Retreatment and beneficiation of weathered material from a coal tailings storage facility: a case study

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Abstract. Most of the mining industry has increasingly focussed on the efficient management and remediation of tailings storage facilities, often involving dry stacking of filtered as-arising tailings as well the reclamation and filtration of legacy tailings dams. This shift has also led to the emergence of tailings reprocessing and beneficiation projects, which aims to eliminate tailings waste while producing saleable products. This study evaluates the feasibility of reprocessing weathered coking coal material from a tailings storage facility using a specialised flotation technology. The work presented in this paper focusses on the development of a technically feasible processing route to produce a marketable product. Furthermore, the economic feasibility of the project is also evaluated. The scope of this study includes the processing plant design, from material reclamation to final product generation. This paper outlines the methodology and key design considerations used to develop the proposed processing flowsheet. Laboratory test work results inform specification and selection of processing equipment requirements, with the final flowsheet critically evaluated for its techno-economic feasibility potential. The findings highlight the potential for reclaiming and beneficiating the tailings material under consideration, demonstrating its feasibility as a sustainable and commercially viable project.

Keywords: *tailings retreatment, flotation, weathered coal processing*

1 Introduction

In recent years, the mining industry has increasingly prioritised the efficient management and remediation of tailings storage facilities (TSFs). This shift has driven a transition towards the dry disposal of as-arising tailings streams, as well as the reclamation and filtration of existing tailings dam material. Another area of significant interest in this regard related to the retreatment and beneficiation of reclaimed tailings dam material.

Tailings retreatment facilities are designed to process reclaimed material from TSFs, not only facilitating the decommissioning of legacy tailings dams, but also enabling the production of an upgraded and potentially saleable product. Additionally, the reprocessing of

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tailings dam material contributes to a reduced TSF facility footprint while enhancing water recovery, thereby improving the overall operational sustainability.

This study aims to establish a viable processing route for the reclamation and beneficiation of material from an existing coking coal TSF, with the objective of producing a saleable briquetted product. This work presented in this paper focusses on the laboratory-scale test work, process design and technical feasibility of the proposed flowsheet. Furthermore, the project cashflow projections are evaluated using varying input parameters and conditions to determine the expected economic feasibility.

2 Background

2.1 Material characteristics

Prior to being mined, underground coal is contained in a confined environment, isolated from atmospheric oxygen exposure. Upon extraction and after being exposed to environmental conditions, the ore is subjected to a complex oxidation process, leading to chemical and physical surface weathering. The degree of surface oxidation and particle weathering is influenced by several factors, including the following [1]:

- Particle size: Finer particles exhibit a larger oxidation surface area per unit volume.
- Rank: Higher-rank coals generally experience less weathering and deterioration.
- Exposure duration: Prolonged atmospheric exposure increases surface oxidation.

Weathered coal presents significant processing challenges due to mineral surface oxidation, which alters the coal physical and chemical surface properties. One notable consequence is the increased material friability, leading to the excessive generation of ultrafine material [2]. Coal is a naturally hydrophobic compound, a characteristic that facilitates mineral recovery via froth flotation. However, extended surface oxidation decreases particle hydrophobicity and negatively impacts the flotation response [1-3].

2.2 Weathered fine coal flotation

Particle surface oxidation and weathering of coal alters the chemical surface properties, reducing hydrophobicity and reducing the probability of successful recovery by means of froth flotation. The change in chemical surface properties have been shown to decrease the probability of successful bubble-particle attachment while promoting particle detachment characteristics [2]. Various strategies have been proposed to mitigate these effects and to reactivate the non-weathered mineral surface. The most pertinent methods prescribed to achieve this objective include surface preparation by means of attrition scrubbing, extended flotation residence times, as well as various chemical approaches to improve floatability. Previously conducted research indicate that the impact of mechanical surface preparation significantly improves the flotation performance of weathered coal [1-2].

The beneficiation of weathered coal by means of froth flotation is thus expected to benefit from high-energy input pretreatment and flotation mechanisms. In this context, the Dual Cell^{TM} flotation technology presents a potential viable alternative, having been successfully implemented on various coal processing applications, as illustrated in Figure 1. In addition to the Dual Cell^{TM} high-energy input, this technology has previously demonstrated improved mineral recovery and selectivity within the ultrafine size fractions (<38 µm). This characteristic is particularly relevant for the current process development, as ultrafine desliming is thus not deemed to be required, thereby potentially improving the overall flotation yield potential.

Fig. 1. ENPROTEC Dual Cell™ fine coal flotation technology.

2.3 Definition of key metrics

2.3.1 Processing criteria

The test work performance parameters are defined on a dry basis, where the relevant wet test work samples undergo dewatering in a laboratory barrel filter and is further oven dried at 60˚C for a duration of three hours. The ash yield, moisture content, flotation yield and combustible recovery is defined based on the dried basis procedure outlined above and can be determined using Equation (1) to (4) [3].

$$Ash\ Yield\ (\%) = \frac{Remaining\ Ash\ Residue\ After\ Combustion}{Dry\ Sample\ Mass} \times 100\% \quad (1)$$

$$Moisture\ Content\ (\%) = \frac{(Wet\ Sample\ Mass - Dry\ Sample\ Mass)}{Wet\ Sample\ Mass} \times 100\% \quad (2)$$

$$Flotation\ Yield\ (\%) = \frac{Flotation\ Concentrate\ Mass}{Flotation\ Feed\ Mass} \times 100\% \quad (3)$$

$$Combustible\ Recovery\ (\%) = \frac{M_C\ (100\% - A_C)}{M_F\ (100\% - A_F)} \times 100\% \quad (4)$$

Where M_i signifies the mass and A_i signifies the ash yield, for both the flotation feed (F) and concentrate (C) streams.

