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Conga Mining Project (Cajamarca, Peru). International Expertise of the Water Component

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ABSTRACT

Given the social conflicts that arose around Conga mining project (gold-copper), the Presidency of the Council of Ministers of Peru commissioned an independent international expert's report, to analyze all hydrological aspects included in the Environmental Impact Study and in the responses to the presented allegations.

The studies have addressed surface water and groundwater, in terms of possible interference with the quality and quantity, from the pre-mine situation, through the mining operation and after mine closure.

The hydro-climatology of the Andean area where the project is located has been reviewed concluding that the interference conditions would be significant only during the dry seasons due to a structural deficit of water outside the mining project. The mitigation measures have been studied and completed. Mitigation is acheived mainly through construction of surface water storage reservoirs, for replacement of affected volumes, with the possibility of ensuring higher low water flows, and with the implementation of collecting boreholes to ensure water supply to surrounding community users.

The designed water storage will allow increasing the availability of water in the required period and better management of water resources for the affected users. The loss of four existing small lakes as a consequence of the project implementation does not affect existing area water supplies.

There are no aquifers in entity that may be affected by the project, and there are well known hydrogeological disconnects between permeable materials. It is for these reasons that the groundwater is not considered as significant alternative for water supply, while sub-surface water, captured by sub horizontal bore-holes can be improved.

From the bacteriological point of view, the quality of groundwater in pre mine conditions is often deficient, as a result of livestock and lack of sanitary controls contamination. Groundwater exceeds the maximum level of heavy metals in some analyses as well.

The international expert's report recommends a set of participatory water management controls, to ensure compliance with provisions and proposals.

Keywords: Conga Mining Project; Peru; international expert report; water quality and quantity interference.

CONTEXT

In January 2012 the Presidency of the Council of Ministers of Peru commissioned an independent international expert report to the authors of this paper. The objective was to analyze the water component of the Environmental Impact Study (EIS) of the Conga Mining Project whose approval had been questioned by different groups opposed to it.

The Conga Mining Project is located at the Andes range, with an average elevation over 4000 m above sea level, east of Yanacocha Mine and 73 km northeast of the city of Cajamarca (Fernández Rubio, López García, Martins Carvalho, 2012). The owner of the project is Minera Yanacocha S.R.L. (MYSRL) (Figure 1).

Figure 1 Location of Minas Conga near Cajamarca, Peru

The geology of the area includes Cretaceous sedimentary rocks, Miocene's volcanic rocks, Eocene/Miocene sub-volcanic and plutonic formation and alluvial, and Quaternary fluvio-glacial and moraines sediments.

Mineralization was found in two cupriferous porphyry deposits (Chailhuagon and Perol) with 0.28% copper and 0.72 grams per ton gold grade. Mining operations are planned for 14 and 19 years, respectively with projections for extraction of 504 Tm of mineral and 581 Tm of low grade mineral and waste rocks.

The project is located within the Marañón river basin, a major watershed of the Amazonian basin and extends over a minor percentage of the headwaters surface of five microwatersheds: Alto Jadibamba (9%), Chugurmayo (0.4%), Alto Chirimayo (8%), Chailhuagón (2%) and Toromacho (2%). The area affected by the project is minimal as compared to that apportioned to agriculture, the activity that produces the largest negative impact on the biodiversity.

