A PHASED DEVELOPMENT SCHEDULE FOR A PLATINUM CONCENTRATOR UTILIZING A DYNAMIC STOCKPILE MODEL

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Abstract

The primary factor contributing to the profitability of a platinum mine and its associated concentrator is the time taken from the first hoist of material from underground to the first batch of concentrate shipped. To minimize the time it would take to produce concentrate without stopping because of a lack of feed material a project was undertaken to integrate the mining model with a concentrator production schedule () in the most capital-effective manner. A secondary goal was to ensure detailed stockpiling requirements, as the concentrator is in an area where 'visual pollution' is to be avoided. To achieve this a dynamic stockpile model was created utilizing the mine production schedule resolved into a daily production figure. Four different concentrator development models were then proposed. The difference between the mine production and concentrator consumption was integrated over the life of the mine to provide the accumulated stockpile tonnages for both Merensky and UG2 ores. The stockpile levels were never allowed to fall below zero to prevent a situation where the concentrator was operational without feed material,. When a development option was selected, the standard metallurgical performance calculations were used to derive a concentrate production schedule, that was then used as a basis for commercial concentrate sale negotiations.

Introduction

In 2010 TWP Projects was commissioned by Wesizwe Platinum to sink a 230 kt/month mine shaft in the Rustenburg area. The shaft provides a combination of both Merensky and UG2 platinum ore. In 2011, the company was also commissioned to do upfront engineering work for an associated 230 kt/month concentrator plant. Both the shaft and concentrator projects are funded through capital raised via loan agreements. A number of key financial factors need to be determined to allow for these loan structures to be utilized effectively and provide the shortest (economically viable) time to first concentrate production.

The key aspect to achieving this is to start concentrator production at the earliest time while taking cognisance of the fact that a concentrator 'ramp up' to full production is relatively quick (three years) compared to a mine (ten years). This means that a stockpile of feed material needs to be built up while the mine shaft is being developed to full production. Since the proposed location of the concentrator site is close to the tourist destination of Sun City strict limitations on the allowable level of 'visual pollution' are imposed meaning that stockpiles have to be carefully managed to ensure that they do not exceed footprint and height restrictions.

To model all the required parameters a dynamic model was developed that allowed parameters such as start date, ramp up time, and phase production rates to be modelled. The aim was to provide the client with a realistic start date that balances mine production, concentrator ramp up, stockpile level, and capital cost (done by others). When the final plant configuration was selected, concentrate production schedules were developed for inclusion in the mine commercial model.

The modelling was done using the Matlab® and Simulink® packages in conjunction with Excel® for reporting.

Background

Mine and concentrator production

A block flow summary of the proposed flow sheet is shown in Figure 1. The proposed concentrator has two primary milling and rougher flotation modules to allow for flexibility in processing Merensky and UG2 ore during blended-phase operation. The combined tailings are processed in a secondary mill and scavenger flotation circuit.

