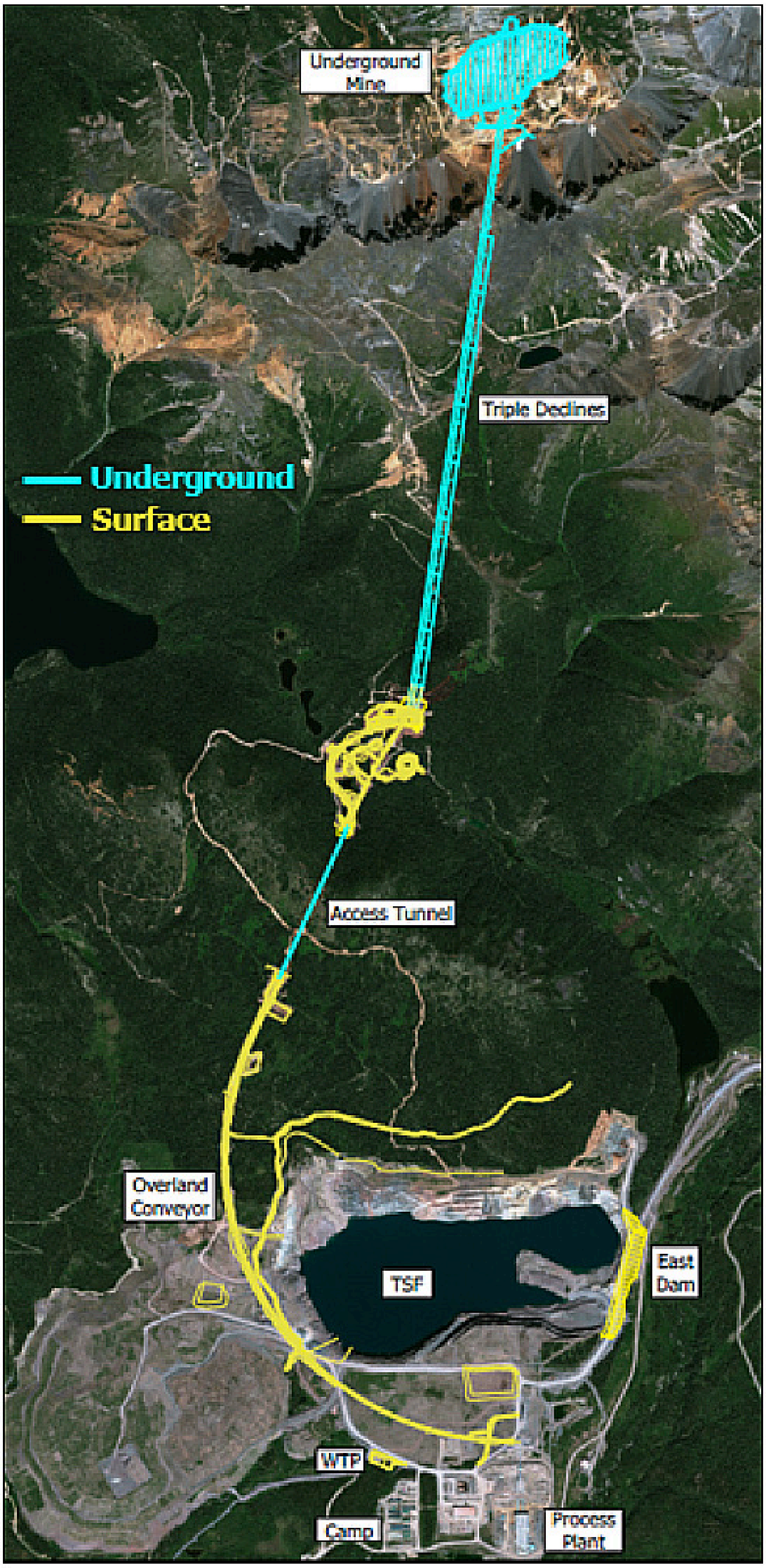

Figure 1 **KUG Site Layout with proposed surface and underground workings indicated**

The mine design establishes a single extraction level that includes 582 drawpoints (291 drawbells). A panel caving approach with a peak mining rate of 35,000 tonnes per day is proposed. The cave will be initiated in the highest grade ore in the northeast of the orebody and progress to the southwest over the life of the mine. LHDs will transport ore directly to four primary jaw crushers, which are located on the extraction level. Figure 3 shows an isometric view of the 2016 Feasibility Study (2016 FS) mine design.

Figure 4 shows the proposed lateral development schedule for the underground mine, starting in Year -3 (Y-3), with Year 1 (Y1) being the year when cave production begins.

