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Possibilities to Construct Combined Mine Waste Dump Facility with Better Operational Sequence

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Abstract: An integrated mine waste facility is designed for the Khan Krum deposit in Bulgaria (Eldridge, Wickland, Goldstone, & Kissiova, 2011). A substantial environmental benefit was achieved by designing such a facility because constructing a conventional tailings storage facility (TSF) would've needed much more surface area. However, the paper from (Eldridge, Wickland, Goldstone, & Kissiova, 2011), is mentioned that achieving a good operational sequence for constructing the facility would be a challenge. This paper evaluates how choosing the proper form for the combined mine waste dump facility (CMWDF) can help in having better control over the operational sequence. For comparison, two designs of CMWDF were designed. Each can accumulate the predicted amount of tailings the processing plant will produce. The first design has a broader construction body, and the other is narrower. It was decided like so because the broader body ensures more cells which means a better operational sequence can be achieved. Also, a conventional tailings facility was designed to compare the surface area and volume of waste rock needed for construction. All the designed Tailings Storage Facilities (TFS) require different surface areas and waste rock to be built.

Keywords: Tailings storage facility, Tailings deposition, Operational sequence

Introduction

The storage of tailings was always one of the major chalenges. There are many ways to store tailings, such as in lakes or in artificial structures such as tailings storage facilities. Tailings storage facilities are challenging to construct and operate. There are approximately 3500 TSF in the world, from which about 3 of them fail in a year (Lyu et al., 2019).

Besides the risk of failure, TSF needs a wide surface to construct, which means cutting local forests and, in some cases removing local fauna. To decrease the environmental impact and increase the factor of safety, Eldridge, Wickland, Goldstone and Kissiova, (2011) designed an Integrated Mine waste dump facility for the Khan Krum deposit in Bulgaria. In the previous paper the authors also said that the IMWF needs only 41 hectares of surface area compared to the 96 hectares required for conventional TSF and waste dump. With that also the need for tailings dam and post-closure of unconsolidated tailings deposit is eliminated (Eldridge et al., 2011).

Combined Mine Waste Dump Facility (CMWDF)

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The new facility for storing tailings and waste rock is based on a combined deposition method of waste mine materials (tailings and waste rock). This design has few significant advantages compared to conventional tailings storage methods. The benefits are that less surface area is required, a more significant factor of safety is achieved, the risk of pollution is minimized, lower costs for monitoring, etc. (Eldridge et al., 2011). Dewatered tailings is recommended to be stored. Thus, water from the dewatering process can be used, reducing the need for additional fresh water (Eldridge et al., 2013).

The combined mine waste dump facility is composed of waste rock and tailings. The tailings are stored in cells built from compacted waste rock. The facility in the Krumovgrad Gold project is built bench by bench, as the front wall of the bench is whole and well compacted with an intervening slope constructed at 2.5 horizontal to 1 vertical (Eldridge et al., 2011). The facility is designed with an underlying drainage system that's meant to drain the water from the tailings consolidation and the atmospheric water. A geomembrane layer is placed under the drainage system to prevent mixing the drainage water with the underground water. Cells are lined with heavy non-woven geotextile and a layer of sand, which will prevent mixing the tailings with the waste rock (Eldridge et al., 2011).

The above-described constructive parameters are from the Krumovgrad gold project Bulgaria for the integrated mine waste facility (IMWF), which is currently under construction by Dundee Precious Metals Krumovgrad EAD (Grigorova, 2011). The facility is constructed with an upstream design method (Eldridge et al., 2011). The tailings from the "Ada Tepe" mine are stored in the facility.

The main disadvantage is that while constructing the facility, an excellent operational sequence is needed, and if this is not the case, it can lead to interruption of the workflow or stop the work of the processing plant. For this not to happen in the Krumovgrad gold project in Bulgaria, Contingency storages are built so that the tailings will temporarily be stored in them when a cell is not ready to be filled (Eldridge et al., 2013). Other disadvantages are the high construction costs and the unavailability or difficulty to later extract the metal that was contained in the waste rock.

