SNOWDEN

TNG: Mt Peake Scoping study
Project No. **499**

Optimisations for the Mt Peake Scoping Study
June 2009

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1 Findings

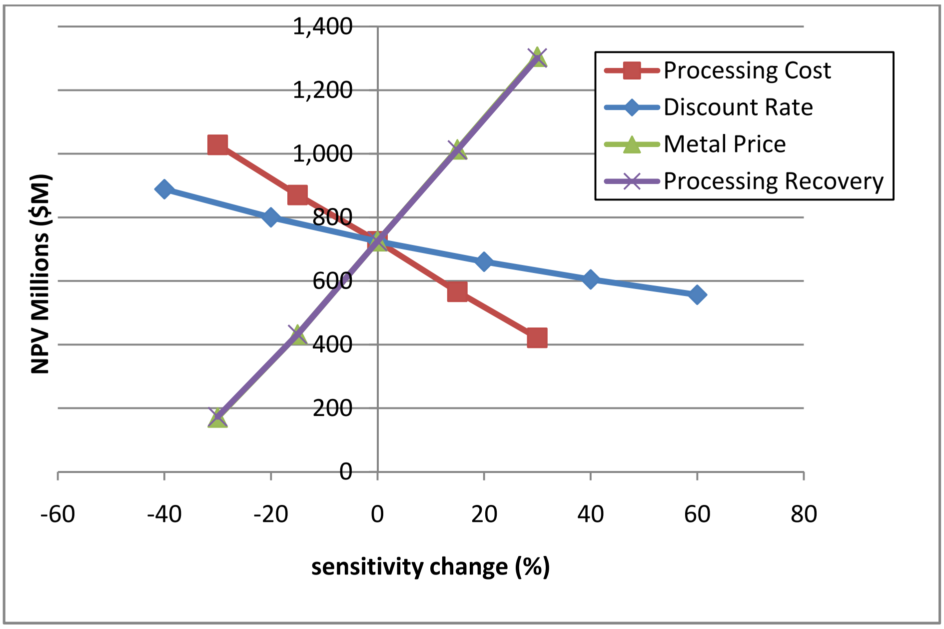
Snowden has undertaken scoping studies on the Mount Peake vanadium - iron - titanium deposit to assess project viability. Snowden used metallurgical cost and recovery estimates, recently developed and supplied by METS, and other costs from their data base to undertake the studies.

Two scenarios were investigated, firstly of recovering vanadium pentoxide only and secondly co-processing the vanadium pentoxide to recover titanium dioxide and pig iron.

A scenario processing vanadium pentoxide at 5 Mtpa has been identified as demonstrating viable project economics, given the parameters and assumptions of the scoping study. At 5 Mtpa the V_2O_5 only scenario has a mine life of 14.5 years for 73 Mt of ore and there is a pre-tax operating cashflow of $800 M. This figure is exclusive of capital expenditure, currently estimated to be $432 M.

The project operating cashflow sensitivity to the process cost, grade, metal price and discount rate is shown in Figure 1.1.

Figure 1.1 Graphical results of sensitivity analysis



The sensitivity analysis shows that the discounted cashflow is most sensitive to metal price and process recovery.

Snowden recommend that for the scenario processing vanadium pentoxide at 5 Mtpa, the Mt Peake project be advanced by way of a Prefeasibility Study so the project viability can be further assessed. Snowden has made recommendations for the advancement of the project in Section 5 of this report, as conclusions and recommendations.

Snowden understand that there are other mineralised targets available for drilling If TNG consider that the grade of these targets could be higher than the Mt Peake deposit, then this should be investigated.