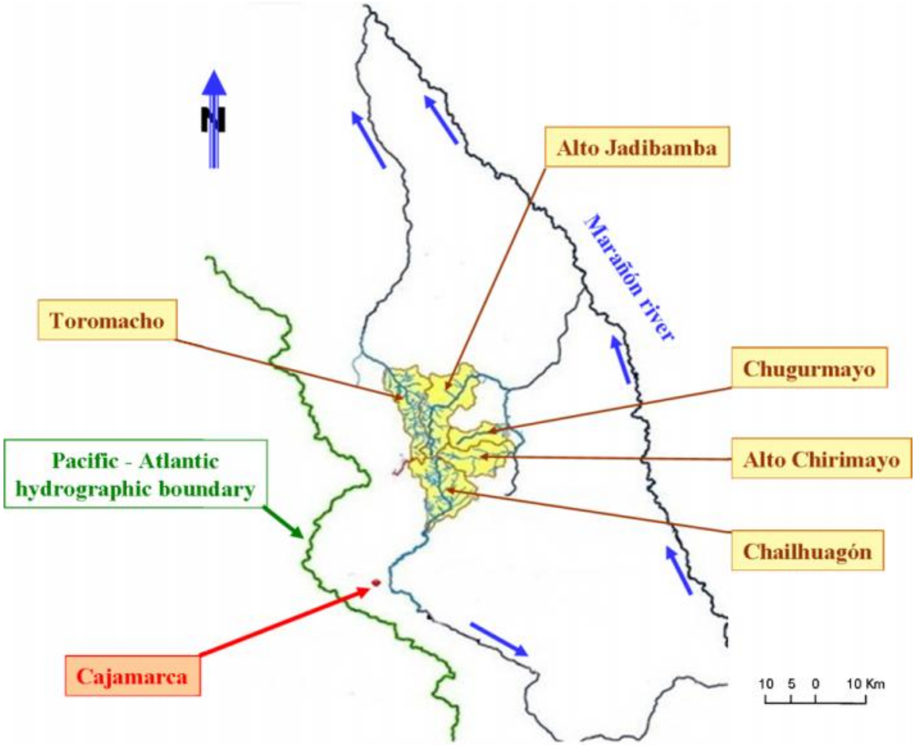

Figure 2 Conga Project footprints and micro-watersheds

SCOPE OF THE EXPERT REPORT

The basis of the report focuses on four major tasks: analysis of the available information; evaluation of the proposed prevention; mitigation and compensation measures; and, finally, proposal of complementary solutions to increase water availability to the downstream users. The report was completed, as expected, in forty days of intensely dedicated work.

The basic groundwork was the analysis of the 18 volumes of the EIS (Knight Piésold Consulting, 2010a) plus the 15 volumes of response to the observations received (Knight Piésold Consulting, 2010b), for a total of around 27,000 pages. These analyses were complemented with on-site surveys and studies, helicopter flights and multiple meetings with technical staff from public and private institutions that provided invaluable additional information as well as with social groups, associations and local residents. The product of these tasks was a 261 page expert report formally submitted to the Presidency of the Council of Ministers of Peru on April 13th, 2012.

The authors greatly appreciate the support provided by David Lorca Fernández, Project Manager of FRASA Consulting Engineers (Spain) and Tiago Carvalho, Production Assistant at TARH – Terra, Ambiente e Recursos Hídricos, Lda. (Portugal).

THE CONGA PROJECT INFRASTRUCTURE

The Conga project includes a number of facilities and specific infrastructures, extending over an area of less than 2,000 has (Figure 3).

