# CHAPTER EIGHT - COAL BENEFICIATION MODELLING OF BENEFICIATION OPTIONS

This Section presents coal processing circuits that could be used to achieve various outcomes linked to different grade products.

## 8.1 Processing Simulations

Process modelling was completed using coal preparation models derived from actual plant operation data (using the Whiten model equation), *Coal Preparation Utilities* (CSIR) and the *LIMN* (flowsheet processor). All the modelling was done for a 500 tph throughput capacity module to allow for comparison. Only physical beneficiation methods were considered. The *Coal Preparation Utilities* is software developed by the CSIR in South Africa for coal preparation modelling and efficiency test work. The *LIMN* “The Flowsheet Processor” software was developed by D.Wiseman in 1994. *LIMN* is a Microsoft Excel based software package that can be used for mineral processing circuit modelling applications (Wiseman, 2010). The beneficiation process parameters included in the modelling in terms of cut point RD, NGM and epm are shown in Appendix G (G1, G2 and G3).

The circuits were modelled according to their feed size classification:

(i) Coarse size fraction: -150+12 mm
(ii) Medium size fraction: -12 + 0.5 mm
(iii) Fine size fraction: -0.5 + 0.15 mm
(iv) Ultra-fine fraction: -150 µm

It should be noted that the models were not developed to full circuits with an intricate amount of detail as this would have increased the data management beyond the scope of this thesis. The data used in this thesis incorporates 2 400 process modelling worksheets (1GB). A number of the parameters for processing and costing (Chapter 10) were factored in based on experience, and if unclear deducted based on literature and advice from design companies. Costing and DCF sheets are included in the Appendix B (B1, B2 and B3).

**Equation 13:** *The Whiten Equation (Gay, 1999)*

$$P_i = \frac{1}{1 + e^{\left(\frac{1.099(\rho 50 - \rho i}{Ep}\right)}} \quad \text{.......... (13)}$$

In Equation 13, $P_i$ is the partition number at the density fraction ($i$), $\rho_i$ is the mean density of density fraction $i$, and $\rho_{50}$ is the separation density or cut-point density. Ep is the probable error of separation or *Ecart probable*. The processing efficiencies and cutpoint densities used in the modelling is summarised in Table 6 and Figure 21 in Chapter Two. The classification cut sizes are based on the identified processing stream size ranges and indicated in Figures 131-138:

(i) Coarse size fraction: -150 + 12 mm (ROM Banana screens, 12 mm apperture)
(ii) Medium size fraction: -12 + 0.5 mm (Desliming screen, 0.5 mm apperture)
(iii) Fine size fraction: -0.5 + 0.15 mm (Classification cyclone, 0.15 mm cut size)
(iv) Ultra-fine fraction: -150 µm (-0.15 mm classification cyclone overflow

For the *coarse coal beneficiation dense medium bath circuit* depicted as part of Figure 131, the drum could be replaced with a Drewboy as a similar circuit configuration exists. The following circuits were evaluated and modelled, processing Witbank Coalfield No. 4 Seam, Waterberg Upper Ecca and Free State coals.

- Conventional single stage dense medium processing circuit with Wemco Drum and DSM Cyclone.
- Double stage conventional dense medium processing design with Wemco Drums and DSM Cyclones.
- Conventional dense medium DSM Cyclones circuit.
- Dry screening and wet de-stoning circuit for domestic power consumption
- Complete dry processing circuit using either XRT sorting or the FGX separator (mainly for domestic production)
- Combined Dry and Wet processing circuit for coarse and medium size feed respectively.

- Conventional circuit to treat fines (-0.5+0.15 mm), using a screen bowl centrifuge.
- Proposed Three Product Cyclone circuit.
- Proposed conventional fines processing circuit to treat the -0.5+0.15 mm and -150 micron material.
- Advanced circuit for optimal sulphur and ash reduction .