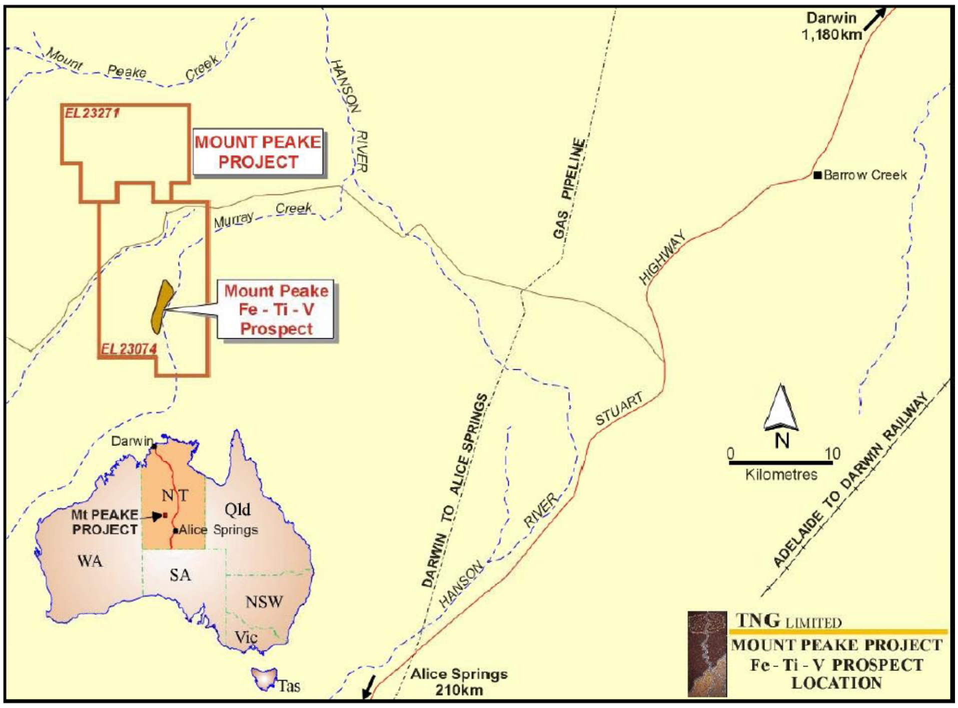
2 Introduction

TNG Limited (TNG) requested Snowden Mining Industry Consultants (Snowden) to complete optimisations for a scoping study TNG are currently undertaking on the Mt Peake Fe-V-Ti deposit, to ascertain the economic potential of the project. This study follows the recent completion of a preliminary resource estimate of the deposit. Currently the site is subject to EL23074 and resource definition drilling is underway.

2.1 Location

The Mt Peake project is located approximately 280 km northwest of Alice Springs in the Northern Territory of Australia and is approximately 70 km from the Adelaide to Darwin railway and 1200 km by road train from Darwin. A locality map is provided in Figure 2.1.

Figure 2.1 Location map (TNG 2009a)



2.2 Scope of work

The scope of work is to assess the economic potential of the Mt Peake project using data from metallurgical scoping studies supplied by Metallurgical Engineering Technical Services (METS), other likely operating costs estimated by Snowden and using the resource block model that was recently completed by Snowden.

The size of the open pit and the mine life is assessed from pit optimisations performed using Whittle software.

All currency in this report is quoted in Australian dollars, unless otherwise noted and tonnes are presented as dry tonnes. Any reference to "ore" is as a generic term and implies no economic significance as defined in the Australasian Code for the Reporting of Exploration Results, Mineral Resources and Ore Reserves, 2004 edition (the JORC Code).

3 Resource optimisation studies

3.1 Block Model preparation

Snowden used the resource block model that was populated with waste and cut to the surrounding topography. All the ore material inside the block model was categorised as inferred material. The Mineral Resource at a 0.2% V_2O_5 cut-off grade is tabulated in Table 3.1.

Table 3.1 May 2009 Mt Peake Mineral Resource at 0.2% V_2O_5 cut-off (Snowden 2009)

Category	Tonnes (Mt)	V_2O_5 %	TiO_2 %	Fe %	SiO_2 %	Al_2O_3 %
Inferred	86.4	0.36	6.4	26.7	31.3	7.5

For optimisation studies the oxide and fresh material were tagged inside a mineralised envelope that was generated by Snowden following magnetic susceptibility interpretation of the geology. The model was tagged with the following ore types.

- mineralised oxide
- unmineralised oxide
- mineralised fresh
- unmineralised fresh

In the resource estimation, the potential waste blocks were assigned low grades for V_2O_5, TiO_2 and Fe grades.

3.2 Optimisation inputs

The block model that was developed in May 2009 was a basis for the optimisation. Blocks were tagged inside and outside the mineralised zone, so the optimisation was restricted to selecting ore from the mineralised zone only. There is a higher confidence in the tonnes and grades of this material as predicted by the geological interpretation that was based on the magnetic susceptibility envelope.

3.2.1 Wall angles

Overall wall angles were not calculated due to a lack of geotechnical testwork on the existing core. Snowden understands that the rockmass is fresh material and the structure of the rockmass is not well understood though the limited data does not reveal a significant presence of faulting, voids or weak materials that require the implementation of shallow overall wall angles. On this basis, an average wall angle of 45 degrees was applied in the optimisation. The model block size was not conducive to the nominated wall angles so the model was reblocked for the optimisation.

3.2.2 Metallurgical parameters

As a result of metallurgical studies completed by METS (METS 2009), metallurgical recoveries were provided to Snowden as summarised in Table 3.2. Two production scenarios were considered for the project. Firstly, the processing of vanadium pentoxide only was assessed and any upside from the inclusion of recovering and marketing the other minerals was not considered. The recovery of iron in the form of pig iron and titanium dioxide was considered in a second process scenario and optimisation. For both scenarios, primary and secondary stage processes in series were considered by METS. The primary process for the recovery of all minerals was coarse cobbing of the ROM ore, followed by crushing and grinding and a magnetic separation process method.

