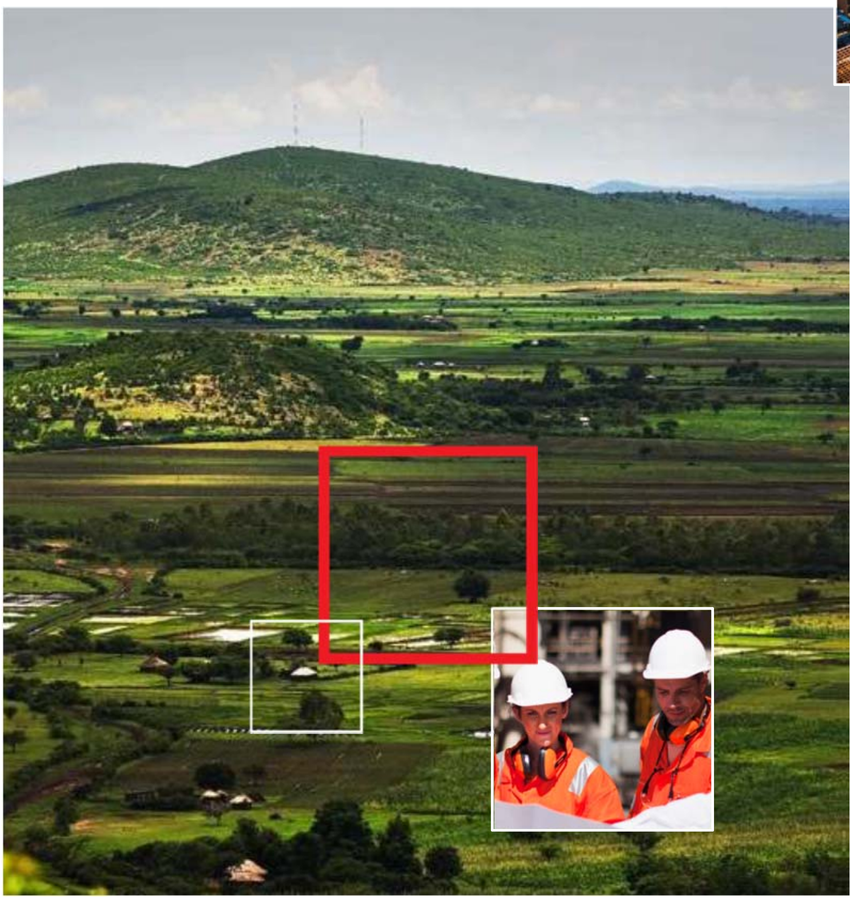
BLACKDOWN RESOURCES LTD

Dutwa Nickel Project

High Level Metallurgical Review



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PROJECT 201000-01076-RPT-0100 – Dutwa Nickel Project

Rev	Description	Original	Review	WorleyParsons Approval	Date	Customer Approval	Date
A	Issued for Internal Review	J Resta	M Reed	N/A	25-Feb-18	N/A	

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1. Introduction

WorleyParsons were engaged to undertake a high level, critical review of metallurgical testwork completed in relation to the development of the Dutwa Nickel Laterite Project.

As part of the review a large amount of information was provided through to WorleyParsons by Blackdown Resources. This included various testwork and consultants reports for various work undertaken up until the BFS was suspended.

1.1 Background

The Dutwa nickel deposit in northern central Tanzania was discovered by African Eagle Resources, a UK listed junior exploration company, in 2008. In 2011 African Eagle updated its earlier scoping level studies on the back of encouraging geological and metallurgical results in turn based on extensive drilling on the prospect. A global resource of the order of 100 million tonnes of nickel laterite ore grading on average close to one percent nickel for almost 1 million tonnes of contained saleable metal (predominantly nickel with only traces of cobalt) has been defined in two ore bodies associated with the Wamangola and Ngasamo hills.

Table 1 summarises the combine Wamangola and Ngasamo resource estimate. The overall resource averages 0.91% Ni, with only minor Co present at 0.026%. MgO, a major driver of acid consumption is moderately high at 10.1% on average, and varies over a wide range. However, it is of note the majority (79.3 Mt) of tonnage sits in the FeSi lithology at an average grade of 5.14% MgO.

