Process Operations Considerations at Victoria Gold Corp.'s Eagle Gold Mine

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Abstract

Victoria Gold Corp.'s Eagle Gold Mine is in the center of Canada's Yukon Territory, approximately 375 kilometers north of the capital city of Whitehorse. The mine is an open pit operation with ore processed via three-stage closed-circuit crushing, and gold recovered through valley-fill heap leaching. The mine poured its first gold in 2019 and has since ramped up production, becoming the largest gold producer in Yukon history.

The operation experienced typical greenfield operation start-up issues; however, many of these were compounded by the extreme climate conditions and often required innovative solutions. This paper summarizes several of the key challenges experienced and lessons learned during the ramp-up phase. The specific and unique challenges in the crushing circuit, leach pad, and ADR circuits afforded by the cold weather operation are discussed with suggestions for consideration in future cold weather operations.

Introduction

Victoria Gold Corp.'s Eagle Gold Mine (Eagle) is the largest gold producer in Canada's Yukon Territory. The mine is located approximately 375 kilometers north of the capital city of Whitehorse and is accessed by a 43-kilometer road intersecting the Silver Trail (Yukon Highway 11) between the towns of Mayo and Keno City. Operations at the mine include conventional open pit mining with ore processed via three-stage closed-circuit crushing, and gold recovered through valley-fill heap leaching with a conventional carbon adsorption-desorption-regeneration (ADR) facility. The first gold was poured in Q3 of 2019 following initial ore placement in the same period, and commercial production was achieved on July 1st, 2020.

The Heap Leach Facility (HLF) is designed to accommodate ninety million tonnes of crushed ore, with design capacity expected to be reached in late 2027. Slightly over twenty-three million tonnes have been placed on the HLF as of July 2022, as stacking has ramped up from commissioning to target a nominal crushed ore placement of over one million tonnes per month with annual gold production targets over 200k troy ounces. Neither ramp-up of operations after start-up, nor processing circuit modifications, are unique within the industry. However, the location of the site has posed unique challenges and requires special considerations that other operations seldom face.

Located at latitude 64º2' N and longitude 135º50' W, the climate at the Eagle site is classified as northern continental. The mean annual temperature for the area is approximately –3°C, with a range of upwards of 25°C in the summer months to low temperatures in winter occasionally dropping below –50°C. The annual precipitation ranges from 375 to 600 mm, with about half of this falling as snow that accumulates over the period from approximately late September to mid-May. The adverse winter conditions factor heavily in process operations and, while there are multiple leaching operations located in cold weather climates (Smith, 1997; Sinha and Smith, 2015), there is a dearth of documented practical solutions available for operations to leverage in overcoming the prevailing challenges. The discussion below is intended to address specific examples related to cold weather heap leaching process operations and to highlight some of the more commonly neglected considerations, along with practical solutions that subsequent projects may draw upon.

Heap leaching operations

Figure 1: Heap leach facility layout at Victoria Gold Corp.'s Eagle gold mine

The design and layout of the Eagle HLF is largely typical of other valley fill operations in the industry. Figure 1 shows the layout and main infrastructure of the Eagle HLF. The leach pad is a valley-fill-type design with ore stacked behind an embankment spanning a natural basin. The embankment provides a buttress for the stacked ore and creates an in-heap pond for temporary storage of pregnant solution. An overflow spillway connects the HLF in-heap pond to the events pond, which is sized to contain excess solution resulting from an extreme precipitation event or other emergency scenario and provides a means to temporarily store process make-up water. Pregnant solution is pumped to the ADR facility from the in-heap pond by four submersible pumps, with a fifth pump serving as an installed spare. Design flow to the ADR is 2,000 m^3 per hour.

After passing through the carbon-in-column (CIC) trains, the barren solution is returned to the leach pad through two main 24" headers running up the east and west sides of the HLF. Distribution piping connects to the headers and progressively reduces to drip emitters used to deliver the leach solution. Relatively little differentiates the Eagle HLF from other heap leach operations in terms of basic process flow or equipment. The unique aspects of the operation are in the details of the execution.

