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Use of covers for reducing the water demand in heap leach pads located in dry weather

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Abstract

Usually in wet weather, covers (raincoats) placed over the heap surface are used with the objective of reducing the rainwater inlet into the heap leach pad, and consequently reducing the solution dilution and the surplus contaminated water with solution which requires recirculation or treatment before discharging into the environment. However, the potential use of those covers presented in this paper, although non usual, in heap leach pads located in dry weather is with the objective of avoiding the evaporation of the heap surface and along with this, reducing the fresh water demand.

This paper presents a water balance case study of a heap leach pad project located in the south of Peru at an elevation varying from 4,000 to 4,700 meters, characterized by a desertic and cool weather, with little precipitation and prevalence of evaporation along the year, where the optimization of the fresh water demand is needed. A water balance was performed for evaluating the inlet flows corresponding to the precipitation over the leach pad lined area, incorporating high residual moisture of clayey ore and considering fresh water for reposition. In the other hand, the outlet flows consist of evaporation in the ore exposed area and in the ponds, considering no discharge into the environment.

In order to reduce evaporation and therefore reduce fresh water demand during the operation of the leach pad, scenarios with HDPE geomembrane cover over the heap surface in the active areas under leaching, were analyzed. Results indicate that although the scenarios analyzed do not satisfy totally the hydric availability, the use of a cover system in 100% on the active area requires just a small increase of the water availability compared with the scenario with no cover system, which could be satisfy with minor effort over the required period.

Hydrology

The hydrological information consists of estimates series of precipitation for the dry, average and wet years whose values were used in the water balance model. The monthly precipitation presents two periods well differentiated, in the wet season (December to March) it precipitates the 92% of the annual precipitation and the remainder occurs in the dry season (April to November). The Table 1 shows a summary of the behavior of the total monthly precipitation for the dry, average and wet years of the project area.

Table 1: Total monthly precipitation (mm) - Project area

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dry	5.6	2.7	4.4	0.1	0.2	0.3	0.1	0.1	0.0	0.3	0.6	2.6
Average	56.2	50.7	27.9	3.6	1.2	1.7	1.7	2.3	0.8	2.9	3.2	17.3
Wet	203.0	228.6	97.0	8.6	0.9	0.7	1.1	7.9	2.4	2.5	3.4	36.5

On the other hand, the evaporation and the total actual annual evaporation of the project area are 1,922 mm and 1,390 mm, respectively, as show in the Tables 2 and 3.

Table 2: Total monthly evaporation (mm) - Project area

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	163	170	168	167	168	164	161	155	158	150	148	150

Table 3: Total actual monthly evaporation (mm) - Project area

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
average	132	112	117	105	95	93	100	116	116	136	142	140

Based on the hydrological information is deduced that the project area is located in a dry weather, because of the annual average precipitation do not exceeds to the average annual precipitation, whose value is equal to 169.5 mm and 1,922 mm according. Figure 1 shows a comparison between the precipitation, evaporation and the actual average monthly evaporation, evidencing the high rates of evaporation existing in the project area. This fact coupled with the limited availability of water in the project area, forced to make efforts to reduce the water demand of the heap leach pad, which is the installation that generates the highest consumption in the mine.