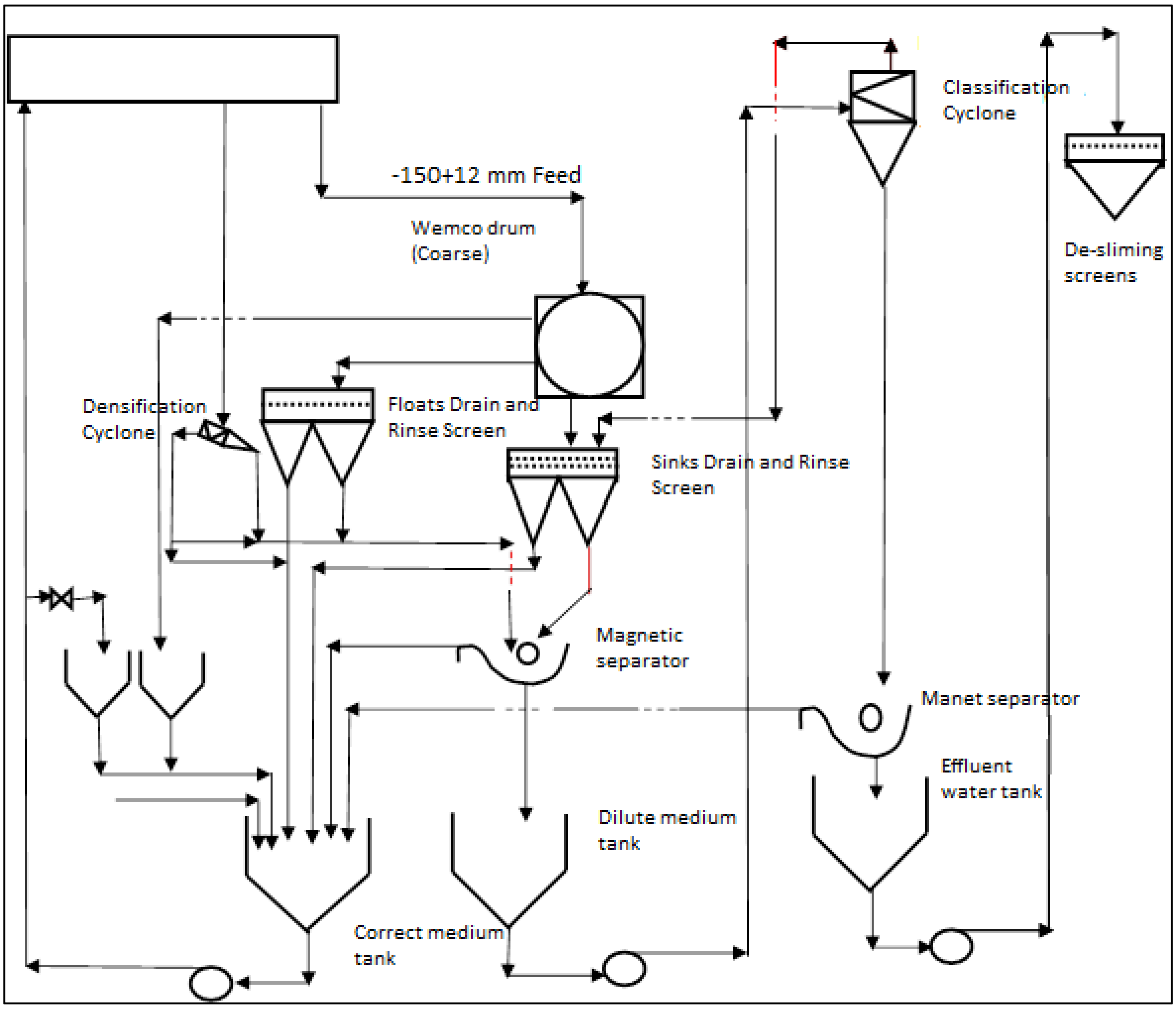


**Figure 131:** *Conventional Single Stage dense medium processing circuit with Wemco Drum for the coarse size fraction.*

A double stage processing configuration can be viewed in Figure 132. In Figure 132 the secondary stage of the double stage circuit involves the re-wash of the primary DSM Cyclone (medium size) floats and Wemco drum (coarse size) sinks fractions to produce a combination of high and low ash products. The products produced from the processes in Figure 132 are made up of the streams as follows:

1. The low ash product (Product 1) consists of primary Wemco floats and secondary DSM Cyclone floats fractions.
2. The high ash product (Product 2) consists of the re-washed and re-crushed secondary Wemco drum floats and secondary DSM cyclone sinks fractions.

The product moistures of the sinks and float secondary DSM Cyclone fractions are reduced through centrifuges.

