Changes in Water Management during Heap Leach Lifetime in Heavy Rainfall Sites

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Abstract

During the last five years, heap leach pads operating in rainy environments in Peru have successfully faced heavy rainfalls, by applying technical solutions for temporary water management in the construction stage. Successes in these conditions have been due to creativity, and the immediate response and joint work of the engineering and construction teams.

Runoff management in heap leach pads may require changes during construction and operation for different reasons, including economic, topographic, operational, and geotechnical issues that were not anticipated during design, or due to drainage structures being urgently built close to the rainy season. These situations make it necessary to modify the projected water management, which can generate additional expenses and important changes to the whole project.

This paper aims to show a current experience of design adaptation during construction of a heap leach pad located in the Peruvian Andes, where each seasonal transition caused setbacks in both construction and operation of the heap leach pad, with heavy rainfall and runoff the major critical factors. To control these issues, a sequential water management system was adopted. This system works temporally for each rainy season, coupled to the raising of the heap leach pad and connected to permanent hydraulic structures to catch and divert runoff of the impacted valley. This temporary water management used check dams for sediments control, inlets, channels, culverts, energy dissipator ponds, outlets, all lined with either geomembrane or stone masonry, which are considered temporary liners that offer low cost and quick installation.

Based on our experience in these types of projects, we can conclude that the support of a consultant technical team during both construction and operational stages increases the probability of success. This is because this support enables immediate action and response to the unforeseen in stormwater management, avoiding delays in the construction schedule, reducing costs in drainage infrastructure and earthworks,

avoiding costs of emergency works and operational expenses, and avoiding other inconveniences that could impact heap leach pad operation and generate economic losses for the mining operation.

Introduction

Commercial production of the case study mine began in 2016 with a production of 12,000 tpd, increasing to 36,000 tpd in 2019. Permits and studies for construction were obtained in 2014. The mining project area is located in an eastern zone of the Andes. The leach heap pad is located between gorges 1 and 2, as shown in Figure 1.

Water management for the final footprint of the heap is made up of perimeter channels near the top of the hills, which descend through rapids and end in sedimentation ponds located at the toe of the heap leach pad, from where it is discharged into the natural streams.

Figure 1: Heap Leach pad location of the case study

Problem to be solved

In this case study the problem to be solved is how to prevent surface runoff from causing delays in the leach pad construction schedule and economic losses during operation. It must be taken into account that in some cases the detailed engineering studies of a leach pad do not consider the water management design of the scheduled raise year-by-year. Instead, they are based either on the ultimate configuration, or on phases intended to facilitate the approval of construction and environmental permits for the whole facility. In these cases, the water management solution is designed for the final or the next phase footprint, when the heap leach pad reaches its corresponding predicted capacity. However, it takes years before the heap reaches its predicted raise; meanwhile, the operator defines the raise annually, according to the operation schedule, or to ensure an area free of runoff for the construction of the next phase. Moreover, the planned designs for water management of the phases further away in the future are taken as a relative reference due to the changes that may occur, so intermediate channels at higher levels can be planned by the operator regardless of that future design, based on other criteria such as constructability advantages, or to avoid very steep alignments. It is not necessary to follow a planned edge that may be adjusted or modified.

In Peru, there is a dry season (from April to October) followed by a wet season (from November to March). According to data from the government meteorological agency (Senamhi), rainfall in the high Andean areas of Peru can be in the form of torrential rains in any year.

In the intermediate phases of the heap leach pad, if the water management design is not done correctly, flooding, erosion, and potential instabilities in components of the heap leach pad may be generated during the wet season. These may generate material losses and delays in the operation schedule of the facility, and consequently significant economic losses.

This case study concerns areas of future heap leach pad expansions upstream of the start platform, which are remote from the perimeter access of the heap that contains the permanent perimeter channel, and to which the temporary channels are to be connected.

Changes in water management of a heap leach pad

The leach pad in its final stage will contain about 140 Mt and will be divided into intermediate phases with an upstream raise. Consequently, it is necessary to review and adjust the performance of surface runoff management from year zero (initial works), through intermediate years and final year. The most common situations that present problems in water management during the development and operation of the heap leach pad, which must be addressed by the supervisors and construction team, are the following:

- During the preliminary works: clearing and grubbing, foundation excavation, underdrain, grading and installation of the liner system, as shown in Figures 2 and 3.

- During the intermediate phases: the same activities, plus removal of the previous phase perimeter berm.
- Complementary constructions such as accesses, platforms, and dikes.

The solution of these problems demands "fast-track" engineering studies to design and construct hydraulic works for water management. To ensure an adequate flow of information to achieve efficient engineering, the following elements must be in place: ongoing updates of hydrological information; knowledge of restrictions due to geotechnical conditions and limitations of permits (e.g. authorized water discharge sites); and timely, scheduled planning, including integration between specialists and mine reviewers.