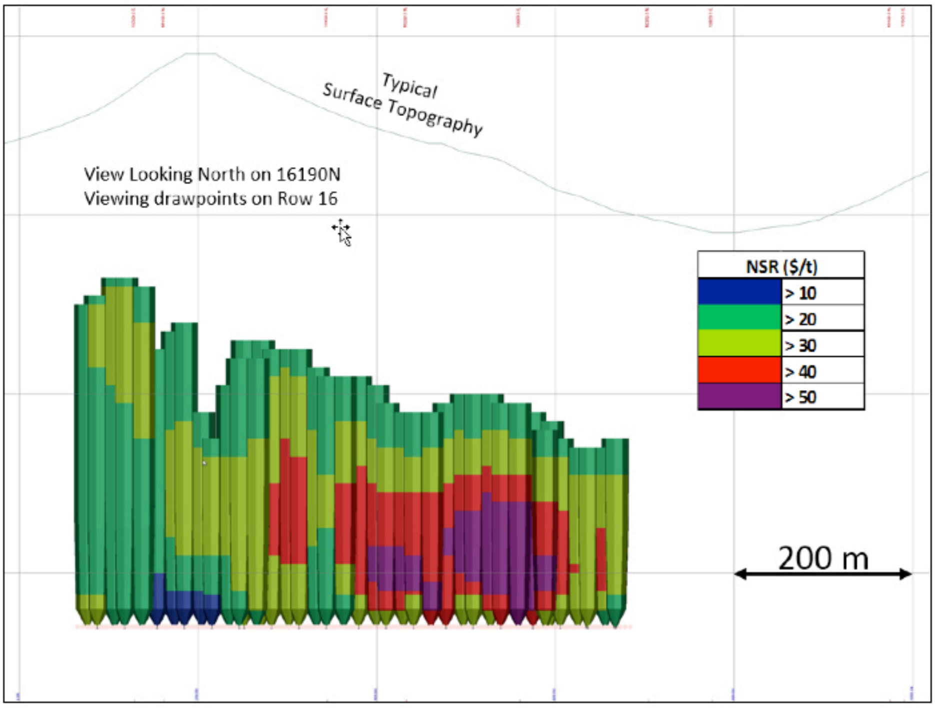

Figure 2 Typical Range of Panel Cave Column Heights

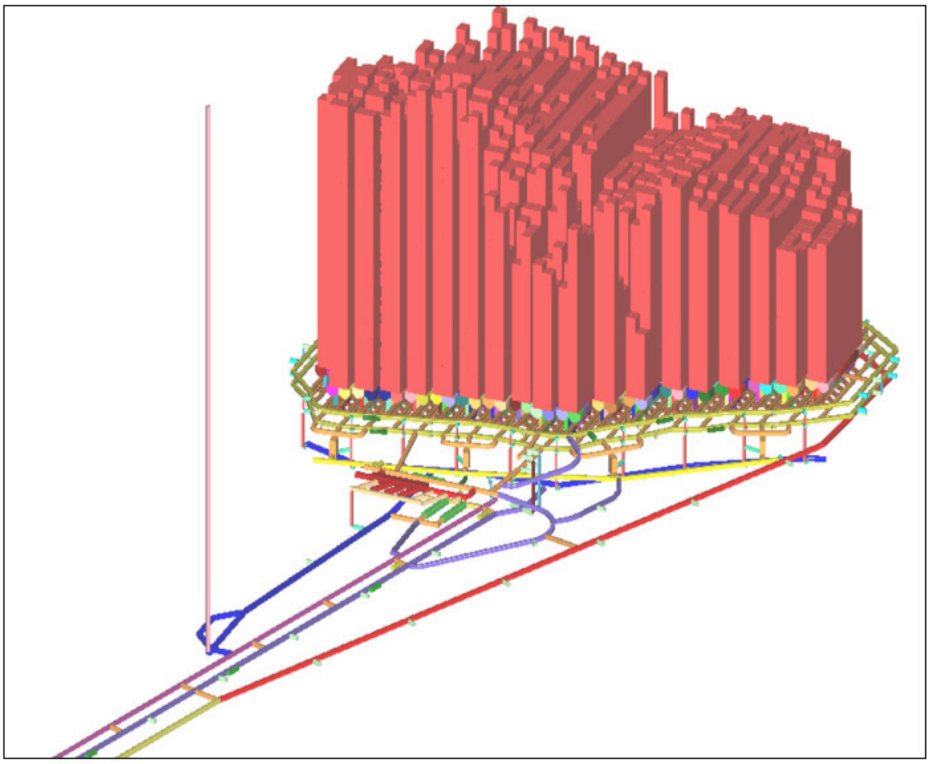

Figure 3 Isometric view of 2016 Feasibility Study KUG mine design

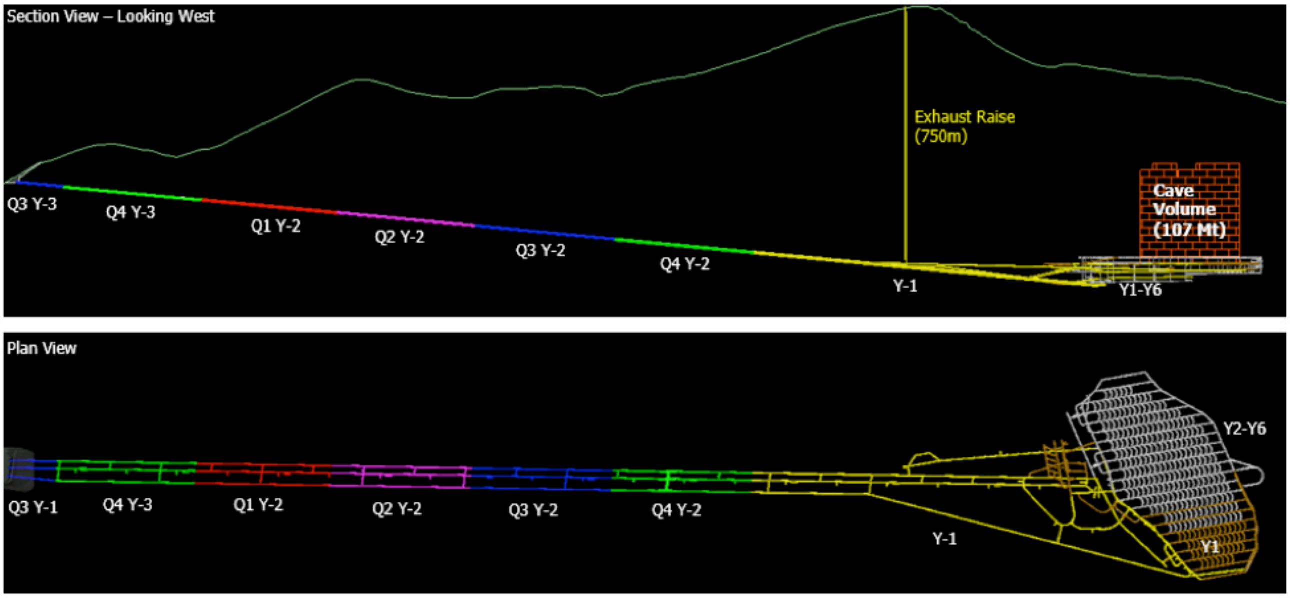

Figure 4 Underground Lateral Development Schedule

2 Pre-construction Activities (2018-2019)

2.1 Surface Earthworks, Equipment, and Infrastructure

Pre-construction activities began in 2018 and continued through 2019. Major activities include: purchase of the first lateral development fleet, preliminary earthworks at the portal locations and along the conveyor corridor, construction of a water discharge system to dewater the future tailings storage facility, installing new camp bunks, and construction of a water treatment plant. Figures 5 and 6 show the earthworks complete to date at the surface portal locations.

Figure 5 Access Tunnel South Portal Location (October, 2018)

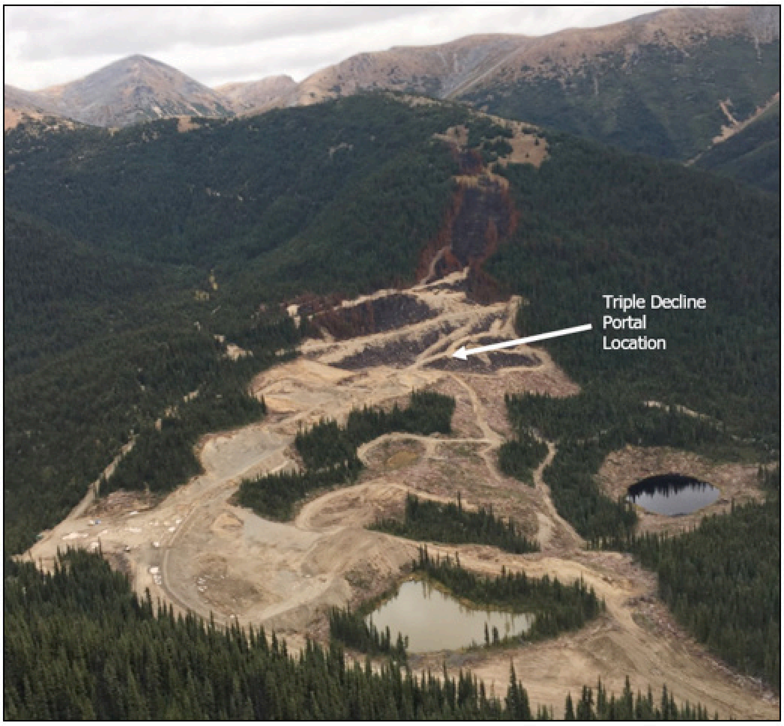

Figure 6 Triple Decline Portal Location (August, 2018)

2.2 Economic update

In 2019, an economic update for KUG was started to improve project economics and capital cost certainty. This included a study to evaluate the maximum productivity achievable with the current mine design and rock mass characteristics of the deposit. The goal of the study was to determine the changes required to the mine design and production plan to increase the daily caving rate from 25,000 tonnes per day (the Feasibility Study assumption) to 35,000 tonnes per day. The cave production schedule was updated in PCBC and then tested with a discrete event simulation model. Simulation results suggested that higher payload LHDs and a different primary crusher layout would be required to meet the increased production targets.

3 Production simulation results

A discrete event simulation model of the Kemess underground mine was created by SRK Consulting (Canada) Inc. (SRK). This model was used to assess the production capacity of the Kemess footprint and tested several different aspects of the mine including different production schedules, various crusher locations, manual vs. autonomous LHD operation and routing, and other operational trade-off sensitivities. All model logic was customized for the Kemess mine to control all aspects of the operation such as daily production scheduling, production LHD activities, hang-ups and oversize events, secondary breaking activities and crusher operation. All equipment includes customized shift schedules, planned maintenance and unplanned failures. Detailed equipment traffic and queuing at the crushers was included in order to fully capture the dynamic nature of panel cave mining and yield the best results possible. The model was setup to run each quarter of the full life of mine schedule.

The first analysis tested the impact of several model inputs, including the autonomous LHD working time, increased LHD bucket size, and crusher feed bin size. Increasing the LHD payload from 15 tonnes to 17.3 tonnes increased production by an additional 7%. Reducing the crusher feed bin capacity from 100 tonnes to 50 tonnes had no impact on productivity.