2.3.2 Test work parameterisation

Furthermore, various facets of the test work results are parameterised to accurately define the relevant characteristics. This includes the particle size distribution (PSD), which is described by the Modified Rosin-Rammler mathematical model, as expressed by Equation (5) [4].

$$Cumulative\ \%\ Passing = \left(1 - exp\left(-0.693\left(\frac{d_i}{d_{50}}\right)^m\right)\right) \times 100\% \quad (5)$$

Where the cumulative PSD is expressed as a function of the particle diameter (d_i) and described in relation to the median particle diameter (d_{50}) and the sharpness constant (m) of the distribution.

The settling test work results are interpreted according to the generalised method to determine the settling rate from batch settling tests [5]. This includes the generation of a batch settlement curve, which describes the kinetic characteristics of the slurry and supernatant interface, as well as the determination of the settling rate at various settlement phases.

The appropriate thickener design settling rate can be determined at the inflection point of the settlement curve, representing the transition from the free settling to the hindered settling phase, prior to further material compaction. The batch settling interface height (H) kinetic characteristics is further expressed using an exponential decay function, as described by Equation (6).

$$H(t) = (H_0 - H_\infty)\, e^{-\lambda t} + H_\infty \tag{6}$$

Where the initial slurry height (H_0), ultimate interface height (H_∞) and decay rate (λ) is utilised to describe the material kinetic settling characteristics. To determine the batch test settling rate, the standard graphical method can be used, the work presented in this paper also utilises a mathematical approximation to establish the applicable settling rate. This is done by determining the first derivative of the exponential decay function provided by Equation (6) with respect to time, and after applying the Chain Rule, results in the settling rate relation, given by Equation (7).

$$H'(t) = -\lambda (H_0 - H_\infty)\, e^{-\lambda t} \tag{7}$$

This equation can be used to determine the settling rate at any given time in the settlement process and can be further utilised to determine the design settling rate at the batch settlement curve inflection point.

The laboratory flotation kinetic response is modelled using the Modified Kelsall model, given by Equation (8) [6].

$$R(t) = R_\infty \left((1-\phi)(1-e^{-k_f t}) + \phi (1-e^{-k_s t}) \right) \times 100\% \tag{8}$$

Where the kinetic flotation recovery (R) is parameterised based on the fraction of slow floating material (ϕ), the slow and fast floating rate constants (k_s and k_f), as well as the ultimate recovery (R_∞). In this paper the flotation release curve or recovery modelling is defined based on the material combustible recovery, as described by Equation (4).

The concentrate grade (G), or product quality as is referred to in the case of coal processing, is further described as a function of recovery, and ultimately as a function of time utilising the parabolic grade and recovery relationship as given by Equation (9).

$$G(t) = \alpha (R(t))^2 + \beta (R(t)) + \gamma \tag{9}$$

Where the concentrate grade, which in this paper relates to the product ash yield, is expressed by fitting the three parameters (α, β and γ) given in Equation (9) to the experimental data.

2.3.3 Economic feasibility assessment

This paper evaluates the projected cashflow for the execution and operation of the remining and beneficiation project under consideration. The key financial and profitability metrics used to determine the economic feasibility include the net present value (*NPV*), internal rate of return (*IRR*), peak funding (*PF*) and payback period (*PBP*), the determination of which is given by Equations (10) to (13) [7].

$$NPV = \sum_{t=0}^{n} \frac{CF_t}{(1-r)^t} \tag{10}$$

$$IRR \mid \sum_{t=0}^{n} \frac{CF_t}{(1-IRR)^t} = 0 \tag{11}$$

$$PF = \min_{t \in [0,\, n]} \{ CF_t \} \tag{12}$$

$$PBP \mid \sum_{t=0}^{PBP} (CF_t) = 0 \tag{13}$$

Where the above financial metrics have been defined with respect to the relevant time period (t), project duration (n), cashflow (CF) and discount rate (r).

3 Study aims

3.1 Primary objectives

The scope of the work conducted and presented in this paper is aimed at achieving the following primary objectives:

- Establishing a technically feasible processing route for the treatment and beneficiation of the weathered coking coal tailings under consideration.
- Conducting laboratory test work to substantiate the technical feasibility assessment.
- Parameterising the material test work characteristics and kinetics to accurately determine the implied processing requirements and equipment.

3.2 Secondary objectives

The work completed and presented in this study is structured to accomplish the following secondary objectives:

- Modelling the expected project cashflows and financial performance based on the outcome of the process development work conducted.
- Determining the project economic feasibility based on various pricing scenarios and key input parameter variations.
- Evaluating the project environmental and sustainability impact potential.

4 Methodology

4.1 Process development and selection

Following multiple iterations of process development, the proposed processing flowsheet to treat the weather TSF material is presented in Figure 2. The process is designed to operate on a continuous basis, with the objective of depleting one of the three tailings storage dams within a five-year period.