Comparison between Different Designs of CMWDF

For comparison, 2 CMWDF are designed. The goal is to store 5.9 milion m^3 of tailings, and the volume of waste rock varies.

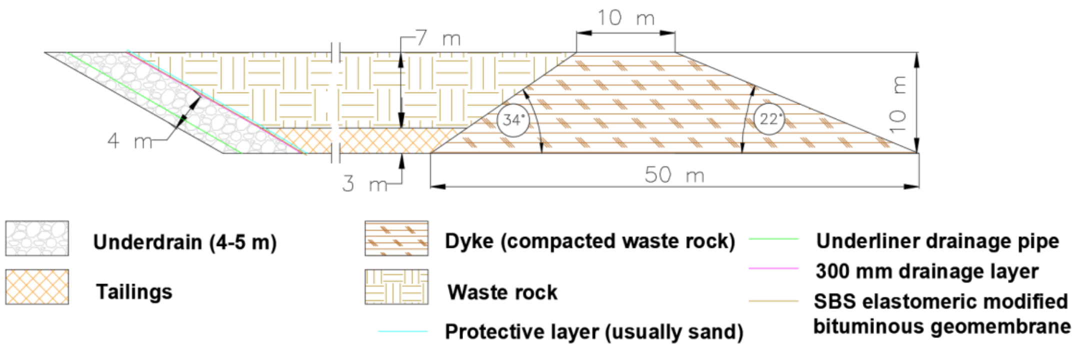

Figure 1. Profile of a single bench with its construction elements (Dimitrov, 2021)

Design 1

Design 1 is started lower in the valley, and its finishing form ends in both ravines (Figure 2). To store 5.9 million m^3 of tailings, 23 million m^3 of waste rock must be used. The height of the tailings is chosen to be 3 m (30% of the bench height). The rest was calculated as waste rock. The total surface area needed for the facility to be built in this way was 628 daa. The area that can be reclaimed and used for different purposes is about 340 daa, 54 % of the land used for building the facility.

The broader body of the facility means that the benches will be wider. Hence the flexibility for building the cells will be more significant, and more cells can be built. The operational sequence can be greatly improved with a greater number of cells. Another advantage for the wider construction is that for constructing a cell with minimal capacity is needed 2-3 times less waste rock in comparison with design 2. That means tailings deposition can start with less initial capital and operational costs.

Building a wider CMWDF allows the construction of more cells, which means that the possibilities for constructing a cell before the previous one is filled will be greater. Hence the need for contingency storage throughout the construction period will be decreased or eliminated. If there is a need for contingency storage, it can be built in the area planned for the facility. Thus using more forest space will not be necessary. A need for contingency storage will emerge if the next cell is not finished and if cells that are built are not capable of accumulating the whole pulp in the processing plant during a need of emergency shut down. There is also a possibility that starting with a broader starter platform can ensure a more stable starting platform for the facility. The other positive thing with a wider design is that the last bench ends with a wide surface. That will leave the opportunity to restart the mining activities if the conditions change (this is only in some cases) or to use it for other purposes such as agriculture or tourism. The negative side of a wider CMWDF could be that more surface area will sometimes be needed to build such a facility.