The second stage processes are proposed as:

- pre-reduction in a rotary kiln and direct reduction in an arc furnace where pig iron is produced
- roasting slag from the reduction process followed by water leaching to extract the vanadium
- HCl acid leaching of the water leached slag from the vanadium process for titanium purification.

Table 3.2 METS Metallurgical recoveries (METS 2009)

Metal	Beneficiation (Magnetic Separation)	Second Stage Process	Overall Recovery
Pig iron	63%	90%	57%
Vanadium pentoxide	90%	70%	63%
Titanium dioxide	65%	90%	59%

The cost of recovering vanadium alone is summarised in Table 3.3. The total co-processing cost is summarised in Table 3.4.

Table 3.3 Cost of processing V_2O_5, TiO_2 and Fe

Process path	Process rate 2 Mtpa (A$/tonne)	Process rate 5 Mtpa (A$/tonne)
Crushing, Grinding, Beneficiation	5	5
Vanadium Roasting	14	14
Pig Iron Production	40	40
HCl Leaching	25	25
Other	14	11
Total	**98**	**95**

Table 3.4 Cost of co-processing V_2O_5

Process path	Process rate 2 Mtpa (A$/tonne)	Process rate 5 Mtpa (A$/tonne)
Crushing, Grinding, Beneficiation	5	5
Vanadium Roasting	14	14
Other	14	11
Total	**33**	**30**

METS advised that the costs were developed with an accuracy of +/- 50% for the study.

3.2.3 Mining parameters

The depth of cover of the deposit indicates that the orebody should be mined using open pit methods. The strip ratio is less than one and indicative of a large open pit low-grade deposit. Open cut mining costs of $3.00 per tonne and a cost for mining ore was also considered at $1.90 per tonne. The ore mining costs relate to grade control and administration. Due to the smooth low grade, no allowance for stockpiling has been made. An additional 5 cents was also considered for each successive 10m bench. Both the V_2O_5-Fe- TiO_2 and the V_2O_5 only production scenarios used the same mining costs.

3.2.4 Ore transport costs

Consideration was made for the transport of concentrate to Darwin for FOB sale of the concentrate. Transport by road for a distance of 700km from the mine to a siding on the Adelaide to Darwin railway was considered. The rail distance to Darwin was 1180 km. Total transport cost in dollars per tonne was applied in the optimisation and these were developed from approximate unit costs as estimated by Snowden as summarised in Table 3.5. The transport cost for V_2O_5 concentrate only was $132.3 per tonne and the transport cost for the V_2O_5-Fe-TiO_2 concentrate was $99.5. The price difference is attributable to the increased tonnage of the multi-product concentrates, particularly the iron.

Table 3.5 Concentrate transport costs

Scenario	Transport	Cents/t.km	Distance	$/t
V_2O_5 only	Rail	3.5	1180	41.3
	Roadtrain	13	700	91
	Total			132.3
V_2O_5-Fe- TiO_2	Rail	2.5	1180	29.5
	Roadtrain	10	700	70
	Total			99.5

3.2.5 Concentrate price and financial data

For the pricing of concentrates, METS advised the following prices based on their recent data:

- V_2O_5 at $US 8.00 per pound
- Fe in pig iron $US 300 per tonne
- TiO_2 $US 500 per tonne.

The selling costs associated with a royalty were not used in the optimisation as they are calculated based on a formula which takes into consideration revenue, operating costs, capital deductions, exploration expenses and other deductions approved by the NT Treasurer. TNG advised an exchange rate of 0.8 US$ = 1$AUD and a 10% discount rate.

3.3 Optimisation results

Snowden considered two cases for optimisations. Optimisations were performed considering collecting revenue from:

- V_2O_5 only
- Co-processing the V_2O_5 - Fe - TiO_2 .

The mine life for the 2 Mtpa case was investigated by Snowden and the mine life calculated by the optimisation was excessive, with the cashflow significantly eroded by the discount rate. Only the optimisations using a process rate of 5 Mtpa were further evaluated. The discount rate was revised to 8%, as this was considered to be less conservative and more indicative of current discount rates. The two optimisation scenarios were initially considered encouraging because:

- At 5 Mtpa the V_2O_5 only scenario has a mine life of 14.5 years for 73 Mt of ore and there are a cashflow of $800 M
- At 5 Mtpa the V_2O_5-Fe-TiO_2 scenario has a mine life of 11.4 years for 57 Mt and a cashflow of $827 M.

3.3.1 Preliminary capital estimate

METS were requested to give an approximate cost for the capital required to fund the two scenarios.

For the V_2O_5-Fe-TiO_2 process scenario, the Capex is summarised in Table 3.6.