The flowsheet incorporates hydraulic mining to reclaim the material contained within the TSF, which is subsequently pumped to the main processing facility. The as-received material

is prepared by removing large foreign objects and tramp metal via a trommel screen. The rotary grinding action of the trommel screen further aids in breaking down agglomerated particles. The screen undersize is directed to a scrubbing sump, where high-energy scrubbing assists in liberating the hydrophobic coal particle surfaces and reducing the weathered characteristics of the as-arising material. The scrubbed material is further processed through a classification circuit, ensuring the removal of oversize material prior to reporting to the flotation feed thickener.

The flotation feed material is processed in a thickener, which serves as both a storage buffer for downstream processing units and as a mechanism for stabilised density control. The flotation feed is diluted to the targeted density in the feed tank, which is followed by primary and secondary roughing within the flotation circuit. The Dual Cell^{TM} flotation technology is incorporated due to the mechanism's high-energy input, which enhances the exposure of weathered particle surfaces and promotes shearing of flocculated material. The proposed flotation technology also has favourable grade and recovery characteristics within the ultrafine fraction, which is pertinent for this application.

The flotation tailings stream is further dewatered by means of a tailings thickener and full-function plate and frame filter press, which allows for optimised water recovery. The tailings filter cake is conveyed and stacked for final disposal. The flotation product is pumped to a product filtration circuit, which dewaters the flotation concentrate stream and recovers water for reuse within the upstream unit processes. The product filter cake is conveyed and transferred to an intermediate storage stockpile, which is used to feed the coal briquetting circuit, ultimately producing a saleable briquetted product.

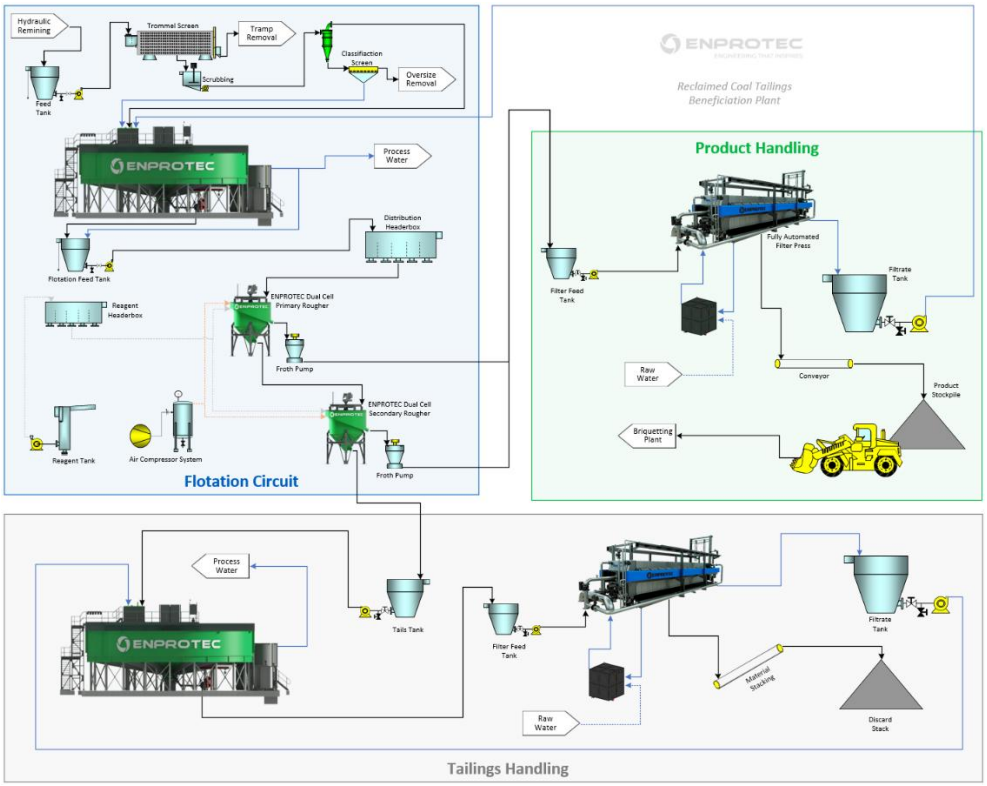

Fig. 2. Proposed tailings material processing route.

4.2 Material sampling methodology

The weathered tailings material contained in the on-site TSF is distributed between three distinct storage dams (I, II and III), as illustrated in Figure 3. Tailings Dam I has been capped for an extended period and would require the removal of the overburden and organic material prior to reclamation and processing. Tailings Dam III is currently in operation and is utilised to support the main dense media separation (DMS) plant. The material contained in Tailings Dam II is readily available for reclamation and processing, making it the primary focus for the initial phase of this project.

To this end, Tailings Dam II samples have been obtained from site to determine the technical feasibility of the proposed processing route. A composite sample was taken from multiple extraction points within Tailings Dam II, consisting of 30 individual subsamples, each with a mass exceeding 2 kg as prescribed by ISO 18283:2022 [8]. These samples were taken with a manual sampling auger and represent a surface-level sample of the tailings material. Future work will involve the collection of a more extensive core sample to assess material variability with depth and the potential impact of the processing plant. This sample would be ideal to support small-scale pilot processing, enabling further validation of process performance, which will be discussed later in this paper.

