REPORT

Marcelo Tunnel Inspection - Lama

Barrick Exploraciones Argentinas S. A., Proyecto Pascua Lama

Submitted to:

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1.0 INTRODUCTION

At the request of Barrick Exploraciones Argentinas S.A. (BEASA) Mr. Carvalho visited the Lama mine site on March 12 – 14, 2018, with the purpose of inspecting the Marcelo tunnel, provide an expert opinion on the stability of the tunnel, and provide recommendations moving forward. Mr. Carvalho had last visited the Marcelo tunnel in November 2013.

The scope of work as described in the request for quote included:

- Review tunnel plug design with SRK Engineers.
- Review as built turnover package and monitoring data (drainage) since valve closure.
- Perform site inspection of tunnel crown support, shotcrete, and ground control embeds.
- Provide written site inspection report and geotechnical risk assessment of current site findings.
- Make recommendations for repairs, if necessary; estimate cost and schedule.
- Make recommendations for ongoing monitoring and maintenance for 3 to 5 years.

2.0 SITE VISIT

The following describes the chronology of the undertaken tasks:

On Monday, March 12, 2018, Mr. Carvalho met with Mr. Martín Yanzón from BEASA and Mr. Fermín Garate from SRK at the Barrick offices in Albardón to go over the plug design and as-built data. This included reviewing the inspection of the tunnel and assessment of the support by SRK prior to building of the plug. Mr. Carvalho travelled to site on the afternoon of Monday.

On Tuesday, March 13, 2018, Mr. Carvalho met with Messrs. Roberto Bally and Martín Juarez in preparation for the tunnel inspection. After the safety induction, Mr. Juarez accompanied Mr. Carvalho to conduct the tunnel inspection. A platform was used to reach the crown of the tunnel to inspect the support (bolts and shotcrete). Due to restricted access to large equipment at the plug face, a basket was available to reach the crown to inspect the support. After lunch Mr. Carvalho went over monitoring data from the tunnel (pull tests, piezometer and flow data).

On Wednesday, March 14, 2018, the Authority arrived on site to conduct their own inspection. After the safety induction, the Authority, accompanied by Messrs. Carvalho, Juarez and Bally, inspected the tunnel and were made available the same equipment to reach all points of interest in the tunnel. After a short debriefing with Mr. Darío Donis, Mr. Carvalho returned from site on Wednesday afternoon.

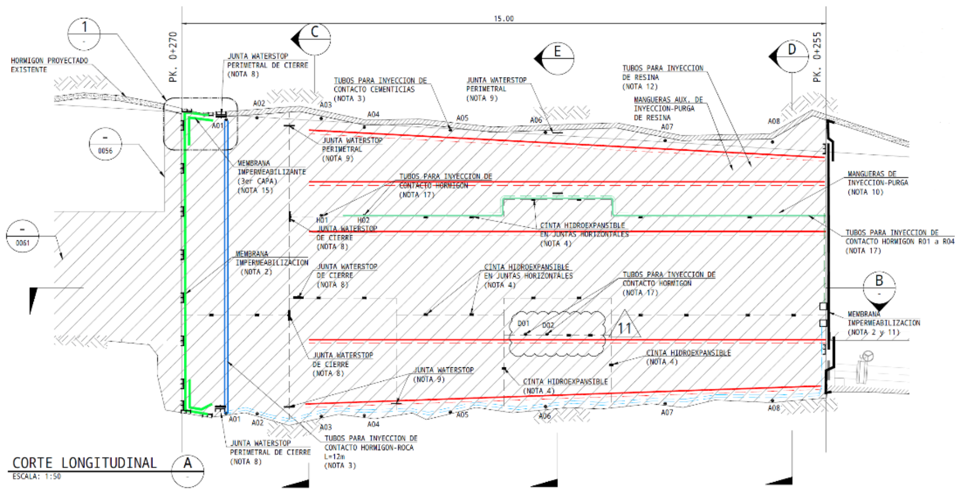
On Thursday, March 15, 2018, Mr. Carvalho debriefed Mr. George Bee on the findings from the inspection.