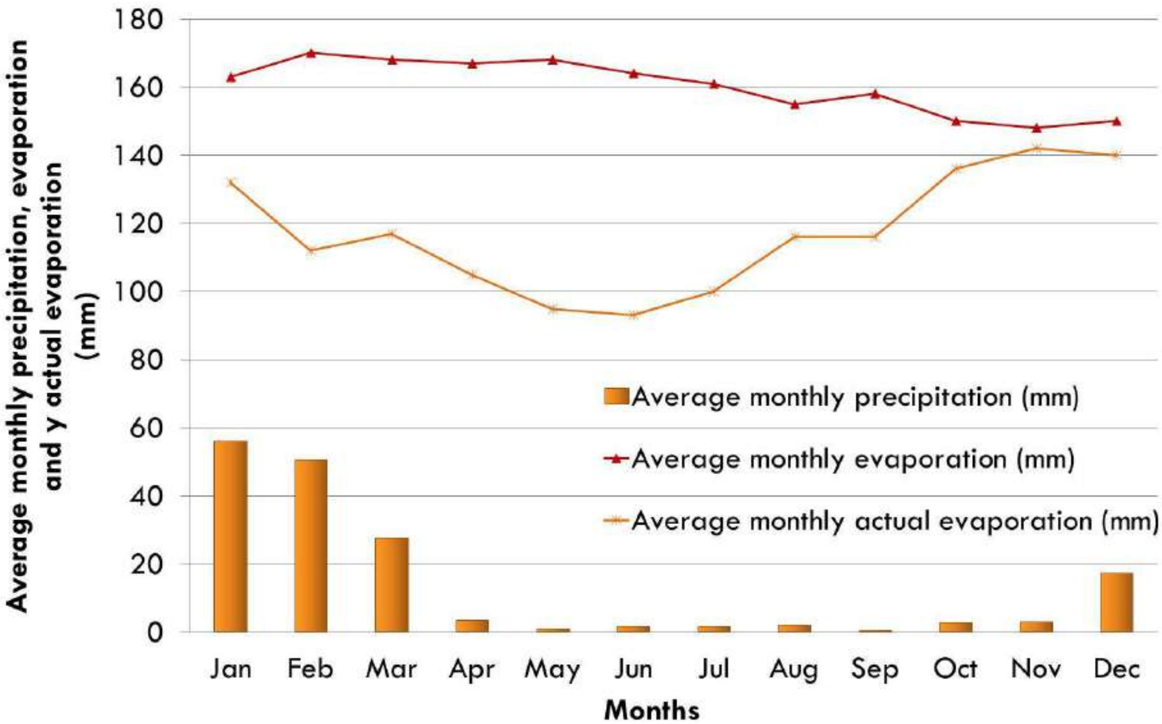

Figure 1: Average monthly precipitation, evaporation and actual evaporation in the project area

Water balance

Description of the water balance model

The purpose of the water balance is to verify the operation of the heap leach pad and its interconnection with the operation ponds, (pregnant leach solution pond “PLS pond” and storm water pond “SW pond”), in addition to define the areas to be covered in order to reduce the water demand. The water balance model was developed considering the water inflow and outflow from all the mining operation, however, it should be noted that the higher demands correspond to the heap leach pad operation. The water balance was performed by using the GoldSim software, which is based on the following formulation:

$$\text{Inflow - Outflow = Changes in the storage capacity}$$

The inflow correspond to the precipitation that falls on the leach pad area (from the active areas under leaching and inactive areas), operation pond areas, drainage areas, and the ore natural moisture. The outflows correspond to the evaporation in the leach pad (from the active areas under leaching and inactive areas with no irrigation), the evaporation in the operation ponds, the ore residual moisture and the demands from different mining components (human and industrial consumption, laboratory, dust suppression, etc.).

Changes in the storage capacity are associated with changes on the moisture content stored in the ore voids and the fluctuation of the water level in the ponds. The recirculation flow between the operation ponds (PLS and SW) and the leaching area, are considered to be internal flows (it does not generate inflow and outflow of the system). In addition, according to the leach pad operation, the water balance considers the lined areas on the inside of the leach pad entering to the system and areas not lined of contribution that are derived by the existing drainage system. Figure 2 shows the water balance simulation layout of the heap leach pad.

