

# **Tailing Storage Within a Heap Leach Facility – An Update on the Success at Yanacocha**

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## **Abstract**

The Yanacocha Operation is an open pit gold mine located in mountainous terrain in Northern Peru. The Operation includes one tailing storage facility (TSF) and four heap leach facilities (HLFs). Given constraints imposed by topography and permitted boundaries, the efficient use of space is a priority. As an example of a design driven by the need to use space efficiently, the existing La Quinua (LQ) TSF was constructed entirely within one of the HLFs (the LQHFL) and uses the heap leach ore to form the containing embankments for the tailings (termed mill sands at the site). The LQHFL has been in operation since the mid-1990's and the LQTSF was commissioned in 2008. The combined facility has consistently performed within its design expectations. However, both have now been developed to their maximum heights (with the maximum height of ore above the liner at 130 meters) and due to additional mining and the existing LQTSF nearing its design capacity, there is a requirement for the mine to develop additional tailings storage capacity. To meet this demand a new TSF was designed beside the existing LQTSF in the same LQHFL. The new TSF, designated the LQTSF North Expansion, is currently under construction.

In contrast to the existing LQTSF, which was progressively developed in a basin in the LQHFL as the facility was being loaded, the LQTSF North Expansion is being built as a new excavation within the LQHFL after the ore had been placed and leached. Key design considerations included (1) stability and deformation potential of the excavation slopes under static and seismic conditions, and (2) water removal from the excavation. Both considerations were for the short term (during the construction), and the long term, thereafter.

The majority of storage will be developed in the basin excavation, but some storage in the upper LQTSF North Expansion will be developed behind a low height embankment across the north perimeter, termed the North Embankment. The embankment is being constructed as an engineered fill structure using the mine haulage fleet to place and compact it. The original intent was to use leach ore from the excavation as fill but high moisture contents in the material led to a requirement to use other borrow sources. The suitability and compaction requirements for these borrow sources were evaluated with test fills, laboratory testing, and fields density testing. Slope displacement monitoring during construction was carried out using inclinometers, conventional prism surveying, and slope monitoring radar.

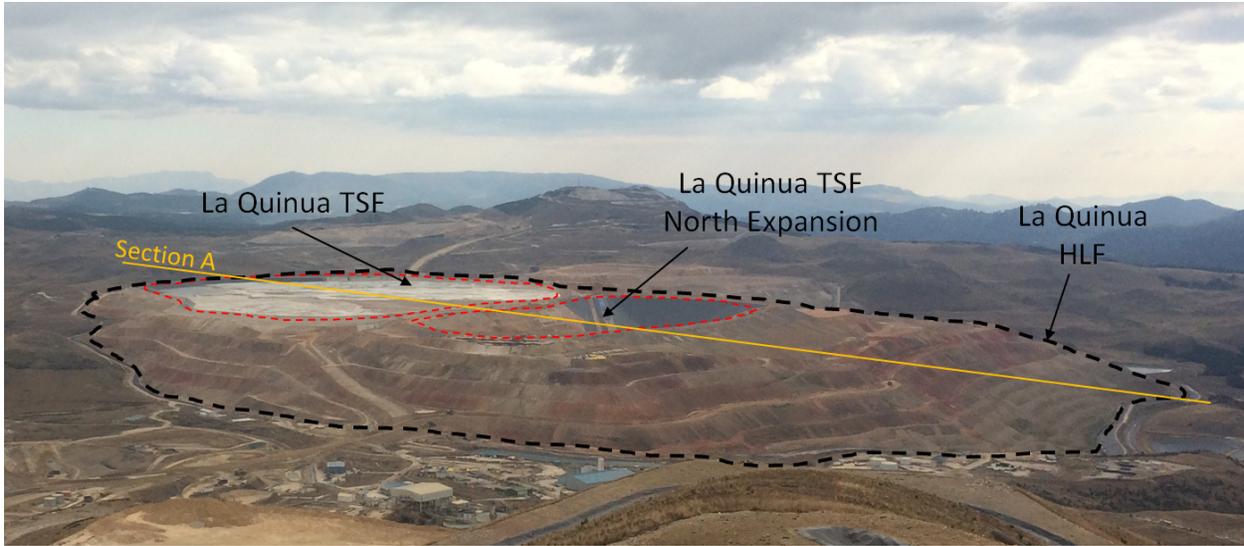
The construction is on schedule with regard to timeline and cost, and operation of the facility is planned to start in late 2017.

## **Introduction**

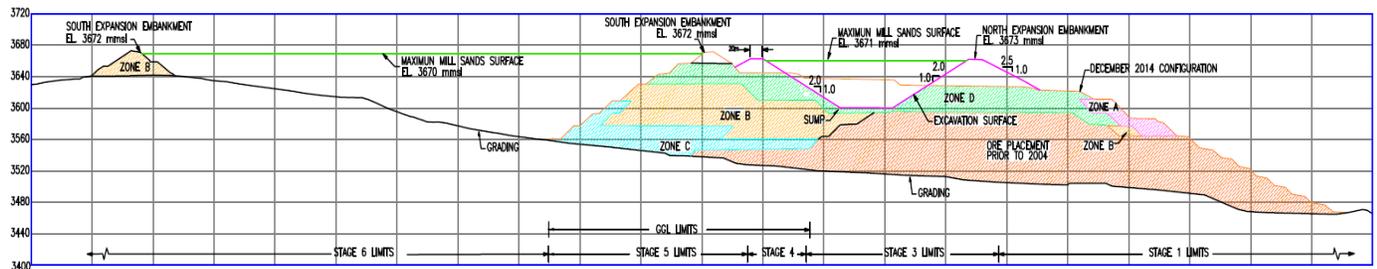
Efficient use of space is often a priority for mining operations. Construction of a TSF within a HLF at the Yanacocha Operation is an example of a design driven by this priority. Due to additional mining and the existing TSF nearing its design capacity, there is a requirement for the mine to develop additional tailings storage capacity. To meet this demand a new TSF, designated the LQTSF North Expansion, was designed beside the existing LQTSF within the same HLF as shown in the Figure 1 and Figure 2.