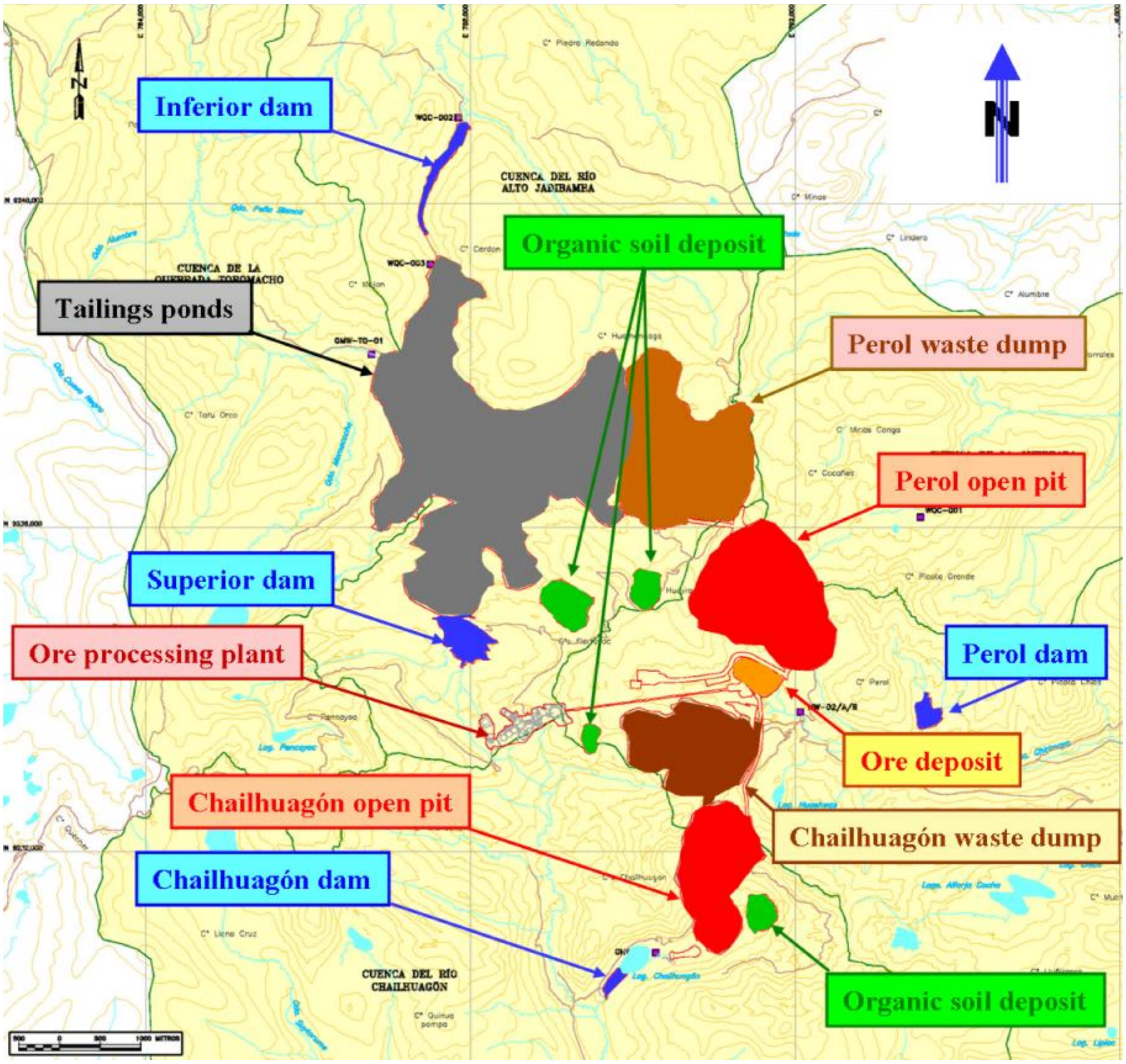

Figure 3 Main infrastructures of the Conga project

In addition to the two open mining pits (Perol and Chailhuagon), two wastes and low grade rocks dumps are provided. Chailhuagon waste dump is expected to not produce acidity, given the presence of abundant carbonate rocks; so its drainage, after passing through control and settling sediments facilities, would be released without issue. Perol is anpotential acidic water producing deposit, will be built upon relatively low permeability materials, but if necessary, a secondary system of interception and collection of water, or waterproofing work will be installed. In any case the natural drainage waters will be discharged by runoff to the tailings deposit, and pumped to the designed water treatment plant.

The planned thickened tailings are stored in sub-aerial conditions, under the protection of two dams (Figure 4), with planned capacity for 315 Mm^3, occupying an area of around 700 has. These dams will rise gradually, as required by the volume of waste; the upper dam will be permeable to retain the solid tailings, and filter the water; the downstream will be waterproof, to retain the effluents that will be pumped to the acid water treatment plant, designed for a flow of 850 m^3/h. Treated, good quality water, will contribute to the Inferior reservoir, to meet the demand of affected users in the months of drought, while the sediments of the treatment (4.45 Tm/h of mud) will be stored in the tailings deposit.

The planned infrastructure also includes: organic soil stockpiles for use in rehabilitation work; ore stockpile to be processed; and the ore processing concentrator plant (with capacity to 92,000 Tm/day), with no use of mercury and cyanide. Natural runoff waters will be directed to solids sedimentation pools or to the tailings deposit, used in the concentrator plant or the grinding, or pumped for their treatment and temporary storage in the reservoirs, in the case of low quality water.