Fig. 3. Overview of the on-site TSF: comprising of tailings dam I, II and III.

4.3 Test work objectives

The objective of the test work conducted on the Tailings Dam II composite sample is to evaluate the technical feasibility of the proposed processing flowsheet on a laboratory scale. The test work programme includes procedures to determine the following:

- Feed material characterisation in terms of PSD and ash yield.
- Impact of surface preparation and mechanical scrubbing on the flotation performance.
- Post-classification flotation feed material settling test work.
- Flotation performance and kinetics using:
  - Reagent Suite A: Petroleum-based collector & frother mixture
  - Reagent Suite B: Oil-based alkene collector & frother mixture
- Flotation tailings settling test work.
- Full function filtration test work on:
  - Flotation product

◦ Final tailings material

It is also noted that the objective of the proposed processing flowsheet is to produce a saleable coking coal product, with a targeted ash yield of less than 10.0% on a gravimetric basis. The laboratory-scale flotation and full function filtration equipment utilised to conduct the test work relevant to this study is displayed in Figure 4.

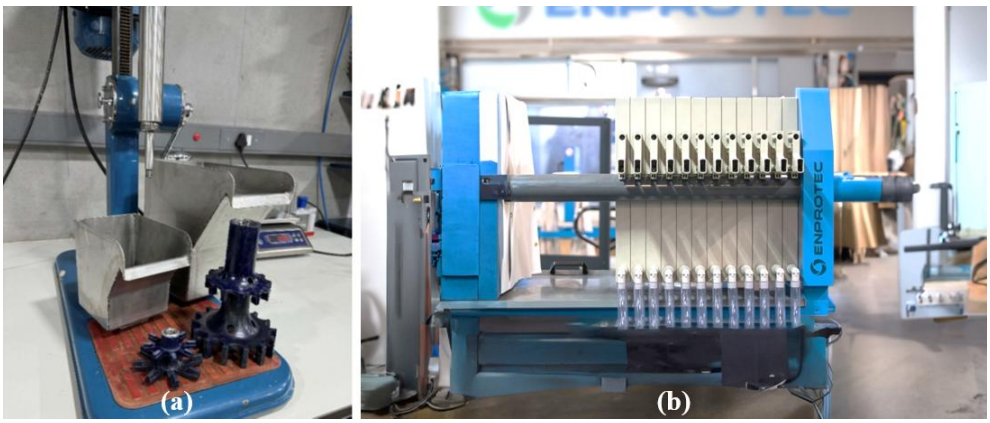

Fig. 4. (a) DENVER flotation machine and (b) ENPROTEC full function laboratory filter press.

5 Results and discussion

5.1 Feed material characterisation

The as-arising material particle size distribution and ash yield by size fraction is presented in Figure 5. Two independent PSD analyses were conducted, both fitted using the Modified Rosin-Rammler model, yielding a median particle size (d_{50}) of between 83 µm and 98 µm and a sharpness constant (m) ranging from 0.668 to 0.675.

From the results presented in Figure 5, it is indicated that approximately 20% of the as-arising material has a diameter of >300 µm, which is generally considered to be too coarse for effective flotation. This size fraction also contained a relatively high ash yield, necessitating its removal to optimise flotation feed quality and particle size distribution.

The PSDs presented in Figure 5 also indicates that approximately 30% to 35% of the as-arising material is present within the <38 µm size fraction, which also exhibits a notably elevated ash yield. Conventional flotation technologies would typically struggle to achieve selective recovery within this size fraction, which is made exceptionally more challenging when processing weathered material.

To effectively beneficiate and upgrade the material contained in this size fraction, a high-energy input flotation technology would greatly assist to enable enhanced bubble-particle collision and attachment. This should enable improved selective flotation of the valuable mineral while rejecting ultrafine gangue particles. This reaffirms the selection of flotation equipment such as the Dual Cell^{TM} technology discussed in previous sections.

The results obtained for the as-arising feed material further support the material handling and classification section within the proposed processing flowsheet. This stage is designed to classify and remove coarse oversize material that would otherwise report to the flotation feed thickener and downstream processes. This section is also deemed critical with regards to the requirement to remove tramp metal and foreign objects that might be present, although not directly present within the Tailings Dam II material sample under consideration.