To evaluate geotechnical characteristics of the leach ore where the LQTSF North Expansion will be located, an extensive field and laboratory testing program was completed, followed by geotechnical engineering analyses. Key analyses included an earthquake – induced liquefaction assessment, seepage analyses, and static and seismic stability analyses.

This paper presents an overview of geotechnical investigations, geotechnical engineering, design criteria, components of the design and current status of the construction as well as geotechnical monitoring during construction of the LQTSF North Expansion.



**Figure 1: General view of the construction of tailing storage within a heap leach facility.**



**Figure 2: Section A with location of LQTSF and LQTSF North Expansion.**

## Background

In 2012, MYSRL commissioned Knight Piésold to investigate the feasibility of constructing the LQTSF North Expansion within the confines of the LQHFLF, immediately the north of the existing LQTSF. In early 2013, a site investigation program was performed to evaluate site conditions and material properties of the leach ore. The purpose of this investigation was to provide confirmatory data that this in-place material was similar to leach ore that had been characterized in previous site and laboratory testing campaigns. These new data were used in conjunction with the results of previous work to provide information for the geotechnical analyses for this project. A tailings characterization testing program was conducted in parallel with this work.

In mid-2014, the detailed design engineering for the LQTSF North Expansion was completed. The design resulted in the need for a significant earthworks effort in order to excavate the impounding basin and construct the North Embankment. This work was executed by Yanacocha’s large construction fleet (mine shovels and haul trucks) with assistance from an outside contractor’s small construction fleet.

The basin and North Embankment construction started in the first trimester of 2015 and finished in early 2016. As of August 2016, the geomembrane and drainage collection system in the basin were being installed, and it was expected that the facility would be completed and ready for operation on schedule later in 2017.

## **Design Criteria**

Key design criteria for the design of the North Expansion were the tailings production rates, tailings geotechnical characteristics, leach ore geotechnical characteristics, embankment stability, climate characteristics, and surface water storage provisions. These are summarized below.

### **Tailings Production**

- Daily rate: 16,500 tonnes per day
- Mine life: 3 years (Total Storage 18 million tonnes)

### **Tailings Geotechnical Characteristics**

- Dry density in place: 1.25 tonnes per cubic meter ( $t/m^3$ ) initially, increased to 1.6  $t/m^3$  over the operation
- Effective stress angle of internal friction: 34 degrees, zero cohesion
- Residual undrained strength ratio ( $S_u/p'$ ): 0.035

### **Leached Ore Geotechnical Characteristics**

- Dry density in place: 1.79 to 1.98  $t/m^3$  based on burial depth.
- Effective stress angle of internal friction (compacted and loose leach ore): 41 degrees, zero cohesion
- Yield stress angle of internal friction (loose, saturated leach ore): 29 degrees, zero cohesion
- Residual undrained strength ratio for loose, saturated leach ore ( $S_u/p'$ ): 0.09

### **Slope Stability:**

- Minimum static factor of safety: 1.5
- Minimum static factor of safety for failures not impacting tailings storage: 1.3 (HLF criteria)
- Minimum post-earthquake factor of safety: 1.1
- Embankment Risk Category: “Very High” based on the Canadian Dam Association (CDA) Guidelines (CDA, 2007)
- Seismic criteria:  $M=8.0$  with  $PGHA = 0.41g$

**Climate Criteria:**

- 100 years -24h storm event: 143 mm
- Average yearly precipitation: 1,555 mm
- Maximum yearly precipitation: 2,145 mm

**Additional Considerations:**

- Leaching operations associated with LQHLP Stages 1 to 5 were completed before construction of the North Expansion TSF.
- Pond capacity: the supernatant pond was designed to store a storm event (100 year -24h) and a 24h outage (no pumping systems dewatering the facility) keeping the designed freeboard.
- The properties of the tailings are similar to those of the tailings placed in the LQTSF.

**Components of the Facility**

Key elements of the design of the LQTSF North Expansion are the basin excavation, and construction of the North Embankment, and the decant systems used to evacuate water from the facility.

**Basin Excavation and North Embankment Design**

The basin excavation and North Embankment were designed with interior slopes of 2.0H:1.0V, and exterior slopes of 2.5H:1.0V slopes. The excavation of the basin ranged in depth from approximately 45 m to 80 m with a bottom elevation of approximately 3,586 masl. The crest elevation for the North Embankment was designed to 3,673 masl.

The North Embankment was constructed using the mine fleet with general fill obtained from the basin excavation and several nearby mine pits. For wider fill zones, the surface of each lift was compacted by evenly routing loaded CAT 793 haul trucks over it. Above approximate elevation 3671 m, where fill zones narrowed near the crest of the embankment, the fill was completed with smaller, conventional earth moving equipment.

A liner system is in place along the base of the LQHLP and existing LQTSF, and therefore extends beneath the North Expansion. However, a geomembrane liner was placed within the North Expansion impoundment to reduce infiltration of tailings seepage into the underlying leach ore. The liner system consists of a 2 mm thick double-side textured HDPE geomembrane placed on a prepared surface in the basin excavation and interior slopes of the North Embankment. Surface preparation involved smoothing the surface and removing larger particles that could damage the geomembrane. The main function of the liner was to reduce seepage into surrounding areas rather than providing environmental containment.

### **Supernatant Drainage (Primary Decant System)**

The tailings will be deposited using discharge points along the south, west, and east perimeter of the dam with frequent rotation of the active points to build consolidated tailing beaches against the slopes and to displace the surface pond water to the southwest, where the Primary Decant System will drain the supernatant pond.

The water from the supernatant pond will percolate through an inclined drainage blanket extending up from a sump at the bottom basin to the top. The water will seep through the drainage blanket into inclined perforated pipes feeding the primary sump where pumps will send it into an external pond. Calculations were completed to size the drainage zone with enough flow capacity to completely evacuate the volume in the supernatant pond within 30 days in the event of a 24-hour storm with a return period of 100 years.