Further analysis was then performed with the southern crusher layout, which includes four (4) crushers along the southern perimeter of the footprint. Figure 7 shows a screenshot of the southern crusher layout.

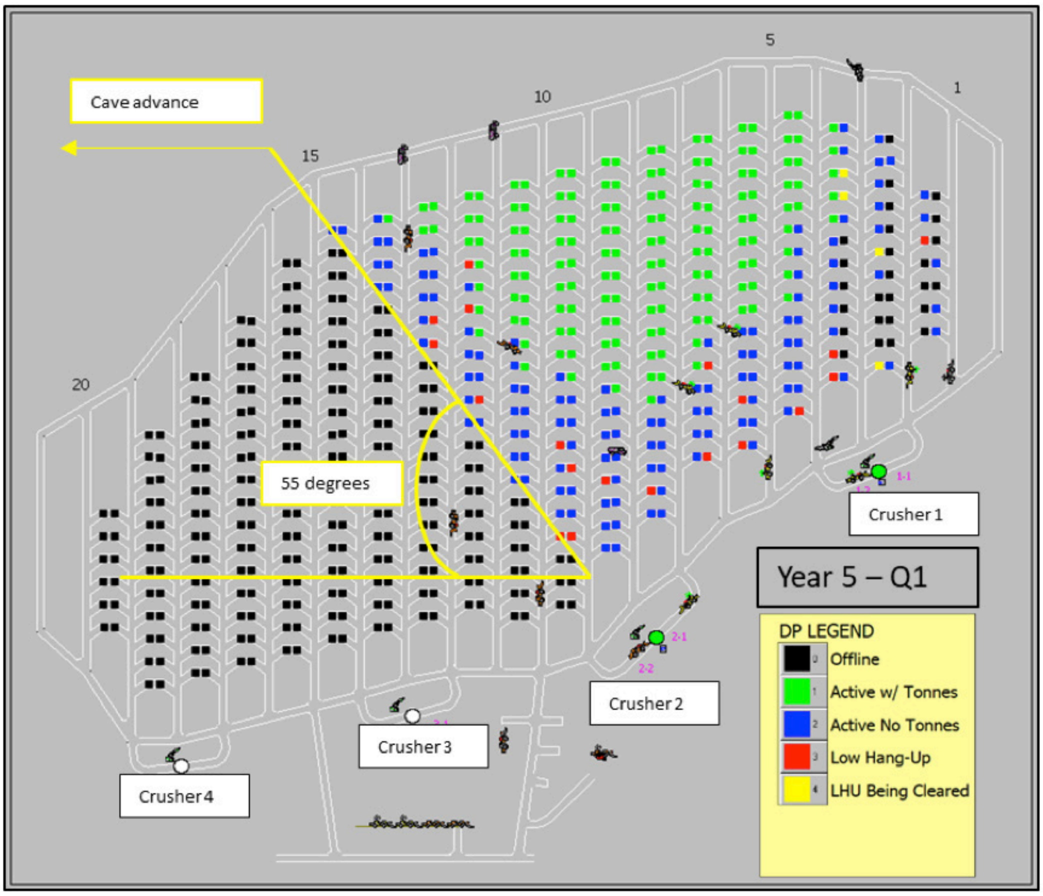

Figure 7 **Kemess southern crusher simulation layout**

For this analysis, it was assumed that extraction drives that are still constructing drawpoints must use manual LHDs. Once all drawpoints in a drive are in full production, the model switches to autonomous LHD operation when its designated tip location no longer has any manual LHDs using it. The preliminary analysis highlighted a significant shortfall of production compared to the scheduled target. Results from the simulation indicated that drives in manual operation could achieve approximately 3,000 tpd while drives in autonomous operation could achieve closer to 3,750 tpd. These findings were used to update the caving sequence and production schedule. Results from Year 7-Q1 are shown as an example in Figure 8.

As seen below, the revised sequence improved the production capabilities, but the model was still unable to achieve the target production. The simulation was then used to test several potential opportunities for improving performance, including decreasing hang-up and oversize events, allowing drives with autonomous LHDs to blast secondary breaking events anytime (or "blast at will") rather than during off-shift periods, increasing the manual LHD seat time and including a third central tip location for each crusher. As seen in Figure 9, the additional trade-offs help improve the productivity of the southern crusher scenario and target is achieved in 20 of the 37 quarters tested.