As may be supposed, one of the foremost considerations in operation of the HLF is management of leach solution during the winter. Incorporation of sufficient backup power generation capacity is a manifest requirement, but a general assumption often encountered regarding cold weather leaching is that the circuit must include a means to heat the solution to keep the leach pad from freezing during the winter (Marsden et al., 1995). This is not strictly the case. The ADR circuit at Eagle has an installed heating capacity of 12.5 MBtu provided by two diesel-fired boilers, but, other than for preventative maintenance and readiness testing, the boilers have only been operated intermittently for a short time between December 2019 and February 2020.

During development and construction, they were included as insurance against the pad freezing causing a major failure. In practice they were soon deemed unnecessary and turned off. In operation the HLF acts like a heat reservoir. An insulating layer of snow helps preserve heat absorbed during the summer and, as a result, the leach solution stays above freezing, reaching essentially an equilibrium temperature only a few meters below the surface. Figure 2 shows the daily pregnant solution temperature measured since commissioning in 2019.

Overall the data show a general yearly trend, and periods early in the project with active heating of barren solution are easily identified. The temperature reaches a high of up to 10°C in the late summer, and then trends slowly downwards over the winter months, before dropping to a low of approximately 3°C in late April or early May. The drop results from the relatively rapid influx of melting snow within the leach pad footprint, and does not present a significant risk to the operation in terms of freezing.

