BUSINESS CENTRED DESIGN PRINCIPLES APPLIED TO PLANT CAPACITY MODELLING AND CAPITAL DECISION MAKING

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Abstract

Alcan Inc. of Canada has recently approved US$1.3bn capital expenditure to expand the production capacity of the Alcan Gove Alumina Refinery. The plant, located on the Gove Peninsula of Northern Territory (Australia), is presently rated at 1.9Mt/y alumina. The expansion will see alumina production capacity increasing to 3.78Mt/y by 2007.

Prior to committing to this investment, a comprehensive 18-month Definitive Feasibility Study (DFS) was conducted. It was recognised early in the DFS that a means of quantifying the interaction between items of equipment in the plant from reliability perspective, as well as unit process performance, was necessary in order to verify that total plant throughput would meet the required overall target production rate.

This paper presents the Business Centred Design approach applied to the capital expenditure decision-making process for the Gove Stage 3 Expansion.

1 Introduction

1.1 *A different approach to common industry practice*

A common approach adopted by many design and process engineers when considering plant design requirements is to focus heavily on plant availability. Whilst availability is an important consideration, this should not be pursued to the exclusion of other significant parameters. A more holistic approach is needed to encompass all the factors that influence plant performance. For the purposes of this paper, this approach has been termed "Business Centred Design".

Business Centred Design (BCD) is a methodology and approach that recognises that process design, plant engineering design, operations and maintenance are all involved in a partnership to ensure the delivery of quality product at the lowest possible sustainable unit cost.

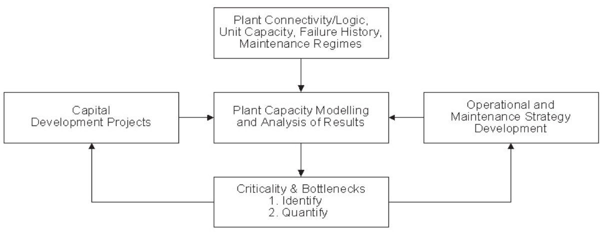


Figure 1 The BCD Process

BCD focuses on equipment capability, capacity, maintainability, connectivity and interaction between the various elements of the plant. This integrated approach provides a sound understanding of the operational implications of proposed equipment modifications or design changes, and thus a more comprehensive decision making process.

Additionally, BCD methodology provides a framework for all stakeholders (process, engineering, operations, maintenance) input into plant design.

1.2 *Quantitative decision making – the basis of good plant design*

The key differentiator of the BCD approach is that it is quantitative and thus overcomes the risk of key decisions being taken based on personal judgement/preferences or precedent alone.

A quantitative approach by its very nature requires that all inputs and assumptions made are documented and are thus subject to rigorous review and challenge where necessary.

Factors quantified as part of the BCD approach for Gove 3rd Stage included:

- Environmental, Health & Safety Issues
  - Workplace health and safety issues
  - Storage of hazardous materials
  - Waste management practices
- Equipment Capabilities
  - Typical Process Flows
  - Climatic Considerations
  - Age Related Equipment Degradation
  - Equipment Design capacity
- Asset Maintenance Requirements
  - Equipment Failure rates
  - Maintainability Aspects
  - Equipment Repair Times
  - Planned Maintenance Downtime
  - Spare Parts Availability
- Equipment Failure Consequences
  - Total Plant Stoppages
  - Reduction in Plant Output
  - Potential Safety/Environmental Hazards
  - Quality Control Issues
- Operational Parameters
  - Operational Downtime Due To Process Constraints
  - Buffer or Interplant stockpile Capacities
  - Material Handling Issues

Consideration of all these aspects required the development of plant capacity simulation models during the definitive feasibility study (DFS) process to reflect the various project options.

2 Methodology

2.1 *Capacity modelling techniques*

Simulation modelling techniques provided the information the design engineers required to quantify the plants capacity for various design or process options, prior to committing to capital expenditure. These tools allowed all the plant parameters to be considered over a number of life cycles and provided the information to justify or prioritise capital project expenditure.

2.2 *Modelling methodology adopted for Gove 3rd Stage*

The capacity modelling technique used in modelling the Alcan Gove 3rd Stage expansion utilised Monte Carlo simulation methods to estimate system and sub-system parameters such as availability, number of expected failures and actual and potential capacity.