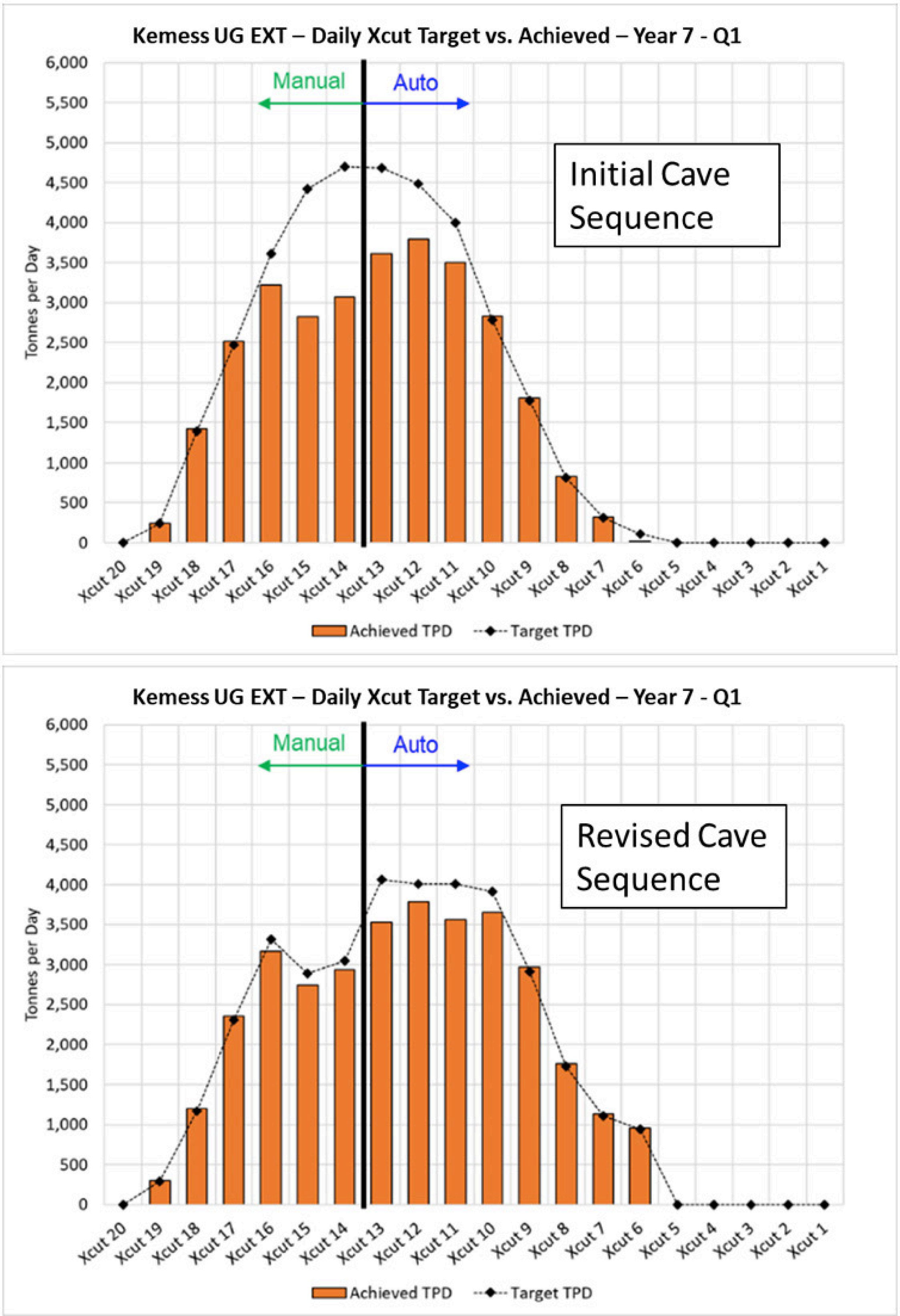

Figure 8 Revised caving sequence example – simulation results

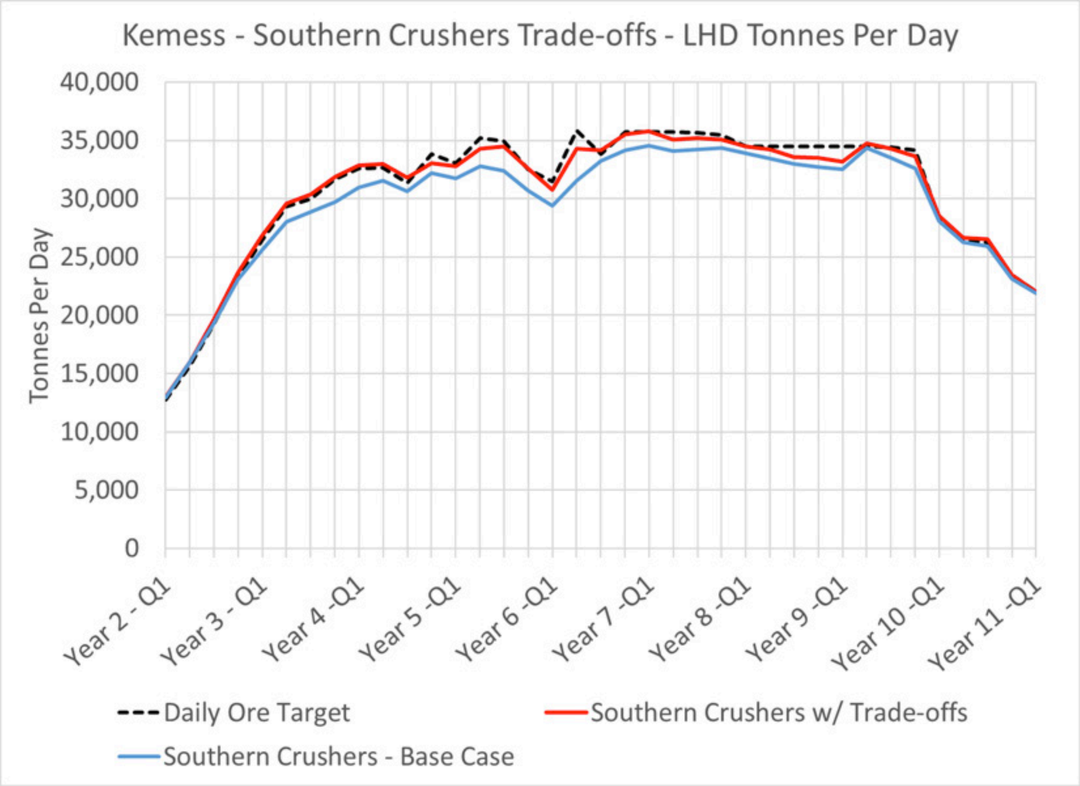

Figure 9 Southern Crushers with Trade-offs – Simulation Results

Based on the analysis of the southern crusher scenario, the model was then used to test a revised mine design which places the four crushers in each quadrant of the footprint perimeter. The revised design also implemented a shallower undercut angle. Figure 10 shows a screenshot of the quadrant crusher layout.