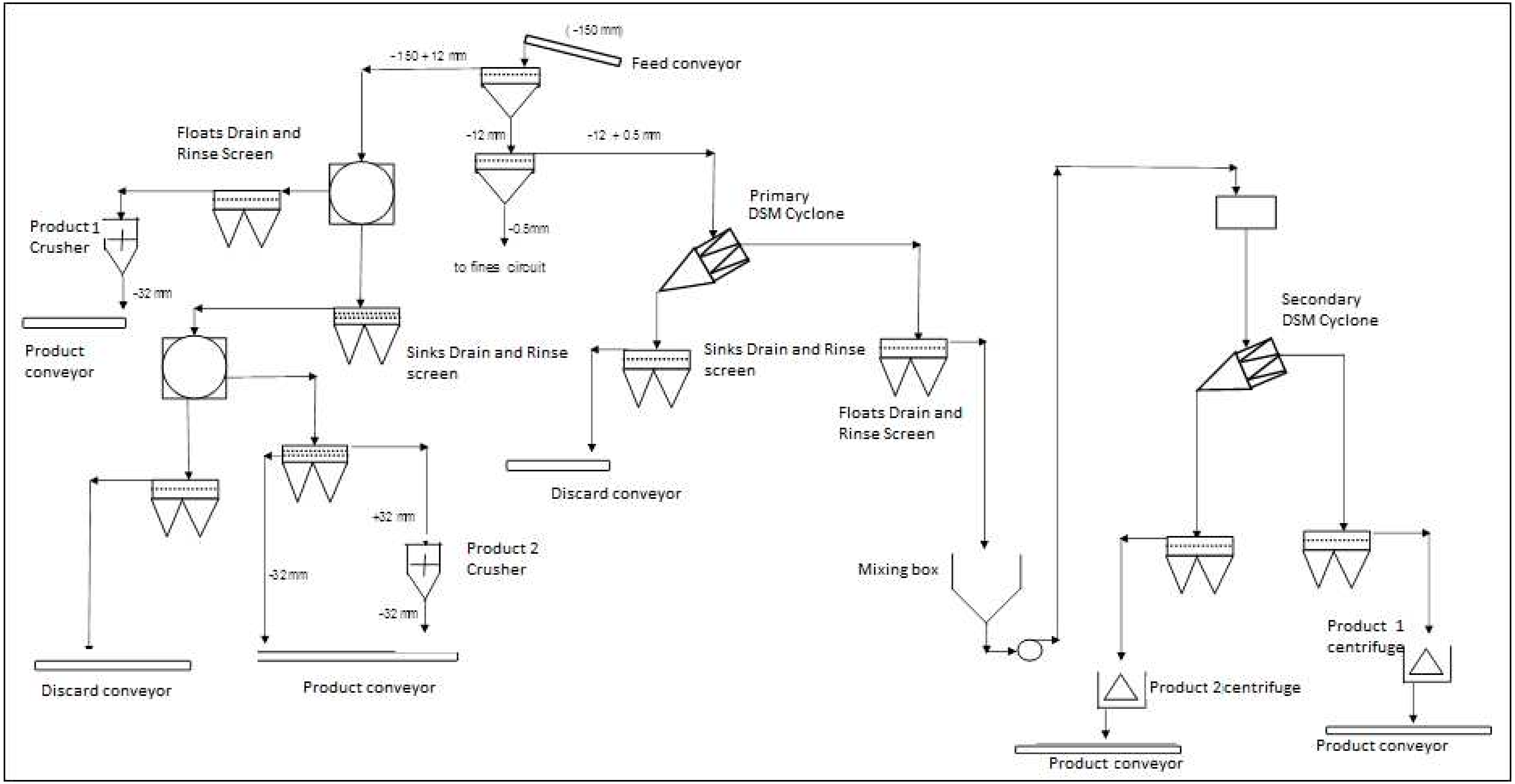


**Figure 132:** *Double Stage conventional dense medium processing design with Wemco Drums and DSM Cyclones.*

For medium sized coal the conventional DSM cyclone circuit was modelled and evaluated, Figure 133.

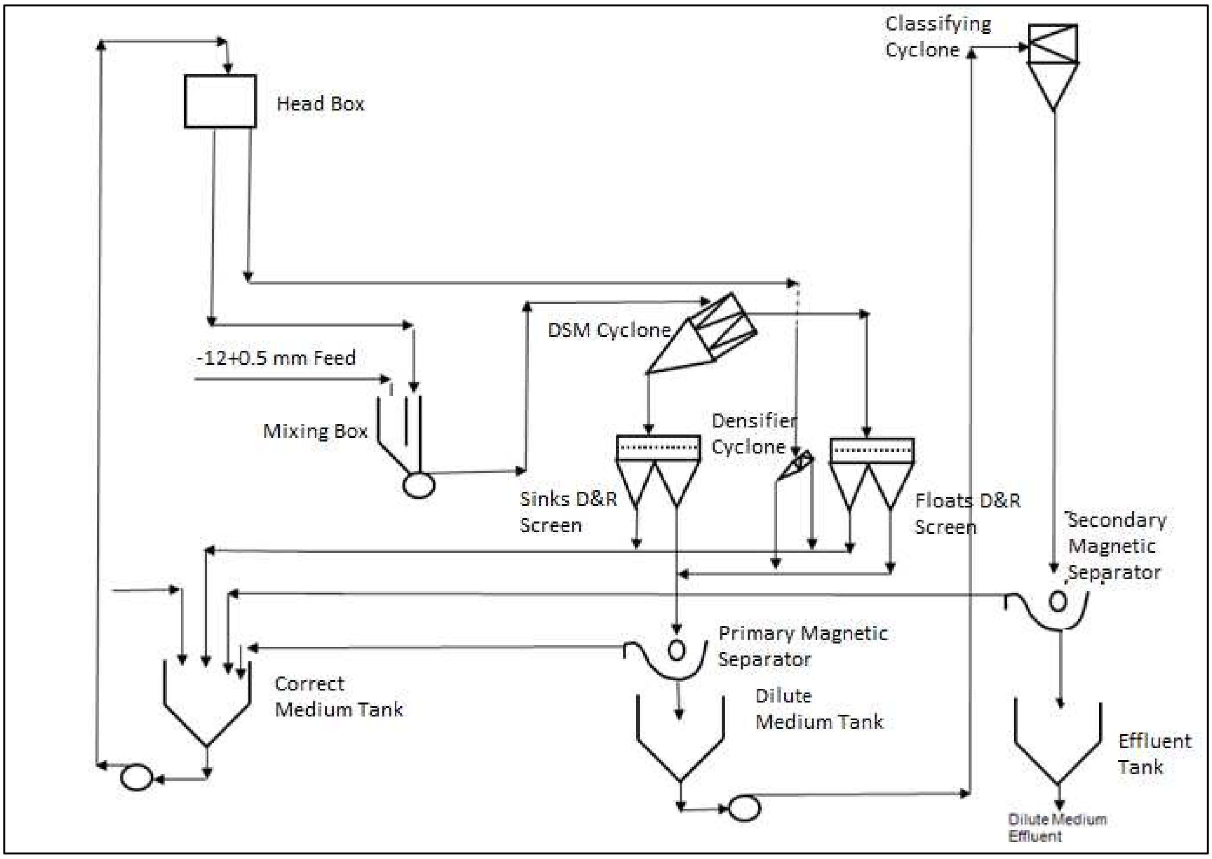


**Figure 133:** *Conventional dense medium cyclones circuit.*

For domestic power station production see Figure 134, as a dry screening and wet de-stoning circuit.

