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Mining Drainage and Water Supply under Sustainable Constraints

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ABSTRACT

Water resources management is becoming more political, ecological and economical than scientific and technological.

In this sense, the mining drainage can play a crucial role, preventing any kind of impact on water environment and providing an important source of water to attend human needs when the appropriate technologies, and the gained experience are applied.

In this paper, we pay attention to two mine water drainage managements, one of them related with the possibility to apply water drainage at an Spanish underground zinc-lead mine to control river ecological run-off and town water supply. The other one in order to insure the compatibility of a new Brazilian open pit iron ore exploitation with the possibility to use the drainage water to supply a large city, preserving the water quality after the mine abandonment.

Key Words: Water management, environmental protection, mine drainage, town water supply.

INTRODUCTION

Water quality and quantity is essential for life under a suitable environment. The extent to which water is abundant or scarce, clean or polluted, controlled or destructive, determines the life quality to a large extent.

Economic downturn, water conservation technologies, increasing cost of water, and conservation efforts have stemmed water demand. All of this implies to the development of a new, more efficient and rational utilization of water.

The mining industry is confident of its environmental management skills and in this framework mine-water technologies have a lot to offer to improve the environment. History shows that mining activity can be powerful catalysts for a global growth and development, in national and local economies, while providing the necessary materials and products. At present, being conscious of the necessities of human growing, once more, we have the chance of sharing a very valuable non renewable resource: the water.

WATER IN MINING

General Appreciation of the Problem

During a long time, many mining operations have had a tendency to regard water management as a separate and non-productive operation: mine water was a mine waste. However, the rapid changes of mining mentality throughout the world, along with the advances in technology, are developing a transformation of many mining environmental aspects, where water plays a crucial role.

Conventional classification divides mines between open pit and underground. From the hydrogeological point of view it is more appropriated to distinguish mining works above and below piezometric level. The second having undoubtedly more hydrological repercussions; nevertheless, the effects of the former on water are not negligible.

We will focus on those works developed below the water table, which usually have incidence on underground and surface water, even at a long distance. In open pits, the water inflows will damage the production or even stop it for long periods. In underground mine the effects of water inflow can be even more severe, mainly with sudden uncontrolled inflows that can cause the mine closure, considering the recovery cost and the production losses. At the same time the mine drainage operations can affected the natural water balance and the ecosystems with impacts that can remain for a long period.

The best way to solve or to reduce water-environment problems related to mining operations, is to combine the appropriate measures to exclude inflow of water into the mine workings with a rational use of the mine drainage water. Active advance dewatering technologies through surface or underground drainage are desirable. In this sense pumping wells, underground drainage holes, dewatering trenches or drainage galleries may be very successful *(figure 1)*, providing some independence between mining works and dewatering processes and improving the possibility to obtain a good quality water.

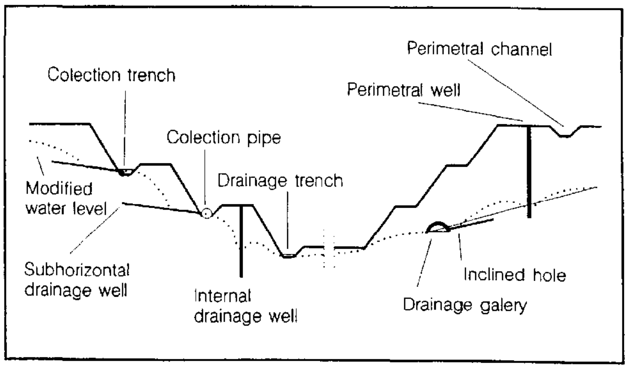

***Figure 1.** Drainage systems (Ayala, 1989).*

Some mine drainage figures can be very significant: iron exploitation in Kursk, in the former Soviet Union, required to pump 50.000 m^3/hour; lignite exploitation in Belchatów (Poland) lignite mine reached a drainage of 62.500 m^3/hour. For the coal deposits of the former Soviet Union it was required to pump 226.800 m^3/hour *(Fernández-Rubio, 1986)*.