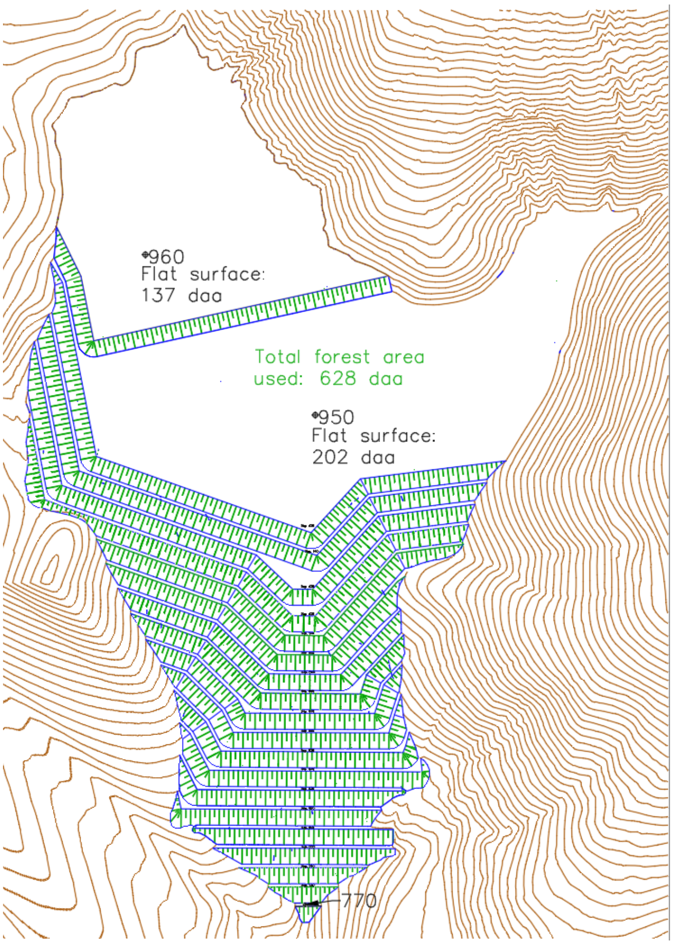

Figure 2. Combined mine waste dump facility with wider construction body (Design 1)

Design 2

Design 2 is designed in the ravines with starting elevation of 825 (Figure 3). The volume of deposited tailings for east and south CMWDF is different, but the overall volume is equal to design 1. However, the volume of waste rock is 29.5 million m^3, which is 6.5 million m^3 more. The surface area needed for both to be built is 783 daa. As mentioned in the description for design 1, for building cells with the volume equal to the volume of tailings produced for the period of consolidation, twice as much waste rock will be needed for this design. This is because the narrow terrain limits the width of the benches, so the starting platform consists of more benches to gain elevation and reach a favorable width of the terrain.

The operational sequence at the beginning of the construction can be challenging as the number of cells is limited even with both ravines being constructed at the same time. Therefore, contingency storage is recommended at the beginning. If possible, contingency storage is recommended to be built in the area planned for construction. Two cases were discussed for constructing design 2.

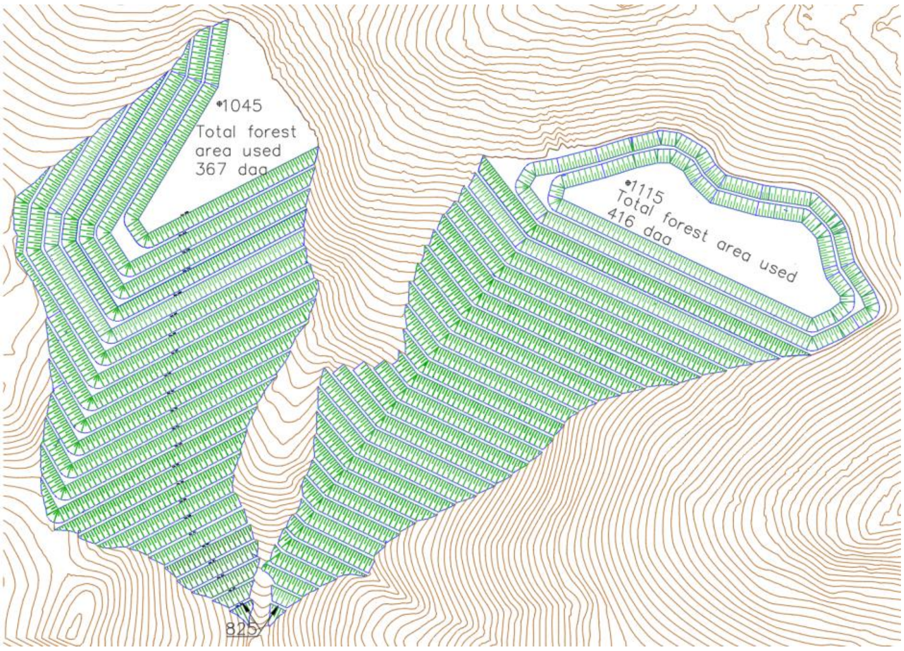

Figure 3. Combined mine waste dump facility built in the ravines (Design 2)