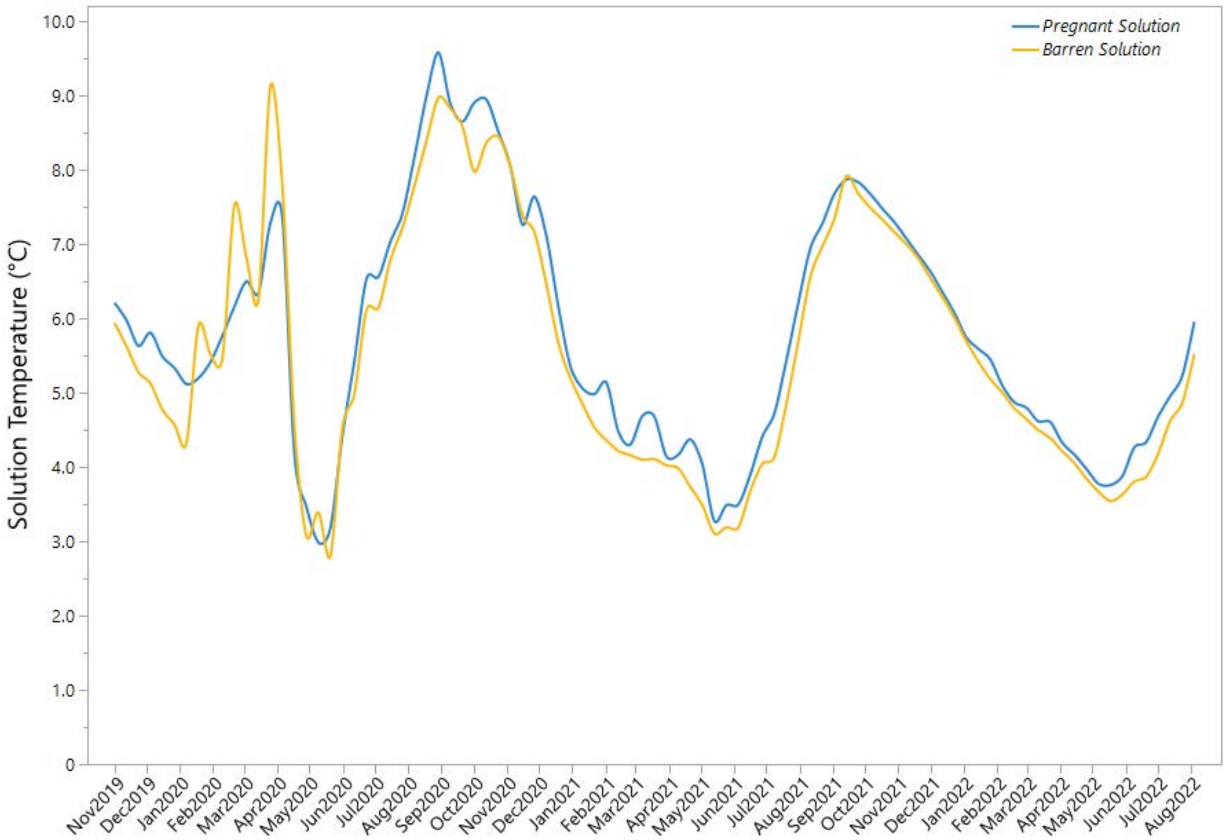

Figure 2: Victoria Gold Eagle mine heap leach solution temperature trends

The primary consideration from a freezing standpoint is preventing potential upsets and minimizing any uncontrolled flow within the solution distribution network. To this end, arranging leach distribution piping on a regular grid that can be plumbed with standard lengths of piping has multiple benefits. Figure 3 shows the convention adopted at Eagle using 90-meter lengths of 12" HDPE as the primary distribution piping, with 45-meter runs of 4" HDPE branching perpendicular feeding the driplines. In this arrangement each 2,100 m^2 panel can be isolated using valves installed at the 12" to 4" junction, minimizing the overall impact to flow if an area needs to be taken offline to address potential issues or make needed repairs.

This standard arrangement also allows piping lengths to be welded before they are needed, and allows for assembly of "ready kits" that contain all the fittings and associated hardware required to affect any emergency repair to any part of the network. The kits are boxed, clearly labelled, and stored in an area where they can be readily accessed and transported directly to the necessary location. Surveying all piping infrastructure and marking the location of key valves with indicators that are visible above potential snow loads and in dark conditions further expedites an operators' ability to isolate areas as needed.