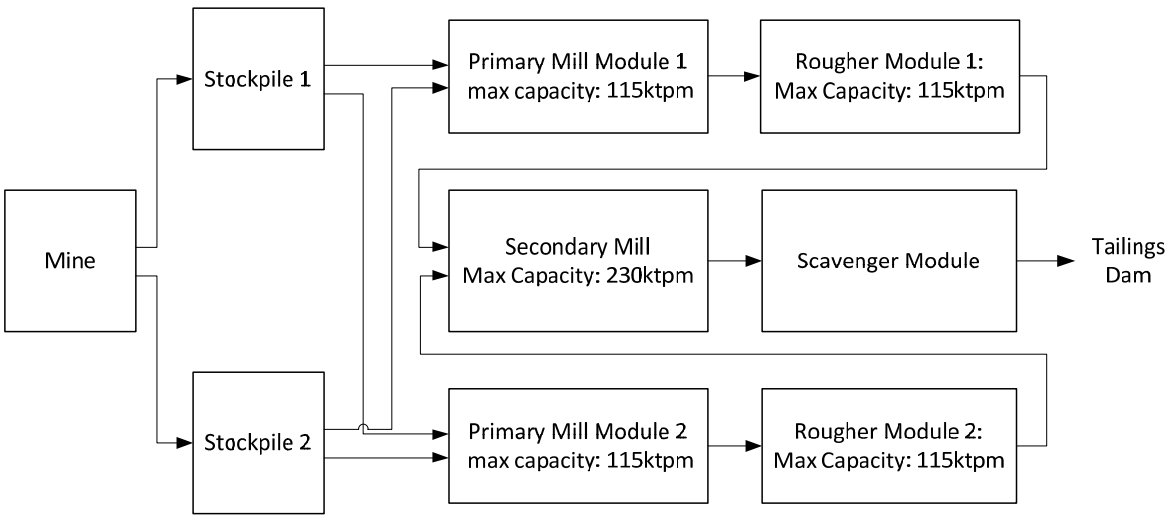

Figure 1-Process block flow diagram of proposed solution

TWP Projects' Mining Division generated a quarterly mine production model using the Mine 4-2D package. The production schedule was converted to a daily hoist rate reporting to a stockpile.

For the model to represent a realistic operational strategy, the concentrator was defined using the following production parameters:

- Phase start dates
- Plant throughput (for each phase of development)
- Ramp up duration
- Mine production rates (taking into consideration breaks)
- Module blend rate (percentage of concentrator feed that is Merensky or UG2)
- Mine availability
- Concentrator availability.

These parameters were used to calculate a daily production target and tuned to determine a feasible and realistic daily production schedule.

Dynamic model

In the late 18th century, Antoine Lavoisier proposed a formalization of the principle of conservation of mass (Wikipedia), which can be summarized to:

$$Mass_{in} + Mass_{produced} - Mass_{consumed} - Mass_{out} = 0 \quad [1]$$

For a dynamic model with no production or consumption of material, equation 1 can be modified to:

$$Mass_{in} - Mass_{out} = Mass_{accumulated} \quad [2]$$

The $Mass_{in}$ parameter is represented by a quarterly mine production schedule and the $Mass_{out}$ represents the amount of feedstock that the concentrator removes from the stockpile. Finally, the $Mass_{accumulated}$ value represents a change to the stockpile. When integrated over time, $Mass_{accumulated}$ represents material on a stockpile. This is used as the fundamental basis of the dynamic model.

The parameters above are tuned for the various options to provide earliest production dates for a given scenario while conforming to the following criteria:

- Stockpiles are never less than zero, implying that there is never a lack of feedstock to the concentrator
- Stockpile levels are minimized as much as possible by changing blend rates.

Together with the criteria listed in the following section it was possible to generate a production schedule for both mine and concentrator that could then be used to produce stockpile profiles for the various scenarios proposed.

Concentrator development scenarios

Four options were proposed for investigation:

- **Option 1:** Three phases of mine development
  - Phase 1: 90 kt/month (Primary Mill Module 1 and Rougher Module 1)
  - Phase 2: 90 kt/month (Primary Mill Module 2 and Rougher Module 2)
  - Phase 3: 50 kt/month (Secondary Mill and Scavenger Flotation).
  - 12 week ramp-up time.
- **Option 2:** Toll selling of mined ore with complete concentrator construction
  - One single construction phase
  - Toll selling of ore until concentrator on line.
- **Option 3:** Modularized approach
  - Build small modules until full production attained.
- **Option 4:** Two construction phases with (mill, float, mill float) MF2 circuit configuration
  - Build in two phases
  - Phase 1: 115 kt/month (MF2)
  - Phase 2: 115 kt/month (MF2)

Representing the original design configuration, Option 1 was used as the base case. Each of the options had different economic benefits, summarized as follows:

- **Option 2:** A single construction phase has benefits in terms of site establishment costs as well as reducing brownfield risk to the site. Toll selling also allows revenue to be generated as soon as possible
- **Option 3:** The benefit of tailoring modules to best utilize mine production implies that the start date for the concentrator can be moved forward as far as possible

- **Option 4:** The site concentrator would be built such that all foundations in the milling and flotation area would be completed and the plant operated in MF2 mode (with a single primary mill in operation) to provide the best balance between earlier start date and better flotation performance associated with an MF2 configuration.