In some cases, the water inflow technical problems, together with pumping operation cost, means surpassing the narrow economic margins of mine business and compels to its temporary or definite abandonment. This has been the case of the excavation of Number 2 Shaft in Konkola Mine (Zambia), which had to be abandoned after pumping $1.4x10^6$ m^3 during seven months without obtaining an appreciable effect on the piezometric level. The mine itself had to be abandoned during six years due to a quick water inrush that produced its flooding *(Stalker, 1978)*. We have to take into account that this mine is widely considered the wettest mine in the world, pumping more than 15,500 m^3/hour *(Sweeney, 1988)*, with a peak of 17,700 m^3/hour in June of 1978 and an average of 13,400 m^3/hour in June of 1990 *(Mulenga, 1991, Fernández-Rubio et al., 1994)*.

With the presence of pyrite the water drainage usually also have quality problems, due to the production of the so called acid mine water with its subsequent heavy metals solution *(Fernandez-Rubio, 1993)*.

But, in many other cases, the mine drainage water can reach the same quality that the natural groundwater existing in the aquifer, appropriate for domestic, agricultural and industrial uses. This happens more and more frequently as consequence on the environmental challenge that mining have to face and with the drainage methods adapted to preserve the original ground water quality, mainly through application of preventive and in advance drainage methods. In this way the integration of hydrogeologist and environmental experts in mine planning and operation from the very beginning is extremely important for a mine facing any kind of water problems.

GROUND WATER MANAGEMENT

Experience shows that in many mining areas an adequate ground water management is possible employing the suitable mining drainage technology. In any case, it is necessary to approach mining drainage in a different way from the traditional miners' vision of groundwater as the mining enemy. Water must be recognized for its major ecological significance as well as a valuable resource.

Generally, pumped water through wells drilled away from mine openings preserve its natural qualities, and subject to regular inspection and meeting of health standards, can be employed for water supply of nearby population. Also it should be appropriate for other domestic, agricultural and industrial use.

To compensate costs, and in many cases to attend the demand, there are a lot of examples in which the water pumped in advance of mining operation is used as water supply of the mine surrounding villages and land irrigation. Such it is the case of the pumped water at Sierra Menera Iron Mine (Teruel, Spain), or at Marquesado Iron Mine (Granada, Spain), where water is used as mine town water supply, as industrial water, irrigation, andrecently for artificial recharge of the aquifer affected by the mine drainage.

In several Hungarian coal and bauxite mines, located North of Balaton Lake in a karstic domain, with a pumping amount over $2x10^9$ m^3, a part of the water is used in a trout fish-hatchery, although most of water is employed in supplying a disperse population of around half a million inhabitants *(Fernández-Rubio, 1981)*. In the Iron Lorena Mines, France, a yield of 4,000 m^3/h of drainage water was employed for the industry and as drinking water *(Herve, 1978)*.

Modern open pit mining, as Post-Betze gold Mine, Nevada (USA), requires an extensive water management program to dewater ore zones in advance of mining *(White, 1994)*. After using about

6% of the water pumped for mining operations, 84% is reinjected into the aquifer while 10% is used to maintain wildlife creating arable lands.

It is remarkable that there are cases in which the aquifers inertia can modulate the drainage, to make easier the integration of this water resource in the general hydrological management. A rational mining planning, together with the latest technology make possible to compatibilize mineral resources exploitation and water and environmental management.

REOCIN UNDERGROUND MINE, SPAIN

Possibility to Employ the Water Drainage as a Source to Provide Water Supply to Surrounding Towns

Figure 2. Reocín Mine location.

Reocin Mine, operated by Asturiana de Zinc, S.A., is the second largest zinc/lead mine in Europe. The mine is located near to the Atlantic Coast, North Spain, some 5 km west of Torrelavega, an important industrial town, and 30 km southwest of Santander, capital of the region and very important industrially, commercially and touristically.

From a geological point of view the mine is situated on the southeastern flank of a syncline constituted mainly by Jurassic and Cretaceous deposits, overlaying a basement folded and fractured during the Hercynian Orogeny.

Despite of the heavy rainfall rate of 1100 mm/year, it is relatively usual to restrict the water supply during the dry season due to the steep orography and the special environmental sensitivity of people living in this region, which does not allow dam construction.

In order to provide water supply solutions, we were requested to analyze the possibility to combine the deep mining water drainage with the use of such water for urban supply, in comparision with other alternatives taking into account: surface water supply through a dam construction, water transfer from the Mediterranean basin, and other aquifers exploitation. Considering all the parameters, including environmental aspects, social acceptance, cost and water quality, the final proposal was favourable for the employment of the water resources existing into the deep karst aquifer and affecting mining operation, with the complementary benefits for the mine economy.