Table 3.6 V_2O_5-Fe-TiO_2 process plant capital cost (METS)

Area	**2 Mtpa (A$ Million)**	**5 Mtpa (A$ Million)**
Direct Costs		
Crushing, grinding and beneficiation Plant	73.8	127.8
Roasting and leaching	79.2	124.2
Refinery	16.2	27.0
HCl regeneration plant	55.8	95.4
Pig Iron production	264.6	302.4
First fill	33.0	82.0
Direct cost sub-total	**522.6**	**758.8**
Indirect Costs		
Working capital	27.0	66.0
EPCM	79.0	114.0
Commissioning	11.0	16.0
Spares and tools	6.0	8.0
Contingency cost	79.0	114.0
Indirect cost sub-total	**202.0**	**204.0**
Total capital cost (A$ Million ± 50%)	**724.6**	**962.8**
Total capital cost per tonne of feed ore (A$/tonne ± 50%)	362.3	192.6

For the V_2O_5 only process scenario, the Capex is summarised in Table 3.7.

Table 3.7 V_2O_5 only process plant capital cost

Area	2 Mtpa (A$ Million)	5 Mtpa (A$ Million)
	Direct Costs	
Crushing, grinding and beneficiation Plant	73.8	127.8
Roasting and leaching	79.2	124.2
Refinery	16.2	27.0
First fill	10.0	25.0
Direct cost sub total	**179.2**	**304.0**
	Indirect Costs	
Working capital	11.0	25.0
EPCM	27.0	46.0
Commissioning	4.0	7.0
Spares and tools	2.0	4.0
Contingency cost	27.0	46.0
Indirect cost sub-total	71.0	128.0
Total capital cost (A$ Million ± 50%)	**250.2**	**432.0**
Total capital cost per tonne of feed ore (A$/tonne ± 50%)	125.1	86.4

For both cases METS advised a ± 50% order of accuracy to their Capex estimate.

3.3.2 Final optimisation and sensitivity

Using the 8% discount rate, the operating cashflow generated by the optimisation for the V_2O_5-Fe-TiO_2 5Mtpa process scenario is $827 M and the Capex for the plant only as advised by METS, is $1,076.8 M. This scenario is considered cashflow negative with the consideration of capital cost and was not evaluated with current estimated economic parameters.

For the V_2O_5 5Mtpa process scenario, the operating cashflow generated by the optimisation is $800 M and the Capex for the plant only as advised by METS is $432.0 M. Snowden recommend that this scenario is of interest over reduced throughput options, which are exposed to the discount rate over extended mine lifes that realise lower operating cashflows. A summary of the output from the optimisation is provided in Table 3.8.

Table 3.8 V_2O_5 5Mtpa Mt Peake process scenario optimisation results

Whittle output	Units	value
Mine Life at 5Mtpa process rate	years	14.5
Total tonnes	Mt	114.3
Waste tonnes	Mt	41.6
Processed tonnes	Mt	72.7
Processed tonnes fresh	Mt	67.8
Processed tonnes oxide	Mt	4.9
V2O5 grade to process	%	0.38
V2O5 grade fresh	%	0.39
V2O5 grade oxide	%	0.28
V2O5 tonnes output	kt	174.3
V2O5 tonnes fresh	kt	165.5
V2O5 tonnes oxide	kt	8.8
Strip Ratio Wt:Ot	t/t	0.57
Mining cost	$M	368.0
Mining cost fresh	$M	227.1
Mining cost oxide	$M	34.8
Average mining unit cost	$/t	3.2
Process cost	$M	2,181.3
Process cost fresh	$M	2,033.7
Process cost oxide	$M	147.7
Average process cost	$/t	31.9
Selling cost	$M	23.6
Income V2O5	$M	3,839.6
Undiscounted cashflow	$M	1,266.6
Discounted best cashflow	$M	830.0
Discounted worst cashflow	$M	711.0
Discounted 75% cashflow	$M	800.3

Capital costs, interest, tax, royalties and depreciation were excluded from the optimisation results. These can be considered in the overall project financial evaluation once process parameters and other project financial parameters are defined with greater accuracy.

The discounted best case cashflow represents shell by shell mining and the discounted worst case mining represents bench by bench mining. The discounted 75% cashflow recognises that staged pit designs will usually result in a discounted cash flow between the best and worst cases.

A graphical representation of the optimisation results is provided in Figure 3.1. A visual representation of the pit is provided in Figure 3.2, with an overlaid N-S and E-W cross section view of the model inside the pit is provided. Indicative shell cross sections are provided in Appendix A.