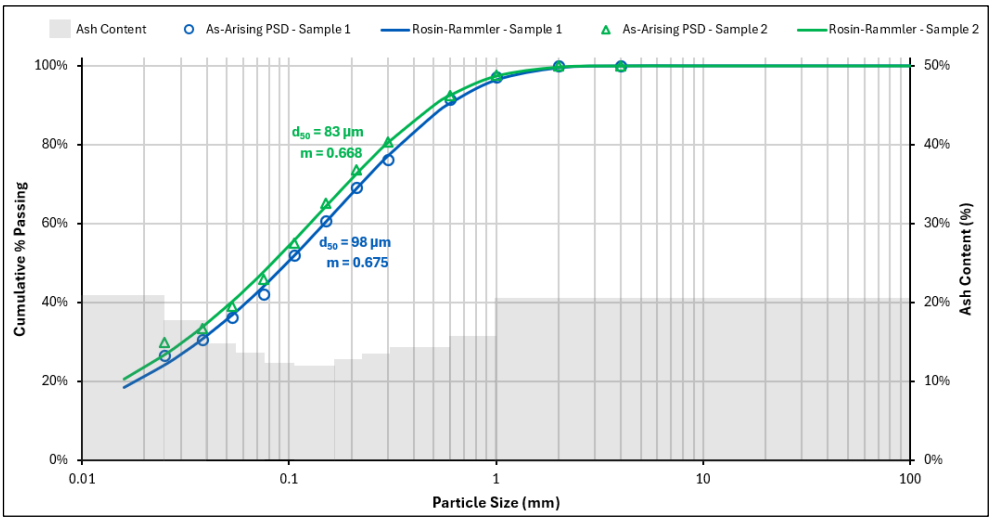

Fig. 5. As-arising tailings dam II material PSD and ash yield.

5.2 Mechanical scrubbing and reagent screening

The impact of mechanical surface preparation on the flotation was assessed in a flotation screening exercise to validate the inclusion of the scrubbing stage prior to froth flotation. The results, which is summarised in Table 1, indicate that high intensity scrubbing notably enhanced the flotation performance at the selected dosage rate of 300 g/t, leading to an increase in both the flotation yield and combustible recovery. This improvement can be attributed to the effective removal of surface oxidation layers, thereby restoring the hydrophobicity of coal particles and facilitating effective bubble-particle attachment within the flotation process.

Table 1. Tailings dam II flotation performance and impact of surface preparation.

	Reagent Suite A		**Reagent Suite B**	
Scrubbing	-	10 min	-	10 min
Flotation Yield	33.3%	39.4%	21.8%	36.4%
Ash Yield	7.9%	6.9%	8.6%	7.3%
Combustible Recovery	36.1%	42.7%	23.2%	39.7%

5.3 Flotation

The laboratory flotation test work demonstrated that Reagent Suite A, including mechanical scrubbing, was more amenable to an effective flotation response, as highlighted in the preceding section. Consequently, the results presented in this section primarily focusses on evaluating the flotation performance achieved using this reagent suite.

Figure 6 illustrates the cumulative flotation yield, ash yield, combustible recovery as well as the corresponding grade-recovery curve (ash yield vs. combustible recovery) for Reagent Suite A. These plots have been generated across four different dosage rates, namely 300 g/t, 600 g/t, 900 g/t and 1200 g/t.

As shown in Figure 6, both the flotation yield and combustible recovery reach an inflection point at approximately the 45 seconds, stabilising after approximately 90 seconds. Considering the targeted ash yield of ≤10.0%, all the dosage rates considered would be

suitable to achieve this objective. The flotation yield and combustible recovery benefit is much more significant between the lower dosage rates considered and the incremental flotation yield and recovery gain diminishes once the 900 g/t rate has been reached. The grade-recovery curve (product ash & recovery) indicates that both higher dosage rates exhibit similar flotation responses. Therefore, it is proposed to utilise the 900 g/t dosage rate, as it results in a comparatively optimised flotation yield and product quality, without incurring additional reagent costs.

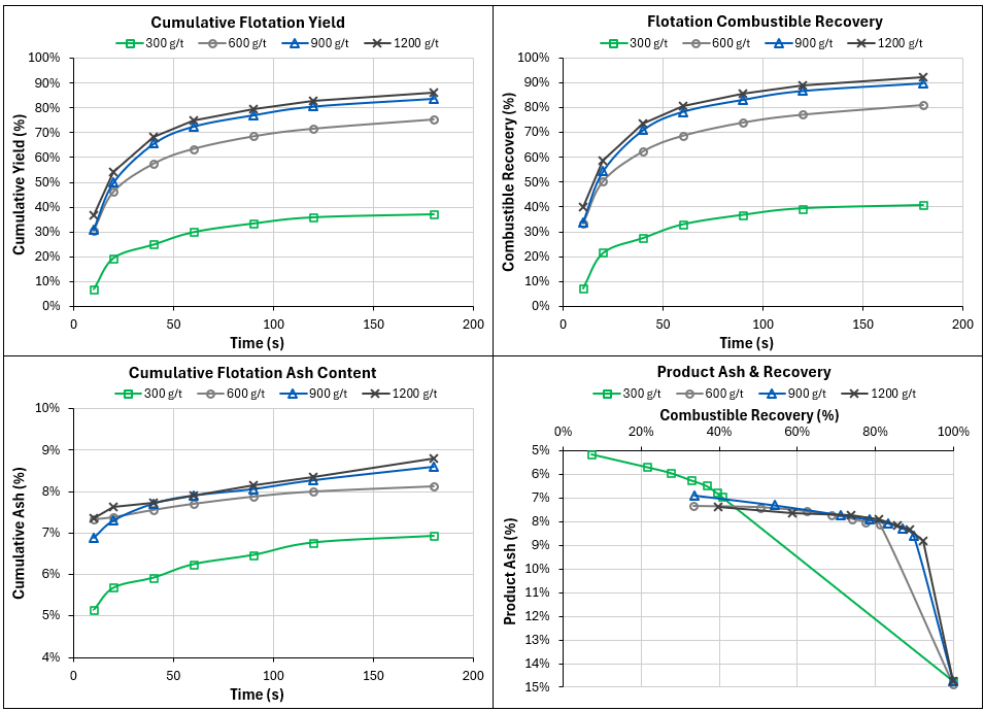

Fig. 6. Reagent Suite A: flotation performance at various dosing rates.