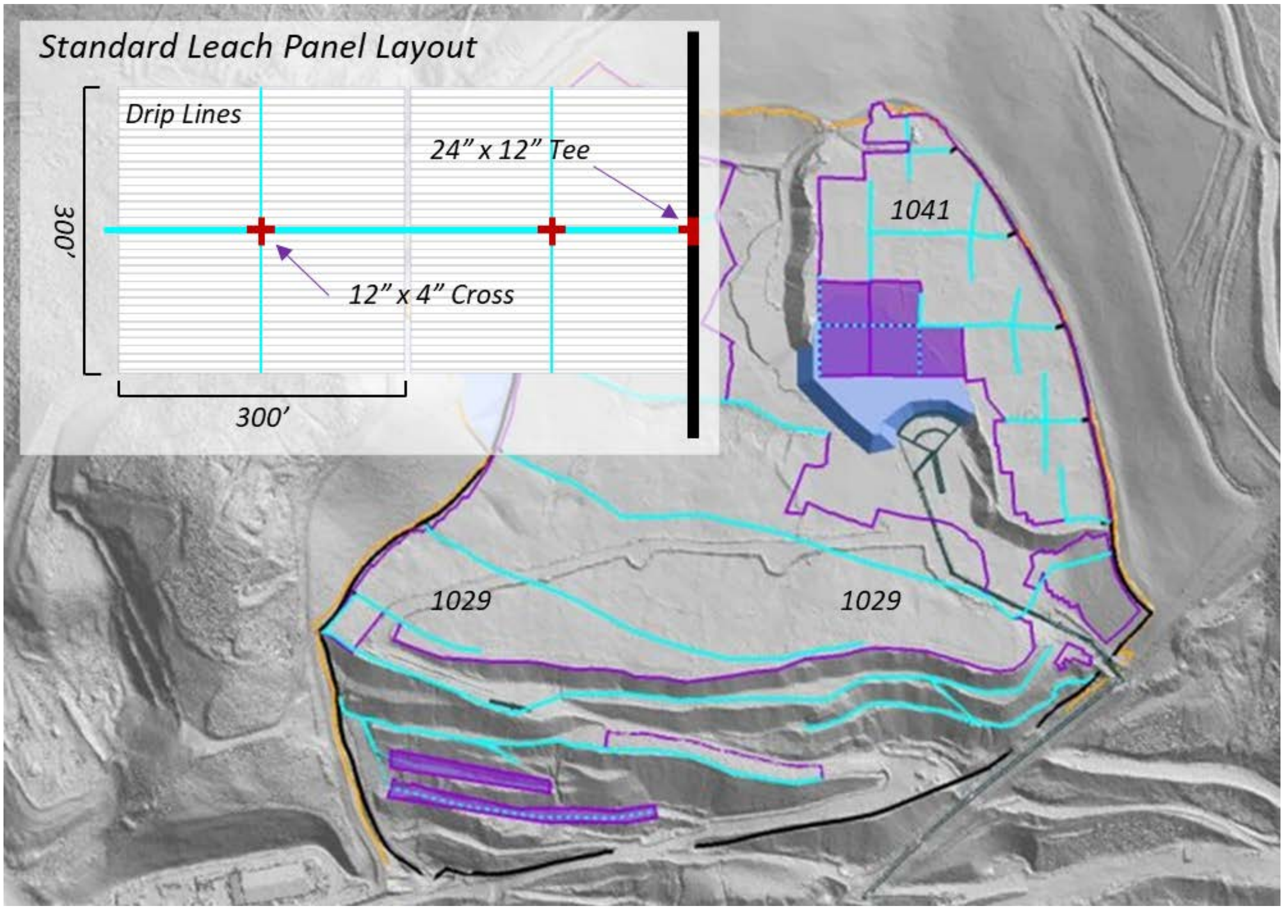

Figure 3: Typical leaching panel true cross layout

Even otherwise small leaks or blowouts can have serious consequences at –40°C. Hence, properly installing drip lines on the HLF is paramount. As in other cold weather applications, driplines at Eagle are ripped approximately one meter into the surface using a modified ripper table attached to a D-6/8-size bulldozer. Modifying the installation sequence to cut and tie off lines before completing the ripping pass allows the ends of the lines to be completely covered. This minimizes the chance for "freeze back", wherein the exposed end of the dripline freezes and becomes a heat sink for solution further down the line allowing the frozen length to grow. It also minimizes potential ponding and ice formation at the exposed ends.

The drawback to this approach is that there is no direct view to gauge the flow across the leaching panel, and care must be taken to ensure that solution application rate is tightly controlled to prevent ponding at the surface. Similarly, additional care must be taken when attaching driplines to the distribution piping. A single blowout can result in the formation of sizable ice masses in a short time. Once formed, the structures are difficult to clear away. The lines must be attached securely, but there must also be appropriate slack between the distribution piping and buried portion; sufficient to accommodate modest settling and swelling without straining the exposed length, but not so much that it protrudes too far above the surface, exposing it to the cold. In addition, the overall flow and pressures must be closely maintained at target levels to minimize the risk of driplines blowing off. Any visible ponding or uncontrolled flow must be addressed as soon as it is discovered to prevent areas from freezing or solution from flowing to unexpected areas. This includes any solution from melting of snow that accumulates on the HLF.

A well-laid and maintained leach panel has no visible features protruding from the covering snow layer but will also feel relatively soft underfoot, indicating uniform flow of leaching solution to the area. Figure 4 shows photographs of cross ripping operations and drip line installation as well as an active leach cell during winter operations.