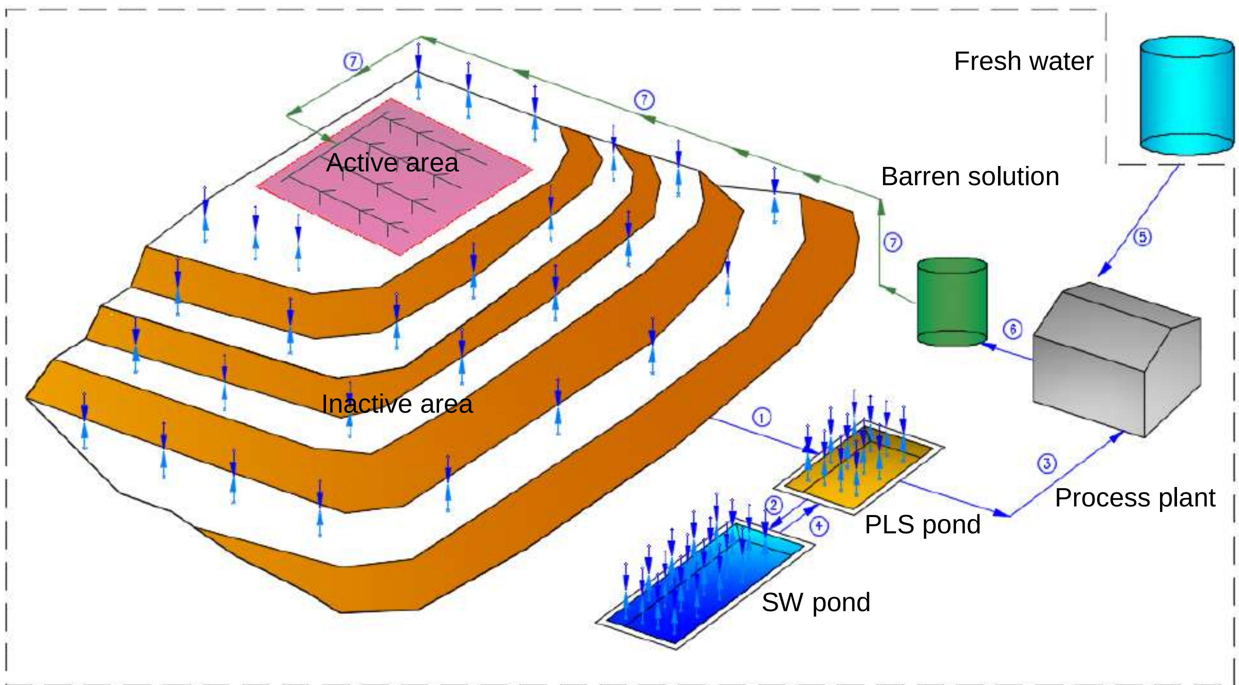

Figure 2: Water balance simulation layout of the heap leach pad

Parameters and simulation criteria

The water balance model depends on the planned ore production plan, stacking plan, ore properties (moisture characteristics, density and leaching cycle), irrigation type, rainfall, evaporation, size of the operation ponds and the initial storage in them. As the water balance is based on the conditions of the plant operation, the results to be obtained are directly dependent on the operating parameters entered into the model, therefore, they are susceptible to changes, so in general, this model must be dynamic and periodically updated by the mining operation. Table 4 shows the parameters used for the water balance simulation.

Table 4: Parameters used for the water balance simulation

Description	Unit	Criterion
Ore reserves (2018-2023)	Mt	43.29
Capacity of the leach pad (design)	Mt	50
2D projected area of the leach pad	ha	133
Daily production rate	t/day	21,000
Period of leach pad operation	years	5.5
fractured ROM ore density	t/m^3	1.58
Nominal application rate	$l/h/m^2$	10
Maximum application rate (design)	$l/h/m^2$	11
Maximum pumping rate	m3/h	1,060
Irrigation method	aspersion / dripping	goteo
Breakdown duration, free draindown time	hours	24
Typical height of the stacked lift	m	8
Leaching cycle	días	60
PLS pond capacity	m^3	45,000
SW pond capacity	m^3	100,000
2D total pond area (PLS+SW)	ha	3.2
Ore natural moisture - Wet season	%	3.05
Ore natural moisture - Dry season	%	2.35
Ore residual moisture (Pit 1 + Pit 2)	%	6.82
Ore residual moisture (Pit 2 since 2022 to 2023)	%	5.6
Pond evaporation factor	-	0.75
Leaching area evaporation factor	-	1.10
No leached area evaporation factor	-	0.15
Dripping system evaporation losses	%	0.0
Volume at the beginning of the simulation	m^3	5,000
Minimum operation volume	m^3	5,000
Use of cover on ore surface (type blanket)	Yes/No	Yes
Month of start of the simulation	-	Jul 2018
Month of the end of the simulation	-	December 2023
Annual total precipitation (dry year, 100-year return period)	mm	17.0
Annual total precipitation (average year)	mm	169.5
Annual total precipitation (wet year, 100-year return period)	mm	592.5
Maximum precipitation (100-year return period)	mm	27.1
Water demand for other areas of the mine	l/s	3.35
Water demand for projects	l/s	1.2 a 1.75
Cover efficiency on the pad	%	80