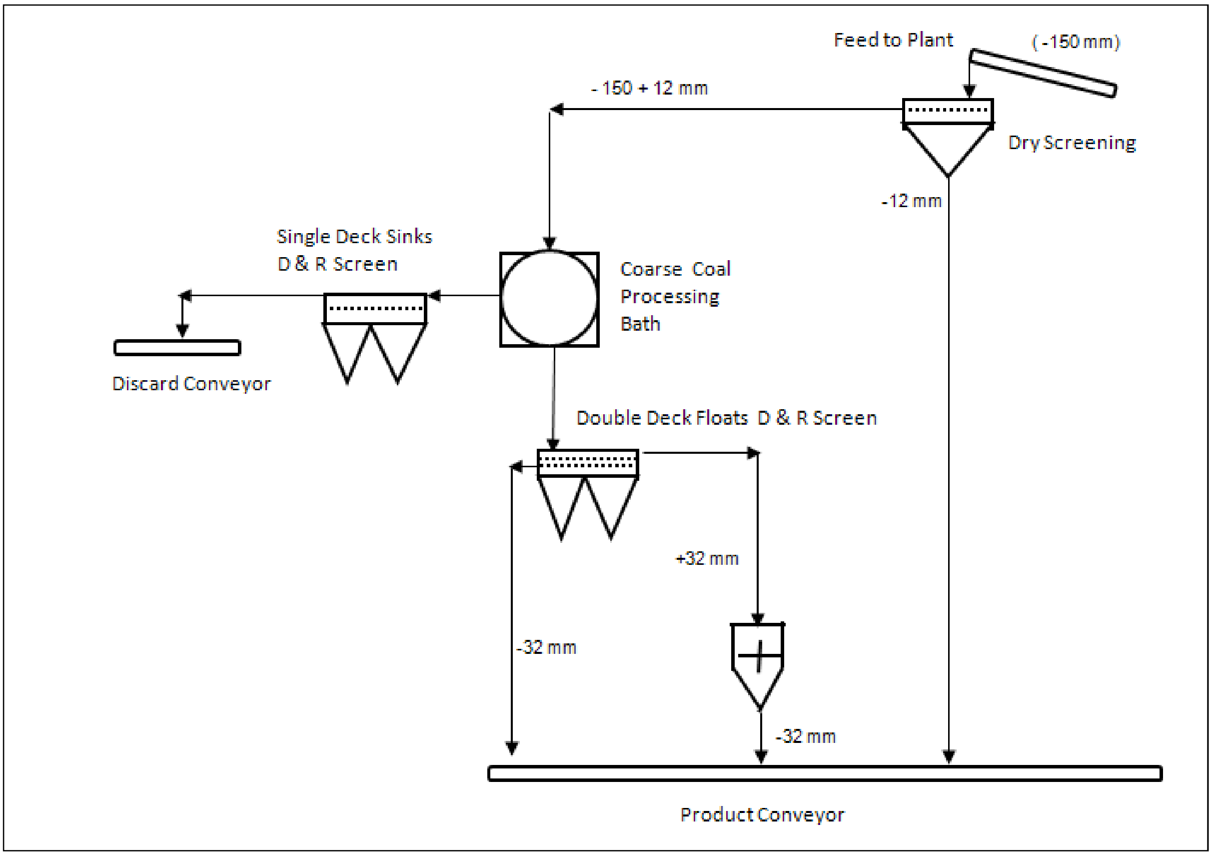


**Figure 134:** *Dry screening and wet de-stoning circuit for domestic power consumption*

For a complete dry processing (screening included) and de-stoning circuit, Figure 135 is proposed. The coarse size fraction is processed with the XRT Sorter and then crushed to minus 32 mm as a product sizing requirement. The medium size fraction is screened out with dry screening and added to the product directly.

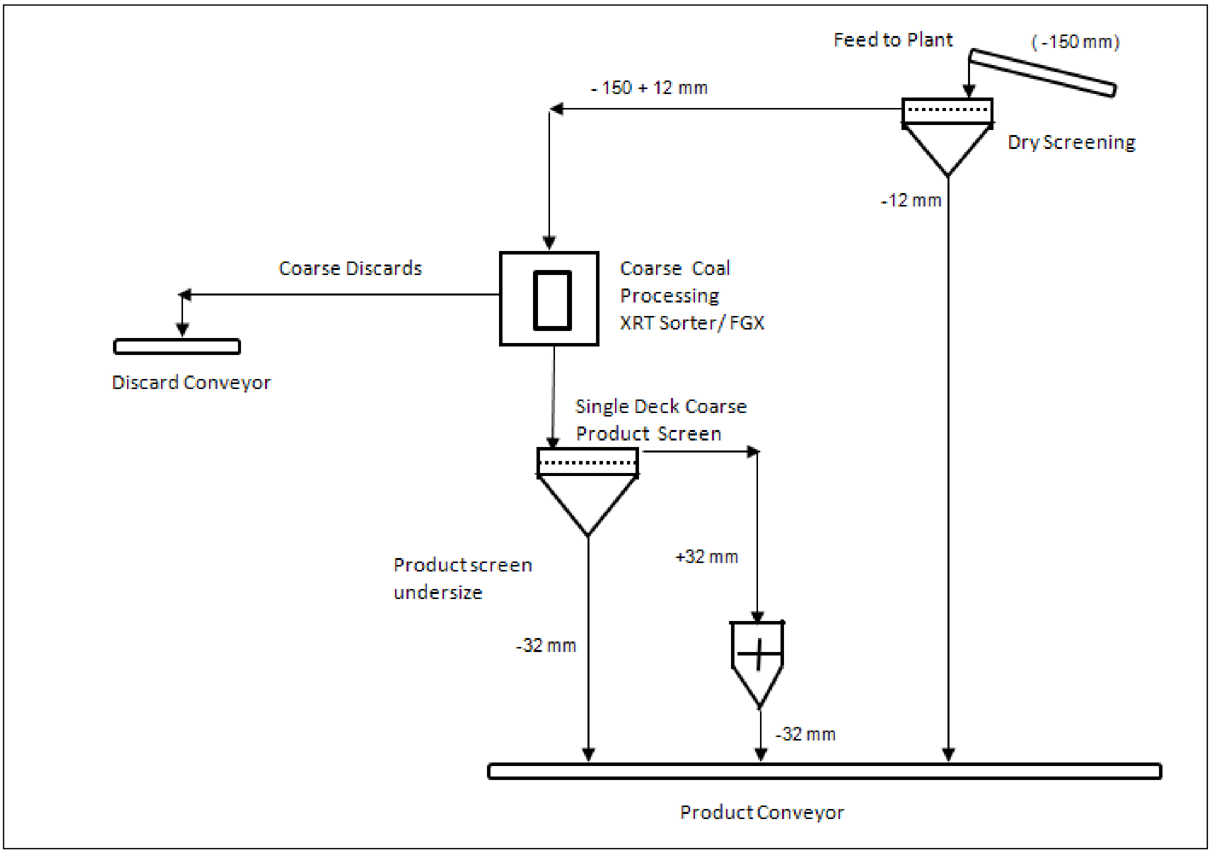


**Figure 135:** *Complete dry processing circuit using either XRT sorting or the FGX separator (mainly for domestic production)*

In the case of variable low grade export production and domestic production a dry separator is proposed for the coarse fraction, and DSM cyclones for the medium size fraction, Figure 136.