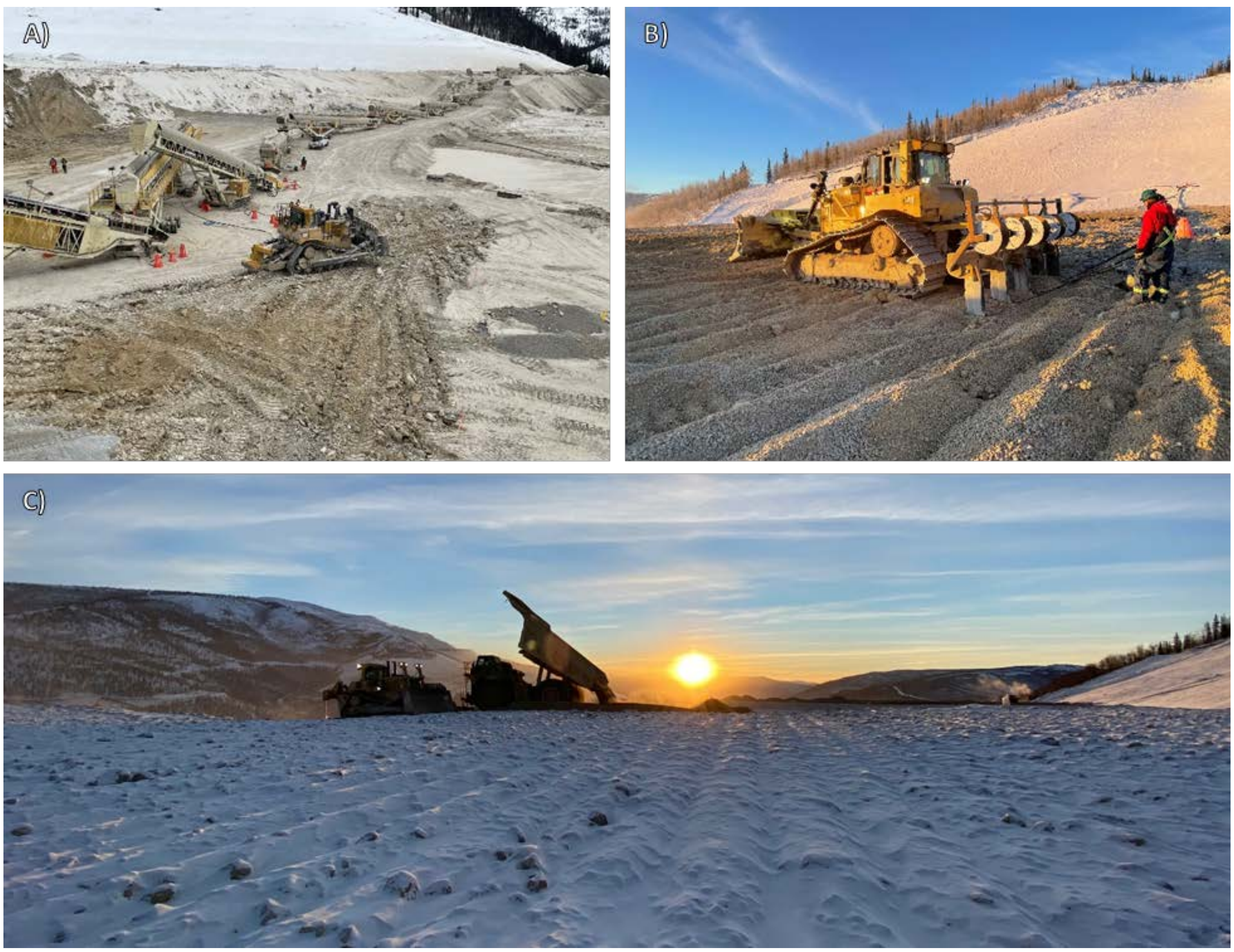

Figure 4: Leaching operations at Victoria Gold Corp.
A) Cross ripping ahead of advancing stacking
B) Installation of buried drip lines
C) Leaching area

Freshet management

The term freshet is generally used to describe the flood of a river resulting from snow and ice melt, but it is broadly applied to the period when there is pronounced and substantial delivery of water to the landscape by snowmelt, heavy rains, or a combination of the two. This typically occurs at Eagle over a two-week period beginning in mid-April to mid-May. During this time the site manages hundreds of thousands of cubic meters of runoff.

Upwards of 180 km^3 is classified as contact water that must be captured to ensure the parameters are within the allowable discharge criteria. Another 25 to 50 km^3 infiltrates directly into the HLF. Figure 5 shows the combined stored solution volume during the 2022 season in the HLF in-heap pond, events pond, and the control pond used to temporarily store mine contact water runoff from the site. Managing these volumes over such a short time requires a substantial amount of planning, but the topic receives very little consideration in the available literature.