Scenarios of simulation

According to the operating parameters listed in Table 4, the water balance simulation was conducted, whose target is to confirm the water demands of the heap leach pad, which compromise the reposition water needs of the mine, and to compare it with the limited water availability of this mining operation located in a dry weather.

In order to have alternatives of water demands optimization in the heap leach pad operation and therefore satisfy the mine water requirements, three simulation scenarios were analyzed which are described below. Dry, wet, and average years were analyzed for each scenario.

- Scenario 1: It considers the parameters listed in Table 4 and does not consider the cover installation on the leach pad.
- Scenario 2: It takes as a basis the Scenario 1 and adds covers on the leach pad surface, consisting in a 1 mm HDPE 1 smooth geomembrane, with an efficiency of 80%. A cover system will be installed to reduce water losses by evaporation on active areas under leaching of the leach pad and therefore, optimize the fresh water demands. 50% of the active area of the leach pad is considered to be covered.
- Scenario 3: The Scenario 2 is taken as a basis, but increasing the active area to be covered up to 100%, using the same type of cover and taking all the considerations explained above.

Residual moisture of the ore

Since 2018 to 2021, the ore from the existing open pit stacked in the initial phases of the heap leach pad, will be mixed with a clayey ore from a new open pit in a ratio of 3 to 1. The clayey ore will reduce the residual moisture from 8.7% to 6.82%, which means that in the above-mentioned period the mixed ore will retain more water, which will favorably affect the water balance results, reducing significantly the demand for reposition fresh water by 23% approximately.

Water balance results

Since the construction and operation of the leach pad will performed by phases, water balance results will vary with the increase of the leach pad extension until the ultimate configuration. These results indicate a negative balance water along the operation period for a dry year condition, which implies the need of permanent fresh water to the system, while the water balance results for the wet and average years provide in some cases positive values.

Reposition fresh water demand

The requirement of reposition fresh water demand to operate properly the heap leach pad is maximum in the dry season and minimum in wet season. The greater water demand occurs in years with minimal precipitation, which means that the amount of captured water by the leach pad is not enough to sustain operations during the dry season. Table 5 shows the results of reposition fresh water demand along the operational life of the heap leach pad.

Table 5: Overview of the reposition fresh water discharges for the mine (l/s)

Scenario	Condition	2018	2019	2020	2021	2022	2022
1	Dry year	19.2	20.1	20.4	18.2	15.9	13.2
	Average year	18.3	16.1	16.4	14.0	11.5	8.9
	Wet year	17.6	12.6	12.9	10.9	9.2	7.3
2	Dry year	16.8	17.7	18.0	15.8	13.6	10.9
	Average year	15.9	13.8	14.1	11.7	9.2	6.7
	Wet year	14.7	10.6	10.9	9.0	7.3	5.6
3	Dry year	14.3	15.4	15.7	13.5	11.2	8.5
	Average year	13.4	11.5	11.8	9.4	6.9	4.5
	Wet year	12.2	8.9	9.2	7.5	5.9	4.2

Purge water discharge

In general, in all heap leach pad the purge water discharge of the pad-pond system progressively increases with the increase of the stacked ore area (active and inactive areas). This occur as long as the capacity of the PLS and SW ponds allows it along the time.