Although not indicated in Figure 135, the DSM Cyclone floats (from the floats drain and rinse screen) will be dried with a medium coal centrifuge prior to discharging on the product conveyor.

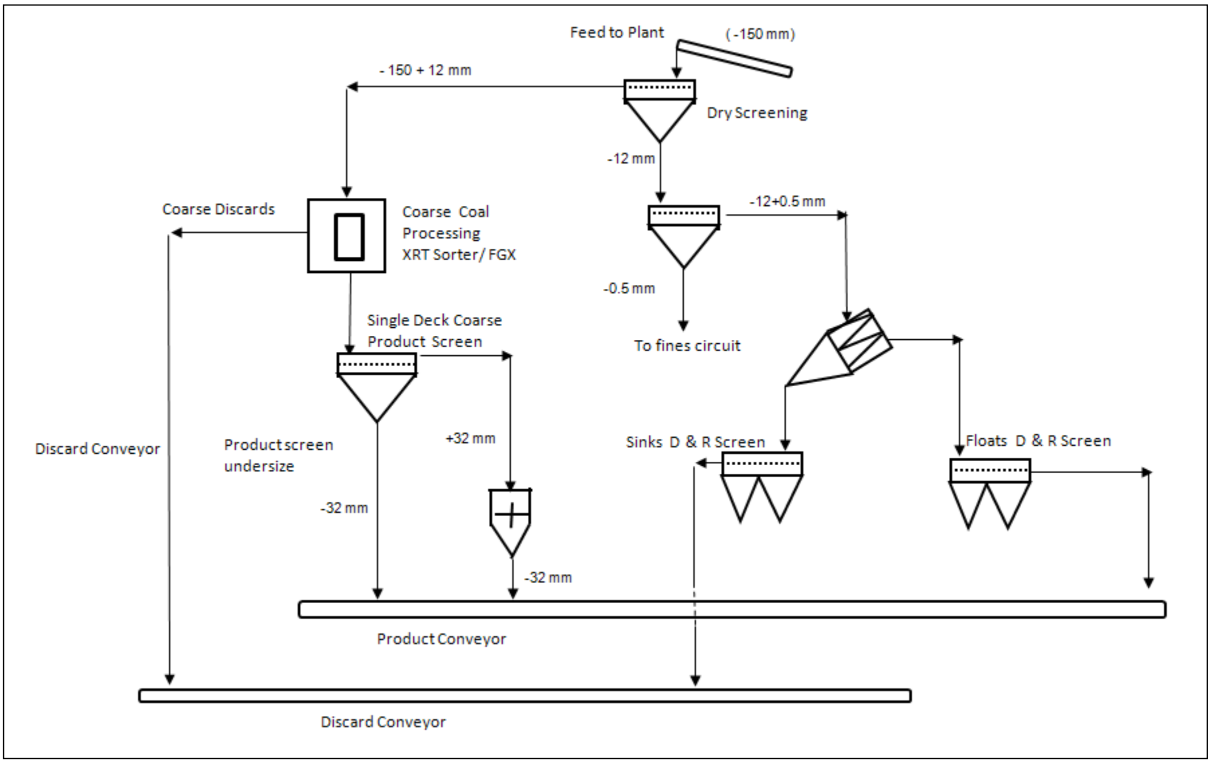


**Figure 136:** *Combined Dry and Wet processing circuit for coarse and medium size feed respectively.*

A conventional fine coal processing circuit is proposed as per Figure 137. A uniform upgrade is estimated in the case of spiral concentrators. In addition, modelling was done for using fine dense medium cyclones. The modelling was done through washability characterisation and industry data.