Figure 3.1 Graphical results of Mt Peak optimisation

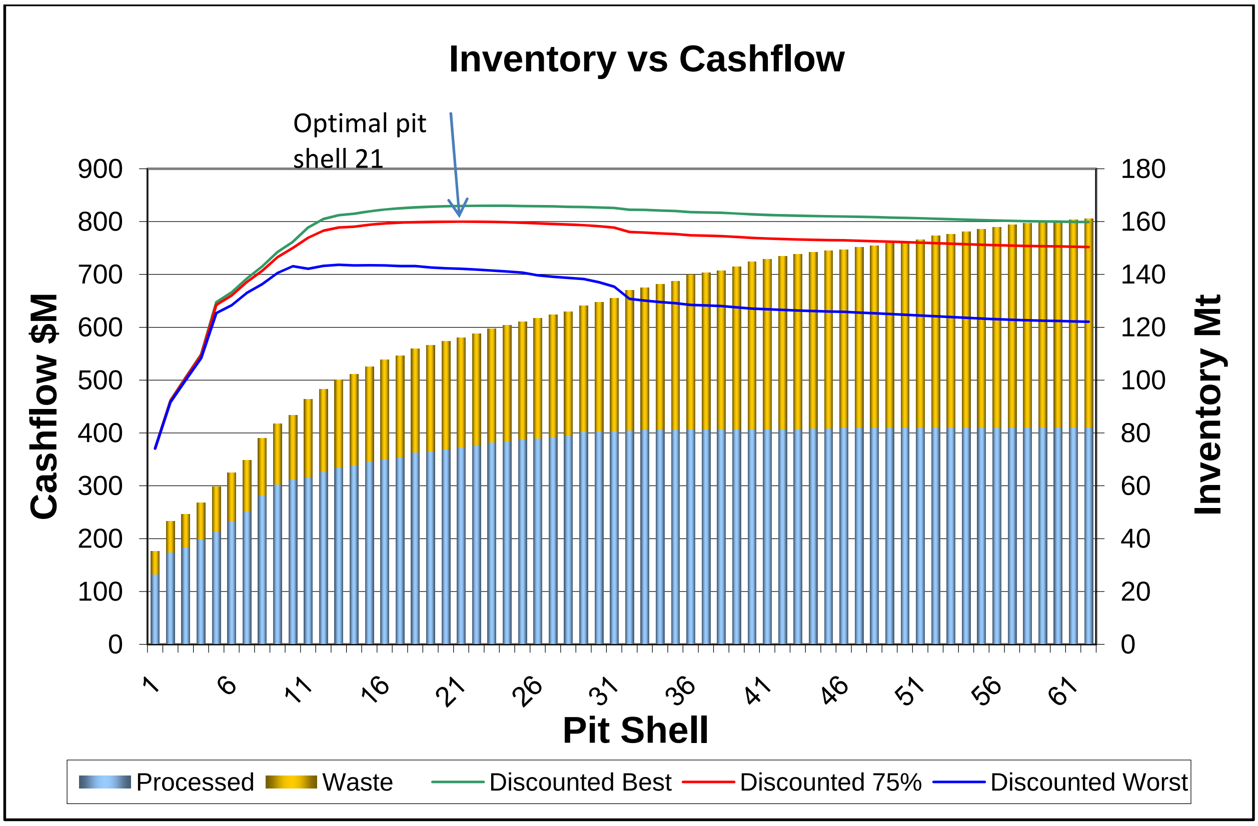
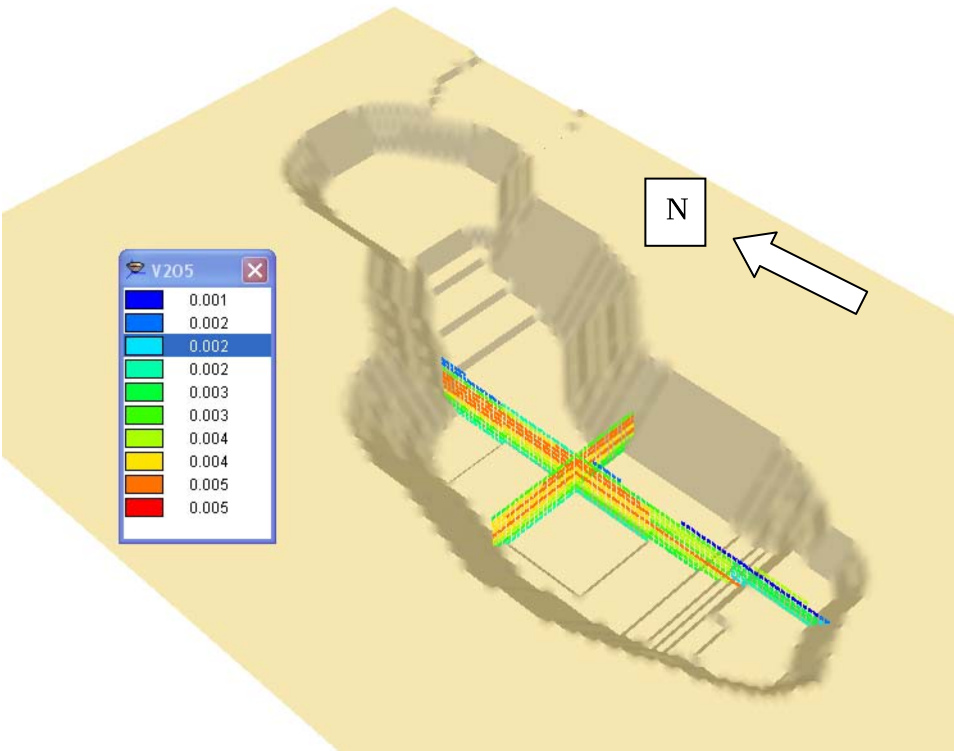