Case 1. To start and continue to build one of the CMWDF. For example, to start with the east one and build contingency storage in the west ravine with a capacity of at least twice the volume of tailings produced for the time needed for a 3 m thick layer of tailings to consolidate. And then leave cells capable of accumulating the same volume of tailings at the top of the CMWDF in the east ravine, which will serve as contingency storage and start constructing the CMWDF in the west ravine.

Case 2. To start with, the construction in both ravines at the same time. This case will need a greater volume of waste rock at the beginning. The construction of both CMWDF will continue until there are enough cells to be used as contingency storage in one of the CMWDF. After that, only one CMWDF can continue with construction. When the construction of one is almost finished, the deposition of tailings can continue in the other one. Before starting to deposit in the other one, it is best to leave 1÷3 cells at this CMWDF serving as contingency storage, ensuring the operational sequence. This case is better and that is why it will be used as an example when discussing "Operational sequence."

Results

Operational Sequence

As mentioned in the papers and reports from (Eldridge, Wickland, Goldstone, & Kissiova, 2011), the operational sequence is critical for the successful and proper construction of the facility. In the paper from (Aleksandrova et al. 2021), the critical path method (CPM) is recommended for managing the operational sequence. The CPM can be used to estimate which operation can be prolonged or for how long it can be delayed (Zlatanov, 2010). Considering the processes that are involved in the construction of the CMWDF few rules are recommended:

1. The time needed for the construction of one cell is less than the time necessary for one cell to be filled with tailings.
2. The minimal volume of a cell for tailings storage is recommended to equal the quantity of tailings produced in the time needed for the tailings to consolidate. However, the cell's maximal volume is also recommended to be limited as it affects the factor of safety. The maximal volume of the cell should be determent according to the rock properties.
3. Operations and construction need to be planned so that the first cell is filled with tailings and waste rock before starting to fill the last cell with tailings (Figures 4 and 5). That will ensure that a cell on the subsequent elevation can be started and finished before the last cell in the previous bench is filled with tailings.

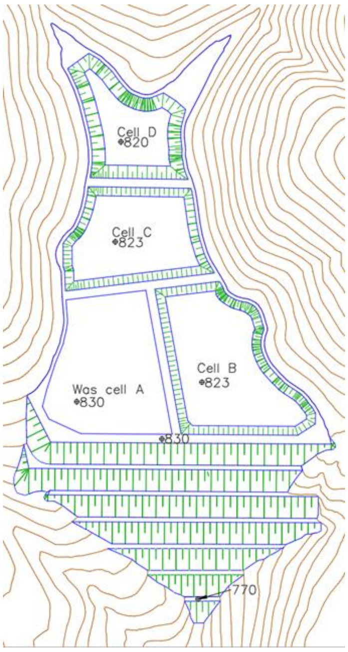

Figure 4. Different stages of cell construction and tailings deposition for design 1

Figures 4 and 5 show the different stages of filling the cells with tailings. Both designs are shown in the stages with the same tailings capacity. Four cells in design 1 are equal in volume to the four cells from both CMWDF in design 2. The cells are shown in different stages of construction. Cell "A" is already filled with tailings and waste rock for both designs. Cell "B" is filled with tailings, and the consolidating process has finished, so it is ready to be filled with waste rock. Tailings deposition in Cell "C" is finished and will start consolidating. Cell "D" is constructed and prepared to be filled with tailings. As shown in both figures (Figures 4 and 5), more cells ensure a better operational sequence.