It should be noted that it is necessary to remove two lagoons (Perol and Mala), for excavation of the open pits (Figure 4), and two others (Azul and Chica) which will be covered by a waste dump.

Figure 4 International Experts Team of the Conga Project water component in the Perol lagoon (from left to right: Luis López García, Dr. Civil Engineer; José Martins Carvalho, Dr. European Geologist; Rafael Fernández-Rubio, Dr. Mining Engineer)

As compensation has projected the construction of four regulating reservoirs, of which three (Inferior, Perol and Chailhuagon) will be used to store runoff in rainy period, which compensate for affections that can cause the mining project in the surrounding micro-basins. The fourth reservoir (Superior) will serve the needs of the project and, once finished the mining operation, will supply water to the surrounding users.

Table 1 Storage capacity, current and future, of the water bodies associated with the mining project

Original lagoon	Capacity (Mm^3)	Reservoir	Capacity (Mm^3)
Perol	0.8	Perol	0.8
Chica	0.1		
		Superior	7.6
Azul	0.4		
Mala	0.1		
		Chailhuagón*	1.6
Chailhuagón	1.2		
		Inferior	1.0
Total	**2.6**		**11.0**

* Originally: 1.43 Mm^3

In any case, the water runoff decrease will be small, given the low dimension of the subtracted area, and taking into account the decrease in rainfall above the elevation of the "optimum rain" (Fernández Rubio, Lorca Fernández & Novo Negrillo, 2014).

SURFACE WATER ON THE CONGA PROJECT

As expected, the surface water component of the Conga project is extensively analyzed in the EIS. The database used is correct but, as usual in undeveloped, small, isolated high mountain areas, is somewhat limited. The methods used are generally adequate, although some minor discrepancies on the procedure or the analysis of results, without significant influence on the conclusions of the EIS, were detected and should be accounted for in future updates. The impact of the project on the surface water is properly assessed and the mitigation measures proposed are correct, even if the expert report recommends some additional complementary improvements.

The mitigation measures are based on the construction of four reservoirs, three to recover the low flow loss derived from the occupation of part of the collecting watersheds and one to insure the availability of water for the mining operations that will also serve to increase water availability in the area after the mine closure. The reservoirs will store excess water runoff during the humid season and make controlled releases of mitigation flows during the dry season. It has been proved that the current estimated low flows can be fully recovered and even supplementary water to downstream irrigation users could be provided by the reservoirs. Therefore, the project will certainly not negatively affect the downstream users. It may however positively affect users, since the excess water of the humid season can be stored and used to fulfill their dry season needs (Figure 5).

The report points out that if the reservoirs are used to increase water availability downstream and not only to release mitigation flows, they must be operated by a participative management board where all stakeholders are represented: mining company, water authorities and water users, basically agricultural. In this way, the two-fold objective of providing mitigation flows and increasing water availability to improve local agricultural output could be achieved with minimum conflicts.