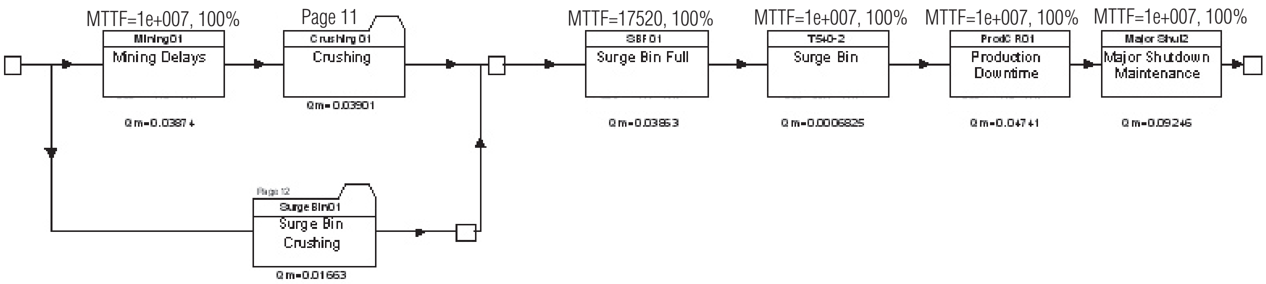


Figure 2 Reliability Block Diagram for Crushing

The modelling involved synthesising system performance over a given number of simulation runs. Each simulation run emulated the plant's real life performance, based upon the input data provided to the model.

The plant simulation involved the creation of network diagrams, which provided the connectivity between all the various components within the plant. These network diagrams were used in the simulation model to demonstrate how component failures interacted to cause system failures. By performing many simulation runs the model was able to build up a statistical picture of each system's performance.

This knowledge of each system's interdependence and connectivity within the plant provided information to the process and design engineers that ensured considered decisions were made in the conceptual and detailed design phases of the project.

2.3 *Development of the reliability block model*

To provide an accurate reflection of how the plant would operate under various circumstances, detailed discussions took place with the process engineers and plant operators. These discussions provided the insight required to better understand the operating constraints imposed from both maintenance and operation activities.

Examining the process flow diagrams enabled the establishment of the reliability blocks that represented the various systems, sub-systems and equipment within the plant [see Figure 2].

2.4 *Establishment of plant reliability parameters*

Initially it was important to assign the basic failure and maintenance characteristics of individual blocks within the network. This information was used to facilitate the establishment of accurate failure density functions and the maintainability aspects for each plant component, in their specific operating context.

Contributing data was obtained by extracting maintenance records from the existing Gove Refinery's Computerised Maintenance management System, over a 5-year period.

The final stage of establishing the reliability parameters involved the analysis of plant maintenance records. Operations and maintenance personnel were then able to challenge and modify the data, according to the group consensus, in relation to the frequency and consequence of the various failure scenarios.

2.5 *Validation of the model*

Validation of the simulation model's accuracy is vital. This was achieved by the creation of a model for the existing plant. The existing operational, maintenance and reliability data was then assigned to the reliability blocks.

The model's forecast data was then compared with the previous year's records of plant capacity and availability, with regard to the total plant and specific process areas.

The model's forecast data was within 0.5% of the existing plant's capacity, and provided a high level of confidence in the model's accuracy for the proposed expansion.

In a green field site minor modification of the operational, maintenance and reliability data for similar equipment, maybe required to reflect real life conditions.

2.6 *Optimisation of the model*

The model contained detailed information on each area's actual and potential capacity and availability. The plant's capacity was further explored by sub-dividing the plant areas into sub-areas. This provided specific detail about where the "bottlenecks" or excess capacity existed within the plant. This drilling down continued in certain areas and identified individual equipment capacities.

Examination of this information provided the detail required to make informed decisions for the Gove Stage 3 Expansion [see Figure 3].

