INFORMATION REQUEST RESPONSE

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Linkage to Other IRs

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Request

Preamble:
Adequate monitoring is essential to adaptive management of the project to help mitigate future risks. As indicated in the DAR, the main parameter being monitored to assess the completeness of the frozen wall is temperature: "In general, these will be temperature monitoring devices." (DAR, p. 6-27) The proposed application of artificial ground freezing is unique with respect to technology (e.g. generating of a frozen wall in unsaturated conditions). It carries unique risks associated with potential non-closure of the frozen wall. Therefore, additional and improved monitoring measures should be considered.

Question:
1. Please present additional monitoring and QA/QC measures that consider the unique situation. These measures must make it possible to evaluate whether:
   a. the freeze pipes have been installed according to design (e.g. borehole depth / orientation) and,
   b. complete closure condition of the frozen wall has been achieved.
2. Please provide a detailed assessment of the risks if the frozen wall does not seal off completely.

Reference to DAR (relevant DAR Sections):

S.6.2.5.6 Instrumentation

Reference to the EA Terms of Reference

S.3.3 Arsenic Containment, Point 1e / Point 8c
- "A description of the monitoring and maintenance requirements of the thermosyphons, the conditions that would require their replacement, and the frequency of replacement."
- "A discussion of the challenges involved, monitoring systems employed, maintenance efforts required, and why some systems had failed in the past."

Summary

QA/QC procedures for the freeze pipes installations will likely be similar to the measures used during the construction of the Freeze Optimization Study (FOS). The design freeze pipe spacing was selected as being the most effective to achieve the temperature performance criteria. Freeze pipe deviations may affect the freezing time, but not the ability for the design criteria to be met. The water pressure sensors installed in the arsenic chambers will be used to track water levels during wetting of the dust and for any loss of water.

The risks and impacts of the freeze wall not sealing off completely due to a large crack in the bedrock material are presented. The risk of a continuous, open crack in the bedrock present from the chamber to the outside of the freeze wall is very low. If such a crack were present, there is a risk of a temporary increase in seepage rates of arsenic saturated water and release of arsenic trioxide sludge during the wetting of the dust. The quantity of seepage would be dependent on the chamber wetting method. Dissolved arsenic present in any seepage would be transported downward into the mine, collected in the mine-water system, and removed by the water treatment plant. As the rate of flow into the crack would be governed by the dust hydraulic conductivity (measured to be 7x 10^{-7} m/s), the slow-moving water would freeze quickly and seal the crack.

Response 1

We recognize the importance of ensuring that the frozen shells are complete. The freezing criteria specifying that the frozen shell reach -10^{o}C over at least a 10 m width were selected after lengthy consultation with industry experts and the Independent Peer Review Panel. Stating the criteria in that manner allows for flexibility in the method of drillings and freeze-pipe installation. An alternative approach would have been to adopt less stringent criteria for the frozen shell, for example a much thinner width at a lower temperature. In that case, we agree that the problems arising from, for instance, inaccurate drilling and freeze pipe alignment could be acute and that more extensive QA/QC requirements would be needed.

Sensitivity analyses indicate that, at the currently assumed freeze pipe spacing of 4.0 m with a 7.0 m offset from the chamber walls, deviations in freeze pipe alignment affect only the overall freezing time. They do not affect the ability for the design criteria to be met. Furthermore, the same sensitivity analyses show the time to reach -10°C over a 10 m width is insensitive to local deviations in hole spacing, as long as the average spacing remains at the design value. The reason is that the space between freeze pipes cools very rapidly, and thereafter the freezing pipes act together as a “line source” of cooling.

Given the choice to adopt very conservative design criteria and the evidence of the sensitivity analyses, we expect QA/QC procedures for the freeze pipe installation to be similar to those used during the construction of the FOS. During drilling and freeze pipe installation, an inspector will be present to ensure that the design drill depth is achieved, periodic down-hole surveys will be completed during drilling to monitor for excessive drillhole deviation, and leak detection testing will be completed in accordance with the design criteria.

Three different surface drilling methods were tested during the FOS. Drilling deviation was typically less than 1 m for vertical holes of roughly 100 m depth. That level of deviation is well within the ranges that have been checked by sensitivity analyses. The FOS results also showed that at least one of the methods allowed efficient drilling at higher accuracy.

The deviations for the underground horizontal freeze holes were greater, with a maximum deviation less than 2.0 m over a length of only 20-30 m. However, the horizontal deviations tended to be parallel, with the average spacing remaining close to design.

As detailed in the DAR s. 6.2.5.6, temperature monitoring devices will be installed in drillholes located around the freeze pipes to monitor the progress of the cooling front into the surrounding dust and ensure that the 10 m wide, -10^{o}C frozen shell is achieved. Water pressure sensors will also be included in monitoring strings inserted into the arsenic chambers. The water pressure sensors will be used to track water levels during wetting of the dust and for any loss of water. The exact numbers, locations, and types of instruments will be determined in a later stage of design.

Response 2

The most likely reason for the frozen wall to not seal off completely would be the presence of an open fracture that is not water saturated during the development of the frozen wall. The risk of a fracture extending from the arsenic chamber and through 10 m of frozen wall is very low, as the chambers are located away from the major fault zones. However, let us assume for the sake of this assessment that such a fracture exists. After the initial freezing stage, the bedrock around the fracture will have a maximum temperature of -10^{o}C.

During the wetting of the dust, there is a potential for a release of soluble arsenic trioxide in seepage that escapes through the fracture. The quantity of seepage would depend on the method used to saturate the chamber. As discussed on Page 6-29 of the DAR, the wetting method remains in concept at this time and additional testing is planned as part of the final design process. One option is to add water to the top of the chamber and allow it to infiltrate down into the dust. In that case, the flow rate into the fracture would be limited by the dust hydraulic conductivity, measured to be $7x\ 10^{-7}$ m/s. The slow-moving water entering the crack would freeze quickly and ice buildup would seal the fracture. If a more energetic blending of the dust was used during the saturation process, there would be a short term potential for a larger quantity of seepage to pass through the crack. However, once the blending stops, the flow rate entering the crack would again be limited by the low hydraulic conductivity of the dust.

Dissolved arsenic present in any seepage that does escape the frozen shell would be transported downward into the mine, collected in the mine-water system, and removed by the water treatment plant, just as it is today. Any significant increase in soluble arsenic reporting to the treatment plant would be noticeable both in influent analyses and in increases in water treatment costs.