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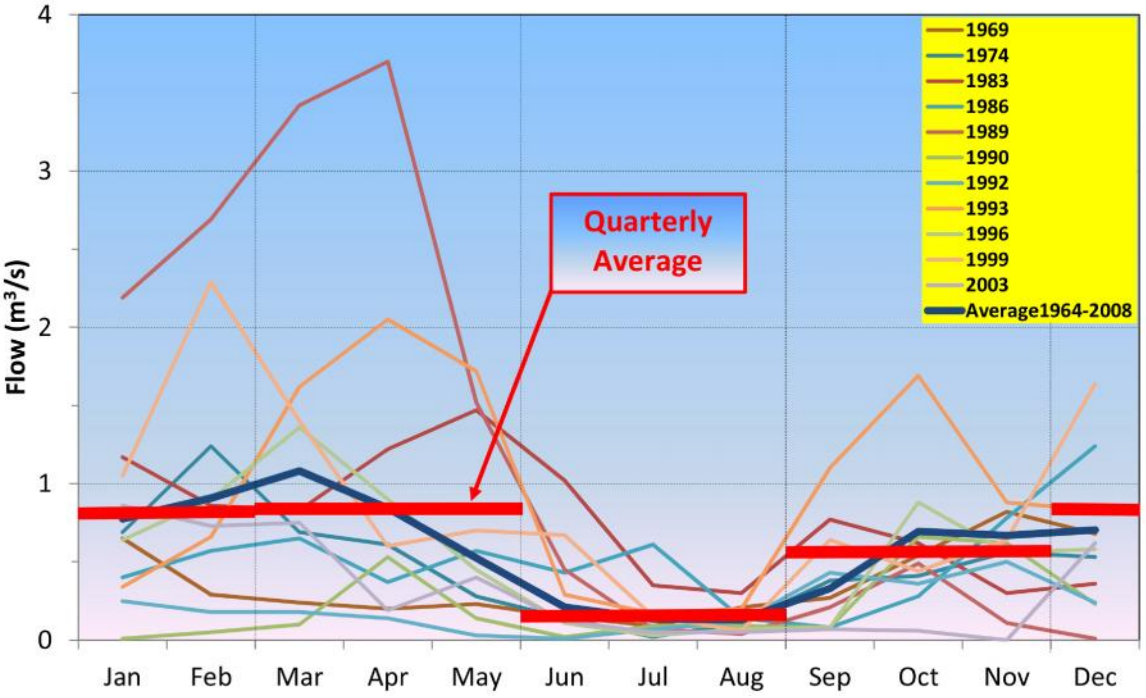

Figure 5 Monthly flow in selected years of the 1964-2008 period in Alto Jadibamba river

Reservoir capacity must be adequate according to the hydrological characteristics of the microwatersheds that receive moderate rainfall but show a significant runoff excess in humid periods, and must take into account an eventual agricultural water demand. Therefore, it is recommended to update the hydrological studies using the data collected at the local hydrometeorological stations built by the project after publication of the EIS. It should be based on a revision of the rainfall – runoff model and, if possible, develop specific models for each microwatershed. Thus, the mitigation flows required could be adjusted and the availability of supplementary water for agricultural users would be a function of reservoir capacity as defined.

Recommendations of the expert report emphasize the need for future real time control of the evolution of the hydrologic variables and the application of the actions proposed on the EIS. Thus, the institutions with responsibility on water resources administration —basically the Ministry of Mines and Energy and the Ministry of Agriculture through the National Water Authority— can verify the degree of compliance with the proposals of the EIS and insure that correcting measures are employed, if necessary. This systematic control will improve the hydrological knowledge of the area and provide transparent information to the local population and institutions.

Therefore, it will be necessary to build and operate a complementary hydrometeorological observation network and design adequate protocols for the collection and analysis of data and the drafting of monitoring reports.

This network should include continuous river flow gauging stations at the outlet of the five microwatersheds, since the stations installed in 2004 were destroyed in vandalistic attacks. The information obtained will be critical for the improvement of the rainfall – runoff models discussed prior. Moreover, it is recommended that at least one unaffected watershed is also gauged, in order to define the natural changes that might take place in the hydrologic regime of the area, not attributable to the mining operation.

Again, these various controls must be participative, involving institutions of the administration, local universities and communities and social groups implicated in the management of the water resources and especially the users of water for irrigation, primary consumers of the area.

The protocols for systematic handling and information must define the frequency and extent of the analysis and reports to be executed, the warning thresholds for emergencies and their associated actions. Dissemination procedures for the information obtained should be established based on the need for transparency and simplicity.

The EIS concluded that the proposed reservoirs, designed to provide only the mitigation flow, would generally be at full capacity, either during mining operations or after closure. Therefore, they are undersized in their capability for regulation of the natural runoff, so any technical and economical feasible capacity increase would augment the availability of water during the dry season and, consequently, the positive impact of the project. This is not the objective of a mining operation but, if properly managed, it would greatly improve the relations with the local population.

GROUND WATER ON THE CONGA PROJECT

A conceptual hydrogeological model and a numerical model were carried out within the EIS. These models have to be recalibrated and validated with the suggestions arising from the Expertise including also the new data to be supplied by the hydrogeological monitoring to update the ground water resource management. With this approach a better estimation of the qualitative and quantitative impacts on the existing micro basins will be achieved.