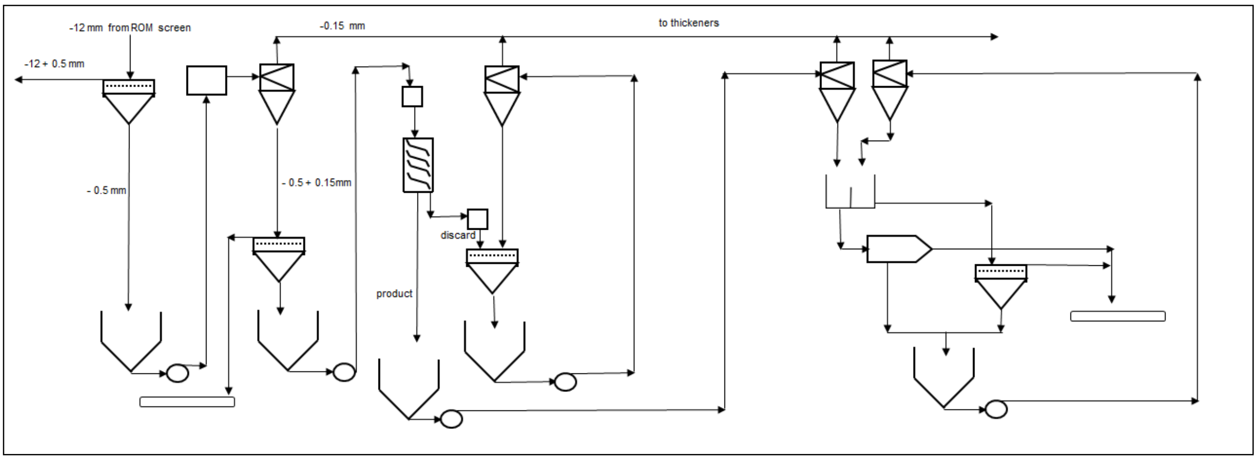


**Figure 137:** *Conventional circuit to treat fines (-0.5+0.15 mm), using a screen bowl centrifuge.*

In Figure 138, a Three Product Cyclone circuit is proposed. The Three-product cyclone was modelled as a primary and secondary dense medium cyclone.

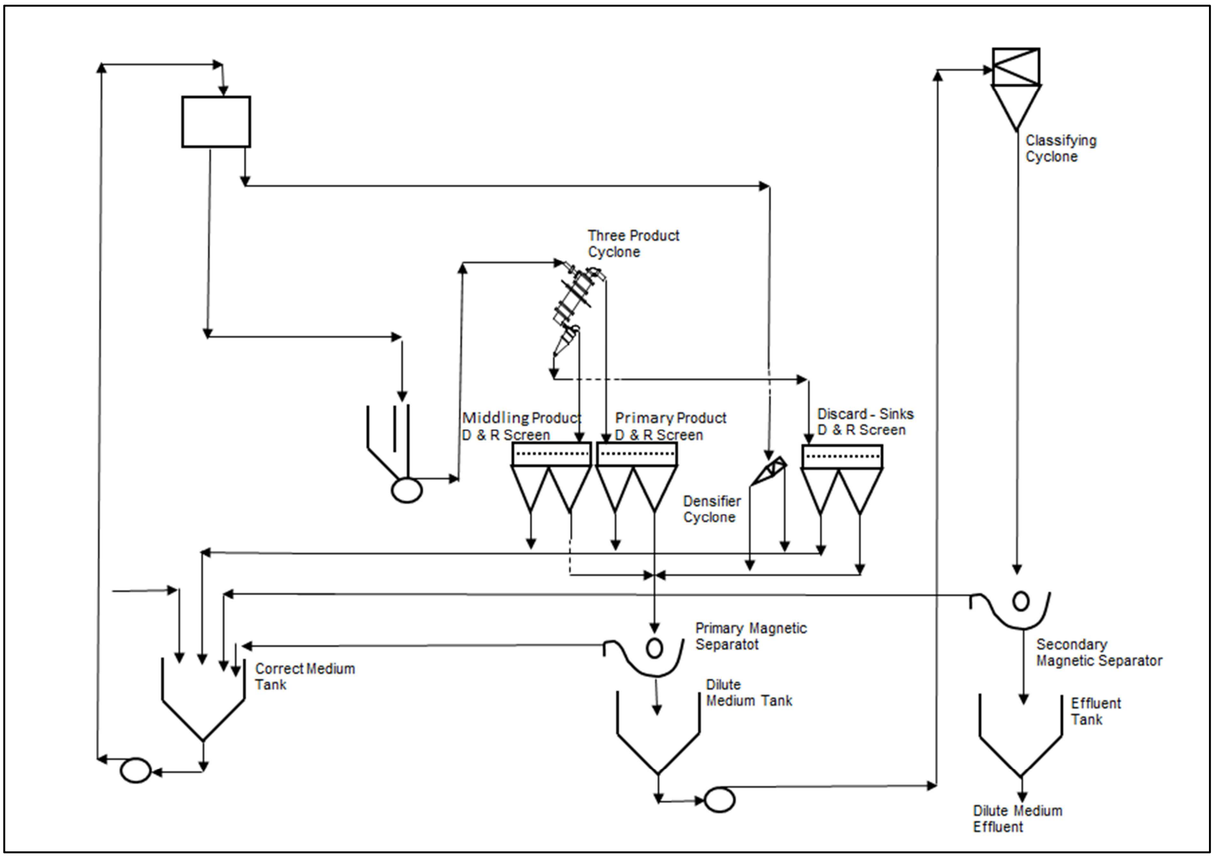


**Figure 138:** *Proposed Three Product Cyclone circuit. Note that the primary product drain and rinse screen can be modified to allow for a split screen. The split screen would allow for the discharge of the primary and middling product separately.*

Flotation of ultra-fines (Figure 139) was not modelled in great detail, due to the fact that in the case of low grade export and domestic production it is not necessarily required. Flotation modelling was only done in the case of high grade export production. In the case of the Witbank Coalfield No. 4 Seam for high grade export froth flotation was considered.