Simulation results

Examples of the Excel® model input sheet (Figure 2), Simulink model output sheet (Figure 3) and simulation output summary (Figure 4Figure) are included for information purposes. A total of 59 variables were defined to allow the simulation to function as required.

The results of the simulations for the four options investigated are shown in Figures 5–8Figure 1. A summary of the start dates and capacities are given in Table I. As expected, the various scenarios produced differing start dates in line with the initial capacity requirements of each option when taking into account the target of minimizing the stockpile levels. Utilizing the Mine 4-2D forecast dates (based on shaft development starting in quarter 1 of 2012), the earliest start achievable was 4 April 2019 with a modularized 50 kt/month plant. The latest start date was 16 December 2022 for the option where initial ore was sold to a third party with the plant coming online only when the mine was at full capacity.

From Figure 9, which shows a summary of the concentrator throughput tonnages, the following observations can be made:

- Option 1 has the best start time, with Option 2 starting last
- Option 1 starts second, but is followed shortly by option 4
- Option 3, although starting last, has the highest ramp-up rate
- Option 2 has a large amount of material that is not processed by the concentrator (2129 kt Merensky and 1285 kt UG2).

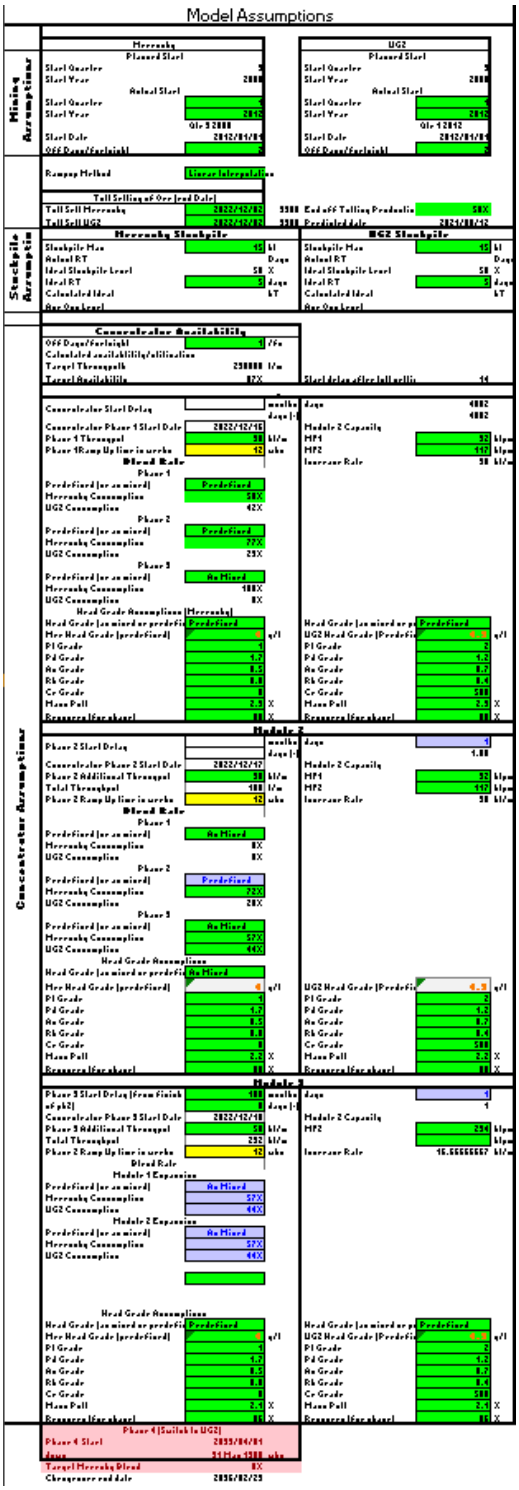

Figure 2-Screen capture of Excel model input sheet

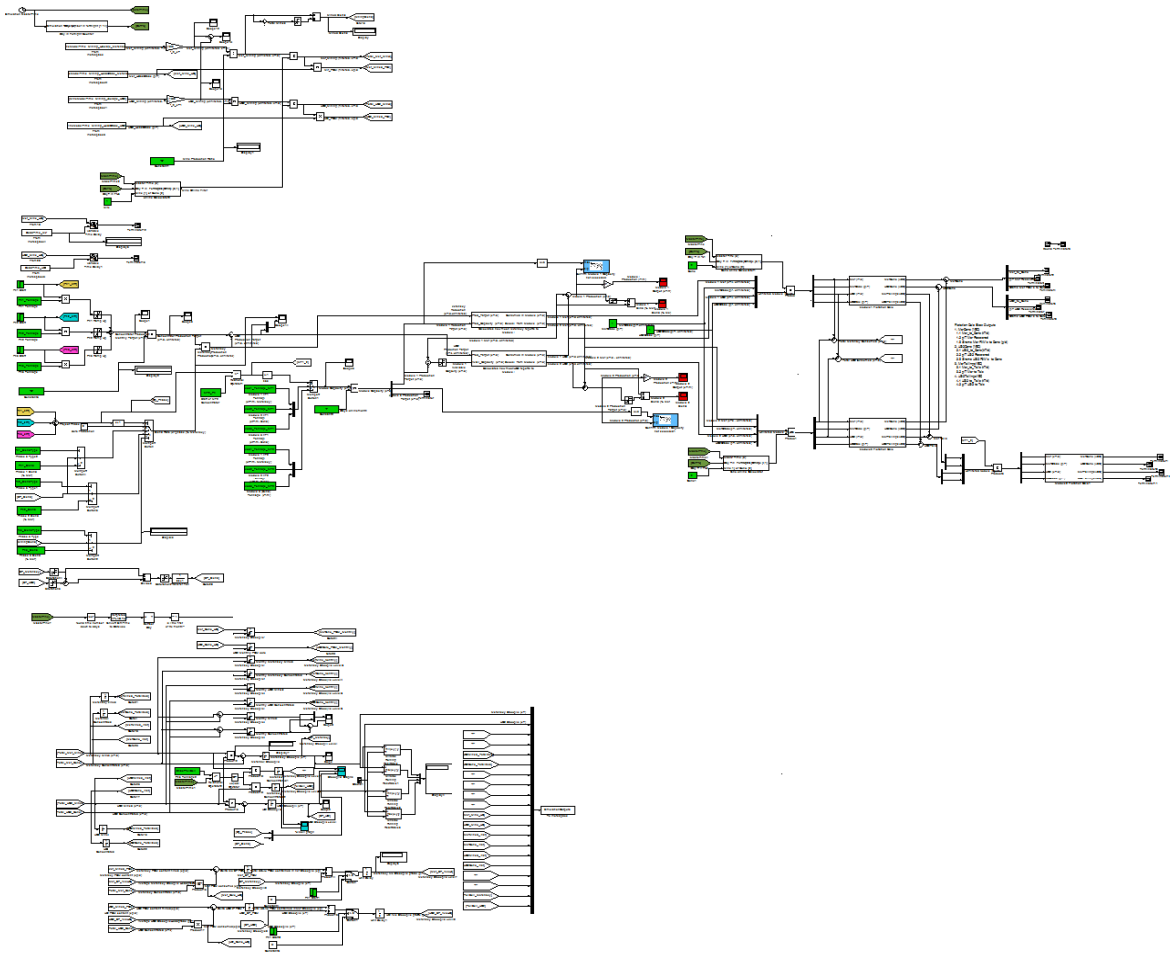

Figure 3-Screen capture of final Simulink model for stockpile

Option Title

Stockpile Levels: Option 2

UG2 Max (20kT)	
2012/01/01	19.8973286
2044/11/08	

Time Range	
Min	40909
Max	52909

Toll Sell Ore (kT)	
Merensky	2129.571
UG2	1285.142

Merensky Max (63kT)	
2012/01/01	62.68841379
2044/11/08	

Legends

		Stockpile Levels (kT)							
		Merensky			UG2			Overall	
Phase	Phase Start	Max	Min	Range	Max	Min	Range	Min	Max
1	2022/12/16	58.85	58.85	0.00	18.81	18.81	0.00	0	62.68841
2	2022/12/17	61.21	58.85	2.36	19.47	18.81	0.66	0	62.68841
3	2022/12/18	62.69	2.31	60.37	19.90	1.78	18.12	0	62.68841

Phase 1 (2022/12/16)
Phase 2 (2022/12/17)
Phase 3 (2022/12/18)