3.0 TUNNEL PLUG DESIGN REVIEW

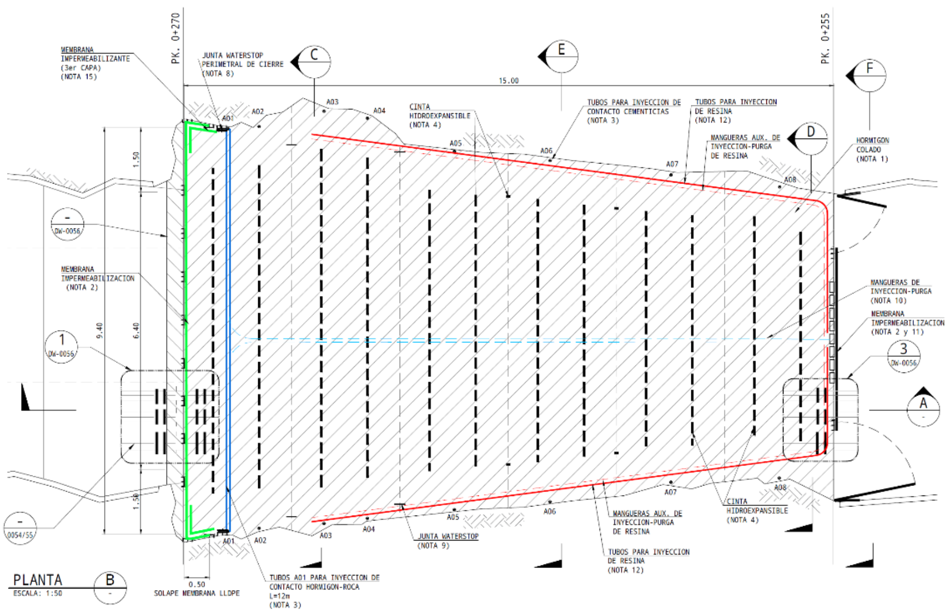
The review of the tunnel plug design comprised a meeting with Mr. Fermín Garate from SRK, who went over the SRK site inspection prior to designing and constructing the plug, the design proper and the as-built reports/drawings. The reviewed data consisted of the rock quality and support assessment (shotcrete condition, including Schmidt hammer tests, and pull-tests on bolts), as well as the additional support installed after the enlargement of the plug area, the grouting program and the installation of the piezometers.

3.1 Plug Design (Shape)

The tunnel was enlarged in the upstream side of the plug and tapered towards the downstream side. This wedge shape for the plug guarantees that there is a good mechanical contact between the concrete and the rock, without the need to rely solely on the frictional resistance of the interface (see Figure 1).



a) Vertical Longitudinal Section



b) Plan View

Figure 1: Plug design - shape and size (after BEASA12210-2211-C-DW-0013-11)

The plug was cast in sections due to the massive volume and the potential heat of hydration generated from the curing process. The construction joints were fitted with expansive strips to act as water stoppers.

3.2 Rock Mass Grouting

The rock mass in the section of the plug was grouted with cementitious material using radial holes prior to the pouring of the concrete. Also, a system of grouting pipes were installed for contact grouting at a later time, after concrete shrinkage stops.

After the construction of the plug, a series of angled holes were drilled for the purpose of resin grouting the plug section, and an additional set of radial holes on the downstream side of the plug also for resin grouting (see Figure 2).