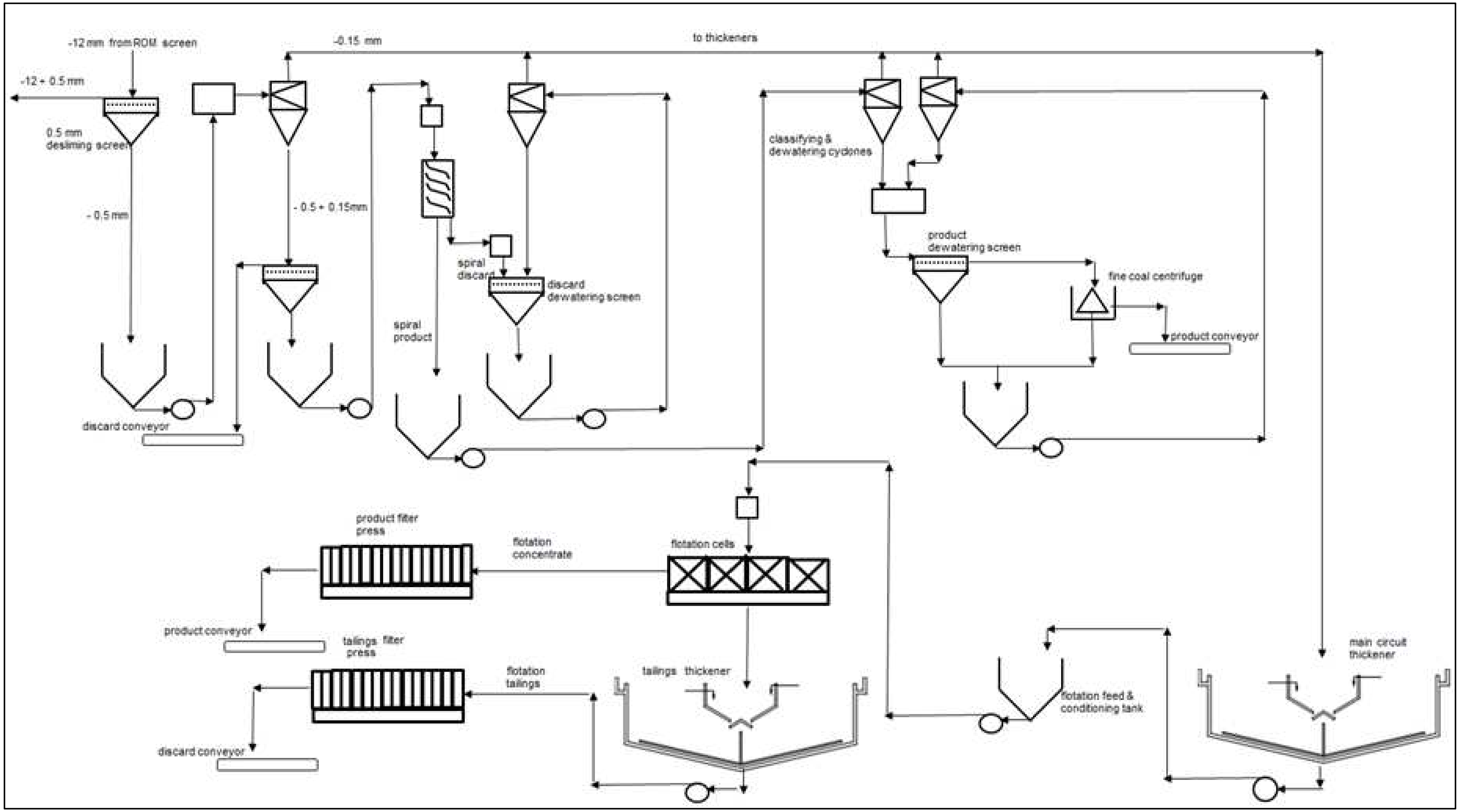


**Figure 139:** *Proposed conventional fines processing circuit to treat the -0.5+0.15 mm and -150 micron material*

### 8.1.1 Waterberg Upper Ecca Optimum Circuit for Export Product Optimum Process

For both domestic and export thermal coal production, the following main process categories were evaluated. The raw data used in the beneficiation modelling are summarised in the Appendix E, Table X and XI:

- DMS Cyclones (Coarse And Medium)
- DMS Bath (Coarse) & DMS Cyclones (Medium)
- Water Jigs (Coarse) & DMS Cyclones (Medium)
- DRY FGX (Coarse) & DMS Cyclones (Medium)
- DRY XRT Sorter (Coarse) & DMS Cyclones (Medium)

It was found due to the high ash content of the medium and fines size fraction (Table XI), that dry processing and addition to product directly was not viable and that beneficiation was required. No flotation or fines processing was considered for low grade export and domestic coal production due to the low quality and high sulphur content of the ultrafine fraction.

### 8.1.2 Waterberg Upper Ecca Optimum Circuit for Domestic Product

The processing of the Waterberg Upper Ecca options evaluated is similar to the low grade export evaluation in Section 8.1.1.

### 8.1.3 Waterberg Upper Ecca Optimum Circuit for Optimum Sulphur Reduction and Associated Trace Elements Process

Due to the fact that the Waterberg Upper Ecca displays a uniform reduction potential in sulphur concentrations with dense medium beneficiation, fine liberation is envisaged not to reduce the sulphur content to optimal levels throughout.

### 8.1.4 Witbank Coalfield No. 4 Seam Optimum Circuit for Export Product

For both high and low grade export with a domestic middling thermal product production, the following main process categories were evaluated. The results from the washability analysis (Table X, Appendix E) were used to the beneficiation modelling:

- DMS Cyclones (Coarse and Medium)
- DMS Bath (Coarse) & DMS Cyclones (Medium)
- Water Jigs (Coarse) & DMS Cyclones (Medium)
- DRY FGX (Coarse) & DMS Cyclones (Medium)
- DRY XRT Sorter (Coarse) and DMS Cyclones (Medium)
- Three Product Cyclone
- DMS Cyclones + Dry Screening
- DMS BATH + Dry Screening
- WATER JIGS + Dry Screening
- DRY FGX + Dry Screening
- DRY XRT SORTER + Dry Screening

### 8.1.5 Witbank Coalfield No. 4 Seam Optimum Circuit for Domestic Product

The processing of the Witbank Coalfield No. 4 Seam options evaluated is similar to the low grade export evaluation in Chapter 8.1.4.