It is understood Blackdown are considering a production rate of 3Mt/y to give a 17 year mine life.

Table 1 – Dutwa Combined Minerals Resource Estimate

(as at February 2013, Ni Cut-Off @ 0.55%)

JORC (2004) Resource Catagory	Lithology	Tonnes (Mt)	Ni (%)	Co (%)	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	MgO (%)	CaO (%)	Metal t
Indicated	Fer-Sil	79.3	0.89	0.029	72.02	2.41	12.52	5.14	0.21	702,981
	Trans	25.9	0.96	0.021	52.45	1.49	12.08	19.02	0.94	249,639
	Saprock	4.6	0.94	0.022	39.35	0.38	8.16	32.41	0.78	42,792
	Total	***109.8***	***0.91***	***0.027***	***66.04***	***2.11***	***12.23***	***9.55***	***0.41***	***995,411***
Inferred	Fer-Sil	1.5	0.85	0.028	71.72	2.64	12.43	5.42	0.27	21,587
	Trans	2.9	0.98	0.018	53.60	1.56	10.99	20.19	0.80	14,846
	Saprock	2.9	0.86	0.017	41.18	0.48	8.30	31.06	0.82	24,708
	Total	***6.9***	***0.89***	***0.021***	***55.09***	***1.51***	***10.40***	***19.29***	***0.61***	***61,141***
	Grand Total	**116.7**	**0.91**	**0.026**	**65.39**	**2.07**	**12.12**	**10.12**	**0.42**	**1,056,553**

Table 1. Dutwa Combined Minerals Resource Estimate

In January 2012, African Eagle committed to a rapid development of the project, and immediately commenced a bankable feasibility study (BFS). An engineering consultancy was engaged to manage the studies, and to complete metallurgical interpretation, process definition, engineering, cost estimation and definitive execution planning for the project. In parallel, metallurgical testwork, mine planning and investigation of transport and logistics were progressed.

However, the bankable feasibility study was suspended on 17 January 2013, prior to completion, due to the down turn in commodity markets.

According to reference 1, at the time of suspension of the BFS, the following had been completed or were close to completion:

- batch scale beneficiation and metallurgical testwork on representative bulk samples of the major ore types
- batch scale beneficiation and metallurgical testwork on representative variability samples of the major ore types
- batch scale product separation, clarification and precipitation testwork on representative samples of some ore types
- analysis and interpretation of metallurgical testwork completed to date
- preparation of a preliminary mass balance

2. Review Commentary

The blockflow diagram considered by the BFS is shown in Figure 2-1.

The BFS was focused on an atmospheric sulfuric acid leach flowsheet, with nickel (and Co) recovery to a mixed hydroxide product, with the run of mine ore (ROM) beneficiated by scrubbing and size based separation prior to leaching. Given the relatively low Ni grade, and low Fe content of the Dutwa ores this approach, utilising beneficiation and atmospheric acid leach, is considered reasonable.

A significant amount of testwork has been completed to date in relation to the development of the Project. This has consisted of both batch and variability testing of samples from the Wamangola and Ngasamo deposits.

The metallurgical testwork which has been completed to date has been undertaken at competent and reputable laboratories, including:

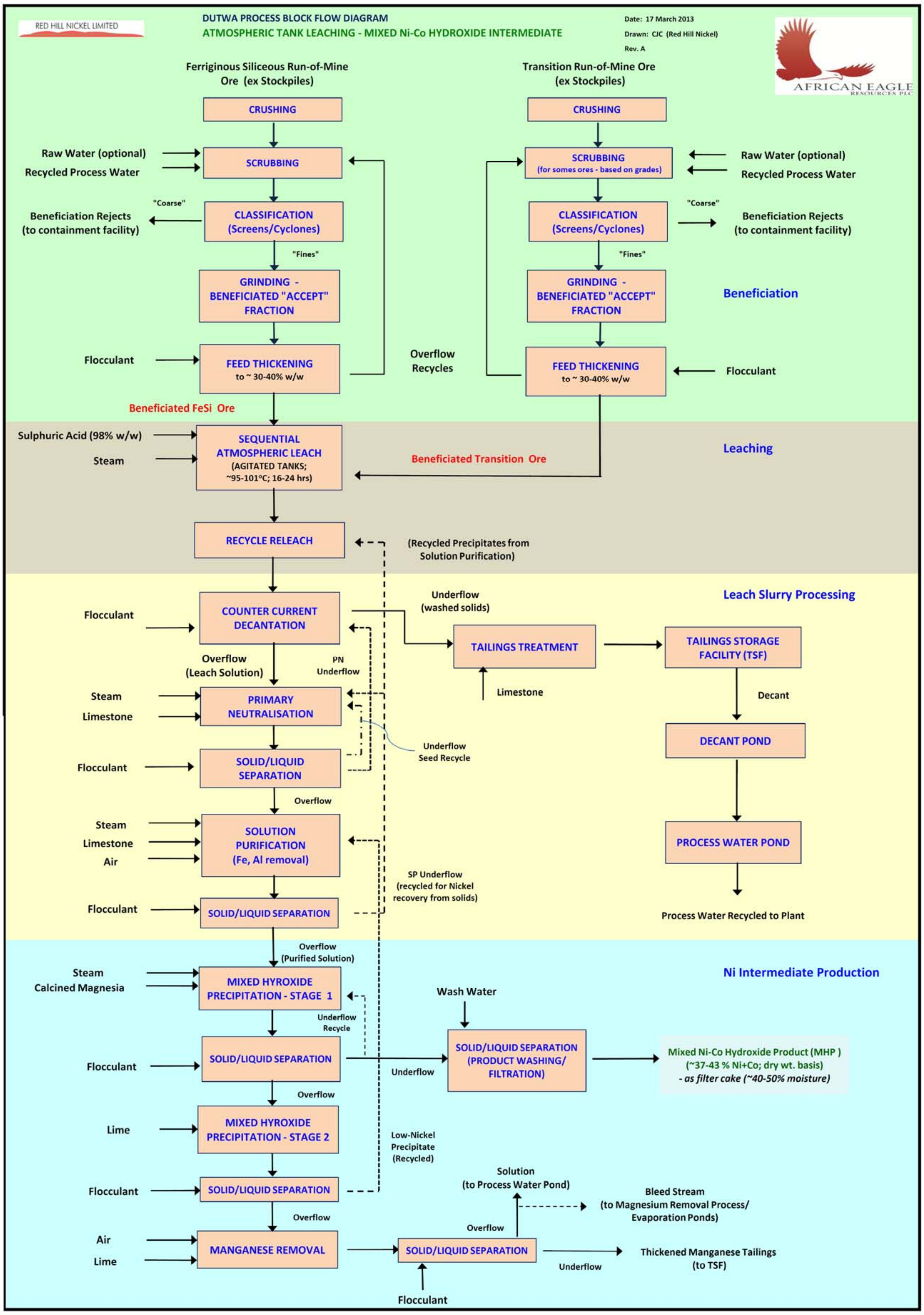
- ALS Metallurgy (formerly ALS AMMTEC) in Perth, Western Australia – 2011 and 2012
- SGS Minerals Metallurgy in Perth, Western Australia – 2012
- Mintek in Randburg, South Africa – 2010 and 2011

The testwork spans the major unit process for the flowsheet, including:

- Mineralogical analysis
- Comminution testing
- Beneficiation testing
- Atmospheric acid leaching
- Solids/liquor separation testing
- Neutralisation, solution purification and product recovery
- Various geochemical and tailings testwork

Commentary is made in subsequent sections of this report on the work completed. Generally this is restricted to high level commentary only due to the nature and time constraints of this review.