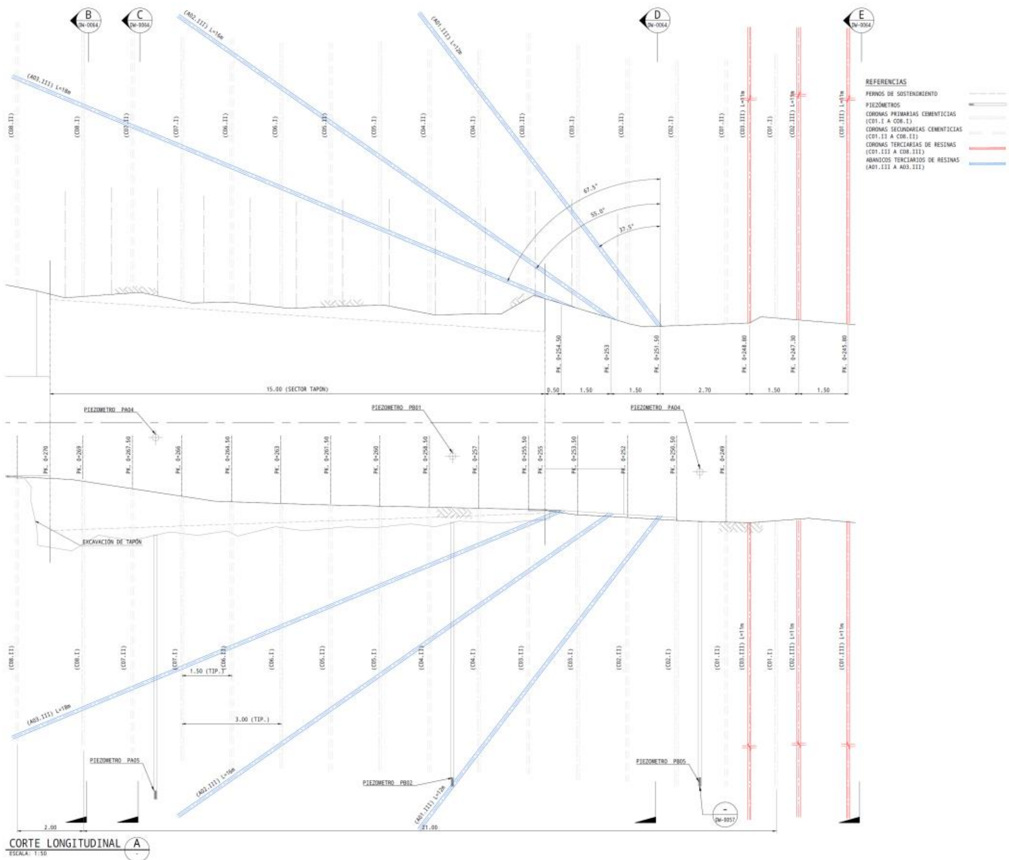


Figure 2: Layout of grouting holes (after BEASA12210-2211-C-DW-0059-6)

3.3 Groundwater Monitoring

A series of piezometers were installed at 4 sections of the tunnel. Three piezometers were installed at each section (2 on the sidewalls, 1 in the floor). One section is upstream of the plug and the piezometers are installed close to the tunnel walls and floor. In the other 3 sections the piezometers were installed 8 m deep into the rock. Two of these sections are within the plug section and the other section is on the downstream side of the plug (see Figure 3).