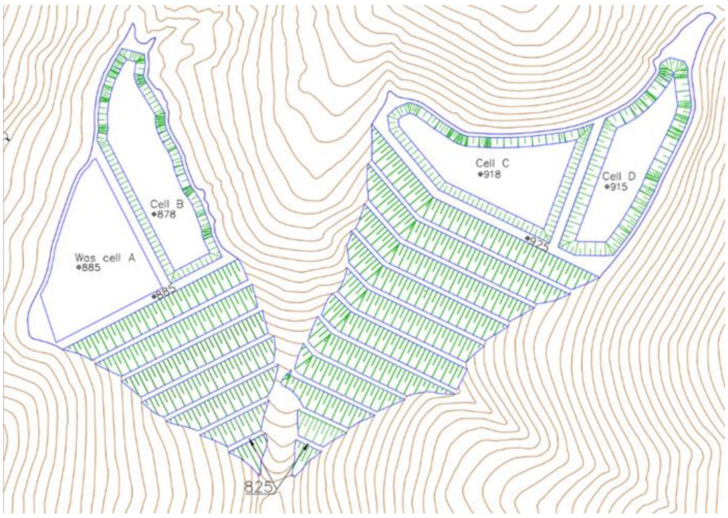

Figure 5. Different stages of cell construction and tailings deposition for design 2, case 2

Comparison between Stored Tailings Used Surface Area and Waste Material (Overburden)

Comparing the line charts from figure 6 to 9, a difference can be noticed between both designs. One is the different volumes of waste material (over burden) needed to store 5,9 million m3 of tailings for different surface areas. The chart from figure 6 shows that design 1 needs 200 daa of surface area and 2 707 400 m3 overburden to hold 725 000 m^3 of tailings. In order to hold this volume of material, the facility will rise to an elevation of 850 a.s.l. The ratio between overburden and tailings stored will be 3,7. After that, it rises. The ratio from 860÷900 a.s.l is 4,4, and from 910÷960 a.s.l is 4,1.

If both KWDF are built together in design 2 on a 200 daa surface area, 2 528 000 m^3 waste material and 529 150 m^3 tailings can be stored. This can be achieved when both facilities reach 905 a.s.l, and the overburden to tailings will be 4,77. The ratio from 915÷995 a.s.l is 4,67, and from 1005÷1115 a.s.l is 4,97. The higher the ratio, the more waste rock is needed to store the tailings. That increases construction costs.

Kaykov and Koprev (2020) investigated a similar problem regarding an overburden waste dump's optimal shape and location. They considered the waste volume to surface area ratio to be a variable that depends on the terrain features, the design features of the waste dump, and the sequence of its construction. Although their research is limited to overburden allocation, a similar approach can be utilized for combined waste dump mine facilities, including tailings and overburden volumes.

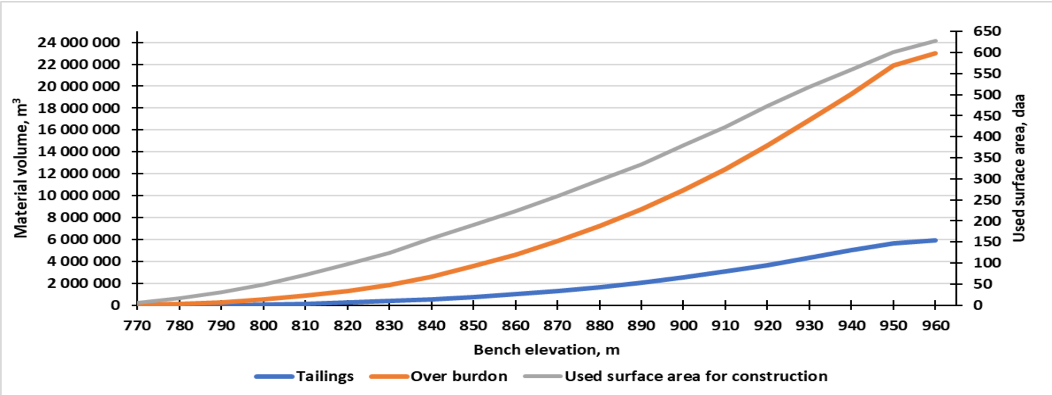

Figure 6. Used surface area and overburden to store 5,9 million m^3 of tailings for design 1