The quadrant crusher layout allows for LHDs to muck northern drawpoints to the northern crushers and southern drawpoints to the southern crusher; this reduces the cycle time for many drawpoints. However, this design requires more crosscuts to share each crusher tip location and increases the tram distance along the perimeter drive which increases the congestion of LHDs trying to access each crusher. Discrete event simulation is the ideal tool to determine if the benefits of the shorter cycle distance justifies the potential congestion increase with the quadrant crusher design.

The simulation model was used to optimize crusher locations by determining the shortest average cycle time for 90 potential crusher locations. The selected locations allowed the average cycle time for all drawpoints to be minimized. In order to do this, the model drove an LHD from each drawpoint to each potential crusher location and determined the optimal crusher locations to minimize the average cycle time for all drawpoints. Once the optimal crusher locations were selected, the simulation model was used to determine the potential production capability of the quadrant crusher layout.

Based on the quadrant crusher layout, LHDs could be used in four (4) operating conditions for each crosscut (or extraction drive):

1. Manual LHDs routing all active drawpoints in a crosscut to the northern crusher.
2. Autonomous LHDs routing all active drawpoints in a crosscut to the northern crusher.
3. Autonomous LHDs routing all active drawpoints in a crosscut to the southern crusher.
4. Autonomous LHDs splitting active drawpoints in a crosscut between the northern and southern crushers.

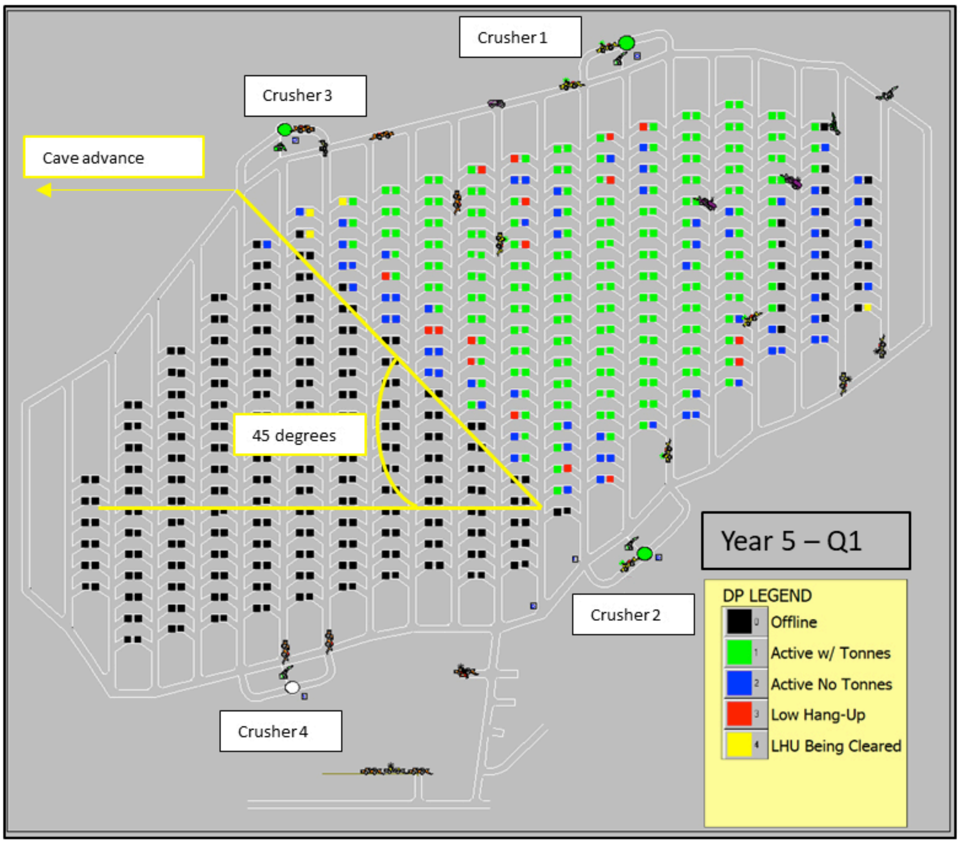

Figure 10 Kemess quadrant crusher simulation layout

Crosscuts located between two crushers could be routed to either crusher, depending on how many tonnes are being allocated to each crusher from adjacent drives. In this way, a dynamic dispatching-type algorithm was implemented, as could be implemented during an actual production shift by dispatch software.

In order to determine the ideal LHD routing option for each quarter, dozens of simulation runs were performed testing several routing options for each quarter examined. Year 5-Q1 is shown as an example in Figure 11. Adjusting the LHD routing has a significant impact on the productivity with a 3,000 tpd difference between routing option 2 and option 4, which equates to a 10% increase in production for this quarter.