The morphology of this stratiform deposit, its dip, plus its lithology caused to use room and pillar extraction methods. Those methods are now being replaced, making use of increased geotechnical knowledge, to cut and fill methods. Using the benefits of mechanization to improve productivity together with modernization of mine facilities and recovery plants.

The principal economic mineralization is located in the lower part of the Gargasian dolomitized carbonates with thickness variation along the length of the deposit. The highly developed joint and fracture systems, together with the great karstification processes that affected the dolomites, are responsible of the large amount of drainage water entering in the deepest mine levels at a average yield of 1200 l/s (103 400 m^3/day).

Many studies were conducted in order to acquire a good knowledge of the hydrogeological conditions of this very karstified environment and its evolution both in depth, and in the mine lateral development. Such studies included detailed hydrochemistry investigations that provide now a very valuable data related to the water quality in the aquifer itself and in the mined areas.

The quality of the water that appears in very large amount in the working faces is perfect for drinking purposes. The relatively small amount of water infiltrated through abandoned mining opening is affected by pyrite and heavy metals solution, and the pH is neutralized by the dolomites. Many metal micro-elements remain solubilized in water afecting the drinking quality of the total amount of pumped water and subsequently the water is wasted, while incurring high energy cost for drainage requirements in the underground mine. In this condition the need to provide potable water supply in this area cannot be over-emphasised.

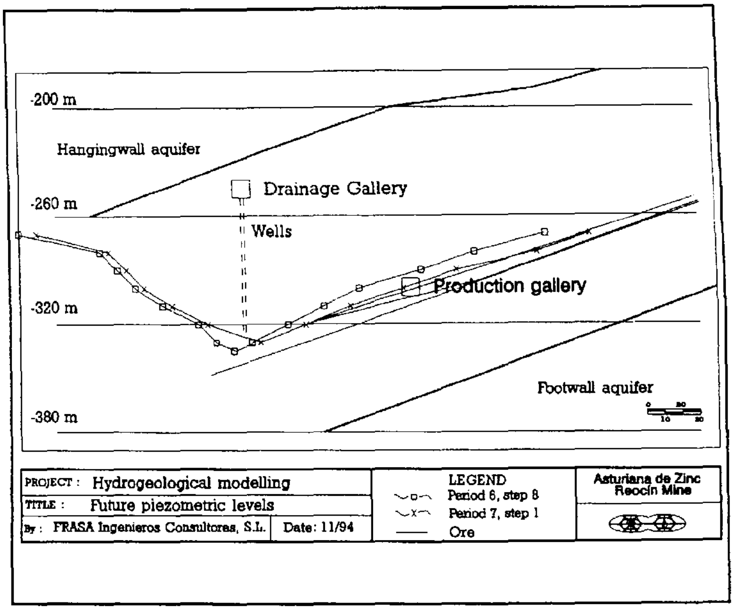

Figure 3. Mine drainage proposed at Reocín Mine, Spain (FRASA, 1994).

Based on the mineralization and hydrogeological knowledge, and taking into account the mining methods and long term planning, it was proposed to adoptd a mine drainage in advance from upper levels through vertical wells to create a water depression around lower mining areas *(figure 3)*. As such water comes into pipes before mining activities, its natural quality can be preserved.

The application of MODFLOW numerical hydrological model *(figure 4)* was used to evaluate the yield required in the future, which was estimated as 1,800 l/s.

In conclusion, based in the detailed hydrogeological and hydrochemistry knowledge, it is possible to secure the water drainage quantity and quality, making compatible mine exploitation with urban water supply.

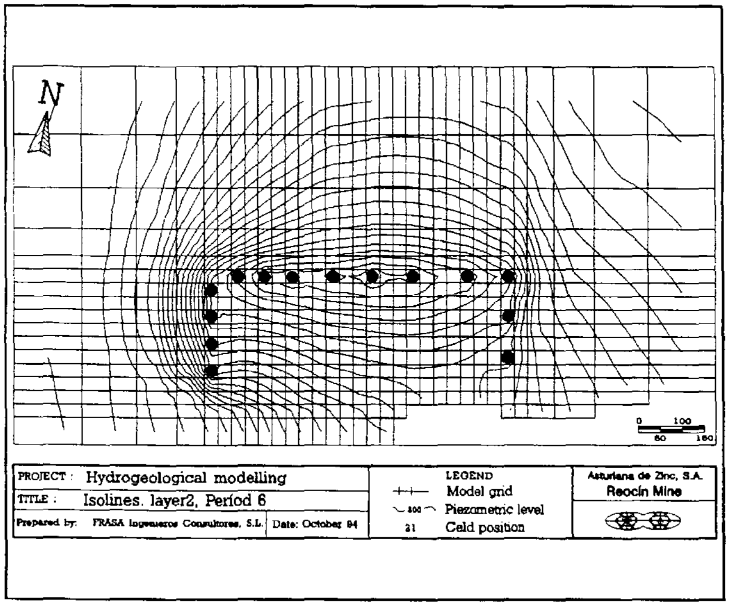

Figure 4. MODFLOW drainage interpretation (FRASA, 1994).

