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SURFACE WATER INFLOW REDUCTION AT THE UNDERGROUND NEVES-CORVO MINE, PORTUGAL

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PLANNING

From the very beginning of the hydrogeological studies carried out at the Neves Corvo Copper/Tin underground mine, emphasis was given to detection of the origin of the mine water and its inflow. Given this objective, a continuous monitoring programme was established to determine spatial distribution of both surface and groundwater with time. This study was aimed at controlling the hydro-chemistry including the determination of minor ions, water temperature and tritium parameters of ground water.

It was demonstrated, that in contrast to previous studies, a significant part of the mine water inflow was due to direct infiltration from the Oeiras River, through sub-vertical faults intersecting the ore deposit covered by the alluvium terrace.

After piezometer and flow monitoring studies, it was confirmed that water was seeping from the river into the mine. As a result, a decision was taken to discharge the pumped mine water downstream side of the mine to avoid re-infiltration. Given such conditions, it was fundamental to define the hydrological characteristics of the Oeiras River and to locate the possible permeable faults.

HYDROLOGICAL CHARACTERIZATION OF OEIRAS RIVER

The decision to reduce the mine water inflow required a good understanding of the hydrological behaviour of the river, especially its maximum flows and the losses produced during its passage over the mine. There was no historical data of the river flows in the upstream basin, so they were extrapolated from data from an existing hydrometric station downstream of the mine. These real measures of flows were treated, correlated and compared to theoretical flows, based on rainfall data, using empirical methods.

Due to the diversity of empirical formula obtained on distinct experimental river basins, one was selected which gave the best fitting results, adjusted for the real time data of the 475.5 km^2 basin area of the existing hydrometric station. The formula was then used to estimate the equivalent flows, over the 131.4 km^2 upstream basin to the mine. According to these results, the Oeiras River can reach at the mine site a maximum average daily flow of 146 m^3/s, a most probable flow of 67 m^3/s, and a maximum instantaneous flow of 221 m^3/s.This data must be cautiously used, since the records do not go back far enough to be representative and there is a certain altimetric difference between the total and the partial basin. Somincor has installed a set of hydrometric stations, to measure river flows and the possible losses of water down to the mine (Figure 1).

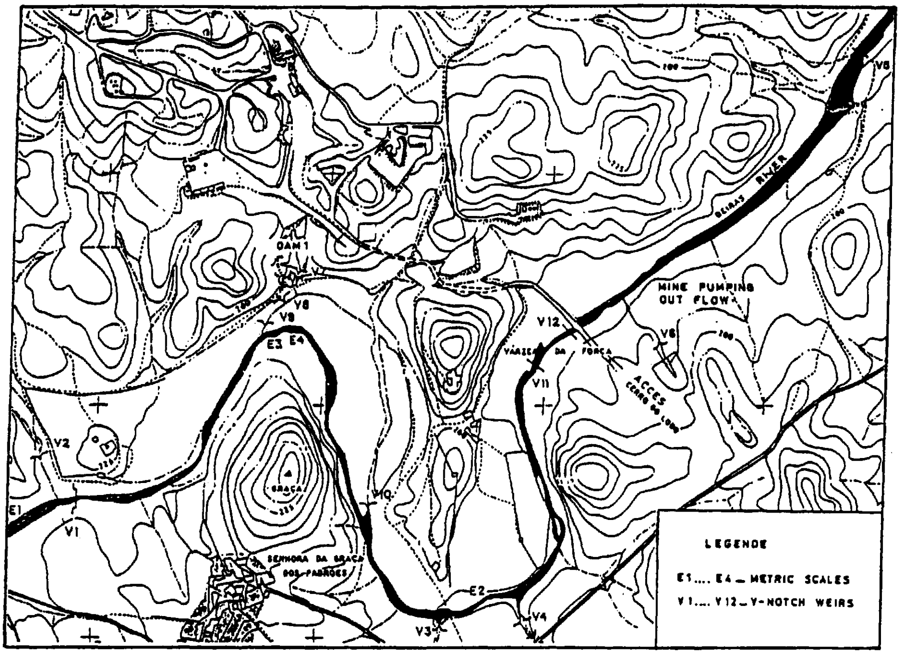

Figure 1. Hydrometric control stations, installed by Somincor on the Oeiras River.