To minimize the risk of fines migration from the tailings into the system sump, two layers of geotextile were included in the zone. The second layer provides redundancy in case tailings penetrate through the first layer.

### **Underdrain Collection System (Secondary Decant System)**

A blanket underdrain (Secondary Decant System) is installed at the bottom of the basin just above the geomembrane liner to minimize the hydraulic head on the liner. The system consists of free draining gravel with perforated pipes that is completely covered with a geotextile layer. The pipe system has been designed to keep less than 1 m of head on liner after accounting for flow reduction under the load of the tailings. The system is sloped to a sump termed the Secondary Sump where the water will be pumped to an intermediate tank and ultimately gravity conveyed to the same external pond that will receive flow from the supernatant system. The decant system will operate as follows:

- Tailings water will infiltrate into the decant system sumps as the tailings are consolidated
- A network of CPT perforated pipes will capture and direct the water into the secondary sump collection.
- A submersible pump system with multiple pumps in a gravel drainage sump will pump the collected water from the sump to the crest.
- A manifold at the crest will combine flows from the different pumps into a single discharge pipe and this water will be directed to an intermediate tank located on the crest of the embankment, and then by gravity in a single pipe to the external pond. The gravity line includes an energy dissipator to account for the large change in elevation.

## **Geotechnical Field and Laboratory Investigation**

Site investigation and laboratory testing programs were completed in the leached ore around the LQTSF North Expansion to gain a better understanding of the in-place materials that will confine the tailings. Investigations were also conducted of the tailings in the LQTSF as the new tailings will be very similar. The field programs involved sonic drilling and seismic CPT programs in both materials as well as surface sampling. The findings were used to develop the geotechnical material characteristics provided in the Design Criteria section.

As design seismic accelerations are relatively high at the site, key analyses were the liquefaction potential and post-liquefied strengths of the leach ore. The objective was to demonstrate that the leach ore confining the tailings would remain stable during and after an earthquake. Material properties to support these analyses were obtained from the seismic CPT probes and cyclic triaxial and direct simple shear tests.

## **Geotechnical Analyses**

Several geotechnical analyses were conducted using information obtained from the field investigation and laboratory testing in order to develop certain design criteria. The key analyses concerned liquefaction and post-earthquake stability of the leach ore that will provide tailings containment. These are discussed below.

### **Earthquake-Induced Liquefaction Assessment and Post-Earthquake Shear Strength Parameters**

The maximum credible earthquake (MCE) for the site was adopted as the maximum design earthquake (MDE) in order to provide a robust design. The MCE was defined as a deep sub-Andean intraplate event, estimated by Alva (2006) to have a magnitude  $M = 8.0$ , and a PHGA at the site of  $0.41g$ .

The evaluation of liquefaction involves the comparison of cyclic stress ratios (CSR) caused by the earthquake with cyclic resistance ratio (CRR) provided by the leach ore. The latter is a measure of the stresses necessary to cause liquefaction or significant strain softening. If the CRR exceeds CSR no liquefaction is expected.

One-dimensional site response analyses were conducted from the design earthquake estimated ground motion parameters, material damping and dynamic shear modulus factors, and CPT data using the computer software ProSHAKE (EduPro, 2001). This generated profiles of CSR with depth at the CPT locations. Similarly located profiles of CRR were generated by means of the computer software CLiq (GeoLogismiki, 2012), also using the CPT data but augmented with Standard Penetration Test (SPT) data from the sonic drill holes. In a second approach, CRRs were derived from cyclic triaxial testing of the

leach ore and compared with the calculated CSR values. In both cases, the majority of the comparative results indicated that the in-place leach ore is loose enough to liquefy if saturated or near saturated on occurrence of the design earthquake event (i.e., the majority of the calculated CRR values were less than corresponding CSR values). This was not a surprising finding since the leach ore is loosely dumped within the facility. Verification of the liquefiable nature of the material then focused the design on taking measures to minimize saturated zones within the leach ore. A key point for the LQTSF North Expansion was that leaching of the ore in the area of the excavation and behind the perimeter slopes that would form the containing structure would remain unsaturated. This was accomplished by stopping leaching of the ore below and around the basin 8 months before construction began, and sampling and testing in sonic drill holes to confirm.

Saturated leach ore (if found to remain in the construction area) required a residual undrained shear strength to characterize its behavior as part of the post-earthquake slope stability evaluations. Robertson (Robertson, 2010) developed a CPT-based correlation to estimate the residual undrained shear strength of a liquefiable soil as a function of its initial vertical effective confining stress (i.e., its residual undrained shear strength ratio) and this approach was adopted. An average residual undrained strength ratio of ( $S_{ur}/p' = 0.09$ ) was calculated based on the data collected during the site investigation and this value was assigned to any saturated or near-saturated zones of the loose dumped leach ore. In the non-liquefiable zones, softening under cyclic loading may occur, and to account for this, the effective stress friction angle representing the unsaturated, dumped leach ore was reduced by 33 percent ( $\phi' = 27$  degrees) for the post-earthquake slope stability analyses. This is a large reduction, particularly when considering the dumped material will likely densify in the earthquake, but it builds in a degree of conservatism in the design. For the compacted leach ore forming the North Embankment, no reduction in shear strength was assumed for the post-earthquake analyses.