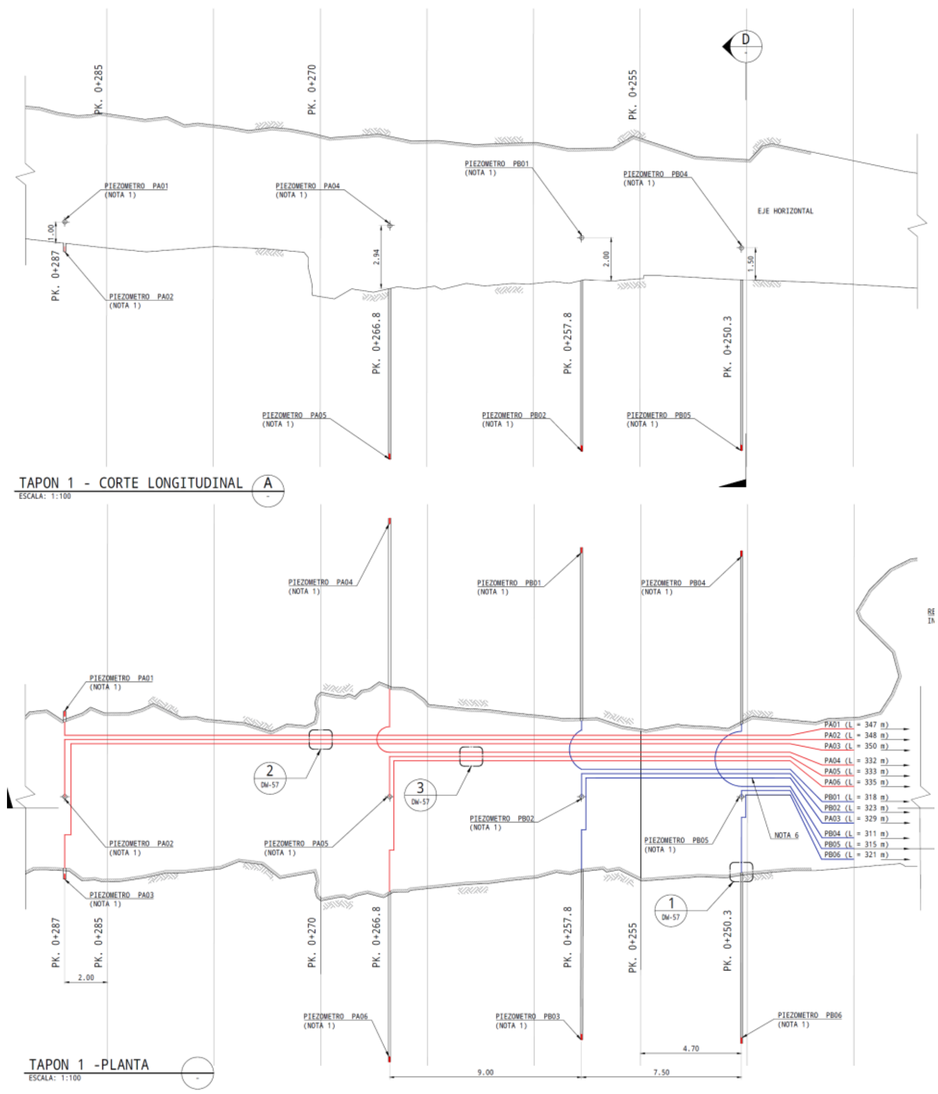


Figure 3: Location of piezometers (after BEASA12210-2211-J-DW-0057-3)

3.3.1 Groundwater monitoring data

Piezometric data has been monitored since early December 2017 and flow data has been monitored since mid-November 2017. The plug construction was completed in mid-January 2018, at which time the pressure on the upstream side was allowed to build up.

Figure 4 and Figure 5 show the time history of the pressure head in the piezometers. It took about 20 days to reach 95% of the full head, and 60 days after completion of the plug, the pressure head has stabilized on all piezometers. The pressure head on the downstream of the plug is between 10 and 15 m, with the higher head on the south sidewall. Figure 6 shows the flowrate history as a result of seepage through the rock around the plug. The flow rate reduced dramatically from 137 L/s to 2.5 L/s at the completion of the plug, and 60 days after completion it seems to be reaching a steady state flowrate of about 8 L/s. After the planned contact grouting is completed, it is expected that the flowrates will reduce further.