The flotation kinetic response is parameterised and presented in Table 2, for the four dosage rates under consideration. The selected dosage rate exhibits a marginally lower ultimate recovery (R_∞) compared to the highest dosage rate, as well as a slightly slower flotation response (k_s and k_f). The fraction of material exhibiting slow floating kinetics (ϕ) is deemed significant, however, it is noted that the slow floating rate constant (k_s) remains relatively high compared to most other flotation applications.

Table 2. Flotation performance parameterisation.

	Reagent Suite A – Dosage Rate			
	300 g/t	**600 g/t**	**900 g/t**	**1200 g/t**
R_∞	44.5%	84.7%	94.0%	94.3%
ϕ	0.203	0.393	0.281	0.364
k_f	2.04 min^{-1}	5.21 min^{-1}	3.79 min^{-1}	5.22 min^{-1}
k_s	0.30 min^{-1}	0.75 min^{-1}	0.63 min^{-1}	0.93 min^{-1}
α	0.082	0.047	0.035	0.066
β	0.012	-0.037	-0.015	-0.065
γ	0.050	0.080	0.070	0.090

Generally, high-grade coal has an extremely rapid flotation kinetic response, necessitating a lower scale-up factor. In this case a scale-up factor of 2.0 was applied for flotation circuit design purposes, the sizing also incorporates an aeration factor of 15% of the cell's active volume to account for gas holdup and bubble dynamics.

The next phase of this study will involve batch-scale pilot testing to further validate the flotation performance under continuous conditions. This pilot campaign will not only confirm the feasibility of the proposed flotation regime but will also generate a bulk flotation product sample for subsequent briquetting test work. Additionally, the batch trial will provide critical data to verify design parameters and scale-up factors applied in the flotation circuit development. Figure 7 illustrates the batch processing facility designated for this stage of testing.

Fig. 7. ENPROTEC batch flotation and filtration processing plant.

5.4 Settling and dewatering

The batch settling test results for both the feed and tailings material is presented in Figure 8, illustrating the kinetic settling characteristics of the material. The slurry-supernatant interface exhibits an inflection point at approximately 7-12 minutes, indicating the transition from free-settling to the compaction zone, thereby indicating the state of hindered settling.

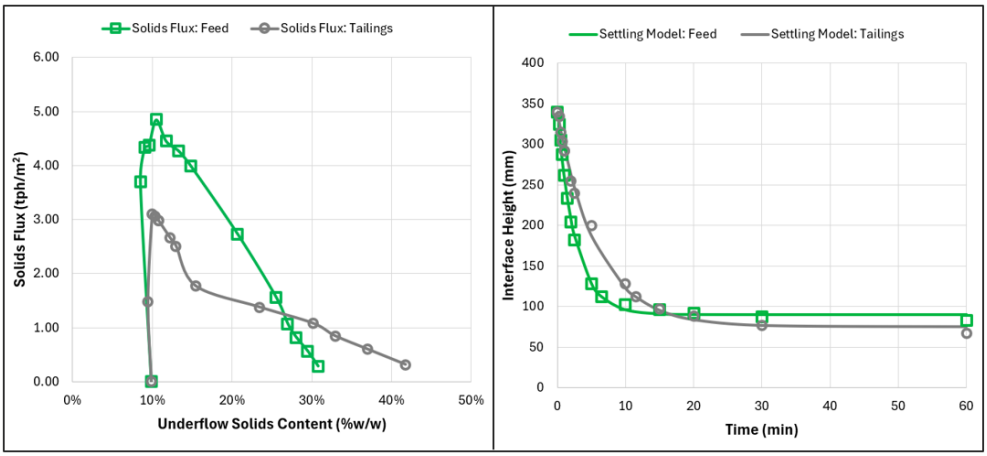

Fig. 8. Feed and tailings material batch settling test solids flux rates and settling kinetic data.

The model parameterisation step was conducted as outline in section 2.3, with the key parameters summarised in Table 3. The results indicate that the feed material exhibits

superior settling characteristics compared to the tailings material, which can be seen in the corresponding settling rate, rise rate and solids flux.

Table 3. Feed and tailings thickener settling parameterisation.

	Feed Thickener	Tailings Thickener
H_∞	90.0 mm	75.4 mm
H_0	340.0 mm	340.0 mm
λ	0.37 min^{-1}	0.17 min^{-1}
Settling Rate	0.67 m/h	0.49 m/h
Rise Rate	0.57 m/h	0.41 m/h
Solids Flux	0.088 tph/m^2	0.064 tph/m^2

The settling rates obtained from the test work were used to determine the appropriate sizing for both the feed and tailings thickeners. A feed material settling rate of 0.67 m/h and a final tailing settling rate of 0.49 m/h, along with a 25% safety factor, were applied to establish the baseline thickener requirements.

Additionally, laboratory filtration test work was conducted to assess the filterability of both the product and tailings streams. The filter feed time was measured at 6.1 minutes for the product material and 7.4 minutes for the tailings. These values correspond to a filterability of 71.5 tph/m² for the product material and 64.1 tph/m² for the tailings.