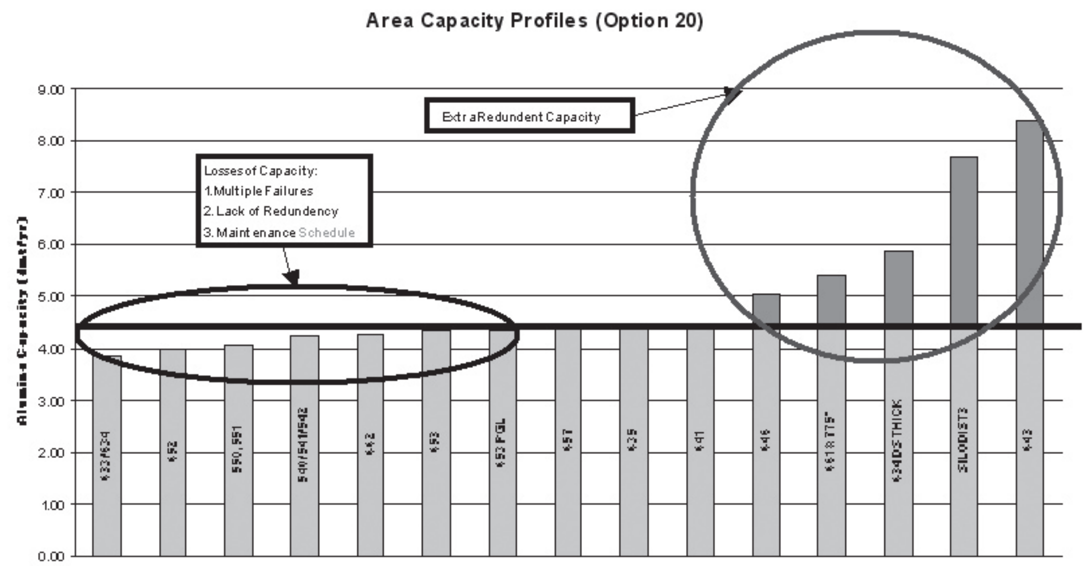


Figure 3 Gove 3rd Stage Area Capacity Profile

Slurry Thickening Review (634)					
Model	Description	Capacity (mt/yr)			
		Deep Cone Thickeners	HP Slurry Pumps	Turbid Liquor Pumps	Total
1	Option 23 Noimal Rates	4.1	4.415	3.87	3.79
2	Remove 1 deep thickener and set to max flow rate 3058.41 m3/hr (Based on Thickener availability = 88%.) (2 operational and 1 standby)	4.1	4.415	3.87	3.87
3	Remove 1xHP Pump and 1 deep thickener and set to max flow rate 3058.41 m3/hr (Based on Thickener availability = 88%.) (2 operational and 1 standby)	4.1	4.415	3.87	3.87
4	Remove 1xHP Pump and 1 deep thickener and set flow rate 2667.2 m3/hr (Based on Thickener availability = 88%.) (2 operational and 1 standby)	3.588	4.415	3.87	3.587

Figure 4 Slurry Thickening Sensitivity Analysis

3 Capacity modelling in action

3.1 *Identification of potential bottlenecks*

Identification of the plant's "bottlenecks" was a significant outcome from the model. Conversely, areas that had been over designed in respect to capacity were also identified. The existing funds could then be allocated to those process areas that were identified as potential capacity risks to the project deliverables.

3.2 *Assessment of project capital options*

Changing the appropriate model parameters and re-running the simulation model easily assessed design proposals. The design team were then able to examine whether the projected improvement in one area realised actual improvements in the total plant output.

This also provided information on the progressive shifting of the "bottlenecks" within the plant.

3.3 *Sensitivity analysis ("what-if" scenarios)*

Modification of the plant configuration can be simply incorporated in the simulation model. The outcomes can be quantified to confirm or reject the proposed modifications [see Figure 4].

3.4 *Project risk profiling*

To illustrate the capability of simulation modelling the following diagram demonstrates the performance of various material handling circuit options, by comparing the level within the Main Bauxite stockpile as plant's capacity was increased from the existing 1.9 Mt/y to the proposed 3.78 Mt/y [see Figure 5].

4 Conclusions

4.1 *A focus on plant capacity and quantitative assessment of options*

Simulation modelling provided an immediate feedback for the Gove Stage 3 design team.

Quantification of the plant performance characteristics, at both the area and plant level enabled risk prioritisation to be made for specific design options. The technique also ensured area improvements could be tracked to ensure the specific plant improvements were delivered.