These stations are on the Oeiras River itself, both upstream and downstream side of the area of influence of the mine, and the main tributaries within it. The hydrological balance of the water flow arriving and leaving the mine area, including pumping from the mine, and industrial and domestic water discharged into the Oeiras River, allowed accurate infiltration estimates to be recorded.

OEIRAS RIVER INTERSECTING FAULTS STUDIES

The geological map of the area (Figure 2), shows the occurrence of the faults, mainly with N-S trend, covered by the alluvium terrace at the Oeiras River intersection sector. These faults, confirmed by evaluation drilling and mine development works (Figure 3), seemed to be privileged circulation paths, as revealed in early FRASA studies and reports.

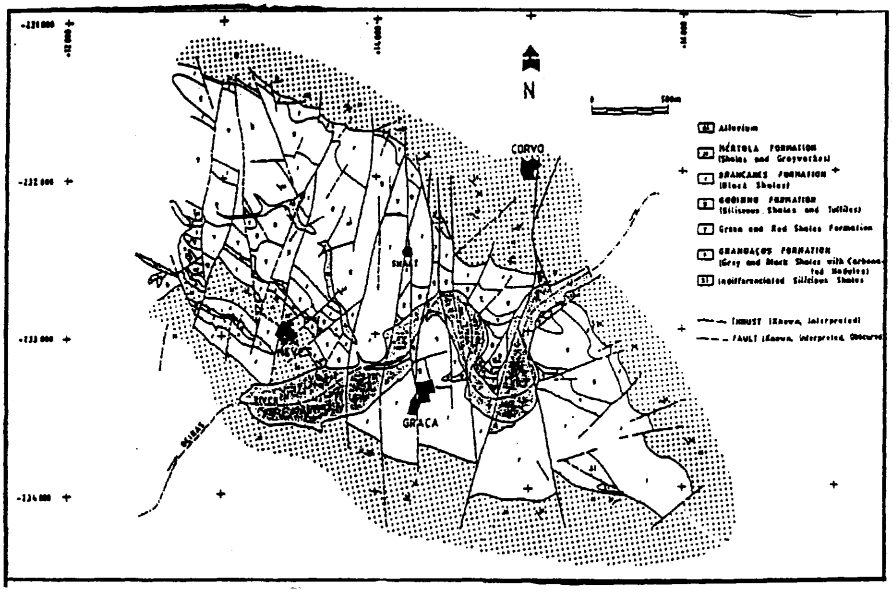

Figure 2. General geological map of Neves-Corvo mine area

To locate these faults, the resistivity rectangle method was applied at 30 meters spacing profiles in E-W sections. A 450 m emission line and potential electrodes equidistance of 5 meters, were also used.

The application of electrical methods are based on the resistivity contrast between the faults and the metasediment and metavolcanic rocks, due to fracturing and weathering. The results of this research can be seen in the resistivity map (Figure 4), including the fault interpretation (uncertain lineaments also represented could correspond to clayey weathering). These results confirmed the main N-S trend fault system (faults subparallel to the sections could have been missed).

A second geophysical research was also applied, namely the refraction seismic method. This used 30 meters spacing profiles oriented at N60°E, each one covered by 6 meters geophones over 72 meters. In each line there was seven shots from which two were external and five internal.

Figure 3. Main faults observed by the Oeiras River alluvium, interpreted after geological mapping and mine workings