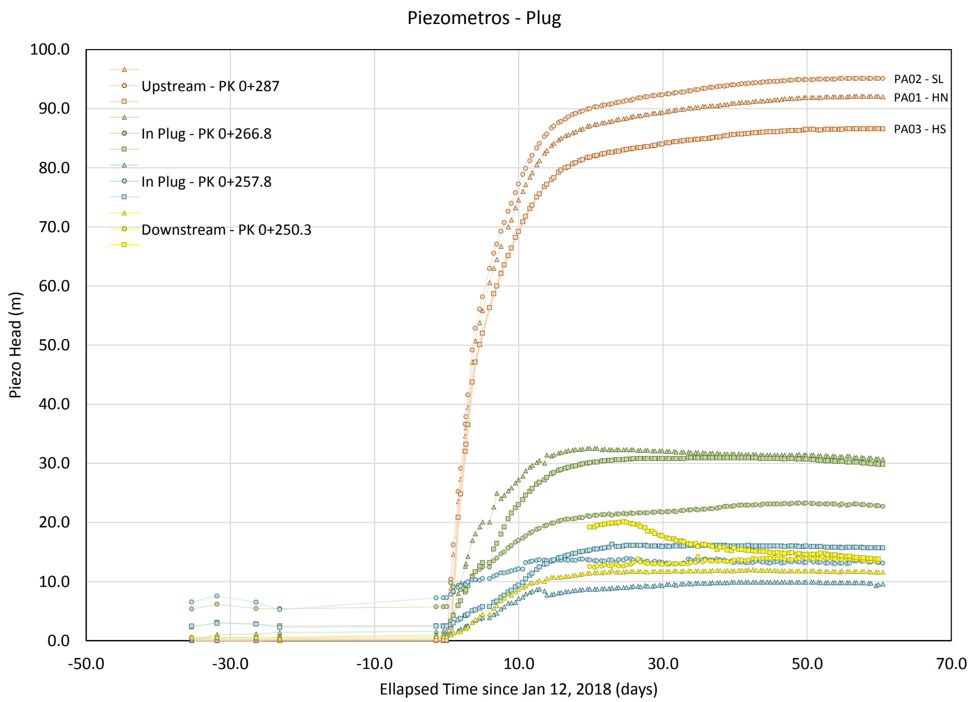


Figure 4: Pressure head history for the piezometers (including the upstream array)

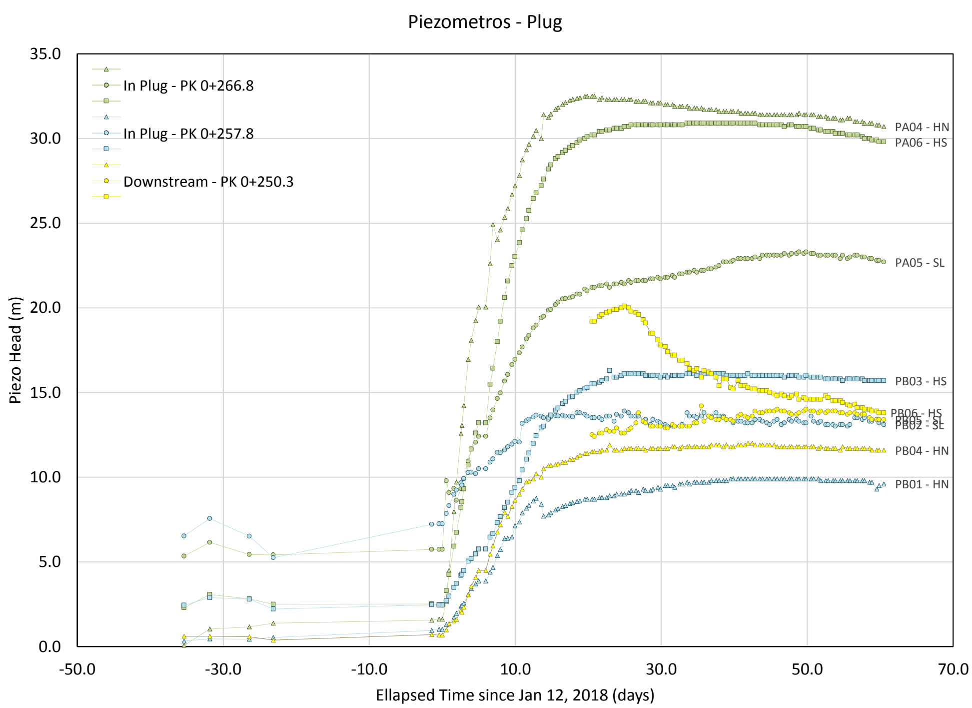


Figure 5: Pressure head history for the piezometers (without the upstream array)