Figure 3.2 Visual representation of pit shell 21



Cut-off grade

The optimisation process applies an economic cut-off grade to each ore parcel it encounters to determine if the parcel is profitable to process or should be directed to a waste dump. The cut-off grade was calculated on a block by block basis using Equation 3.1.

Equation 3.1 Cut-off grade calculation

$$COG\% = \frac{P_{cost}}{(P_{rev} - R_{roy}) * Rec}$$

Where,

COG% = V_2O_5 % cut-off grade

P_{cost} = processing cost ($/t ore)

P_{rev} = V_2O_5 price per ten kilograms ($/10kg)

R_{roy} = Ore royalty/refinery cost per ten kilograms ($/10kg)

Rec = V_2O_5 metallurgical recovery (%)

This returns a cut-off of 0.22 % V_2O_5.

Optimisation sensitivity on V_2O_5 5Mtpa process scenario

The overall cashflow for the V_2O_5 5Mtpa process scenario is positive and Snowden recommended to TNG that economic sensitivity be performed on the optimisation parameters, so that risk to project viability could be understood. Sensitivity was performed on:

- price
- recovery
- process cost
- discount rate.

The mining cost will not be influential given the low strip ratio, so this was not sensitised.

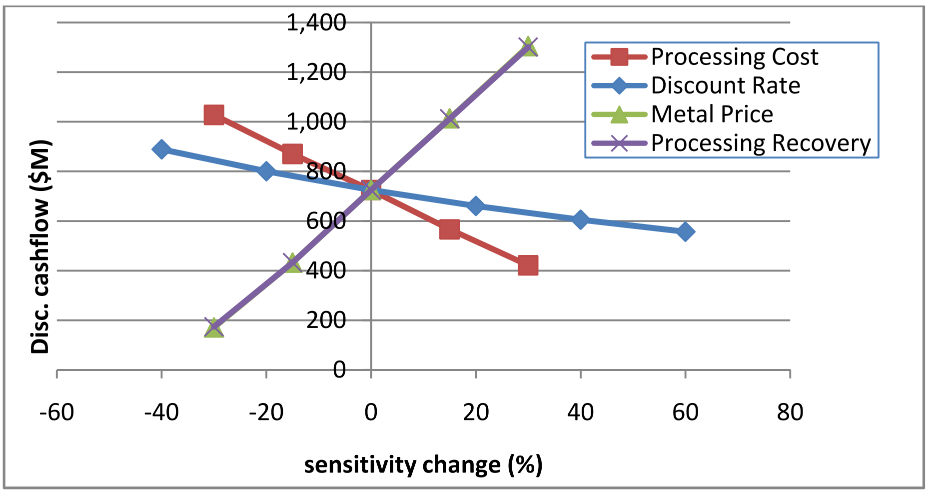
The sensitivity analysis shows that the discounted cashflow is most sensitive to metal price and process recovery. Reduction the metal price by the same percentage as the recovery demonstrates that the revenue from the recovered metal is similar. The next most sensitive parameter is the process cost and the cashflow is least sensitive to the discount rate. The sensitivity results are summarised in Table 3.9.

Table 3.9 Sensitivity results

Description	Sensititivity %	Waste Mt	Processed Mt	Cashflow $M
Processing Cost +30%	30	26.4	48.9	421.1
Processing Cost +15%	15	37.1	62.2	566.1
Basecase	0	41.6	72.7	724.8
Processing Cost -15%	-15	38.9	77.2	870.1
Processing Cost -30%	-30	38.9	82.9	1,027.8
Discount Rate +30%	60	37.5	66.8	556.5
Discount Rate 14%	40	39.2	69.2	604.9
Discount Rate 12%	20	39.2	69.2	660.5
Basecase	0	41.6	72.7	724.8
Discount Rate 8%	-20	41.6	72.7	800.3
Discount Rate 6%	-40	41.6	72.7	888.8
Metal Price +30%	30	42.7	82.8	1,305.1
Metal Price +15%	15	40.6	76.9	1,013.7
Basecase	0	41.6	72.7	724.8
Metal Price -15%	-15	35.4	60.2	432.1
Metal Price -30%	-30	21.1	39.0	170.7
Processing Recovery +30%	30	42.7	82.8	1,301.3
Processing Recovery +15%	15	40.6	76.9	1,012.1
Basecase	0	41.6	72.7	724.8
Processing Recovery +-15%	-15	35.4	60.5	432.3
Processing Recovery -30%	-30	21.1	39.1	173.3

The graphical representation of the sensitivity shows the relative magnitude of each of the sensitivities.