Since the PLS pond (45,000 m^3) and the SW pond (100,000 m^3) have the capacity to maintain flows of water discharge during the rainy season within the pad-ponds system, these purge water discharge will be controlled by the SW pond during the operation of the heap leach pad. Therefore there will not be discharges outside the ponds and the mine does not need a water treatment plant. Table 6 shows the results of the purge water discharge of the pad-pond system that will be controlled by the SW pond.

Table 6: Overview of the water purge discharges for the mine (l/s)

Scenario	Condition	2018	2019	2020	2021	2022	2022
1	Dry year	0.0	0.0	0.0	0.0	0.0	0.0
	Average year	0.0	0.0	0.0	0.0	0.0	0.0
	Wet year	0.0	52.3	50.2	56.6	72.4	79.2
2	Dry year	0.0	0.0	0.0	0.0	0.0	0.0
	Average year	0.0	0.0	0.0	0.0	0.0	0.0
	Wet year	0.0	74.6	71.1	78.8	94.7	101.4
3	Dry year	0.0	0.0	0.0	0.0	0.0	0.0
	Average year	0.0	0.0	0.0	0.0	0.0	0.0
	Wet year	0.0	77.0	74.1	81.3	97.1	103.9

Hydric availability

In order to meet the water demands of the mine, a hydrogeological study for water supply was conducted for the project, an underground flow model for predicting the hydric availability was analyzed in the aquifers in the area, as the main source of water supply for the mine operations. According to this hydrogeological study, the water extraction wells can supply a constant flow of 13.5 l/s along the mine life.

Water demand versus hydric availability

According to the results of the water balance simulation and the results of the hydrogeological study, comparisons of the water demands versus hydric availability for the three scenarios were performed. Figures 3, 4 and 5 show the comparisons for the three scenarios analyzed, and for dry, average and wet years, respectively. Dry year shows in Figure 3, corresponds to the most critical condition. The following comments considering the most critical condition represented by the dry year condition are presented:

- For the Scenario 1, the water demand is not satisfied practically along the entire operation phase of the leach pad, the water demand is only satisfied since January 2023 to December 2023, i.e, the last year of the mine life.
- For the Scenario 2, the cover system up to 50% of the active area and considering 80% efficiency, the water demand is satisfied by the hydric availability since January 2022 to December 2023.
- For the Scenario 3, the cover system up to 100% of the active area, with 80% efficiency, the water demand is satisfied by the hydric availability from March 2021 to December 2023.