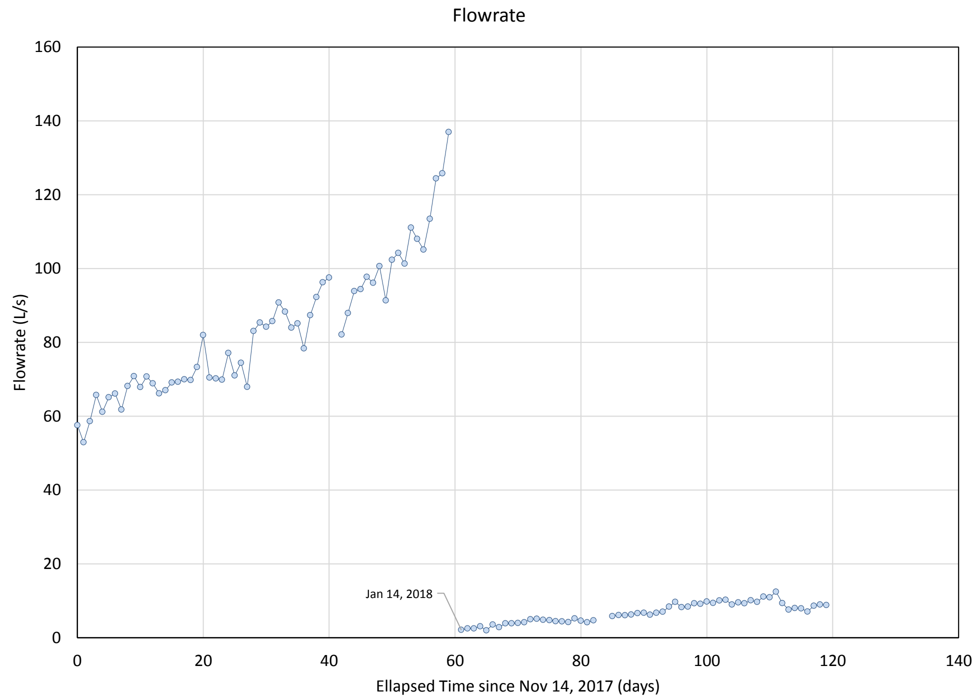


Figure 6: Flowrate history through the rock around the plug

Figure 7 shows the pressure head profiles across the plug for the piezometers in the sidewalls and the floor. The average pressure head on the upstream side of the plug near the sidewalls and the floor is about 91 m. The pressure head drops across the plug to about 28 m at PK 0+266.8, and to about 13 m at PK 0+257.8. At the downstream array (PK 0+250.3) the average head is 13 m.

3.4 Bolts Pull Testing (resin grouted threaded bolts)

As a part of SRK's inspection prior to the design and construction of the plug, bolts at 35 locations between the portal (PK 0+000.0) and the plug (PK 0+255.0) were targeted for pull tests. Due to some practical constraints, (e.g., short bolts, damaged threads, bent bolts, etc.) only 19 bolts were tested; however, there was still an adequate sampled distribution along the tunnel.

Where possible, the bolts were tested to 5 tonnes and held for 1 minute, and then tested to 10 tonnes and held for 10 minutes. In 2 or 3 instances the 10 tonne test was not possible due to insufficient bearing capacity for the loading frame.

The tests were all successful, except for one bolt which spun in place. The results indicate that the bolts that were properly installed have not lost capacity, and can hold at least 10 tonnes. The bolt capacity is higher than 10 tonnes; however, the pull-testing was limited to 10 tonnes since the intent was to perform a non-destructive test.