CAPAO XAVIER OPEN PIT MINE, BRAZIL

An Example of New Mining and Urban Water Supply

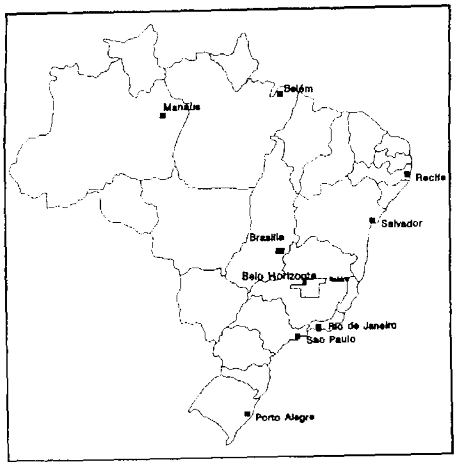

Figure 5. Quadrilatero ferrifero locatión.

The Quadrilatero Ferrífero of Minas Gerais, Brazil, is one of the most important iron ore district in the world. Because of this mining companies operating in the area have already acquired an enormous experience in mining facets, the respect in concerns of industry, the economy and the community.

Mineraçoes Brasileiras Reunidas (MBR) planned to begin the Capao Xavier open pit mine located in the area where COPASA, the Minas Gerais water supply body, have some important catchment for supply with fresh water foir the populated city of Belo Horizonte. Based on the geological information provided by the MBR mining company, the hydrological background collected during many years by COPASA, and many different studies conducted by FRASA Consulting Engineers, it was possible to evaluate hydrogeological conditions, planning mine water drainage to allow mining operations while providing fresh water for urban supply during mining operation and also, designing mine closure bearing in mind technical and environmental aspects.

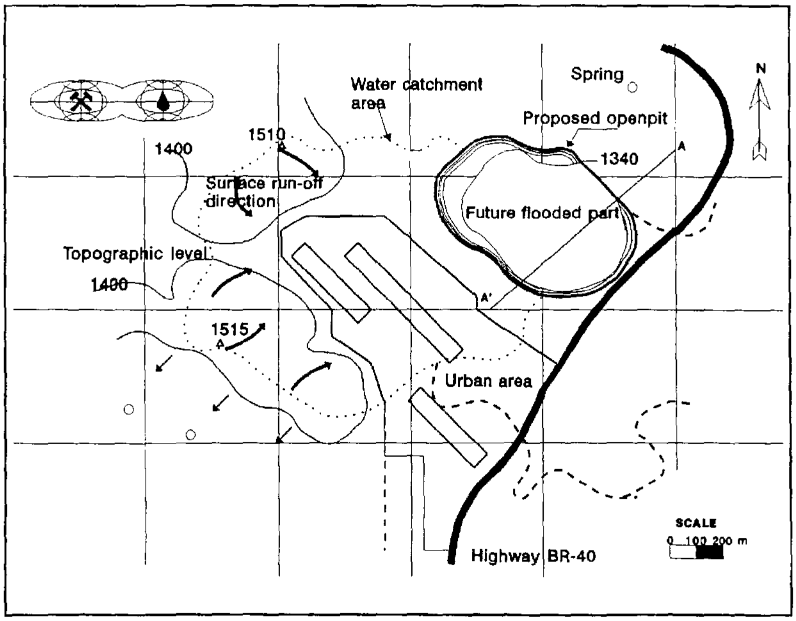

Figure 6. *Schematic drawing of Capao Xavier Mine surface hydrological behaviour (FRASA, 1995).*