### 8.1.6 Witbank Coalfield No. 4 Seam Optimum Circuit for Optimum Sulphur and Associated Trace Elements Reduction Process

In Figure 140 a conceptual plant design is proposed for optimal ash and sulphur reduction. Liberation to 150 micron of all product material would be required to allow for subsequent froth flotation. On industrial scale this can be deemed impractical. The product and discard from the process would require filtration (on discard and product) and subsequent agglomeration (briquetting in this instance) on the product material. Briquetting can provide for an agglomerated product that would entailed easier handling of the material and at lower product moistures than raw ultra-fine material. The circuit is given to reflect on a possible solution that would provide for optimal liberation and combustible recovery. It should be noted that the 150 micron size referred to is purely theoretical and is based on size classification design parameters in modern coal beneficiation circuits in South Africa. Nevertheless, process modelling was done using the LIMN flowsheet processor. This was done by using adjusted washability data from the liberation test work (Table X, Appendix E). The financial modelling of the process (Chapter 10) was not evaluated because of the envisaged OPEX that would be too high to allow for a financially feasible solution.

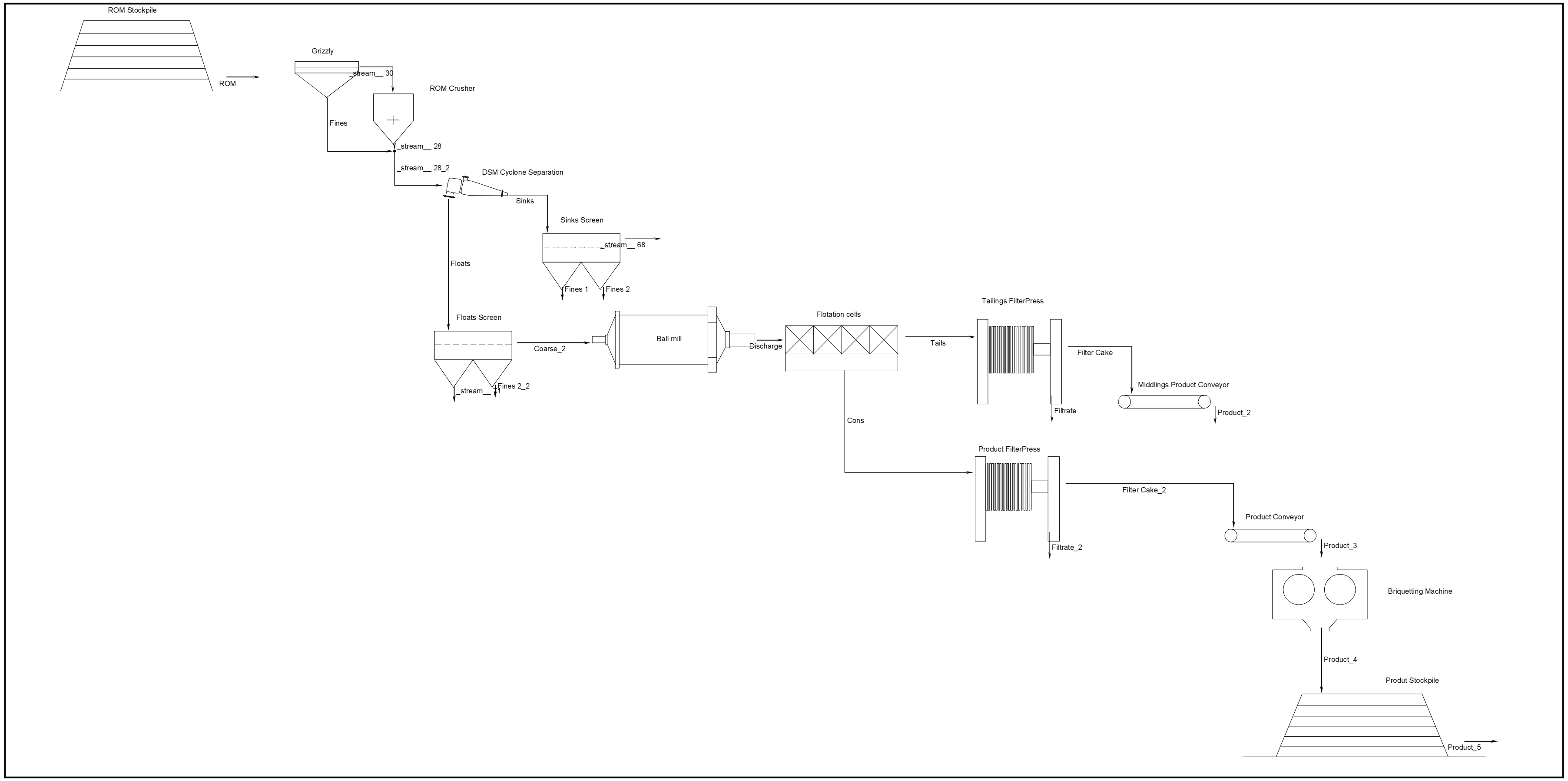


**Figure 140:** *Advanced circuit optimum sulphur and ash reduction*

## 8.2 Processing Resources Requirements Modelling

Resource requirements for the various processes were evaluated, but not modelled in great detail.

For wet dense medium an average of 0.25 litres/ton/hour feed was determined, and estimated from the mass balances of previously modelled circuits. The circuits were however costed with closed water circuits, i.e. filtration of the tailings slimes generated was accounted for.

Power requirements of individual CHPP's were determined and given in greater detail. This is discussed in Chapter 10.

Magnetite requirements were evaluated, but had a marginal effect on operating cost.

For complete dry processing circuits (dry screening, FGX and XRT sorting) a standard water consumption of 1 % (1 ton of water per ton of coal processed) of the total feed is assumed and could be deemed too marginal to take into account.