5.5 Economic feasibility assessment

Upon completion of the test work program, the processing plant and associated infrastructure were designed to meet the annual throughput requirement necessary for reclaiming and beneficiating the 2.1 million dry tons of tailings material contained within Tailings Dam II. Additionally, capital cost estimates were obtained for project execution on an Engineering, Procurement and Construction (EPC) basis, covering the full project scope.

To refine the financial analysis, detailed supplier quotations were sourced to accurately estimate all the project's operational expenditure. These cost estimates, in conjunction with the key financial assumptions outlined in Table 4, were utilised to develop a comprehensive financial model to evaluate the expected project profitability.

Table 4. Financial model key assumptions.

	Assumption
Annual Throughput	420 kt
Annual Operating Hours	7000 hrs
R/$ Exchange Rate	18.90
Coking Coal Price	$188.00 per ton
Producer Price Index	6.0%
Discount Rate	8.0%

The economic feasibility assessment was conducted using the prevailing coking coal price as a baseline input [9]. The results of this assessment, summarized in Table 5, indicate a projected Net Present Value (NPV) of $62.6 million, with a peak funding requirement of $35.0 million. Additionally, the initial capital investment is expected to be recovered within a period of less than two years from the commencement of operations, yielding an Internal Rate of Return (IRR) of 67.8%.

It is important to note that these financial projections are based solely on the execution and operation of the initial phase of the project, which focuses on the reclamation and beneficiation of Tailings Dam II. The analysis does not account for the potential long-term value associated with the retreatment of additional material contained within Tailings Dams I and III.

Table 5. Baseline financial model key outcome summary.

	Baseline Outcome
Net Present Value	$62.6m
Internal Rate of Return	67.8%
Peak Funding	$35.0m
Payback Period	1.79 yrs

Another factor that is considered as part of the project economic feasibility assessment is the sensitivity of the financial model to variations in underlying costs and key assumptions. To this end, a comprehensive sensitivity analysis was conducted to the parameters exerting the most significant impact on the project's economic feasibility, as is illustrated in Figure 9. The analysis indicates that, across all considered scenarios, the project maintains a strongly positive NPV. However, it is observed that the project is most sensitive to fluctuations in the coking coal price, which is inherently a volatile input. This sensitivity underscores the importance of price forecasting and risk mitigation strategies in ensuring the project's long-term financial sustainability.

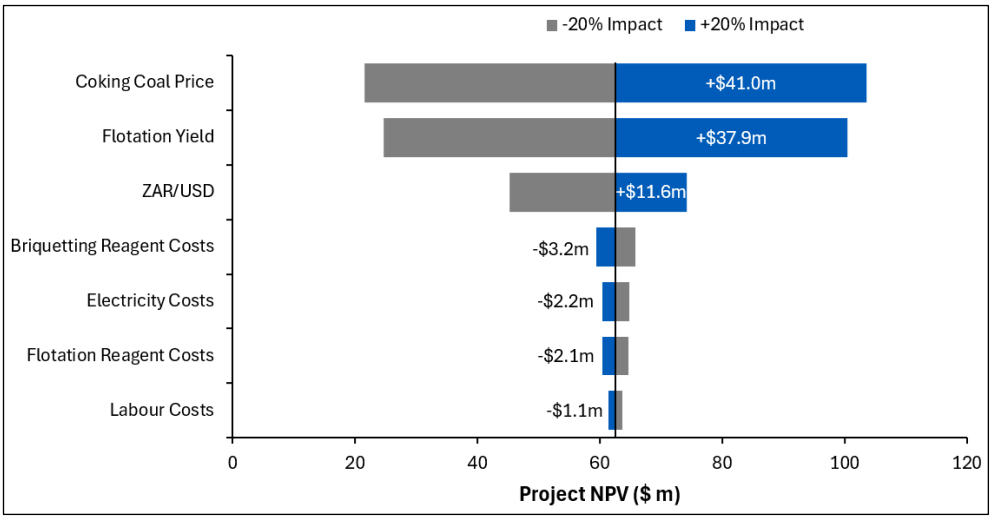

Fig. 9. Sensitivity analysis: impact on projected net present value.

As noted above, the coking coal price plays a critical role in determining the overall project feasibility. Consequently, a detailed analysed was conducted to assess the expected impact of this parameter on the overall project profitability. Figure 10 presents the historical market prices of coking coal over a five-year period, revealing three distinct pricing channels (low, moderate & high) [9]. To evaluate the influence of price fluctuations, the mid-point of each pricing channel was incorporated into the financial model, and the corresponding project cash flow was determined. The results, as depicted in Figure 10, indicate that all these scenarios yielded a positive NPV and a reasonable payback period. This analysis further reinforces the economic viability of the project, even under varying market conditions.