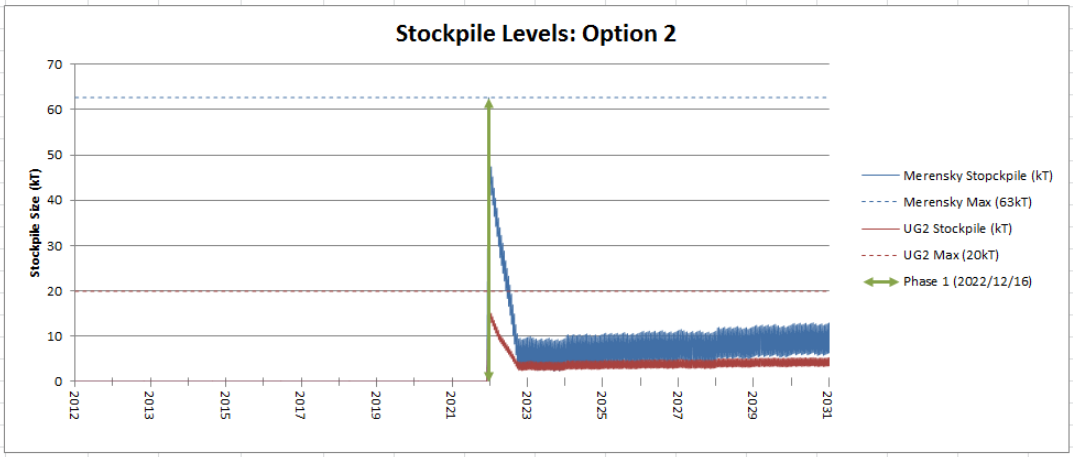

Figure 4-Screen capture of simulation output summary

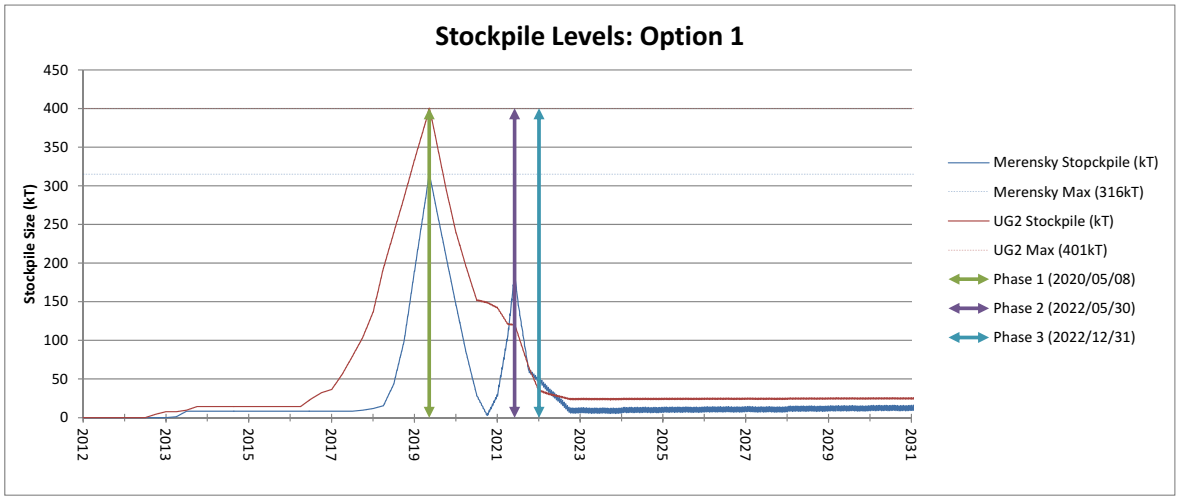

Figure 5-Stockpile level predictions for Option 1

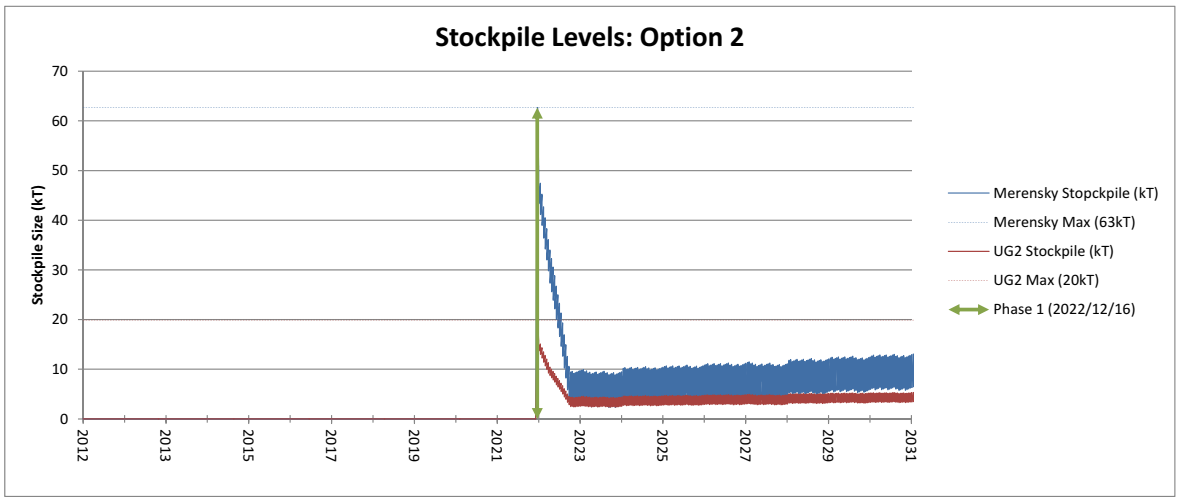

Figure 6-Stockpile level predictions for Option 2

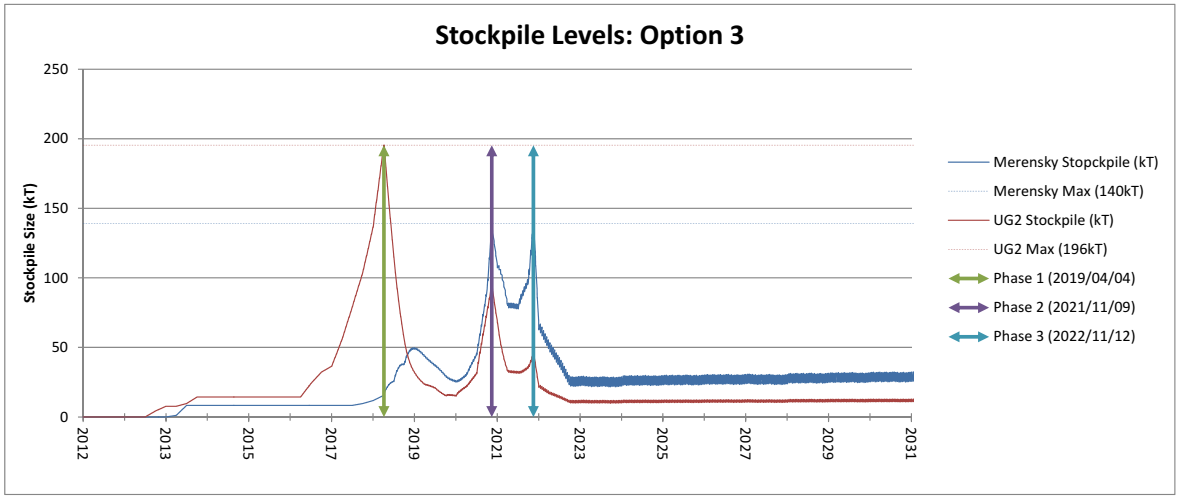

Figure 7-Stockpile level predictions for option 3

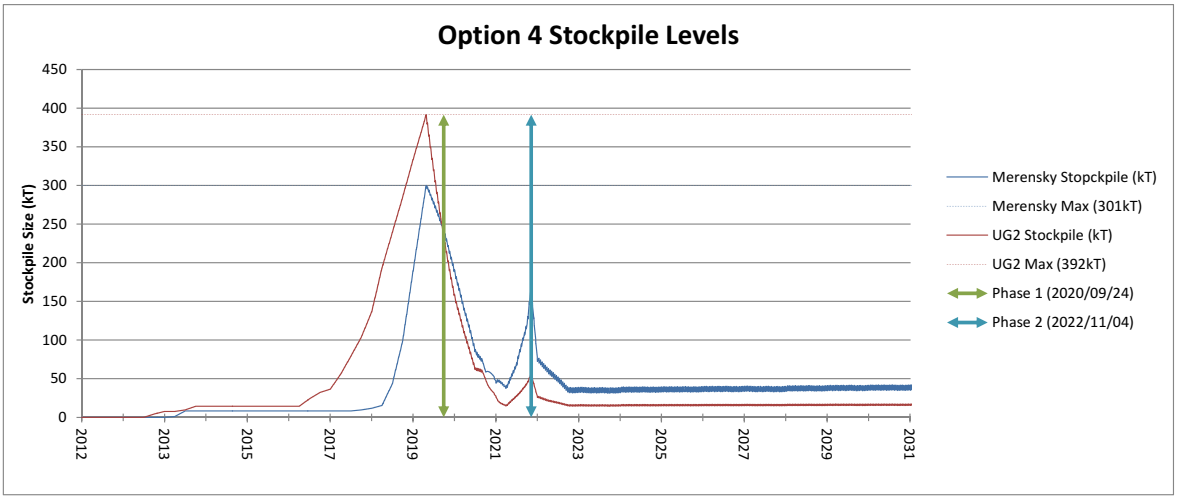

Figure 1-Stockpile level predictions for Option 4

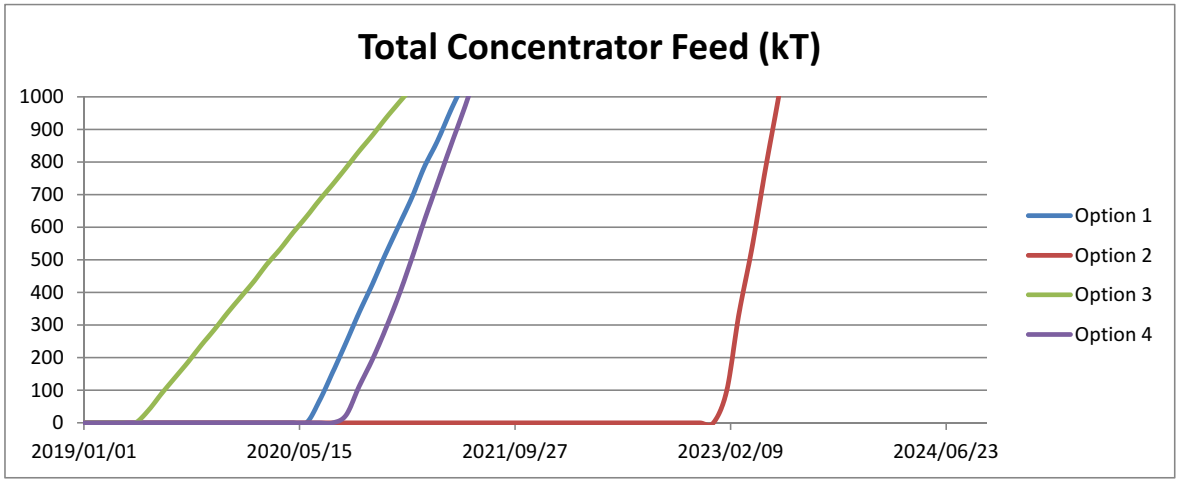

Figure 2-Total concentrator feed for various concentrator development options

Table I-Summary of concentrator start and full capacity dates

Option	Early start	Full Capacity
1	2020/05/08	2022/12/31
2		2022/12/16
3	2019/04/04	2022/11/12
4	2020/09/24	2022/11/04

Discussion

The benefits, drawbacks and final decision for each of the options investigated are summarized.

<u>Option 1:</u>

Positives:

- Second-best start time
- Standard size modules with the ability to run either as MF1 or MF2 configuration, which allows circuit to 'grow' as the capacity increases.

Negatives:

- Three phases of development
- MF1 circuit as designed initially will not produce the best recoveries.

Final decision:

- Running circuit on MF1 for initial stages of operation cannot be justified according to capital requirements as well as the cost of three-phase development

Option 2:

Positives:

- Early revenue through toll selling or ore to a third party
- Single development phase
- Lowest stockpile requirements.

Negatives:

- Toll selling agreements are notoriously difficult to negotiate and manage
- Reduced return margin
- Timing of full production from mine and concentrator is absolutely critical.

Final decision:

- Toll selling agreements are too risky for initial conceptual study, although options should be kept open going forward.

Option 3:

Positives:

- Concentrate will be produced much earlier in the project, which will provide the first income to the project and help with repaying of debt.

Negatives:

- The development of modularized concentrator modules is not preferable over the long term due to the inefficiencies inherent in small plants. For example, milling circuits would have differing capacities

- Capital deployment means that almost the full plant infrastructure needs to be developed for the plant to be ready for such a small throughput, which is not the most efficient way of utilizing loaned capital
- Three construction phases require additional 'Ps & Gs' (preliminaries and generals).

Final decision:

- Benefits of early production do not outweigh cost of developing infrastructure as well as phased development costs.

Option 4

Positives:

- Slightly delayed start over Option 1 (4 months)
- MF2 circuit configuration from start
- Two phases of development
- Fastest ramp-up rate to full production.

Negatives:

- Construction of final phase will proceed on an operating plant
- Last started of the non-'toll selling' options.

Final decision:

- This is the selected option, as is provides the best balance between reduction in stockpile capacities, starting as early as possible, and utilizing capital in the most efficient manner possible.

Conclusions

The final selected option (Option 4) was selected to provide a balance between capital usage in both site and infrastructure development, stockpile levels, and most profitable flow sheet (MF2). As the selected option, it was possible to use the production data for the concentrator to negotiate concentrate offtake agreements with third parties, which results in better financial modelling of both the project risk as well as cash flow for the overall project.

In addition, if changes occur to the mining model that might delay the project, it is simple to re-optimize the model to predict modified start dates, which will ensure that the concentrator is not built too late or too early, either of which could be financially disastrous to the client and the financial institutions that are funding these projects.

Going forward, there is a need to further develop and refine the circuit configurations to firm up details of the final solution (better information on floatation profiles). This will provide additional detail which will be required when negotiating take-off agreements.

Reference

Wikipedia (http://en.wikipedia.org/wiki/Conservation_of_mass)

The Author

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I have been involved with the platinum industry for 6 years mainly with Anglo Platinum project ranging from dynamic modelling of unit operations through development of Functional Control Specifications. More recently I have been working more closely within the Process discipline on debottlenecking of Anglo Platinum's flagship plant (Mogalakwena North 600ktpm plant). As an process engineer with a process control background, it is a logical progression to look at dynamic modelling such as what was performed for the Wesizwe Stockpile model.