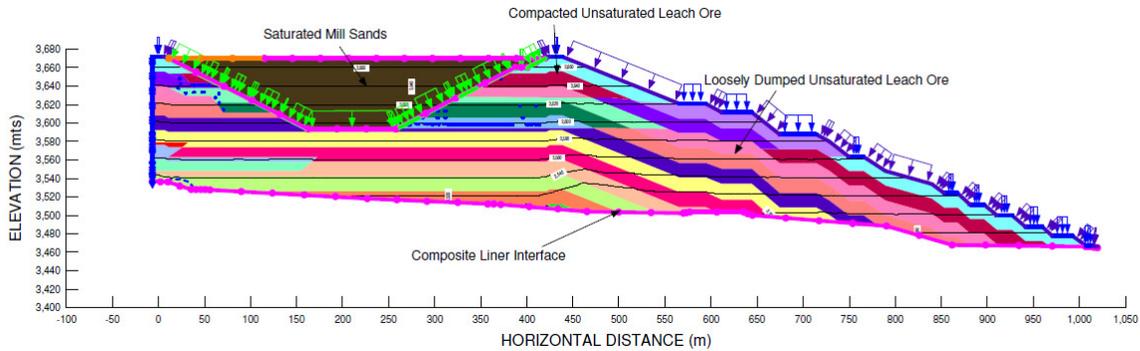
By way of comparison, the majority of the mill sands samples tested exhibited a residual undrained shear strength ratio of 0.035 and this value was assigned for subsequent post-earthquake slope stability analyses.

### **Pore Pressure Distribution and Finite Element Seepage Analyses**

Because of the potential for liquefaction to occur within the saturated leach ore, the presence and extent of saturated zones within the existing LQHLEF was a key input for the slope stability.

During investigations, static pore pressures from pore pressure dissipation (PPD) tests within the leach ore below the proposed area of construction were typically observed to be near zero, except in localized areas, where the pore pressures increased to as high as five meters of pressure head. The area had not been under active leach for some time, and these areas of inhibited drainage were estimated to

consist of higher fines content ore where the leach solution/precipitation may have been taking longer to completely drain down. Moisture content testing from sonic drilling provided further verification that the majority of the in-place dumped leach ore was less than saturated.



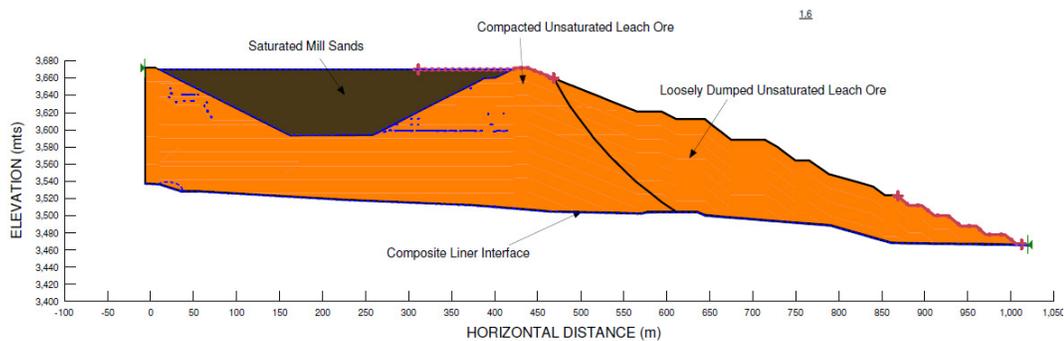
**Figure 3: Seepage Analysis Results**

Two-dimensional seepage analyses were conducted for several cross-sections through the confining heap leach ore using the finite element computer program SEEP/W Version 8.0 (GEO-SLOPE, 2012a). Boundary conditions were applied to the section geometry to represent anticipated field conditions (see Figure 3).

The results indicated that a small amount of water from the new tailings in the LQTSF North Expansion will seep downward into the leach ore below and around the facility through possible small imperfections in the geomembrane. However, there was no indication that large, continuous saturated zones will develop.

**Static and Post-Earthquake Limit Equilibrium Slope Stability Analyses**

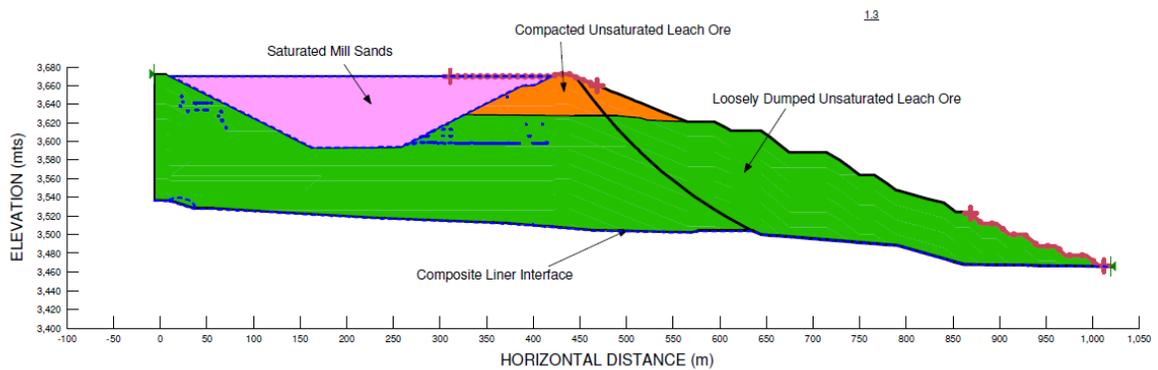
Slope stability analyses were completed using the computer program SLOPE/W (GEOSTUDIO, 2012b) for key sections around the facility. The Spencer method (Spencer, 1967) was used to search for the critical slip surface for both static and post-earthquake loading conditions (see Figure 4).



**Figure 4: Static Slope Stability Analysis Results**

Because the leach ore is expected to remain unsaturated, the steady-state effective stress friction angle was assigned to the entirety of the compacted and loose dumped leach ore for the long-term static slope stability analyses.

It was assumed that the leach ore, although unsaturated, may maintain a relatively high degree of saturation but only in localized areas. Because of this, it was considered overly-conservative to assign a residual undrained strength ratio to the dumped leach ore; however, shear strength for this material was reduced by 33 percent for the post-earthquake stability analyses in order to account for the potential of strain softening during and after the earthquake event. The compacted leach ore comprising the North Embankment was not considered to strain soften for the post-earthquake analyses as this material was compacted at or near the optimum moisture content. Because the mill sands will be saturated, residual undrained strength ratios were assigned. For the key sections analysed, the static and post-earthquake factors of safety met or exceeded the minimum acceptable values set forth as the design criteria (see Figure 5).