A complete integration of all data of the hydrogeological inventory is recommended, including its geo-referentiated location, defining the water points to be considered in a future monitoring network (springs and wells) down gradient of the main mining installations. This the future monitoring network will include controlling measurements in adjacent basins not affected by the project.

The deep ground water circulation is quite low in the volcanic rocks and even in the existing limestone units as they are confined between aquitards. The investigations carried out in the EIS and our field investigations did not demonstrate the occurrence of karst aquifers and fissured deep systems. The occurrence of fissured semi confined or confined aquifers are possible in limited sectors but they can allow the propagation of influenced levels, and mass transport over considerable distances after the closure and flooding of the main mining excavations. However, the hydraulic continuity between aquifers is not significant or is not present.

The available information allows for the conclusion that area ground water are mainly present in cutaneous (skin) aquifers and in alluvial and fluvioglacial deposits, all located at shallow depths and only following the seasonal precipitation. This ground water temporally feeds lagoons and the surface water runoff of ravines, gorges and rivers (Figure 6). Ground water recharge was estimated at about 34 mm/years, approximately 3% of the average annual rainfall.

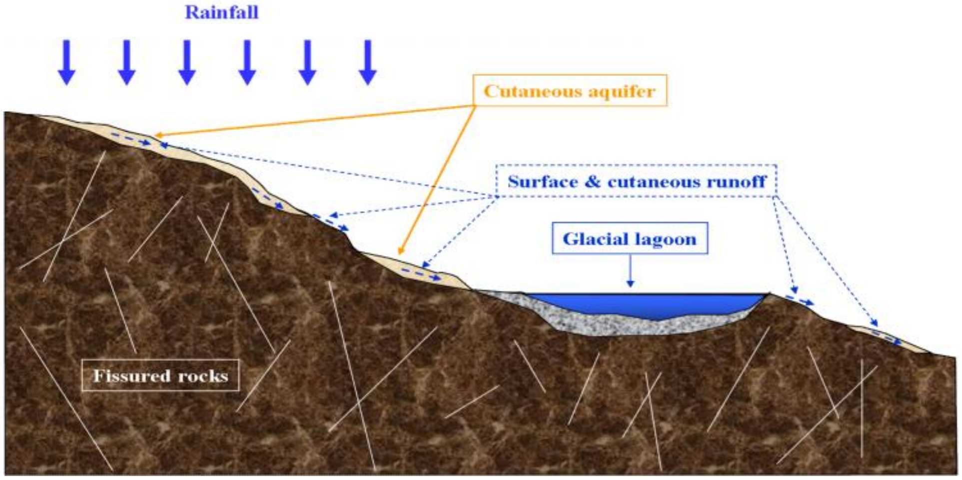

Figure 6 Hydrogeological context

The main groundwater resources are located inside cutaneous shallow aquifers and its management shall be done in conjunction with surface water. Ground water resource is small and does not allow its systematic utilization for irrigation.

Additionally to the prevention, mitigation and compensation measures adopted by the EIS, the Experts suggested the execution of an appropriate vulnerability to contamination mapping to support technically the protection and mitigation activities for the future waste dumps and tailings dam. The design of wellhead protection zones for ground water sources used for public supply, considering chemical and biological contamination, is also suggested.

The Expertise also proposes the exploitation of the numerical model as a management tool considering the main mining project structures operation and its closing. The conclusions must be taken in account to the wise management of water resources and on the design of preventing and corrective activities, even considering that the Expertise classified the impacts as marginal over the discontinuous hydrogeological units (“aquifers”) of the volcanic basement and of the interbedded limestone.

Among the mitigation and compensation measures, in addition to the surface reservoirs to be constructed, alternate water exploitation structures should be considered, such as sub-horizontal boreholes. This, offers better water management capabilities than springs, and the “rain sowing water” (managed aquifer recharge, MAR) in the cutaneous (skin) hydrogeological units using recharge channels (the well-known “acequias amunadoras” of the San Andrés de Tupicocha in the Peruvian Andes), very efficient and with great social acceptance.

WATER QUALITY

Comprehensive information on water quality, from analysis of accredited laboratories, from Cajamarca, Lima and Ontario (Canada), using standard process control and quality assurance is included in the EIS. According to these data we can highlight the following subjects.