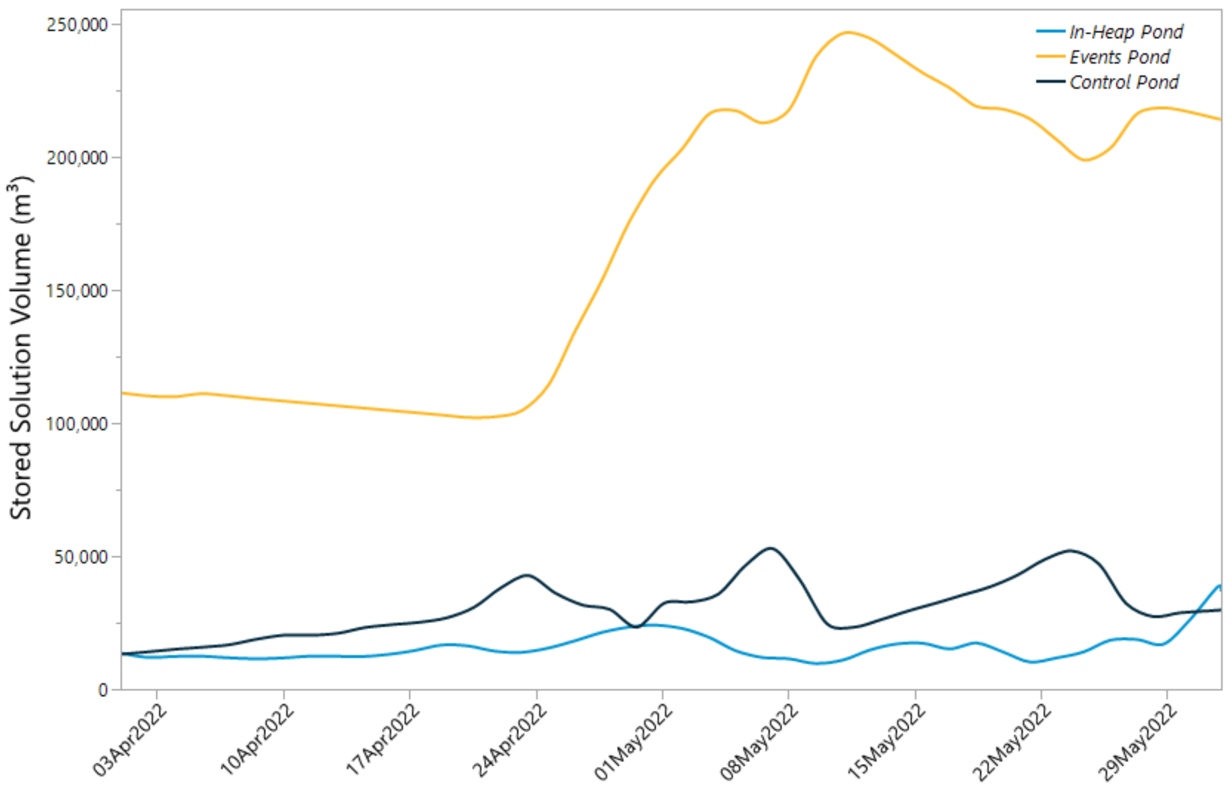

Figure 5: Freshet 2022 stored solution volume trends

Typical stormwater management measures and practices (e.g., sumps, ditches, etc.), are used to direct and control run-off from the site. While the overall volumes are considerable, with the proper measures and pump capacity in place, the impact of freshet to the overall operation is relatively small. The same is true for process operations, but maintaining the overall HLF water balance within safe levels requires additional considerations and tactics. One of the most useful is using sprinklers or hoses deployed during the warmest times of the days before the melt begins in earnest to controllably advance and protract the melt period.

This allows the overall rate that solution must be accommodated to be slowed significantly, providing much more flexibility in managing pond levels.

The most important consideration, however, is ensuring that there is fresh ore available to soak up the influx of melt water and buffer the impact on the operating water balance. At Eagle each tonne of crushed ore requires approximately sixty litres of solution to make up the difference between the placed moisture content and the field capacity at drain down. By strategically delaying placing new areas under leach and minimizing water addition ahead of freshet, the unleached ore becomes a reservoir that can be readily tapped to absorb solution and further dampen potential swings in the pond levels.

As the HLF continues to grow, additional consideration will be given to furthering this approach to deliberately limit leaching of ore during the period from mid-December to mid-March. This would minimize leaching operations during the most difficult time of the year and provide ample ability to absorb the increasingly greater melt with no adverse impact to overall production.

One additional aspect of freshet that receives little attention but has potentially enormous implications is the impact of the essentially daily freeze-thaw cycles during freshet. Aside from the potential safety hazards with changing and slippery conditions, the cycle can lead to the build-up of ice from runoff in areas, particularly those partially shaded during the day, and lead to unexpected flow paths potentially washing out material or resulting in an untoward release of process solution. Incorporating this consideration in the design of infrastructure expansions, stacking plans, and daily operations is standard at Eagle. Careful attention is given to areas prone to freeze-thaw with drains and sumps to direct potential runoff to the interior of the HLF wherever potential problems could arise.

ADR plant operations

The Eagle ADR plant has a conventional design that features two five-tank CIC trains with a combined design flowrate of 2,000 m^3 per hour. Each tank is sized to contain four tonnes of activated carbon, and the circuit includes complimenting acid wash and strip circuits. The plant operates according to design. The only noticeable impact of cold weather conditions in operation is a slight reduction in the acid wash efficiency due to the process fresh water used reaching as low as 2°C in the winter. However, the overall impact is negligible. and plant recoveries of over 97% with barren solution grades of less than 0.01 ppm Au are easily achievable.