**Figure 5: Post-Earthquake Slope Stability Analysis Results**

Permanent deformations induced during an earthquake based on methodology by Makdisi and Seed (1978) considering the MCE event were estimated using the critical slip surface from the static analyses. The analyses resulted in deformations ranging from 19 to 50 cm for two of the sections, and were negligible for the remaining sections. Because deformations estimated by Makdisi and Seed analyses are often considered conservative, and the analyses estimate movement along the crest of the sections analysed and not necessarily along the base of the potential sliding block where containment of the facility is more critical, these estimated deformations were considered to be tolerable for the facility.

## Construction

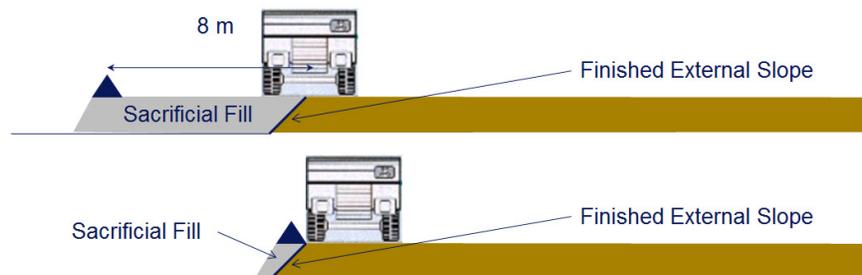
The original design intended use material cut from the basin to construct the North Embankment (see Appendix A – Mine Plan Construction), using fill layers 2m thick, compacted by routing loaded haul trucks (CAT model 793C) to reach 95% of the standard proctor maximum dry density.

In order to verify the original moisture content of the leach ore material that would be excavated from the basin, a drilling campaign was completed with a sonic drill rig. Samples collected during this campaign showed moisture contents above optimum in the upper part of the heap, and lower moisture contents with depth. However as the basin cut was developed, it became clear that the excavated leach ore was wet of optimum, and given the construction schedule, it could not be used as the sole source of embankment fill. Alternative borrow sources that were evaluated included waste rock from the El Tapado Oeste and Cerro Negro pits, blended at a 2:1 ratio with leach ore; and Yanacocha Pit waste rock, which was derived from a shattered silica rock mass; and Yanacocha pit waste rock mixed with Cerro Negro pit waste rock. These sources were evaluated for consistency with design assumptions (shear strength, unit weight and stress path behavior). The Yanacocha pit source was required during wet weather, but the blended waste rock and leach ore was acceptable during dry weather.

The truck count was the initial field control of compaction for the fills, using test fill data, then as-built data to correlate the number of truck passes with compacted dry density. The initial compaction was done with the discharge and additional compaction was developing with a loaded truck in order to reach the compaction criteria.

Compared to the concepts and specifications that were in place prior to construction, the following modifications were implemented with approval of the designer:

- Reduced the amount of sacrificial fill on external slopes (reduced from almost 8m width of extra fill to be trimmed to final slope after placement, down to 1m-2m) (Figure 6).
- Increase the thickness of fill layers placed by the large fleet to 2m layers
- Alternate borrow sources for the embankment fill
- Scarification between each 2m layer in order to increase the friction between layers (Figure 7).



**Figure 6: Reduce sacrificial fill on external slope**

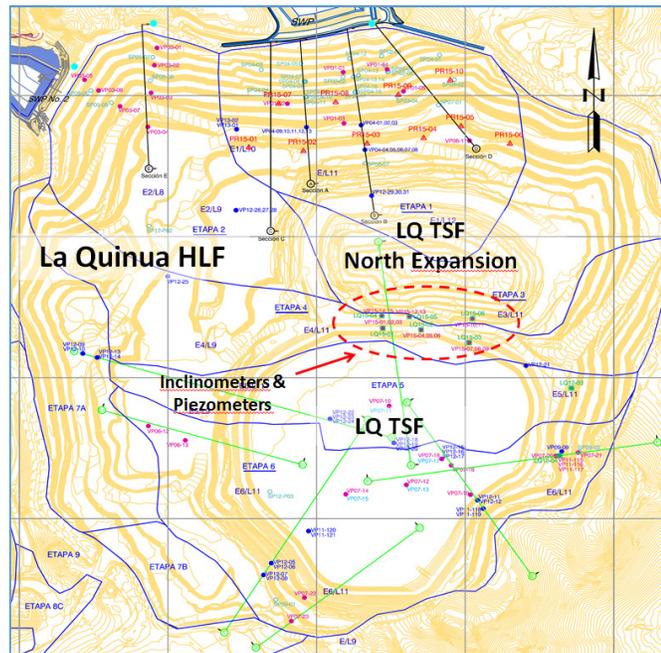


**Figure 7: Scarification between layers**

### Geotech Monitoring During Construction

The LQTSF North Expansion basin is surrounded on the north, east, and west sides by the North Embankment; and on the south side by north embankment of the existing LQTSF. The north embankment for the existing LQTSF therefore serves as the south embankment for the North Expansion (Figure 8).