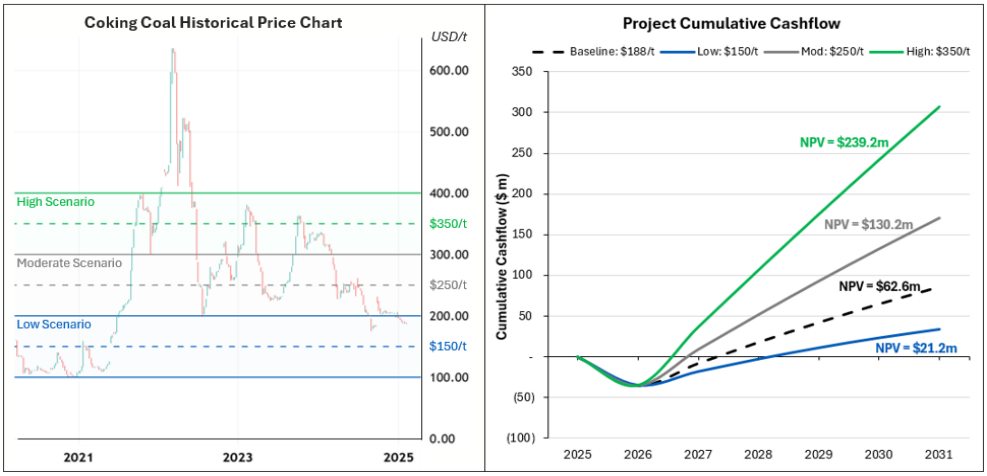

Fig. 10. Coking coal historical prices and project cashflows based on three pricing scenarios [9].

5.6 Environmental impact

The complete process was further simulated using the METSIM® software package, as illustrated in Figure 11, to comprehensively evaluate all the process inputs and outputs. The outcomes of the processing model and simulation indicate that the process is set to recover approximately 18.2 m^3/h of water, positioning it as a net positive water recovery circuit. Additionally, the project will facilitate the elimination of an existing TSF, thereby mitigating some of the environmental risks associated with long-term tailings deposition.

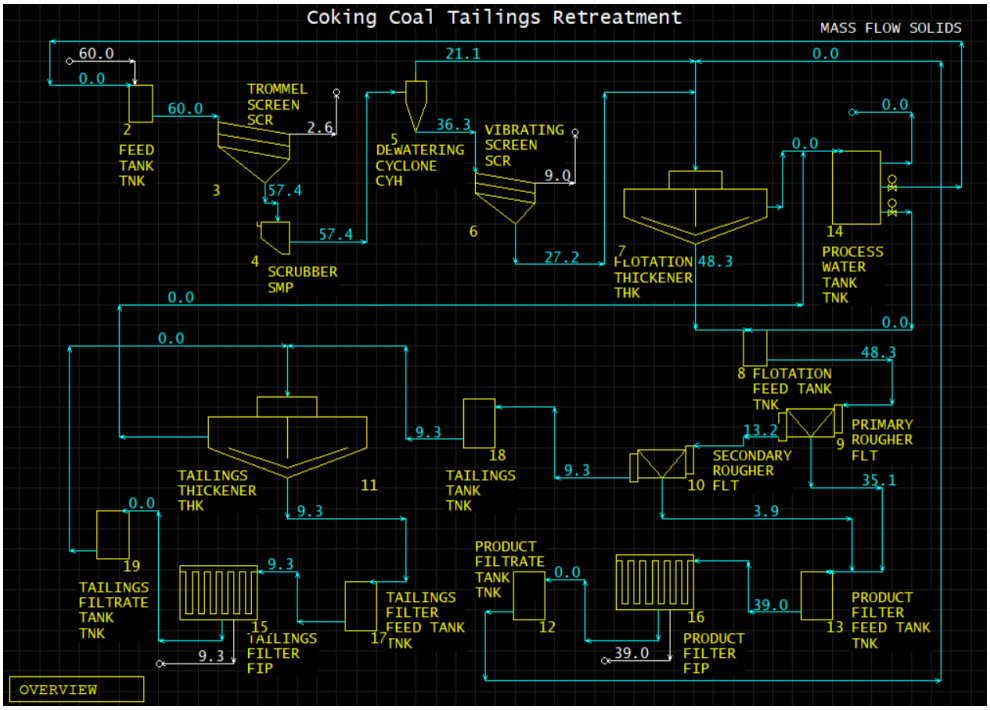

Fig. 11. METSIM® processing model and simulation.

6 Conclusion and recommendations

This study demonstrates the technical and economic feasibility of reprocessing the weathered coking coal tailings from the operation under consideration. Laboratory-scale test work was used to support the process development and design, indicating that high-energy input flotation coupled with mechanical surface preparation enhances the overall product quality and flotation yield. The processing flowsheet was developed and validated to optimise material handling, classification, recovery by froth flotation, and dewatering, ensuring efficient separation and upgrading of the coking coal product.

Detailed economic modelling, indicated a strong project financial outlook, with a projected NPV of $62.6 million, an IRR of 67.8%, and a payback period of under two years. A sensitivity analysis further validated the project robustness, with profitability remaining positive across varying scenarios. Beyond economic benefits, the project offers significant environmental advantages, including an additional water recovery of 18.2 m^3/h, and the decommissioning of an existing tailings storage facility, thereby reducing long-term environmental liabilities.

Overall, the findings in this study highlight the techno-economic feasibility of reclaiming and beneficiating weathered coking coal tailings as a sustainable and commercially attractive solution. Future work will focus on batch-scale pilot processing to further validate the outcomes realised in within this study. Batch-scale processing will also assist in managing and mitigating scale-up and technological risks, thereby providing an additional layer of assurance to the project owners and investors.

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