The primary challenge associated with cold weather operation is the freezing of ancillary systems in the ADR plant. The process water, fire water, carbon transfer, and caustic mixing and distribution circuits have all been upgraded with full heat trace and insulation following multiple freezing episodes in 2020 and 2021. The need for heat trace is particularly acute in any piping that parallels outside walls and should not be neglected in any comparable installation. Similarly, another key recommendation is to locate any valving for process or freshwater circuits, as well as fuel and reagent delivery systems, inside the main building. This reduces the potential for freezing but also minimizes the risk to operators and maintenance staff in accessing the valves in icy and snowy conditions.

Freezing of reagents is also a consideration as temperatures can drop below the eutectic point for many commonly used reagent mixtures. Providing an enclosed reagent storage area is more than a convenience and should be factored into the overall design of the facility.

Crushing circuit operations

As noted above, the Eagle crushing plant features a three-stage closed-circuit flow sheet. A Superior 5065 MKII gyratory crusher operates as the primary crusher with a target 5.5" closed size setting discharged to either a live coarse ore pile (COP) or a long(er)-term stockpile area. Two Joest Pan feeders reclaim material from the COP. The reclaimed ore is conveyed into the secondary and tertiary (SECTER) crushing building and screened with the oversize discharging to a Nordberg MP 1250 secondary crusher. The crushed product is recombined with the undersize material and then conveyed to the tertiary crushing feed bin. Three additional Nordberg MP 1250s operate in parallel, each with dedicated feeders and double-deck banana screens immediately ahead of the feed chutes. The final crushed product is then transported to the HLF via a 1.5 km overland conveyor, and stacked using a sequence of fixed and mobile conveyors.

In contrast to ADR Plant operation, the impact of cold weather on the operation of the crushing circuit is much more significant. The nominal design throughput for the secondary and tertiary crushing circuits is 2,040 dry tonnes per hour with an overall utilization of 80%. However, achieving these metrics, particularly in the winter months, has proved formidable. The foremost challenges are all related to bulk material flow.

Feeders and chutes at the front end of the circuit are often plagued by "frosties." These conglomerates of frozen material are often large enough and hard enough to completely choke off the flow of material, requiring operators to shut down and lockout the circuit to manually break and chip them apart. The incurred downtime only increases the likelihood of additional frosties forming in feed piles, chutes, and hoppers.

The most effective preventative measure is to always keep the crushed material moving but this is not possible, and experience has shown that it is crucial to incorporate some amount of localized heating to prevent larger vaults and feed hoppers from freezing up to the point that operations cannot be restarted without manually clearing the frozen obstructions. Likewise, incorporation of convenient access ways sized for appropriate equipment, and designing structures and equipment specifically to hasten and simplify material clean-up, are vital and should be paramount in the design and layout of the circuit.

Freezing material also factors heavily into normal operations and maintenance activities. Clearing build-up of frozen fines during the winter protracts essentially every task. Figure 6 shows the extent to which frozen fines can build up in the primary crusher dump pocket and how they can block screen panels with openings upwards of four inches. Factoring these impacts into plans and schedules is critical as they can affect crusher operations and increase the time necessary to complete routine maintenance tasks by upwards of 200% above the actual tool time required.