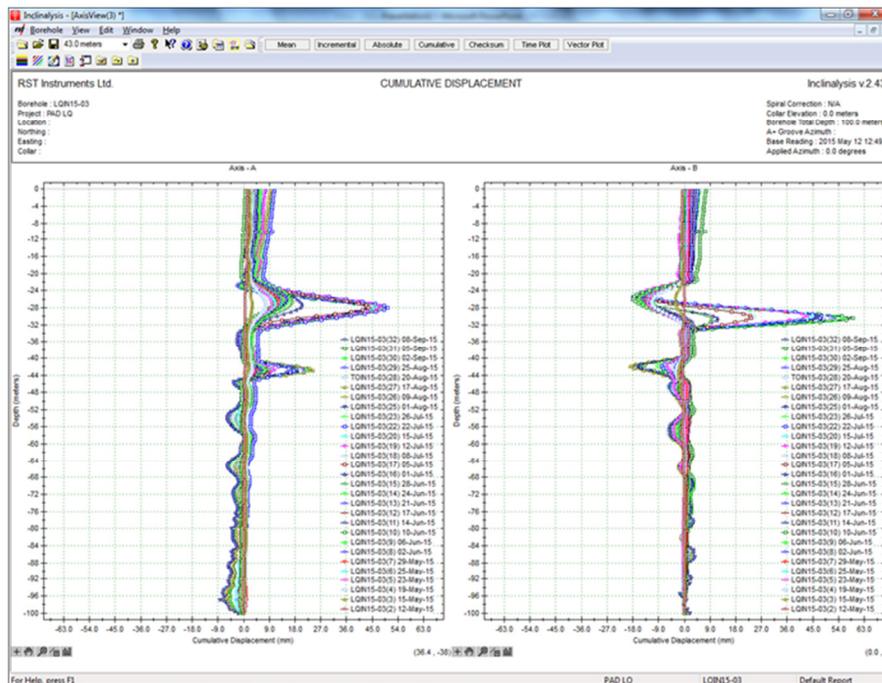
Six inclinometers were installed along the south side of the basin to monitor potential subsurface displacements as the basin was excavated. Inclinometers LQIN15-01, LQIN15-02, and LQIN15-03 were collared on the crest of the north embankment of the existing LQTSF. The remaining installations were completed at the crest of the basin excavation (Figure 8). All of the inclinometers were terminated in leach ore, above the native foundation.



**Figure 8: Inclinometer Collar Location**

Figure 9 shows a typical cumulative displacement plot for the inclinometers. The “swings” on the plot are not credible signatures for slip surfaces or a shear zones. Instead, they were interpreted as vertical loading and “buckling” of the casing. Possible explanations for this include:

- Stiffness contrasts across ore lift surfaces, or between the engineered fill embankment in final raise of existing LQTSF, and the underlying leach ore
- Incomplete grouting, leaving un-supported section(s) of casing that could be prone to buckling (grout was poured in from the surface, rather than bottom-up, so this is a possibility)
- Consolidation of leach ore due to construction of the 3660-3673 embankments for the existing LQTSF.



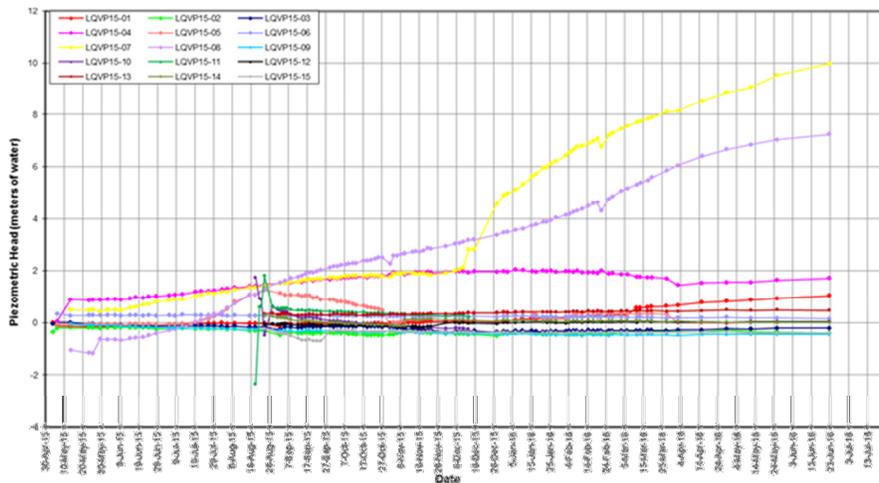
**Figure 9: Inclinometer Readings**

Two or three vibrating wire piezometer (VWP) sensors were installed in each inclinometer hole, attached to the inclinometer casing. The installations are summarized in Table 1, and pore pressure hydrographs are shown in Figure 10. Because of timing and equipment issues, grouting for the installations was carried out by pouring grout in from the surface, rather than with a bottom-up approach.

Most sensors indicate essentially zero head. Positive heads are all less than 2m, and for sensors that do register positive heads, pressures are much less than hydrostatic. VWP's LQVWP15-07 and LQVWP15-08 both installed in the inclinometer LQIN15-03 indicate increased head with time, and will be the subject of continued monitoring and investigation.

**Table 1: VWP installations (Pressure head measured 22 June 2016)**

Hole	VWP ID	Depth, m	Elev, mRL	Pressure, m H2O	Comments
LQIN15-01	LQVP15-01	95	3,576.74	1.05	Increase head with time
	LQVP15-02	50	3,621.74	0	
	LQVP15-03	10	3,661.74	0	
LQIN15-02	LQVP15-04	95	3,576.76	1.71	Probably dry
	LQVP15-05	50	3,621.76	0	
	LQVP15-06	10	3,661.76	0.14	
LQIN15-03	LQVP15-07	95	3,576.77	9.97	Increase head with time
	LQVP15-08	50	3,621.77	7.24	
	LQVP15-09	10	3,661.77	0	
LQIN15-04	LQVP15-14	70	3,590.82	0	Probably dry
	LQVP15-15	35	3,625.82	0	
LQIN15-05	LQVP15-12	70	3,588.31	0	Probably dry
	LQVP15-13	35	3,623.31	0.47	
LQIN15-06	LQVP15-10	70	3,589.26	0	Probably dry
	LQVP15-11	35	3,624.26	0.22	



**Figure 10: VWP pressure hydrographs (meters of head)**

A Reutech MSR300 radar was deployed to monitor displacements along the south side of the excavation and the existing LQTSF embankment above in late August 2015. Figure 11 shows a heat map, and time vs displacement data from the radar over the period in early September. No significant displacement was detected by the radar.