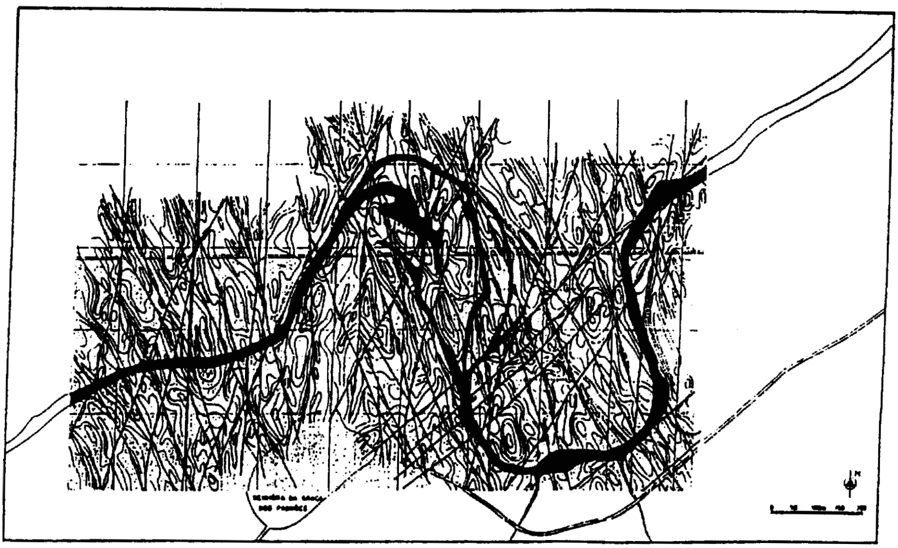

Figure 4. Fault locations intersecting the Oeiras River, after electrical geophysics by Nunes de Sousa (1987).

This method is based on a smaller wave propagation velocity in tectonic settings, due to fracturing and weathering of this environment.

Final interpretation has created a bedrock topographic map (Figure 5) where N-S treading depressions were related to faults. In the same study attention was given to other depressions, relatively deep and large, which were interpreted as probably associated to palaeochannels of the Oeiras River.

Figure 5. Faults location intersecting the Oeiras River, after seismic geophysics by Nunes de Sousa (1989).

In conclusion, it must be said, that the geophysical investigation carried out, confirmed the existence of a large number of faults, mainly oriented N-S, which intersect the Oeiras River, and are covered by the alluvial terrace. Although some of them would be uncertain or non penetrative, most of them are good water feeders to the mine. In view of the conclusions reached by these studies, it was necessary to establish a strategy to prevent the access of surface water into the mine, which might increase the future inflow either due to a progressive reopening of fractures following water circulation, or mine developments below the river.

TREATMENT ALTERNATIVES

To reduce the mine water inflow via the Oeiras River, the following alternative approaches were studied:

- o to build a dam in the Oeiras River, upstream of the mine site and to deflect the dam water through a deviation channel,
- o to grout the sub-vertical faults, beneath the river bed and alluvium deposits, by drilling injection holes, and

- o to concrete the river bed.

The solution adopted was the last one. Notwithstanding, it is considered interesting to resume here the fundamental aspects of the various alternatives.

DAM AND DIVERSION CHANNEL

There are no engineering works in the Oeiras River for hydraulic regulation, so run-offs mainly associated with rainfall in its hydrological basin, shows large flow variations, practically from zero during summer, to maximum estimated flows of 220 m^3/s during heavy rain periods. The reason why this alternative approach, to build an upstream dam, was put forward was to allow regular discharge flow in the diversion channel.

A morphologically and geologically appropriate setting existed about 3 km from the mine (Figure 6), where a 32 meters high dam with a capacity of 35X106 m^3 could be built, allowing the complete regularization of the Oeiras River run-off, estimated at an average between 22 to 37X106 m^3 annually. This dam would smooth the overflow during the rainy seasons, draining them in a regular manner through the diversion channel. This channel, 3000 metres long and located at the 225 metre elevation on the right margin, with a capacity of 1 200 l/s, would reach the Oeiras River downstream of the mine site, reducing infiltration in this sector. Other advantages of the dam would be its use for irrigation, public and industrial purposes, as well as recreational, or even maintenance of an ecological flow in the river. The construction of this infrastructure was beyond the scope of Somincor,s activities..

SUBVERTICAL FAULTS GROUTING

The second possibility to reduce water inflow into the mine, would consist of impermeabilization of the subvertical faults, below the river bed, using drilled injection holes. The work to be done would consist of fans of inclined holes, allowing five or six intersection points in each fault. Each borehole would be approximately 50 metres long and would then be injected with an impervious clayey based mixture according to techniques developed by STG in Ukraine.

In this approach the injection technique would present the following restrictions:

- o due to the existence of numerous faults, highlighted by the geophysical investigation studies, and covered by the alluvium, it would be necessary to drill a large number of holes with the risk of missing parts of faults which would then not be grouted, and
- o it would be difficult, complex and costly, to locate and treat those sections, if ineffective impermeabilization were to be found afterwards.