Figure 3.3 Graphical results of sensitivity analysis



4 Project risks

Currently the parameters used to assess the project viability are based on limited data. The economic evaluation based on the optimisation is preliminary and based on a resource developed from 6 drillholes. The variability of the resource has not been defined by this limited data. This presents a risk to the understanding of the grade continuity within the deposit. There is a risk that the grade variability could be high and this needs to be understood so the true tonnes and grade are reflected in the model and the likelihood of blending and any differing ore types is known. The economics of the project is highly sensitive to grade.

As there has been no logging of the core for geotechnical data there may be a risk of wall instability.

Metallurgical testwork is of a preliminary nature and will need to be representative of the ore type that will make up most of the feed. If the testwork is not comprehensive the true recovery may not be correctly estimated. As stated above, the economics of the project is highly sensitive to grade. The robustness of the metallurgical recovery to changes in the grade needs to be assessed. The metallurgical capital and operating costs are also preliminary and there is a high risk these will change. If these costs increased, this may present a risk to the project economics.

The current world annual production of vanadium is approximately 60,000 tonnes. As the optimal shell produces about 12,000 tonnes per annum, there is likelihood that an increased supply may erode the vanadium price.

Approvals, leases and required licences may be slow to acquire, given the nature of the product. Also the transport of the product may be subject to stringent environmental restrictions.

Snowden understands the price of vanadium is susceptible to market fluctuations and has demonstrated that the project operating cashflow is very susceptible to vanadium price in this study.

5 Conclusions and recommendations

Snowden has reviewed data supplied by METS and used the process cost and recovery data to undertake a series of optimisations using two process rates of 2.0 Mtpa and 5.0 Mtpa. The 2.0 Mtpa optimisation results showed an excessive mine life, so only the 5.0 Mtpa process rate was of interest. A scenario processing vanadium pentoxide at 5 Mtpa has been identified as demonstrating viable project economics give the parameters and assumptions of the scoping study. The co-processing of vanadium pentoxide, pig iron and titanium dioxide was considered, however the excessive capital required for a co-processing plant resulted in this option not being pursued in this study.

Current parameters for the optimisation outlined in this report show that the project is potentially viable and that a 14 year lifespan could be sustained. This would produce approximately 12,000 tonnes of vanadium pentoxide per annum or 6700 tonnes of pure vanadium per annum.

Snowden recommends a study projecting the vanadium demand and price should be undertaken. Vanadium pentoxide prices ranged from $7.30 to $18.40 per pound of V_2O_5 and averaged $14.75 for the year 2008, about 100% higher than that of 2007, according to US Geological survey data, (U.S. Geological Survey (2009)). With current world demand estimated at 60,000 tonnes, the potential annual production would be greater than 10 % of world demand.

Because the deposit is sensitive to grade, Snowden recommend further resource drilling within the exiting mineralised envelope to more confidently define the tonnes and grade of the resource. Snowden understand from TNG that there are other vanadium exploration targets and these should be investigated for higher grade.

Further process recovery testwork and confirmation of process flows should be undertaken so the level of accuracy of the data can be reduced from +/- 50%. The effectiveness of the recovery at the low cut-off grade of should be further tested, given that the optimisation results are most sensitive to grade.

The process cost needs to be further developed. Any revisions to the process flow or recoveries will lead to more accurate cost estimates and level of accuracy of the capital and operating cost data can be reduced from +/- 50%. If the revised capital and operating costs are favourable to the project economics, the mining cost will need to be substantiated by vendor “budget price” quotation. Snowden consider that given the mine life, owner and operator mining scenarios could be considered. The transport of the product may cost more than assumed for a reduced amount of product.

Snowden recommend a study to assess the marketing potential of vanadium pentoxide be undertaken to confirm product price demand. This data can be used to determine the process rate. Snowden understands from Web sources that the traditional demand associated with steel production could be increased by use of vanadium in battery cells (V-fuel 2008). The option of marketing of ferrovanadium should also be assessed.