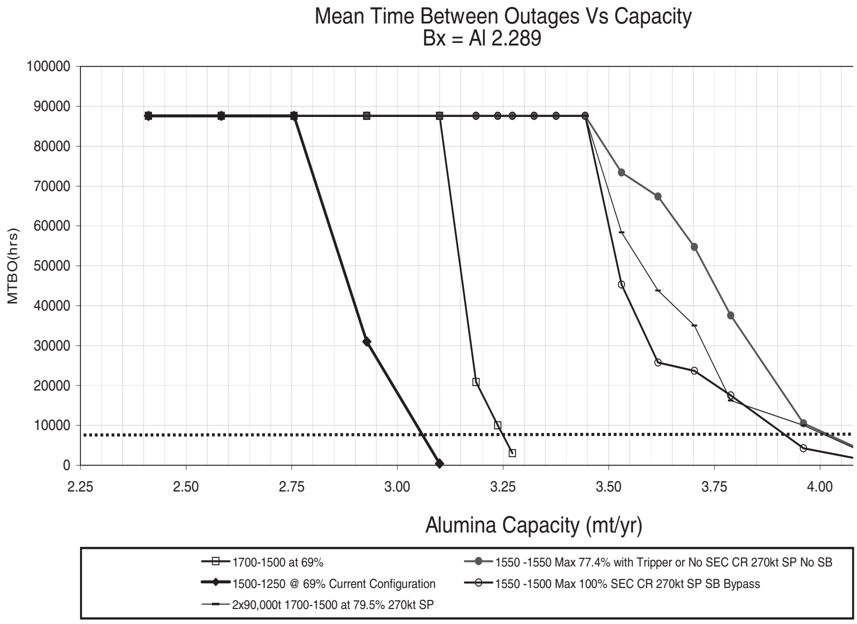


Figure 5 Gove 3rd Stage Materials Handling Risk Profile

4.2 *The fit within Alcan's broader continuous improvement framework*

Alcan's corporate goal of continuous improvement is based on the implementation of strategic step improvement initiatives and the involvement of all relevant company employees.

Continuous improvement is intrinsic to the BDC approach (refer back to figure 1.1) and was thus embedded within the design team for the Gove Stage 3 DFS, resulting in a robust project proposition for review and approval by Alcan senior management.

5 Appendix – Typical Worked Example (Gove 3rd Stage Project – Reclaim System)

The example below comprises one of many plant capacity assessments undertaken as part of the Gove 3rd Stage Project. It compares two cases, one of which (Model B) considers removal of two conveyors from the plant design to reduce capital cost.

Memo:

To: Gill Tetly, Paul Mastin		Project No.	770110
From: Chris Chatto		Reference	
Copy:	1	No of Pages	6

Subject: Availability Simulation-Reclaim System

1. Object

This document details the results of a reliability simulation study using AVSIM+ to determine the capacity and availability impacts on the overall materials handling delivery system.

2. Scope

This document only considers –

- Equipment from the mine feed bin hoppers to the slurry pumps.
- Option 23 capacities for crushing, conveying, milling.
- The following models
  1. Model A Existing Plant 1017
  2. Model B Modified Plant 1017 No C633-301 & C550-6-19

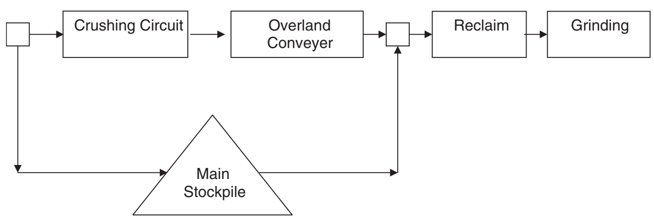
This document does not consider –

- Capacity or availability impacts downstream from the slurry pumps.

3. Summary

The Gove Third Stage Expansion project will require expansion and upgrades to the Materials Handling Reclaim System. A reliability block diagram (RBD) has been constructed to reflect the plant logic, capture the minor and major maintenance shutdown and equipment failure characteristics. Diagram 1A is a high level representation of the models logic.

The reclaim system considered under both Models A & B has the capacity to move 16.8 Mt/yr of bauxite based on the assumptions stated under Section 3.1. However Model B indicates a non-steady state feed, with the surge bins running low every 727 hrs for duration of 9 hours. Also Model B would require interruptions to crusher production to prevent the Main Stockpile over filling when the Northern Reclaim System is stopped. This indicates that Model A represents a lower degree of risk to operations than Model B.