Once the ideal LHD routing was chosen for each quarter, the simulation was run using the same inputs and assumptions as the southern crusher base case scenario. As seen in Figure 12, the quadrant crusher case (solid red line) outperforms the southern crusher case (solid blue line) and can achieve the target production for nearly all quarters examined. The quadrant crusher scenario typically requires fewer LHDs than the southern crusher scenario even though it has a higher production rate (dotted red line vs. dotted blue line).

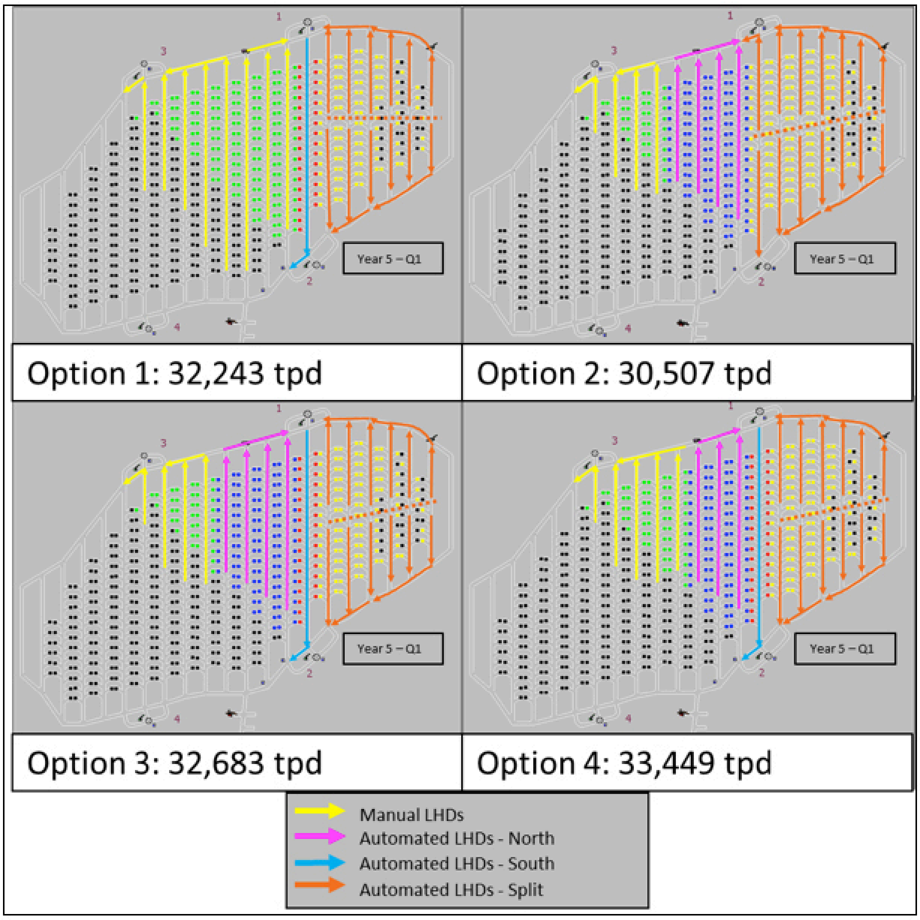

Figure 11 Kemess LHD Routing Options Example

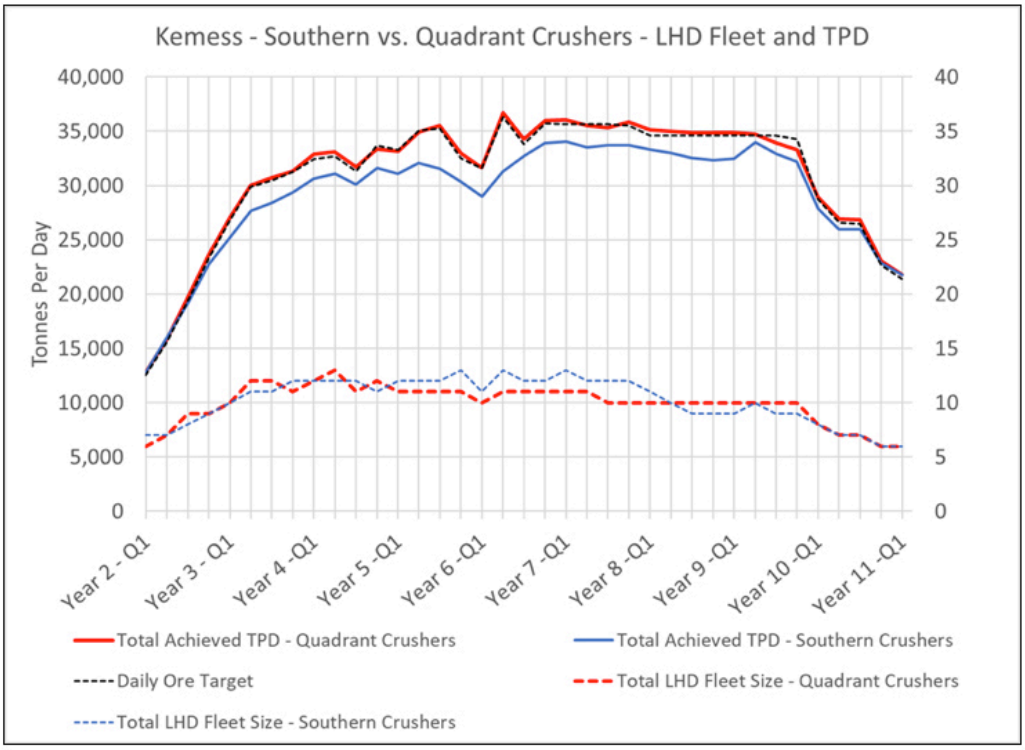

Figure 12 Kemess Southern Crushers vs. Quadrant Crushers – Simulation Results

4 Quadrant crusher mine design update

Following the simulation results, an extraction and conveyor level design was created to incorporate the quadrant crusher design. Figures 13 and 14 show the two layouts tested in the simulation model, with the crusher-conveyor system highlighted in green.