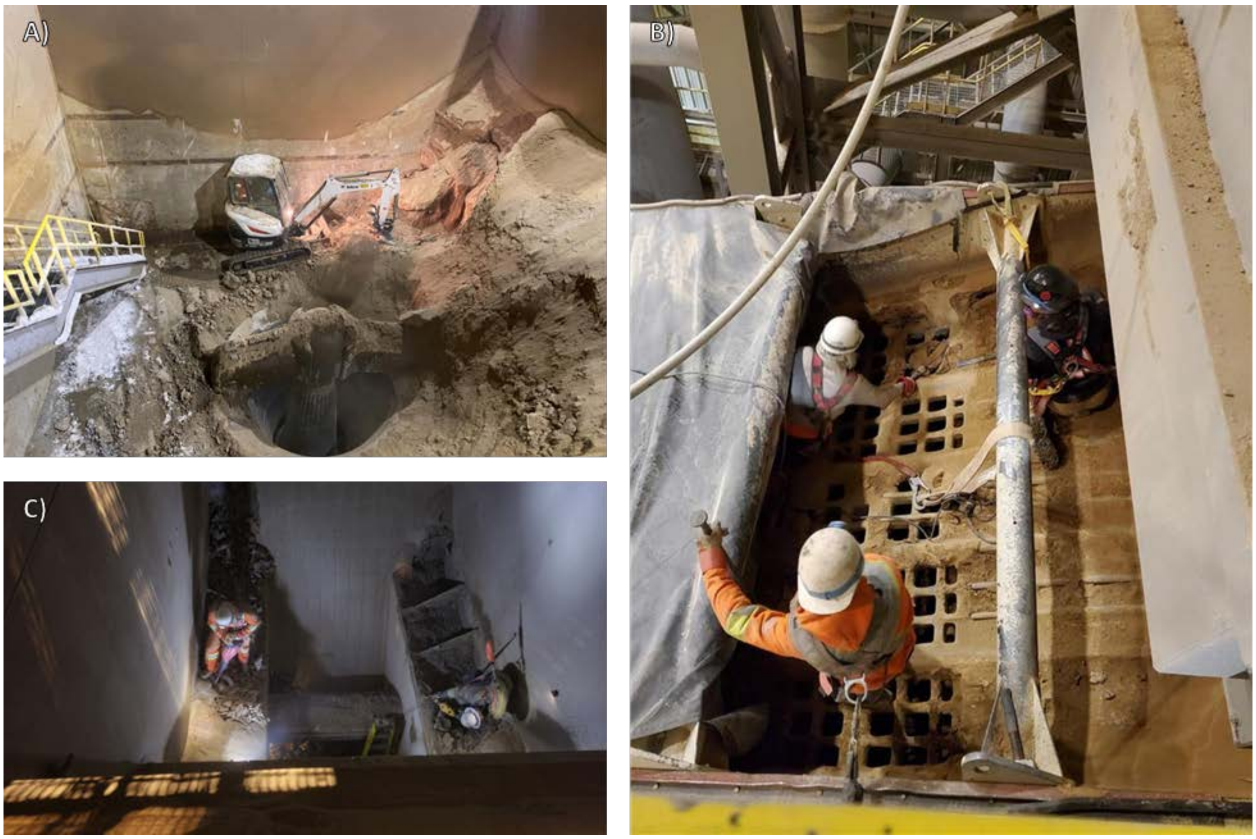

Figure 6: Crushing circuit maintenance operations at Victoria Gold Corp.
A) Clearing the primary crusher dump pocket
B) Chipping fines build up on the secondary screen
C) Scaling the tertiary crusher feed chute

The cold weather also impacts aspects of the operation in ways that are otherwise taken for granted in most cases. Incorporation of cooling systems on equipment lubrication circuits is standard and is necessary during normal operation, but it is also critical to incorporate heating capabilities to ensure that equipment can be safely restarted after prolonged downtime at –40°C. Tooling limitations at these temperatures can also be restrictive. Pneumatic tools quickly freeze up, rendering them useless, and battery-powered units have diminished output capacity and life.

Any electrical designs should account for these limitations and afford multiple receptacles in appropriate voltages near any areas requiring routine maintenance or prone to upsets. Lighting plans should also not be overlooked. During much of the winter the site receives only a few hours of twilight each day and lighting upgrades have been required in multiple areas, particularly along conveyors and in high traffic areas.

Incorporating lessons learned in the cold weather operation of the crushing circuit to achieve greater consistency in operation is one of the foremost objectives at Eagle as operations continue to ramp up.

Summary

Victoria Gold Corp.'s Eagle Mine is the largest gold producer in Yukon history. The severe winter climate presents unique challenges, but these can be overcome with appropriate planning and tactics. Heap leaching and ADR operations are, for the most part, typical of any valley-fill type operation, but require consideration of the extreme cold and yearly influx of snow melt. These problems are mitigated by diligent operation and planning. Crushing operations during the winter are more heavily impacted by the cold climate. Experience has demonstrated equipment and overall circuit design are key to consistent crusher operation. These issues are foremost in the planning of future operations and increasing overall capacity at Eagle.

References

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