Quality of surface waters in the pre-mine state

The water quality in lakes, streams, rivers and canals is studied in the EIS from historical data, for the five micro-watersheds located in the area, including various studies and controls developed for the Conga project, since 2003 until 2009.

The general characterization achieved, concerning composition of surface water, is considered adequate and its extension to more control points is recommended, for better knowledge of the pre-mining state, keeping track of spatial-temporal quality during the mining operation. It is also recommended to select referential points in similar basins unaffected by proposed mining activities.

In the EIS, analytical data are considered in the framework of national environmental quality standards for water (ECA), established by the Ministry of Environment and specifically, with Category 3, corresponding to irrigating high and low stem vegetables and to animal drink, as this is the primary use of these surface waters.

As for the quality of superficial water in the pre-mining state, the following could be highlighted:

- The major chemical facies is calcium bicarbonate, correspondent to low salinity waters, as a result of the low solubility of lithological materials where these waters flow; although some samples are calcium bicarbonate-sulfated and others are calcium sulfated.
- The pH measured in the field, for most samples, is higher than 7, even reaching 9; occasionally there are values between 6.5 and 7, and in wetlands ("bofedales") pH becomes very low (from 3.0 to 6.4 with medium values of 3.1 to 4.2).
- The total dissolved solids range from less than 3 mg/L to 302 mg/L, values that can be classified as low.
- The minimum alkalinity values were recorded in wetlands (<1.0 to 12 $CaCO_3$ / L, with a mean value of 1.3), which shows the poor quality of these waters. In the remaining tests, variable values were observed, surpassing 202 equivalents of $CaCO_3$ / L. In some ponds and irrigation canals values below 20 were measured, reflecting its poor quality for maintenance of animal life.
- The sulfate content may be considered low (<0.5 and 42.9 mg/L), although the presence of pyrite (especially in mineralized rocks), confirms its no-reactiveness, as a result of being under water and, therefore, without oxygen.
- In general, the recorded concentrations of heavy metals (Al, As, Cd, Cu, Fe, Mn, Ni, Pb, Sb and Zn), are low (sometimes even below detection limits) without values exceeding ECA´s Category 3, although in some analysis relatively high contents are observed, deriving from the presence of particulates, either in suspension or settled.
- In relation to the biological quality, content in fecal and total coliforms often exceed the limits set by the ECA for Category 3, especially in rivers, but also in channels, and samples exceeding the limits of these pathogens are frequent in water for human consumption, resulting in ill conditions for livestock and human activity.

Groundwater quality in the pre-mine state

EIS discusses the composition and quality of groundwater in the project area and its surroundings, from periodic analyzes by several laboratories, especially since 2009.

Since these waters are used primarily for human consumption, its quality was evaluated using the ECA standards, established by the Ministry of Environment for Category 1 - Subcategory A1 (water which may be turned potable with simple disinfection). The results were processed using statistical techniques and graphical displays, also using standard geochemical modeling programs. The results provide a good contribution to the knowledge of the characteristics, composition and behavior of groundwater quality.

Among the notable aspects, these can be highlighted:

- The majority chemical facies are calcium bicarbonate, although there are sodium-potassium calcium, and other chemical facies.
- The pH is generally neutral to alkaline, although there were analysis with very high values (over 11), possibly due to grouting additives used in drilling holes.
- Total dissolved solids is usually very low to low, but there are values higher than 4,000 mg/L.
- Most metals regulated for human consumption are below the maximum established values; however, in a series of water samples from wells the values were exceeded regarding the contents of Al, As, Fe, Hg, Pb and Mn in different sampling campaigns, a situation attributable to natural geochemical background, from a geological area that has received deep mineralized fluids.
- Values for total and fecal coliforms are generally low, although in some groundwater were obtained values that exceed the limits established by ECA regarding fecal coliforms, which highlight the human or animal influence.
- In terms of dissolved oxygen, DBO and DQO, some samples do not meet the ECA standards.

Quality of contact water in the mining and post-mine stage

Forecast for water quality that could be drained on a mining operation, always has a degree of uncertainty, especially for water in contact with reactive rocks (presence of pyrite and oxygen).