Figure 2: Heap leach pad – preliminary works

Figure 3: Heap leach pad – start of operation

Update of hydrological criteria

An important aspect is the review of hydrological criteria, to improve accuracy and representativeness. The maximum rainfall frequency curve was revised, since in areas such as that of the case study, there is a relevant limitation: a scarce and widely separated network of meteorological stations with a short recording period. With the information from the station on the site (local station), for comparison, it was inferred that the rainfall on the site is higher than that reported in nearby stations, although without conclusive statistics on its magnitude. So, combined with the update of information from nearby stations, instead of the frequency curve, it was decided to use the upper limit of the confidence interval, the respective 95% quantile.

The design risk level of the temporary drainage works (channels and culverts) was determined from the risk level of the permanent perimeter channels (in the sense of the duration of the entire operation). According to the practices of the mining industry, in operations of between 10 to 20 years, the return period is estimated at 100 years, which is based on the consequences of the risks. For the temporary channels, a scale was devised according to their operating time, maintaining the level of hydrological risk of the permanent canals (approximately 18%). For the case study, a single scale of 10 years of return period was decided upon for the design of temporary channels, whose function is expected to be 2 to 3 years before they are covered by the raise and construction of the intermediate stages of the heap leach pad. Likewise, it was necessary to review and modify the perimeter channels for intermediate situations, in this case maintaining the 100-year standard, so that any interior overflow can be intercepted by the temporary channels.

Planning and integration between specialists and mine reviewers

For rapid design development there was a need to allocate a design engineer in the mine offices for an extended period, supported remotely by senior staff from the main office. The design engineer reported continuously and simultaneously to the director of the mine operator's planning and development office and worked in conjunction with the field data collection personnel; but had autonomous power to take design decisions. In this way, a rapid flow of information was achieved, including feedback based on direct observation of the performance of the work. This enabled design corrections and adjustments based on the most available construction alternatives, and in general a better alignment of the design with the restrictions of reality.

Recommendations

As a result of this and other experiences, for water management in a heap leach pad in general, it is recommended to consider the following:

- Request updated site information from the operator: topography, soil classification, geodynamic risks and as-built drawings, reflecting nearby structures and components, to identify restrictions for design and construction. This updated information should be coordinated with the design office to avoid overlaps or interference of plans, such as the construction of new accesses not being communicated.

- Develop an annual water management plan for the work zone, which consists mainly of temporary channels on the edge of the area, in order to divert flows to authorized watercourses without affecting other mining components.
- Evaluate the runoff contribution area that was not considered in the original designs for the temporary channels. Consider the area that is altered, and how it will be in the near future, to evaluate the production of runoff and infiltration.
- As always there will be a gap between what is designed and what occurs later. It is recommended to use a factor on the runoff area, which can be statistically evaluated by comparing the design assumptions with subsequent as-built drawings. However, while that statistical information is developed, based on experience, it is recommended to use a 20% contingency.
- The design should focus on the greater capture and conduction of flows generated by surface runoff through temporary channels with a wide section. The optimum hydraulic section to capture and conduct the flows is the trapezoidal one. Also, consider maintenance needs that require modifying the design and construction of wider sections than those required only by hydraulic conduction, so that cleaning can be carried out with light machinery, since maintenance done without machines does not provide the speed necessary for timely cleaning.
- The design slopes for the temporary channel must achieve the behaviour of flows with a subcritical regime ($Fr<1$) to avoid high velocities that require the construction of dissipation ponds, which is complicated by the limitations of the steep terrain.
- For the management and control of sediments, consider the construction of ponds located in different direction. The dead volume for sediments in the ponds must be at least 10% of their total capacity.
- It is recommended to use a temporary liner for channels and other drainage works, as these are easy to install and dismantle; this guarantees the protection and liberation of the work area. Smooth HDPE geomembrane can be used to form drainage works; but its use should be avoided in areas susceptible to continuous rockfalls from the cut slopes that impact the liner.
- Temporary water management must undergo constant repair and cleaning to prevent leaks and clogging of structures. Periodic inspection or after each rain event is recommended.
- Pay more attention to the areas that, due to soil conditions, can generate, under the activating effect of infiltrations, mass movements, cracks and displacements. It is recommended, among other measures, to identify them, increase the size of the runoff collection channels, and densify the drainage network in the area.

Conclusions

The construction of a heap leach pad in areas of intense rainfall entails updating the water management plan annually during the stages of execution and operation of the leach pad.

Surface runoff on leach pads causes flooding and instability of existing accesses due to the action of water flows, and infiltrations cause instability in the cut slopes, especially during the initial years of operation.

The impact of surface runoff can be reduced by the coordinated participation of the design engineer on-site with the planning and design of the mine operator to design and execute a water management plan in the shortest time possible.

This case study demonstrated that the cost of a temporary liner using a smooth 1.5 mm HDPE geomembrane for the water management system corresponds to 50% of the costs of a permanent liner, such as stone masonry.

The water management of a heap leach pad should be updated annually before the wet season and designed for each construction phase to avoid the issues presented in this summary. Most of the recommended actions described above can be applied for efficient water management control in a heap leach pad.