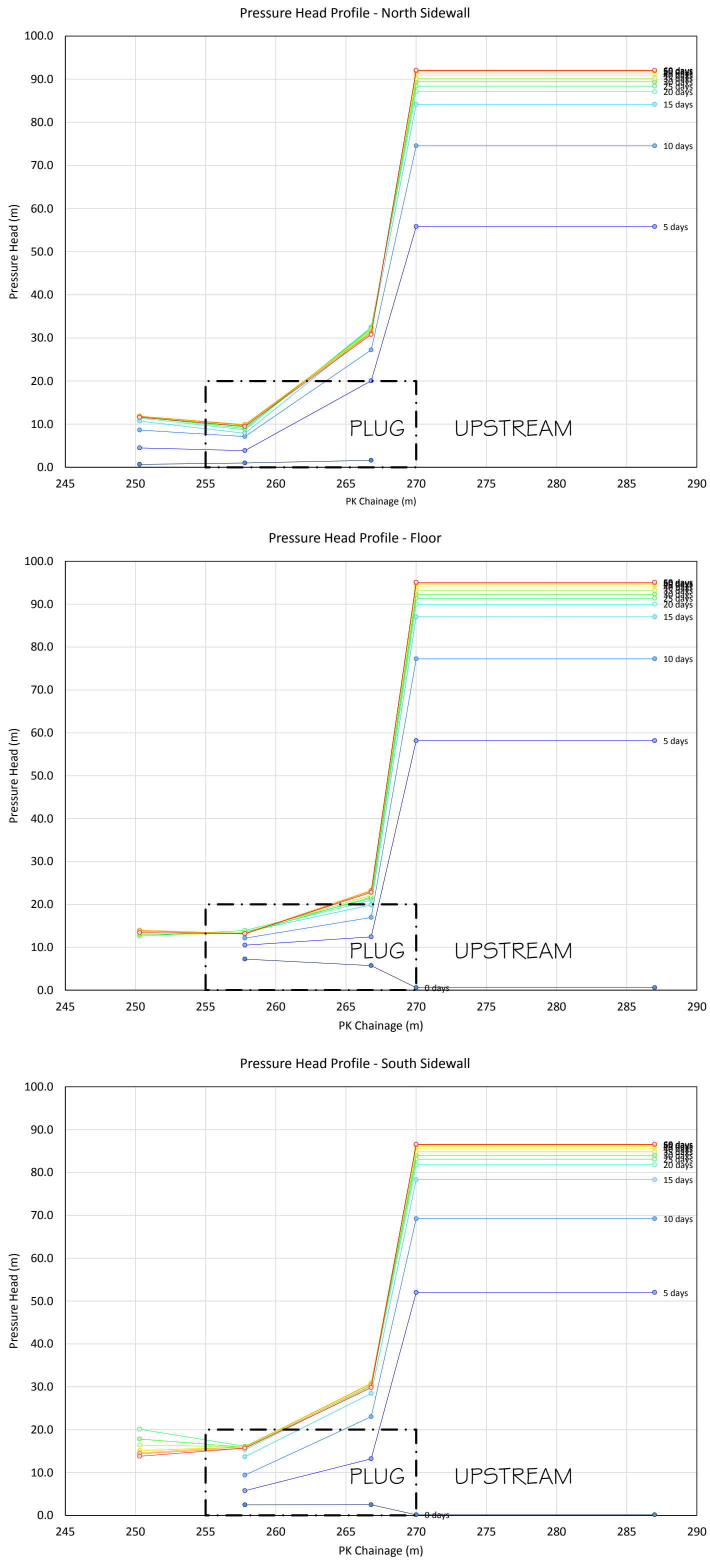


Figure 7: Pressure head profile in the rock around the plug

3.5 Observations on Plug Design

The preparation of the plug area in terms of temporary support and permeability control was adequate. The design and construction of the plug meet the requirements to hold the head of water upstream of the plug. The geometry of the plug ensures that it will be mechanically stable over the long term.

4.0 OBSERVATIONS AND RECOMMENDATIONS

The tunnel was inspected by Messrs. Carvalho and Juarez on Tuesday, March 13, 2018, and then again on Wednesday, March 14, 2018, jointly with the Argentinian authorities. During the inspection, the shotcrete was checked by sounding with a geological hammer and/or a scaling bar. For the most part, the shotcrete was strong and had good adherence to the walls. The shotcrete is fiber reinforced with synthetic fibers, which are not compromised by the presence of aggressive water. In addition to the pull test records by SRK, bolts were checked by observing corrosion (very little corrosion was observed) and by hitting their heads with a hammer to assess how well they were grouted.

In general, the support is performing as it was intended by the design. Observations and recommendations are summarized as follows:

- In the 2013 site visit, the assignment was to make recommendations for ground support to keep Barrick on hold for 2-years;
- The tunnel support is in good condition after 4 to 5 years and stability of the tunnel is not a concern;
- The shotcrete is generally good, the fiber in the shotcrete is synthetic and not subject to corrosion;
- There were a couple of spots where there was loose rebar or loose shotcrete, but very localized. Future inspections should continue to monitor these locations;
- At the plug face there is one injection hole in particular where the packer blew out during grouting and water comes out. This point source wets the area causing most of the “rain” up in the plug area; the upcoming planned contact grouting of the plug should improve the conditions (i.e., reduce the inflow). Barrick should assess and record the impact of the contact grouting on the inflow at that time and monitor changes going forward;
- The Authority is in general agreement that the support conditions are good and the tunnel is stable;
- The Authority expressed concern about the effect of the acid water on the support;
- It does not appear that pressure is building behind the shotcrete causing instability, the shotcrete weeps and depressurizes;
- Barrick should develop an inspection plan (periodic inspections) for the tunnel;
- The plan should involve regular inspections which will comprise “sounding” the shotcrete with a hammer and some pull test on bolts. Barrick should set up control marks on the walls and prepare a log sheet to have a formal registry of the inspections;
- The frequency of the inspections should be higher to begin with and then reduced if conditions are found to be unchanged (bi-weekly to month to quarterly);

- Barrick may have to do some minor mesh support, say 2 m square, where some shotcrete has peeled off or fallen;
- There is no need to install additional or major support.

5.0 INSPECTION / MONITORING PLAN

It has been established through the inspection that the support (bolts and shotcrete) currently is in good condition and it is performing as per the design. The concern with respect to the long-term performance hinges around the aggressiveness of the groundwater and how it might affect the effectiveness of the support. The fact that the support has been exposed to these conditions for about 5 years now and it shows no loss of performance is a positive sign, i.e., the water chemistry has had little effect on the support up until now, suggesting that, if there is an impact, it is at a very slow rate.

In order to ensure that the support continues to perform adequately, an inspection plan along with continued monitoring of the installed piezometers and flowrate should be implemented. This plan should comprise the following components:

- Inspection of the shotcrete section by section (e.g., 10 m sections); this should consist of a description of the condition based on a visual assessment combined with sounding of the shotcrete with a geological hammer and/or a scaling bar;
- Inspection of the bolts section by section (e.g., 10 m sections); this should consist of a description of the state of the bolts with respect to corrosion based on a visual assessment; the bolt heads should be hit with a hammer to assess the quality of the bond between the bolts and the rock; also, once a year, 2 or 3 of the previously tested bolts should be pull tested again to establish whether they have lost any capacity;
- Estimates of the inflows section by section (e.g., 10 m sections); these should be compared with previous estimates to assess if the groundwater conditions continue to be stabilized;
- Continue to monitor the piezometers and the flowrate from the plug area on a prescribed schedule. The water chemistry should also be tested for pH, electrical conductivity, total solids and redox potential.

These observations and measurements shall be entered on pre-printed log sheets and archived to establish a record of the inspections and any action items resulting from the inspections.

A sample of a log sheet is provided in **Table 1** to be used in the inspections.

5.1 Frequency of Inspections

The inspections should begin at a tight frequency and subsequently relaxed as confidence in the performance of the support increases with every inspection. The following schedule is proposed:

From now until the contact grouting of the plug takes place:

Inspections once every two weeks

After contact grouting is completed:

Inspections once every month for 3 months

After 3 months of monthly inspections:

Inspections once every 6 months

Should conditions deteriorate at any time, frequency should revert back to bi-weekly inspections.

Measurements of piezometric heads and flowrates should be taken daily until the contact grouting of the plug is completed. Measurements should be taken weekly after completion of the contact grouting.

Table 1: Sample Tunnel Inspection Log Sheet

Date:					**Inspected by:**						
PK		**Location**	**Shotcrete**		**Bolts**			**Inflows**		**Recommended Action**
From	*To*		*# checked locations*	*Description of condition*	*Description of corrosion*	*# checked bolts*	*Pull test*	*Estimate*	*Description of groundwater*	
0+000	0+010									
0+010	0+020									
0+020	0+030									
0+030	0+040									
0+040	0+050									
0+050	0+060									
0+060	0+070									
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0+180	0+190									
0+190	0+200									
0+200	0+210									
0+210	0+220									
0+220	0+230									
0+230	0+240									
0+240	0+250									
0+250	0+255									

Signature Page

We trust that this report meets your current needs. If you require additional information or have any questions, please do not hesitate to contact us.

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