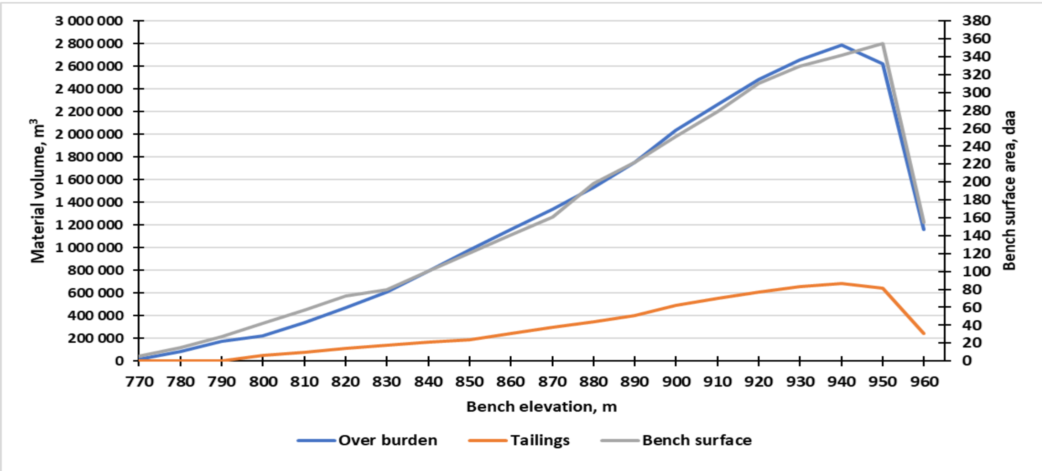

Figure 7. Used surface area and overburden for every bench to store tailings for design 1

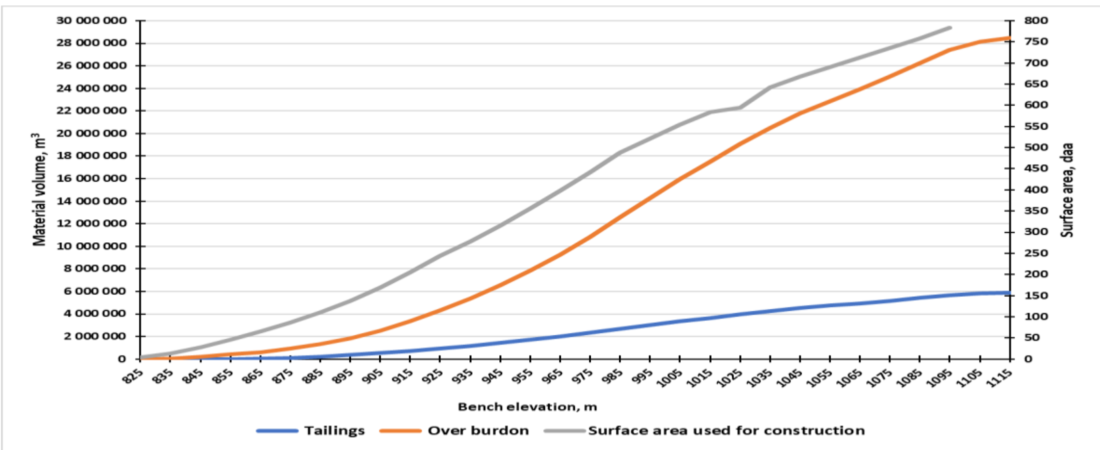

Figure 7. Used surface area and overburden to store 5,9 million m^3 of tailings for design 2