3.1 Model Assumptions

3.1.1 Scraper Reclaimer

Item	Description
Reclaimer	Capacity 1250 t/hr
Maintenance Shutdown	Monthly for 10hrs
	Failure Rate 4380 hrs for 8 hrs
Chains & Buckets	Failure Rate 2190 hrs for 12 hrs

3.1.2 Existing Reclaimer

Item	Description
Reclaimer	Capacity 700t/hr
Maintenance Shutdown	Monthly for 10hrs
	Failure Rate 2190 hrs for 12 hrs

3.1.3 Front End Loader Reclaim

Item	Description
Front End Loader	Capacity 1000 t/hr
	Failure Rate ??? for ??hrs

3.1.4 Mills

Item	Description
Mill	Capacity 515 t/hr
Maintenance Shutdown	12 Weekly for 168hrs
	2 Yearly for 168hrs

3.1.5 Crushing

Item	Description
Primary Crusher	Capacity 1700 t/hr
Maintenance Shutdown	Fortnightly for 24hrs
	3 Monthly for 48hrs

3.1.6 Overland Conveyor

Item	Description
OLC	Capacity 1500 t/hr
Maintenance Shutdown	Fortnightly for 24hrs
	3 Monthly for 48hrs

The reclaim system capacities are based on the relative max set point of 2232 t/hr of Bauxite through an air slide in silo distribution. Equipment relative capacities are as follows:

Equipment Code	Capacity (t/hr)	Relative Capacity (%)
C550-6-6	700	31.4
C633-1	1000	44.8
C633-2	1350	60.5
C633-3	1350	60.5
C551-6-7	2000	89.6
C633-201	1000	44.8
C633-301	1350	60.5
C633-302	1350	60.5
C550-6-19	700	31.4

Note: Relative Max Set Point = 2232 t/hr Bx.

4. Conclusion

4.1 Model A Existing Plant 1017

The output from Model A Existing Plant 1017 RBD for a 10-year simulations for crushing, reclaim and mill circuit is as follows:

Area	Capacity (%)	Bauxite (Mt/y)	Availability (%)
Total System	45.97	8.99	99.6
Reclaim and Grinding	46.11	9.02	99.8
Materials Handling	50.5	9.87	76
Crushing	56.16	10.98	85.16
OLC	55.08	10.77	81.97
Reclaim System	85.7	16.76	100
North Reclaimer	55.4	10.83	100
South Reclaimer	30.7	6.0	98.6
Mill 01	21.08	4.12	90.8
Mill 02	21.08	4.12	92
Mill 03	3.98*	0.78	99.99

*Mill 03 is indicating that it will utilise 3.98% of capacity out of 23.1% during normal operation.

The reclaim system has the capacity to move 16.76 Mt/y of Bauxite based on the Model A configuration & assumption in Section 3.1.

The reason for high throughput is because of Transfer Station 201 Bi-frication capability. Ultimately there are 3 feed points to conveyors C633-301/302. Even if Northern Reclaim System has a breakdown or comes off for scheduled maintenance, the Southern Reclaim system still operates and can be topped by the FEL System. Also the dual conveyors 301/302 have the capability (1350 t/hr) to handle total feed to the mills surge bins.

The main stockpile will not run high unless downstream flow issues occur.

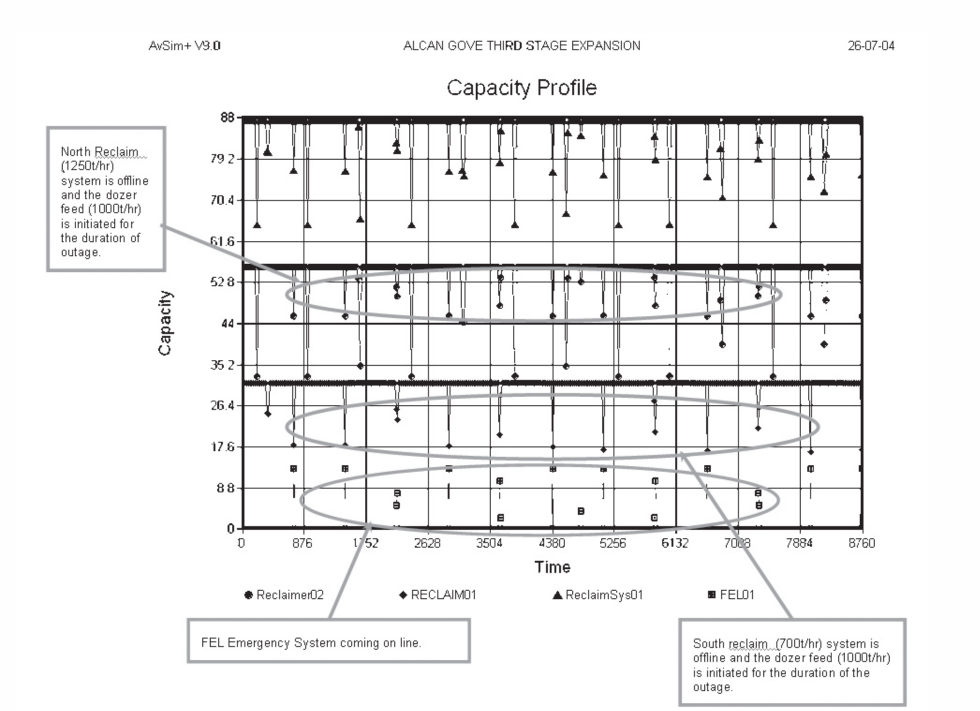
The following graph represents the capacity profile of the Model A Reclaim System.