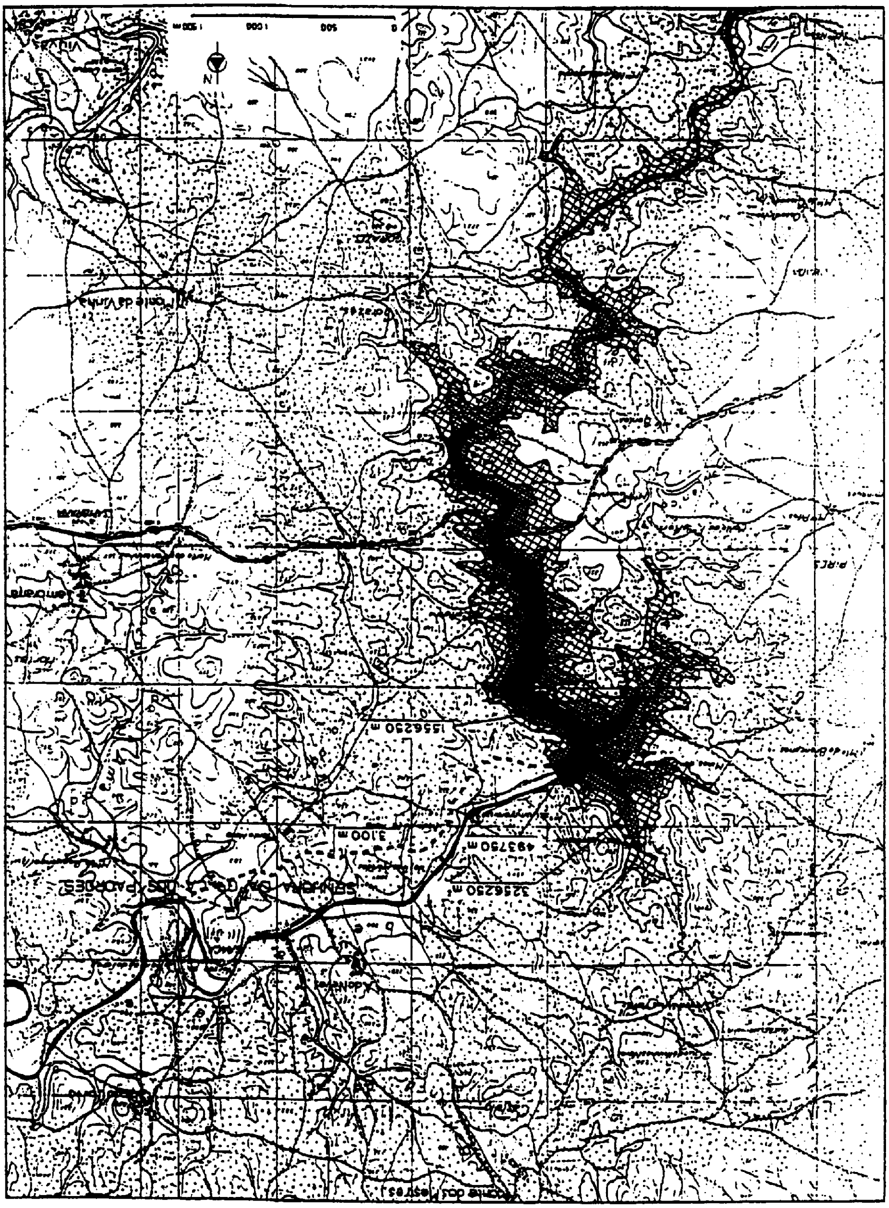

Figure 6. Dam and deviation channel project in the Oeiras River.

REGULARIZATION AND CONCRETING OF THE OEIRAS RIVER

After studying the two former options, they were abandoned and the third one was adopted and later implemented, as follows:

- o to regularize the river section at an average 6 metres width, eliminating meanders, and cleaning all the floor for vegetal matter, sand, gravel and boulders, until bedrock was reached, where possible,
- o to concrete the new river bed and margins with concrete, steel mesh and anchorages (Figure 7).