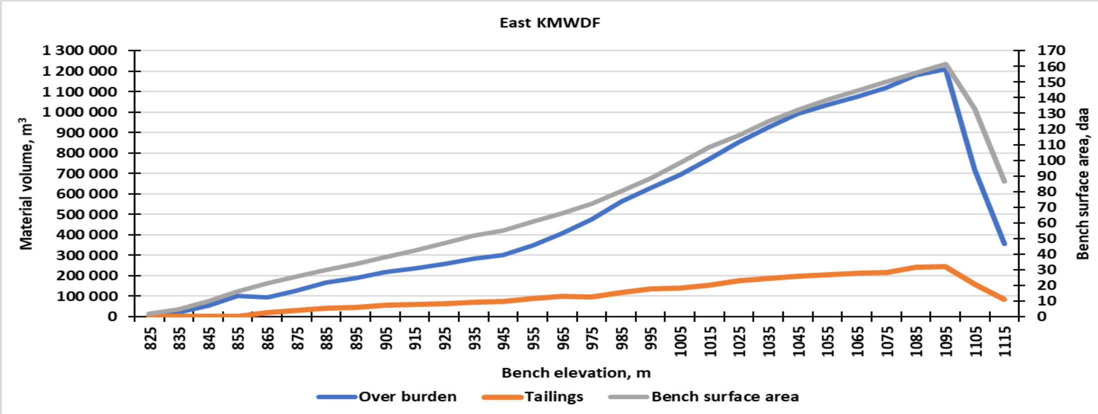

Figure 8. Used surface area and over burden for every bench to store tailings for design 2

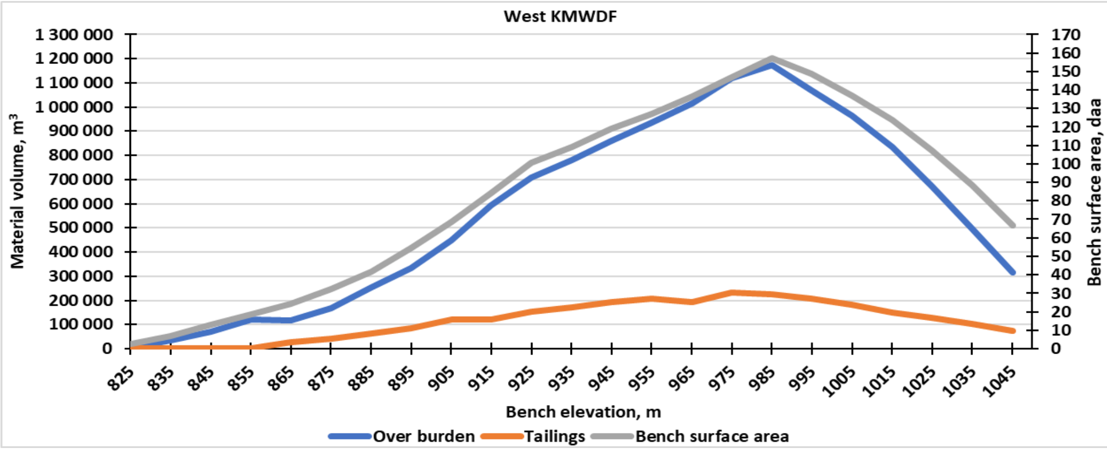

Figure 9. Used surface area and overburden for every bench to store tailings for design 2

Conclusion

With choosing to build a wider construction, a greater number of cells can be fitted in one bench. Thus, a better operational sequence will be achieved because the construction of the cell will not lay on the critical path. With constructing wider CMWDF, the need for contingency storage throughout the lifetime of the mine will be eliminated because of the capability to have a greater number of cells from the early stage of construction. The wider design would end with a wide flat bench leaving the possibility to restart mining activities if there were reserves left behind that were not economically extractable at the time.

To achieve a good operational sequence, a minimum of 3 cells in different stages is recommended at all times. One that the consolidation of tailings is over, and it can be filled with waste rock, one that the deposition of tailings is over, and one that is constructed and ready to be filled with tailings. The minimal volume of a cell is recommended to be designed so that the volume of tailings produced in the period needed for consolidation of the tailings can be accumulated in the predicted volume of the cell.

Steep and narrow terrain can limit the space for cell construction. That can be noticed in the case of CMWDF from design 2. As the facility rises in height and the benches get wider, cells with better form can be constructed, so the volume ratio between tailings and the cell volume increases. The volume of tailings accumulated in the cell when the bench is narrower is 24 %, and it rises as the bench gets wider.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Acknowledgements or Notes

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