For an approximated value, a number of studies and hydro-geochemical leaching tests (including tests in humidity cells) were conducted in the EIS, to predict future water quality. For safety reasons, it is planned in the EIS to submit to water treatment all potentially quality-affected water. These changes in water quality are expected to be higher in waters in contact with rocks from the Perol open pit, as it presents pyrite and marcasite that, when exposed to this environment, would be the main generating source of acidity, having little material to support natural neutralization except from Chailhuagón open pit where limestone is present.

Regarding the reactivity of the tailings in the presence of water and oxygen, and given its small grain size, no doubt they will be acid generating materials, which may incorporate: As, Cu, Mo, Sb and Zn . Therefore, an operating facility of acidic water treatment in the long term is included in the project design.

The process plant for mineral treatment will not use cyanide nor mercury, and reagents used for the differential flotation of targeted metals, will be in part, recovered and reused in the process, in a closed circuit. Another portion of reagent content will be incorporated into the produced concentrates, destined for export and transported by truck; and a third fraction will remain in the deposit, designed with zero discharge.

In the EIS it is proposed a sub-aerial disposal for the thickened tailings. To avoid the need for a very prolonged treatment of acidic waters, alternatives such as underwater tailings storage exist, avoiding the generation of acid waters and dramatically reducing the need for treatment, but requiring water, while it reduces the storage volume, which would require having a second tailings storage area.

RECOMMENDATIONS

The expert report proposes some improvements related to the infrastructures planned, whose feasibility must be confirmed after the necessary detailed studies. If proven possible, they could reduce the negative impacts identified in the EIS and increase the positive impact of hydrologic and environmental measures.

Moreover, the report emphasizes the opportunities to improve the expertise on the hydrologic behavior of high altitude Andean systems provided by the project. It would also enhance the environmental and hydrologic management practices in such areas.

Accordingly, the expert report recommends starting investigation, as soon as possible, of several aspects that could environmentally improve the design of some infrastructures:

- Optimize the conservation conditions of organic soils recovered from different areas of facilities in the provided storage (piles), for better preservation of its seed bank.
- Properly maintain humic materials from the dismantling of wetlands (“bofedales”), for later use in rehabilitation work.
- Evaluate technical and economically alternative relocation or displacement of the wastes and low grade Perol rocks dumps, to avoid cover the Lagoons Chica and Azul.
- Study the possibility of encapsulating residues from the treatment of acidic waters, in a secure deposit.
- Analyze the suitability of employing biotechnological passive methods of treatment of acid water, and in particular wetlands with planting of reeds (“totoras”) (Fernández Rubio, 1991).
- Analyze the possibilities for the increase in capacity of the designed reservoirs, in order to optimize the management of the water resources generated in the project area by. More specifically:
  - Expand the capacity of the Inferior reservoir to increase the availability of water during the dry season.
  - Expand the capacity of the Perol reservoir, if there is evidence of the need for supplementary water to the downstream users.
  - Expand the capacity of the Chailhuagón reservoir, to its feasible maximum to benefit downstream users (MYSRL has already undertaken this proposal). Thus it would happen in a current capacity of the lagoons of 1.2 Mm^3 to a current availability of reservoirs of 11 Mm^3.
- Build or improve intake structures for water supply of small urban populations that currently use natural springs, through sub-horizontal boreholes allowing control of the outflow.

- Systematically implement the "Water Earth Technology" (WET), or "rain sowing water" using recharge channels (the well known "acequias amunadoras" of the Peruvian Andes), to "collect water" through the "water harvesting" downstream during the dry season.

However, the need for a realistic framework that avoids the creation of false hopes must be emphasized. There is a strong risk of encouraging the misleading idea that a mining project has to solve the structural shortages of water during the dry season.

The recommended actions could be a first step towards the development of the water resources management system of the microwatersheds that should be complemented by the Peruvian National Water Authority through the Watershed Management Plans currently being drafted.

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OFFER

Those interested in obtaining further information, not for commercial use, may ask for the complete expert report (in Spanish) and a power point presentation (rfrubio@gmail.com).

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