4.2 Model B Modified Plant 1017 No C633-301 & C550-6-19

The output from Model B Modified Plant 1017 RBD for a 10-year simulations for crushing, reclaim and mill circuit is as follows:

Area	Capacity (%)	Bauxite (Mt/y)	Availability (%)
Total Sytstem	45.79	8.95	99.6
Reclaim and Grinding	45.91	8.98	99.8
Materials Handling	50.4	9.87	76
Crushing	56.16	10.98	85.16
OLC	55.08	10.77	81.97
Reclaim System	85.7	16.76	100
North Reclaimer	54.7	10.7	98.6
South Reclaimer	30.7	6.0	98.3
Mill 01	21	4.1	90.8
Mill 02	21	4.1	90.8
Mill 03	4*	0.78	99.99

*Mill 03 is indicating that it will utilise 4% of capacity out of 23.1% during normal operation.



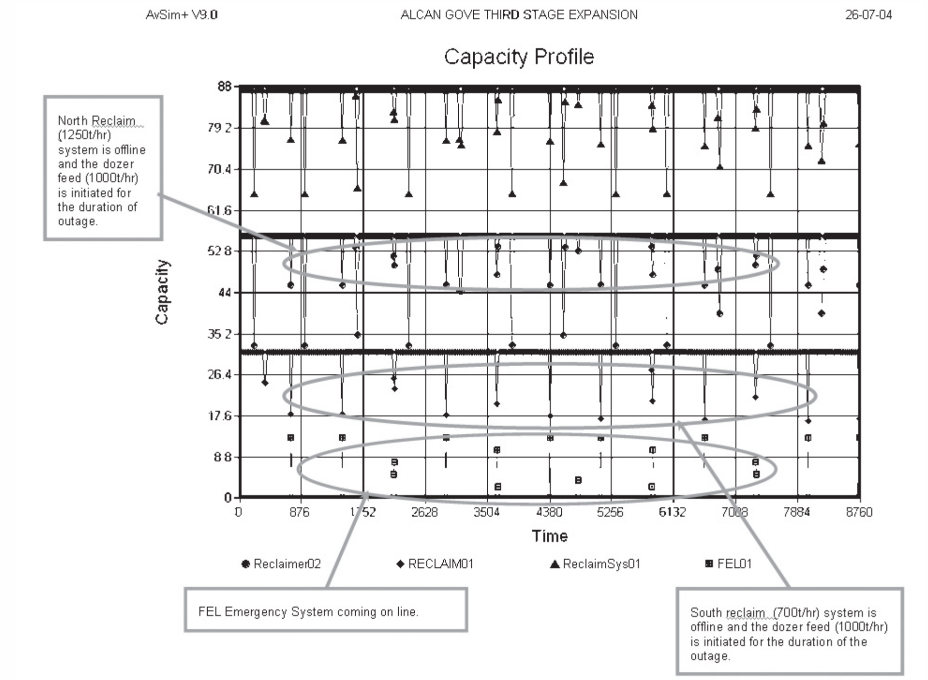
Overall the system is indicating steady state feed to the mill surge bins

The reclaim system has the capacity to move 16.76 Mt/y of Bauxite based on the Model B configuration & assumption in Section 3.1.

With the removal of conveyor C633-301 & C550-6-19 the risk to the system has increased. This is mainly because C633-301 has become a critical conveyor and therefore restricts use of the C551-6-7 and FEL Emergency System upon failure. Also during maintenance periods of C633-302 the system is rated down to 700 t/hr feed to the surge bins, therefore increasing the risk of surge bins running low. The restriction of model is indicated by the capacity profile plot below, which is demonstrating the low usage of the FEL System due to the impact of the critical conveyor.

The main stockpile is indicating an increasing capacity at 7200t/month if no control on the crushing circuit is applied.

The following graph represents the capacity profile of the Model B Reclaim System.



Overall the system is indicating non steady state feed with the surge bins running low every 727 hrs for duration of 9 hrs.