A financial analysis should be performed as soon as the accuracy of the supporting data is confirmed and improved. The provision for royalty, tax and depreciation should be included in this financial analysis. Indicative royalties should be sourced from the Northern Territory Government Treasury Department.

Snowden recommend that for the scenario processing vanadium pentoxide at 5 Mtpa, the Mt Peake project be advanced by way of a Prefeasibility Study so the project viability can be further assessed.

6 References

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A Pit shell cross sections

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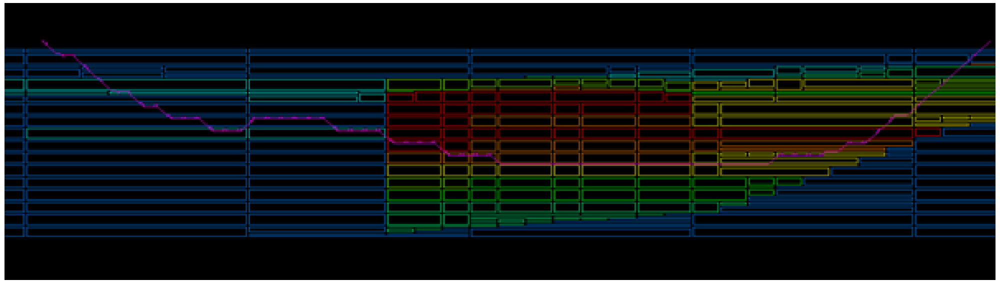

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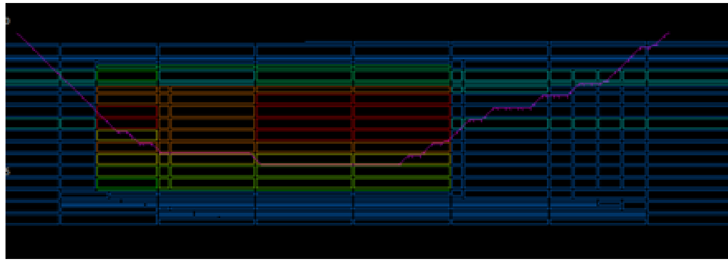

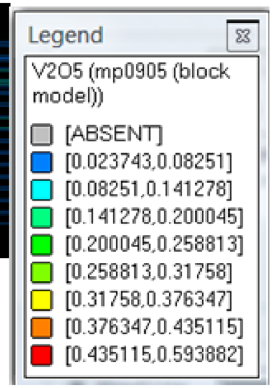

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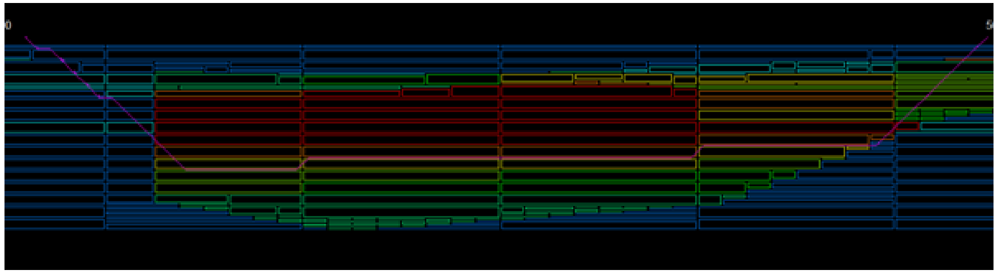

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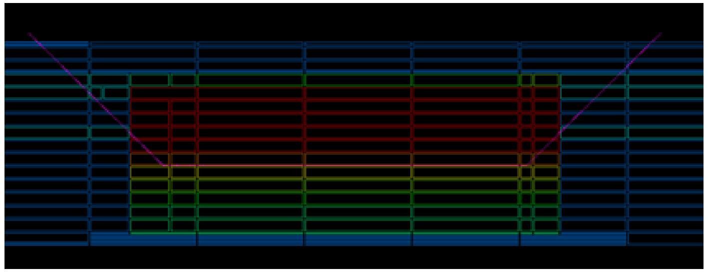

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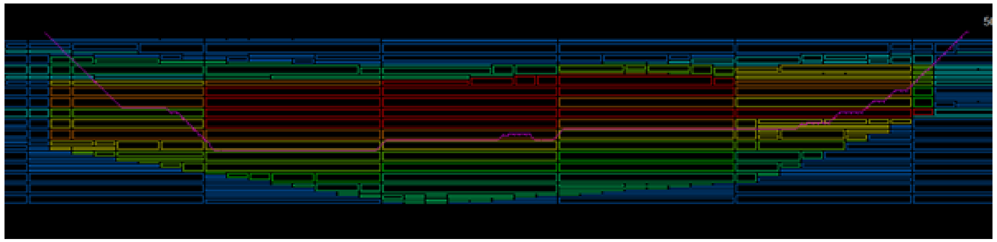

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