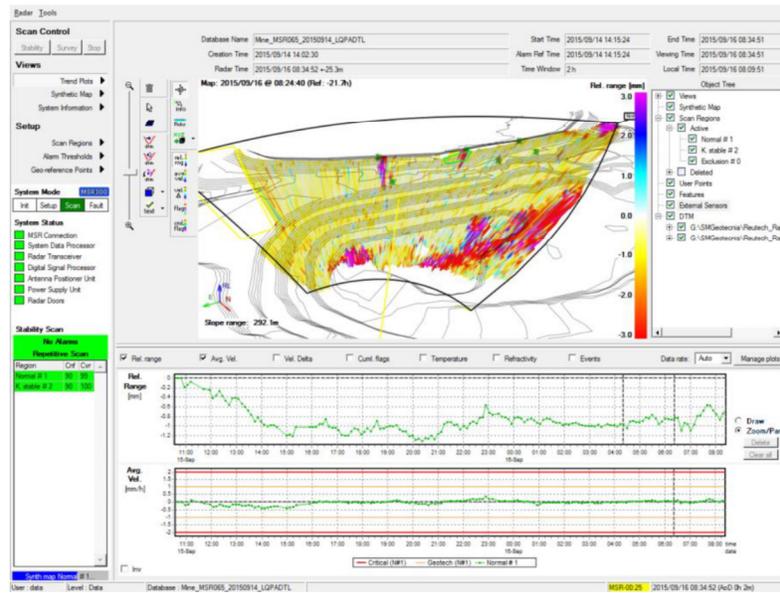


Figure 11: Radar Monitoring

## Conclusion

In contrast to the existing LQTSF, which was progressively developed in a basin in the LQHFLF as the facility was being loaded, the LQTSF North Expansion is being built as a new excavation within the LQHFLF after the ore has been placed and leached. Key design considerations included (1) stability and deformation potential of the excavation slopes under static and seismic conditions, and (2) water removal from the excavation. In accordance with the selection of the “Very High” consequence category for the LQTSF North Expansion under the CDA guidelines, the recommended MDE was the MCE for the site, which was defined as a deep sub-Andean intraplate event, with  $M_w=8$ , and estimated PGA of 0.41g.

Key elements of the design of the LQTSF North Expansion are the basin excavation, and construction of the North Embankment, and the decant systems used to evacuate water from the facility. The basin was excavated within the existing LQHFLF, and the North Embankment was constructed as a compacted fill, surrounding the basin on the north, east and west sides. The North Embankment ties in with the embankment of the existing LQTSF to form containment along the south side of the basin. The basin and the interior slopes of the North Expansion were lined with a 2mm double-side textured HDPE geomembrane in order to minimize seepage into the underlying leach ore.

The primary decant system consists of an inclined drainage blanket located at the south end of the impoundment, with perforated pipes that feed a primary sump. From that sump, pumps will send water to an external pond. The secondary decant system will consist of a drainage blanket that overlies the geomembrane, with pumps to send the collected water to an external pond.

In order to provide reliable information to be used as inputs to geotechnical engineering analyses, investigations completed during the design process included seismic CPT with PPD tests, sonic drilling with SPT, and an extensive laboratory testing of leach ore and tailings samples. Key analyses completed to support the design included liquefaction assessment of the leach ore; slope stability analyses under static and seismic loading; permanent deformations under seismic loading; and seepage in the leach ore, with a view to identifying the potential for development of saturated zones. Results of the field investigations and the analyses include:

- Since the leach ore is currently largely unsaturated and is not expected to become saturated in the future, liquefaction of the ore is not expected upon the occurrence of the design earthquake event.
- Limit equilibrium slope stability analyses for static and post-earthquake loading cases indicated that static Factors of Safety met the desired minimum of 1.5; and post-earthquake Factors of Safety met the desired minimum of 1.1.
- Earthquake induced deformation analyses estimate that deformations up to 50 cm may be expected as a result of the design event. These deformations are not anticipated to compromise the mill sands containment.

Although the original intent was to use leach ore from the basin excavation, high in-place moisture contents for the leach ore led to the use of alternate fill sources, including blends of leach ore and waste rock. The suitability and compaction requirements for these borrow sources were evaluated with test fills, laboratory testing, and field density testing. After developing correlations between truck passes and in-place dry density, truck passes were used as the initial field control of compaction, supplemented by field density testing.

Inclinometers and slope stability radar were used to monitor surface and subsurface displacements during construction. No significant displacements were detected.

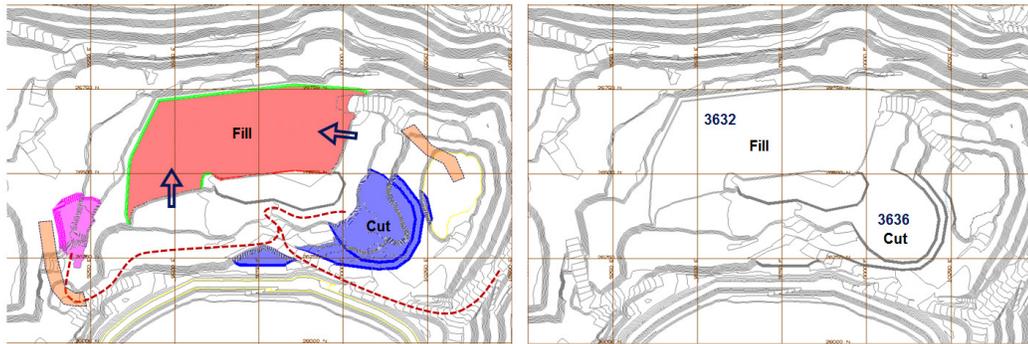
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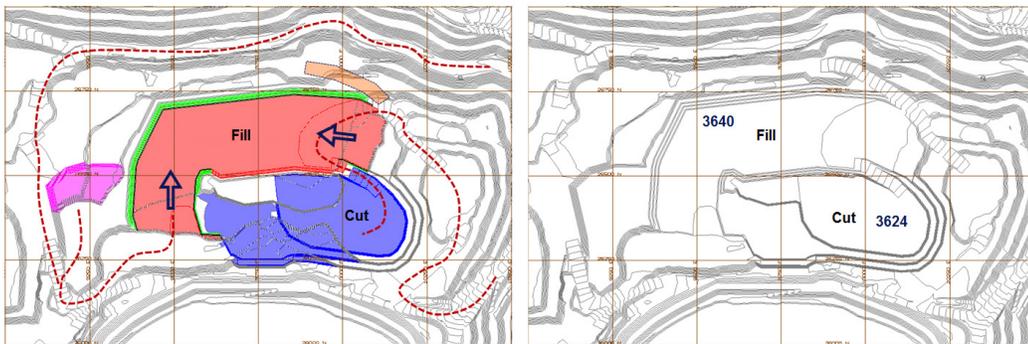
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## Appendix A – Mine Plan Construction