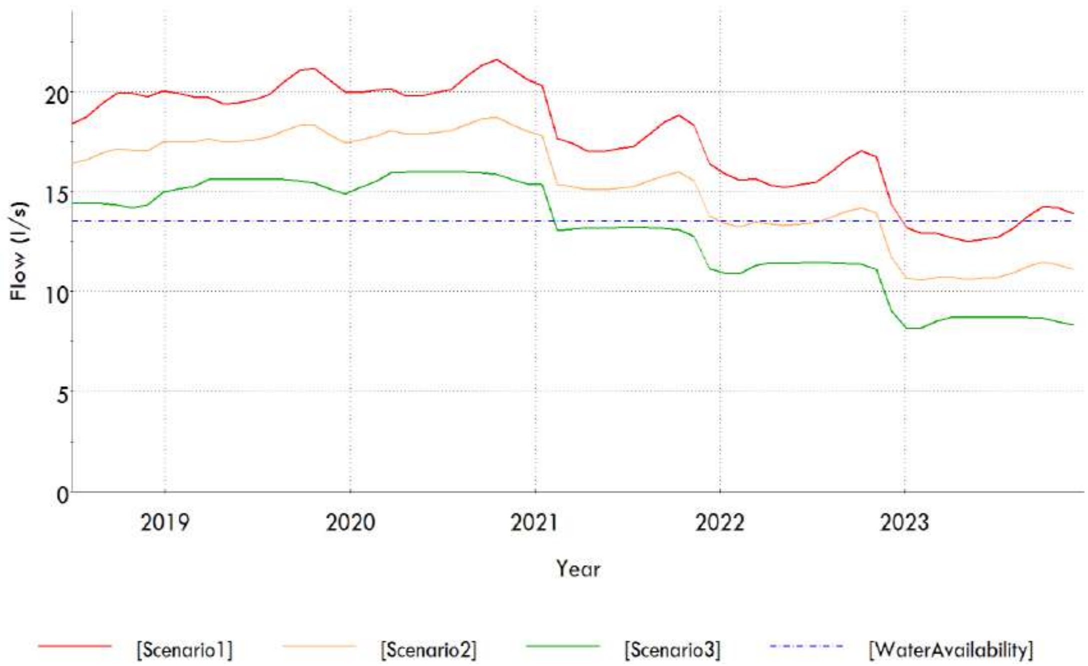

Figure 3: Comparison of water demand versus hydric availability for dry year

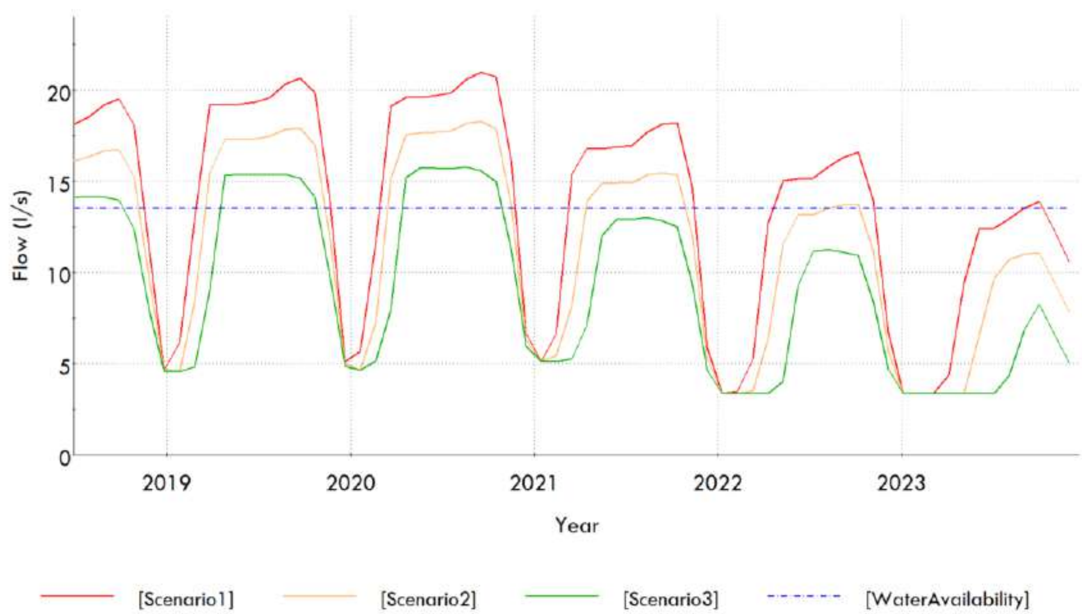

Figure 4: Comparison of water demand versus hydric availability for average year

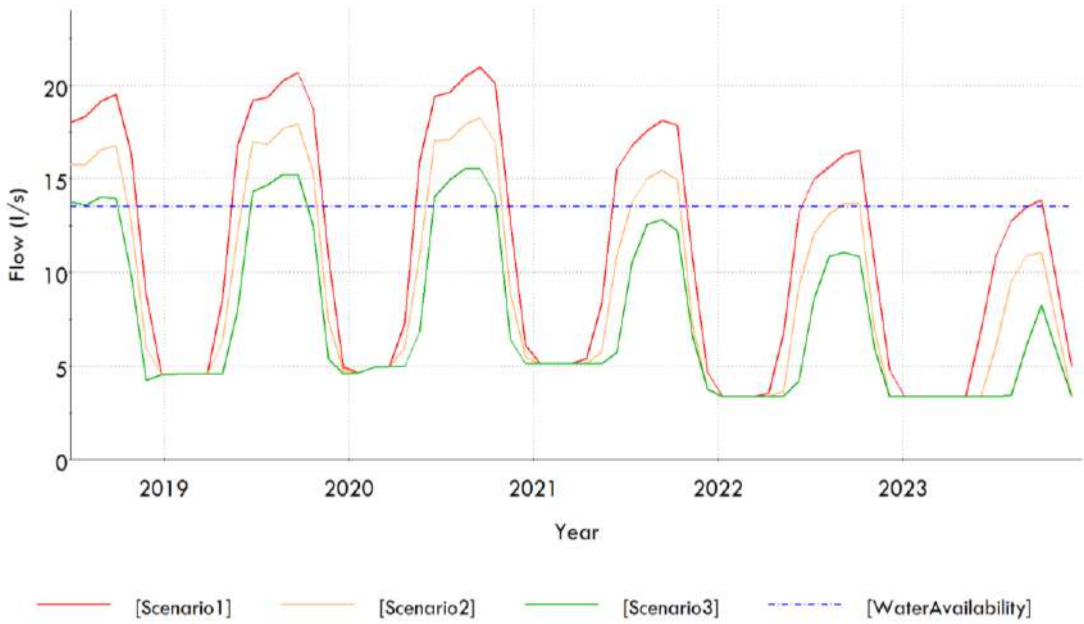

Figure 5: Comparison of water demand versus hydric availability for wet year

Conclusions

Usually in wet weather, a cover system installed over the heap surface is used for reducing the rainwater inlet into the heap leach pad. However, the potential use of those covers presented in this study in heap leach pads located in dry weather, is with the objective of avoiding the evaporation of the heap surface and along with this, reducing the fresh water demand.

The water balance of a leach pad located in a dry climate was analyzed under three scenarios. In the first scenario the use of a cover system over the ore heap surface was not considered, while the second and third scenario a cover system consisting of 1 mm HDPE smooth geomembrane were included. This cover system should be placed on the active areas under leaching of the heap leach pad. For the second and third scenarios, it was considered that the cover will extend 50% and 100% of the active area, respectively.

For the scenarios 1, 2 and 3 analyzed, the average values of fresh water demands for a dry year for the mine vary from 13.2 to 20.4 l/s, 10.9 to 18.0 l/s, 8.5 to 15.7 l/s, respectively. The average values of fresh water demands along the entire period of operation are equal to 17.8, 15.5 and 13.1 l/s, respectively.

From the comparison between the water demands for coverage equal to 100% of the active area versus the hydric availability current and future, this study can conclude that for the dry year condition, the water demand is not still satisfied during the leach pad operation phase since July 2018 to February 2021. For conditions of average and wet years, the water demand is satisfied in the wet months but is not satisfied since July 2018 to November 2020.

Based on the results of the three scenarios analyzed we conclude that, although none of them completely satisfy the mine water availability, the use of a cover system on the surface of the leach pad up to 100% of the active area, requires to increase the hydric availability from 13.5 l/s to only 16 l/s during 2018 to 2021 for the dry year condition, which can be achieved relatively easy looking for alternative sources of water supply close to the mine. This effort will be much larger and more expensive if a cover system is not used to reduce evaporation, in which case it is required to increase water availability to 20.5 l/s.

A schedule for the cover system installation should be developed with respect to the water demand over the life of the heap leach pad, which will allow an optimization of the operating cost of the cover system installation.

Ore residual moisture is a parameter which influence significantly in the results of the water balance of the leach pad, therefore, this parameter must be continuously monitored during the operation of this facility and the water balance updated on a regular basis in order to assess the change effects of this parameter, and any other that may affect this calculation.

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