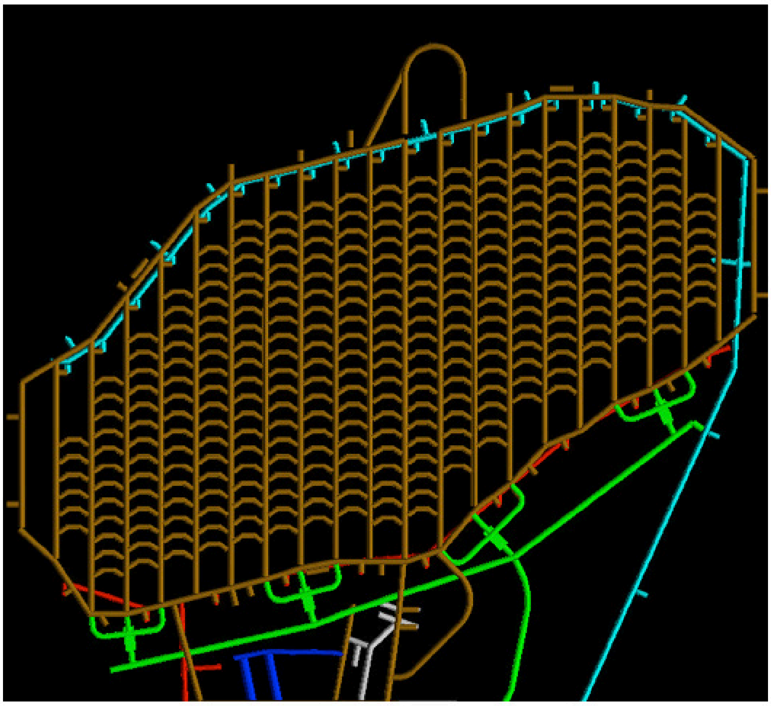

Figure 13 Southern Crusher Mine Design (from 2016 Feasibility Study) – Crusher-Conveyor system shown in green

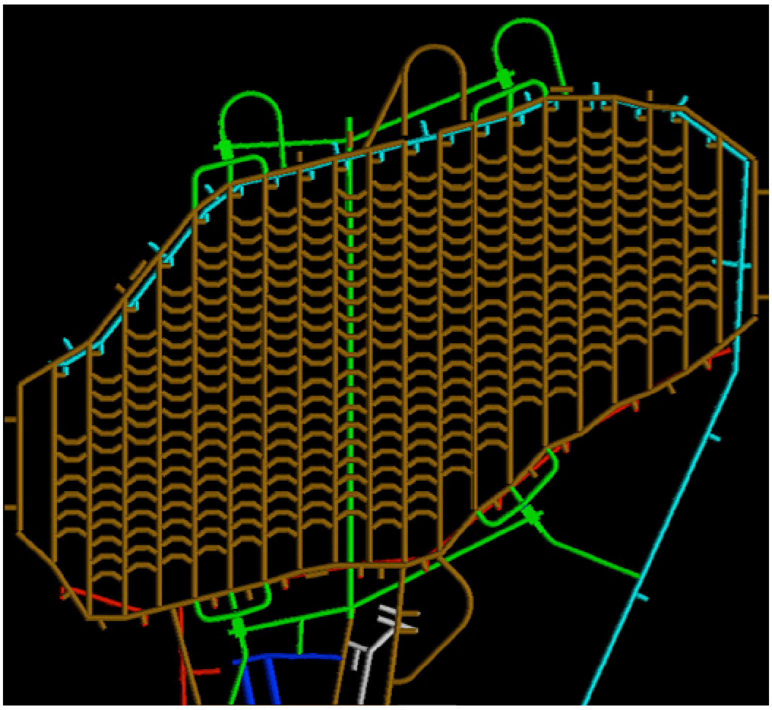

Figure 14 Conceptual Quadrant Crusher Mine Design (2019) – Crusher-Conveyor system shown in green

A trade-off study evaluated the potential increase in cave production versus the incremental capital investment required for the quadrant crusher scenario. Table 1 shows the additional development that would be required for the quadrant crusher layout. The trade-off study indicated that the increase in production offered by the quadrant crusher design would justify the additional mine development costs.

Table 1 Incremental Cost for Quadrant Crusher Scenario

Item	Quadrant	Southern	Change
Lateral Development (m)	1,702	550	1,152
Vertical Development (m)	52	-	52
Bulk Excavation (m^3)	31,668	30,642	1,026

5 Conclusions

The Kemess Underground project has begun pre-construction activities and is currently undergoing optimisation studies to improve overall project economics. As part of a study to increase the KUG caving rate from 25,000 to 35,000 tonnes per day, a discrete event simulation indicated that larger payload LHDs (17.3t) and a quadrant crusher mine design is required.