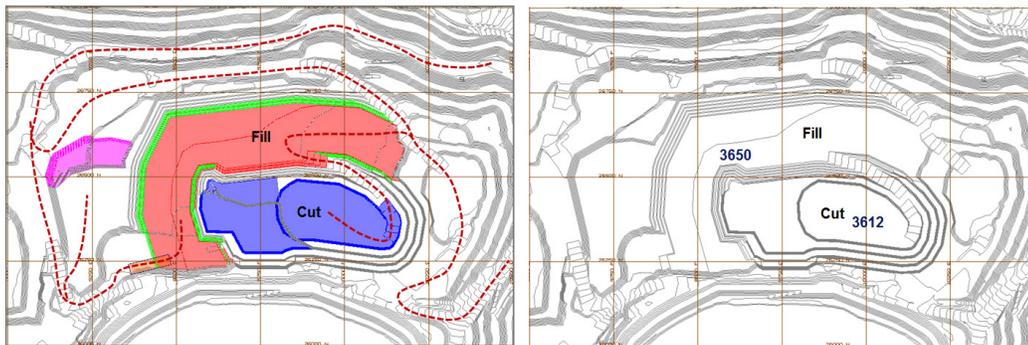
### 1st Month



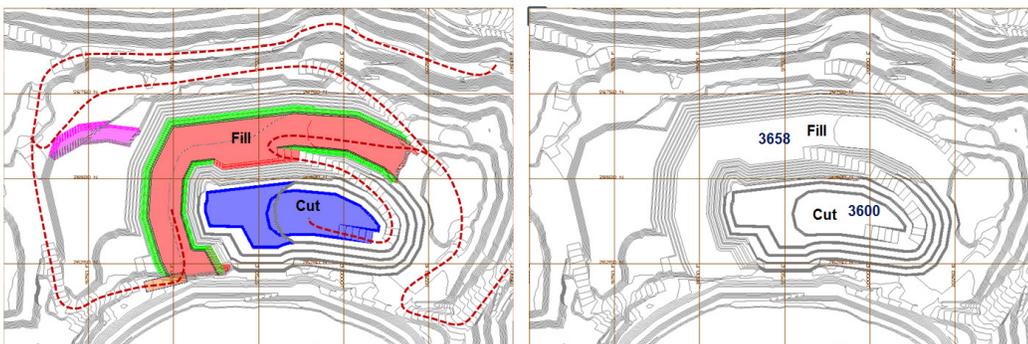
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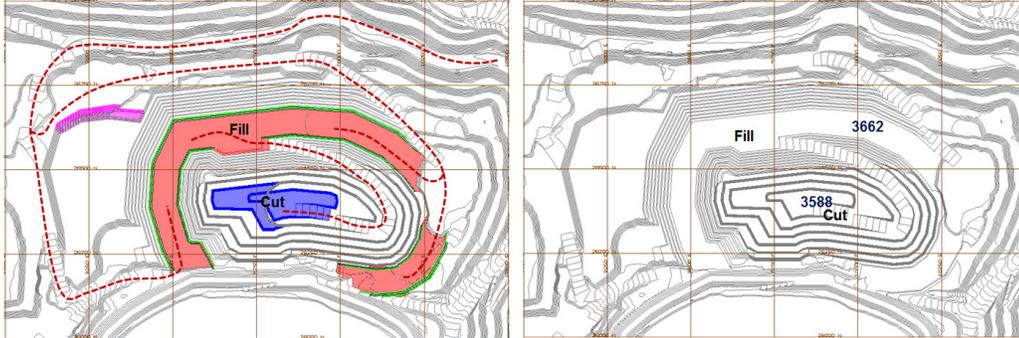
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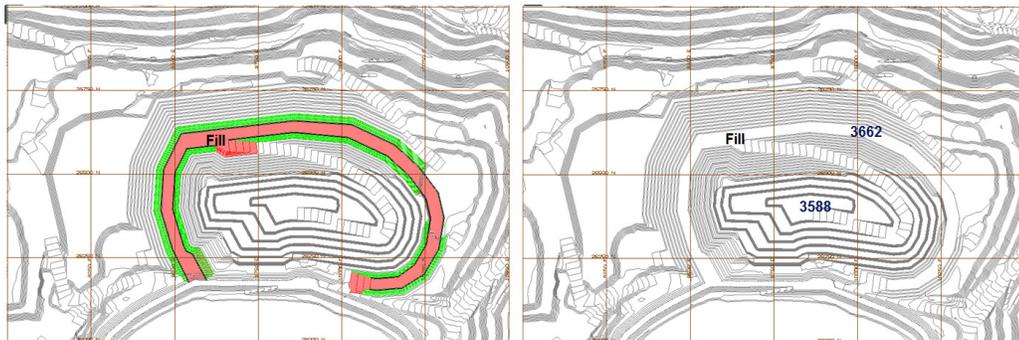
### 4th Month



**5th Month**



**6th Month**



**7th Month**