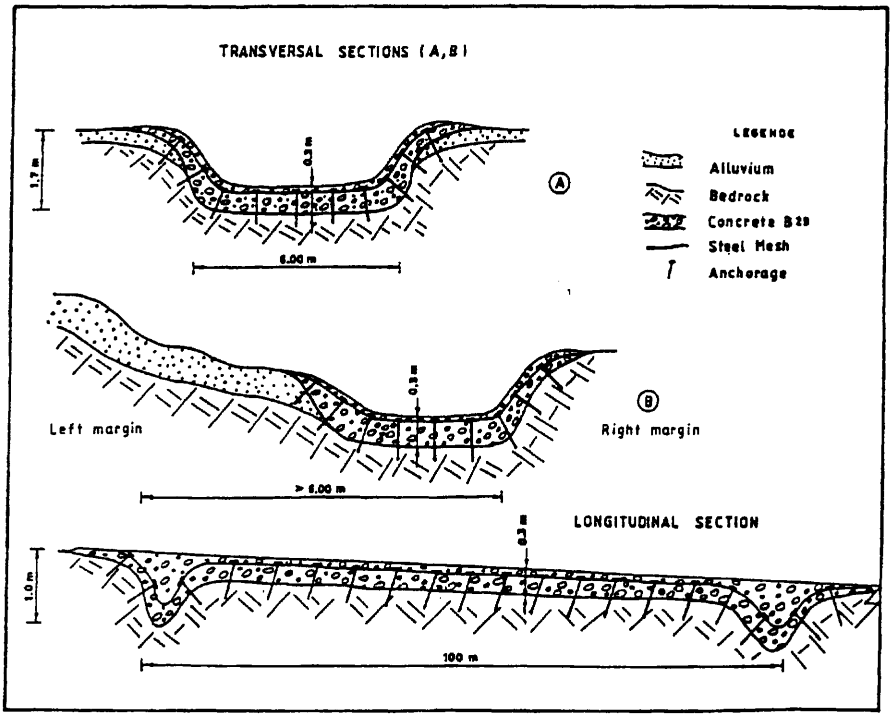

Figure 7. Schematic concrete works of the Oeiras River.

This work was done in phases, over two years, restricted to the dry seasons when there was no water flow.

This regularization and channelling of the river has been proved efficient, reducing quite significantly the mine water inflow. Today the existing pumping facilities installed underground have a capacity four times higher than needed, reflecting the improvement from the serious water problems at the beginning of mining operations, to the controlled condition existing today.

Water gains and losses of the Oeiras River in the mining area (Figure 8) are depicted for the summer period of 1989, during which the concreting works were underway. In this figure the transition can be seen between losing conditions prior to grouting works, to the stage where gaining conditions encountered due to mine pumping discharge.

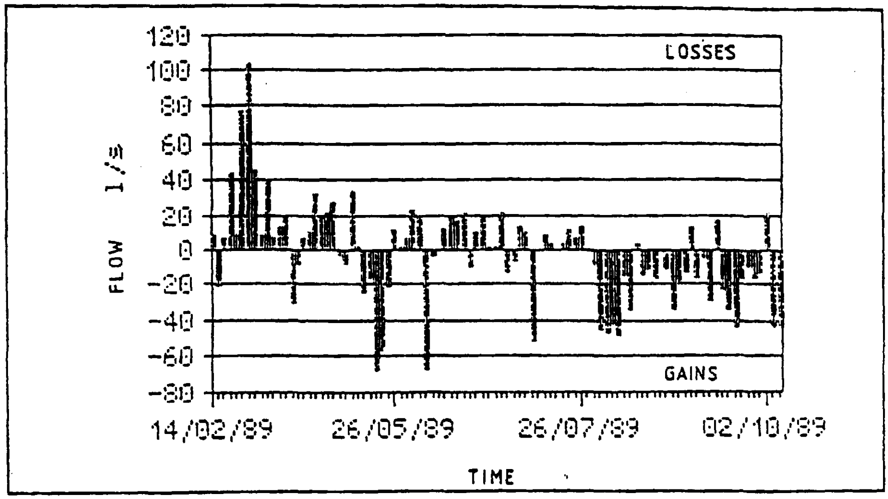

Figure 8. Losses and gains of water in the Oeiras River, during its passage over the mine.

The difference between the two conditions during the dry season was estimated at 70 to 80 l/s, which could be much larger during the rainy periods, when run-off in the Oeiras River is very intense.

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