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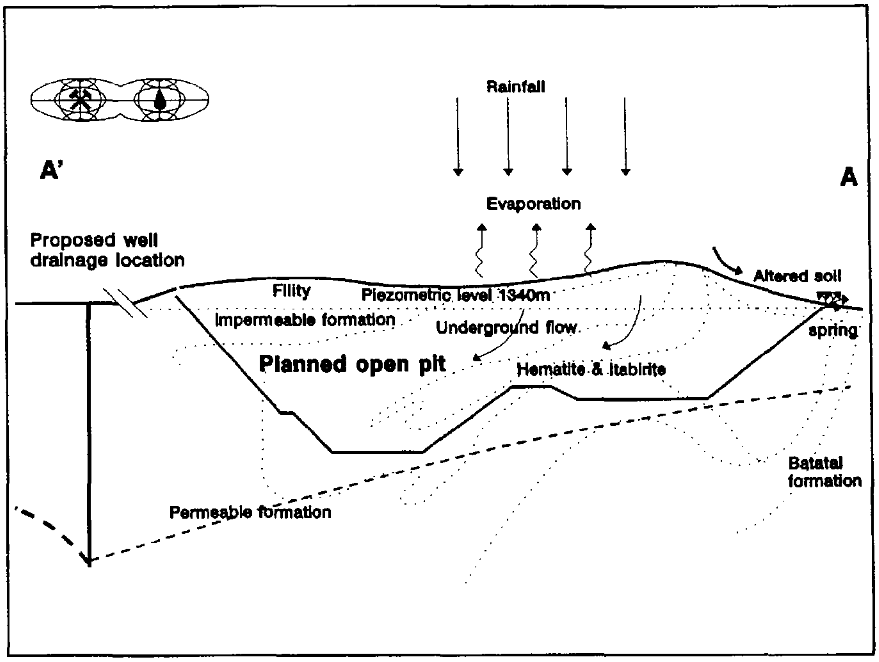

Figure 7. *Schematic transversal geological cross section and proposed drainage system (FRASA, 1995).*

The water table at Capao Xavier mine is located approximately at the level of 1340 m. To guarantee mining conditions, a previous drainage of ground water will be required. On the base of the local hydrogeological condition, advanced drainage prior to excavating open mine level benches, below the water table, would be the best approach.

The presence of water in the bottom of the pit can come from heavy precipitation, from water infiltration through the permeable overburden *(canga)* and, eventually, from surface run-off. In order to dewater such water accumulated on the botton of the pit, it would be necessary to implement an infiltration basin, and eventually a floating pumping station. These dewatering systems are fully considered in the design practices of mine planning, since the earliest stages.

To establish a sustainable solutions, as there will be loss of spring yield that provide water supplies for Belo Horizonte town, due to water table depression during mining activities, the huge amount of water planned to be pumped in advance dewatering wells could be discharged into the water canals for urban supply.

This pumped water will not present any quality problems, because it is the same flowing from the natural spring. In this condition the advance mine dewatering practice will not affected the Belo Horizonte water supply mainly thanks to the very low grade reactivity of the rock with water.

However, as the employ of such water drainage is planned, mining activities and facility installations must be designed in order to prevent any kind of water contamination.

After mining it is usually uneconomical to fill the pits worked out, even if material is locally available. Capao Xavier Project plans to excavate a tunnel to transfer barren material out of mined area to back fill Tamanduá Mine, a near open pit near to finish of its mine life. So Capao Xavier Mine will ultimately form a lake, exposing its water to climatological excess of evaporation over precipitation. The behaviour of such lake will depend upon its water and salt balance. If evaporation is higher that rainfall this would provide a high potential for rapid salinity increase in exposed water bodie.

Analysis of meteorological and hydrogeological data shows that the lake will be a recharge point of the karstified aquifer, where the water quality will be maintained throught the yearly rainfall, providing water to the aquifer discharge through the periferical spring. At the same time this lake will be very interesting place to preserve and to observe the aquatic birds near to Belo Horizonte.

In conclusion, MBR as mining operator, and COPASA as water supplier, with the advisory of FRASA as consulting firm, have designed a project in which the environmental protection, together with the mining exploitation and the water supply constraints are compatible.

CONCLUSIONS

It is important not only to reduce the impact of any kind of water on mining, which is often of major concern, but also it is necessary to implement the best technologies to prevent mine-water problems in advance, and to provide the possibility to apply the drainage water to provide the water requirement in the area, with the appropriate quality standard.

In this way it is possible to combat the water presence, and at the same time to take benefit of the drainage water, preserving the environment. Such attitude can reduce, in many cases, the cost of mine dewatering. In conclusion, proper water management is essential in order to protect the sensitive natural balance of the environment *(Netchaef, 1988)*.

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