Figure 2-1 - DUTWA PROCESS BLOCK FLOW DIAGRAM: ATMOSPHERIC TANK LEACHING - MIXED Ni-Co HYDROXIDE INTERMEDIATE



From the information reviewed it appears only limited preliminary engineering work had been completed when the BFS was suspended. Although a significant amount of work has been undertaken notable gaps remain. Notable gaps include:

- Finalisation of testwork, and analysis of results for work which was in progress at time the study was suspended:
  - In a number of areas there would be value in completing more detailed analysis of the results of work which has already been completed;
    - Particularly for the beneficiation and leach circuits, to better evaluate the trade-offs between nickel recovery and acid consumption, and to develop predictive expressions for use in mine plan optimisation
- Completion of various additional testwork required to support BFS level engineering. Including (but not limited to):
  - Additional 'optimisation' testing
  - Additional testing to confirm process design criteria, expected process performance, and support equipment sizing/selection
  - Integrated and pilot scale testing
- Detailed process flowsheet development and optimisation:
  - The block flowsheet which has been developed is considered preliminary
  - The block flowsheet which has been developed is considered preliminary only, being based on incomplete (but substantial) testwork. This requires further optimisation supported by additional testwork and analysis
  - Overall there remains considerable scope for optimisation of the flowsheet
- Preparation of process design criteria
- Development of detailed optimised mass and energy balances

2.1 Testwork in Progress

Various references are made in the Interim metallurgy report[2] (and various other reports) to both testwork in progress and various pending results at the time of writing/when the BFS was suspended. If it were possible to view the testwork-results from the earlier work in progress it may provide additional information or fill some of the gaps that are identified later in this report.

It is WorleyParsons understanding that this would not be possible and although a detailed reconciliation of outstanding work and review of outcomes of such work is recommended the gap analysis at end of this document will hopefully fill in various gaps.

2.2 Sample Selection

The sample selection basis for samples used in the metallurgical testwork has not been reviewed in detail by WorleyParsons. However, the sample selection basis for bulk samples and variability samples used in comminution, beneficiation and leaching variability testing appears to have been well considered [(5,6)], and made reasonable attempt to represent the major domains, FeSi and Transition, of both the Wamagola and Ngasamo deposits. Overall the number and selection of samples used in testwork appears reasonable.

2.3 Comminution and Beneficiation

Comminution testing has been conducted on a reasonable number of variability samples from both the Wamangola and Ngasamo deposits. Generally, the Dutwa ores are harder than typical nickel laterite ores, and appear highly variable with respect to their comminution properties.

This high level of variability will need careful consideration in both mine planning/ore scheduling, and selection of appropriate design properties for the comminution circuit, to minimise the impact on varying properties on achievable throughput and nickel production.

It is recommended to review available comminution data and sample information to attempt to develop an empirical relationship to predict comminution properties to aid in mine planning/ore scheduling.

It appears no comminution testwork has been carried out on the "accept fraction" product produced from beneficiation. It is expected comminution properties of the "accept fraction" are significantly different to those of the whole ore and reject fraction.

It is recommended appropriate comminution testing be carried out on the "accept fraction" products to assess the requirements of the milling circuit post beneficiation, and variability in comminution properties post beneficiation.

2.3.1 Crushing Work Index (CWi)

- There is a large range in measured CWi values for Wamangola FeSi ore, ranging from 5.2 to 37.9 kWh/t (extremely high)
- There is also significant variation in CWi results from PQ and HQ core samples:
  - This issue requires further investigation
  - Correlation of results with SMC testing is recommended. However, it is not clear whether the relevant SMC results have been received (quoted as "outstanding at the time of writing"[2])
- Wamangola shows a large range of variability; 1.70 to 39.2 kWh/t
- It appears both Ngasamo and Ngasamo Transition show much more moderate CWi values and reduce variability

2.3.2 Beneficiation

Beneficiation testing has been conducted on a reasonable number of variability samples from both the Wamangola and Ngasamo deposits. Generally the testing has shown:

- Wamangola FeSi ores respond reasonably to beneficiation, achieving an upgrade ratio of ~1.7 to ~2.0, with moderate Ni losses of ~22%
- Wamangola transition ores respond poorly to beneficiation, achieving only modest Ni upgrade ratio of ~1.4, but with high Ni losses:
  - It is noted however the average head grade for the Wamangola transition ore variability samples was comparable to that of the upgraded FeSi ore
- Ngasamo FeSi ore achieved a reasonable upgrade ratio, but with high Ni losses.
- Ngasamo transition ores respond reasonably to beneficiation, achieving an upgrade ratio of ~1.75, with moderate Ni losses
- Minor selectivity for Ni over Mg is seen in the beneficiation variability work for the Wamangola and Ngasamo FeSi ores, with Ni to Mg recovery ratio of ~1.1 seen
- A high level of variability is seen in the response to beneficiation across the various ore types:
  - This, together with the variability seen in comminution properties, could adversely impact operation stability and achievable Ni production. This high level of variability will need careful consideration in mine planning and scheduling
  - To assist this is it recommended to attempt to develop empirical relationship to predict both comminution properties and beneficiation outcomes

Further more detailed assessment is required to assess the optimum scrubbing energy input, and cut size. This should consider:

- Coarser cut point further:
  - The most significant changes are seen over the range 12.5 to 100 mm. In the range <12.5 to >0.5mm response is relatively flat with only incremental changes rather than step changes seen
- Overall beneficiation and leach performance combine:
  - There may be more value in operation at a coarser cut point in increase Ni recovery to leach feed, and operation at a lower acid dose and lower Ni extraction in leaching
- Impact on Mg input and acid consumption per unit Ni leached:
  - Deportment of Mg and other acid consumers across the beneficiation circuit does not appear to have been considered in work to date
  - Need to consider Ni/Mg selectivity and Ni/acid consumption in accessing cut point

It is expected with further analysis a lot more can be teased out of the available data to better assess the merits of beneficiation on the downstream processing costs per unit Ni produced.

In the further assessment of the beneficiation circuit it would add considerable value to establish a minimum leach feed grade (combination of Ni, Mg and/or acid consumption) criteria, rather than focus on upgrade ratio.

2.4 Leaching

Batch leaching testwork has been carried out on a variety of samples from both the Wamangola (FeSi and Transition) and Ngasamo (FeSi and Transition) deposits, both on "whole ore", and beneficiated ore, with an analysis of this work presented in Reference 2.

The testwork appears to have largely been focused on exploring the impact of varying total acid dose on nickel extraction. The criteria for selecting acid dose for individual samples is not clear.

It appears no attempt has been made to maintain acid concentration to set target levels in any of the testwork. This is somewhat of a flaw in the work completed and limits the interpretation of results for various tests, and assessment of the variability of different samples. That is, conditions for the various samples were not held constant (e.g. to a final acid concentration), therefore comparison of the response of different samples is limited.

It is recommended all further leaching testwork be carried out to maintain a target free acid concentration in the leach.

The testwork shows nickel extraction for both the whole ore and beneficiated ore generally increases with increasing acid dose, as does the extent of gangue leaching. Generally nickel extractions of around 80% appear to be achievable given sufficient acid dose and leach residence time.

The leaching testwork also shows leaching of nickel initial proceeds rapidly (reaching in the order of 80% of the final extraction) in the first 2 to 4 hours, then leaches at a much slower rate beyond this to beyond 15 hours. Over this slow leaching period extractions for gangue species continue to rise, contributing to increasing acid consumption and sequent solution purification reagent requirements. Given the dominance of reagent costs for the Dutwa project it is recommended to review the leach results with the aim of understanding the most economic operating point for the leach.

None of the analysis presented comparing leach response of whole ore and beneficiated ore appears to have considered nickel losses in the beneficiation stage ahead of leaching. It would seem sensible to compare leach results of the whole ore and beneficiated ore at equivalent total nickel recovery to solution. As such it is recommended to review the leach results in more detail to assess the trade-off in beneficiation losses with reduced nickel extraction in leaching for the whole ore.

Table 2 shows a summary of leach test data for beneficiated Ngasamo ores reproduced from reference 2. As can be seen acid consumption spans a wide range from ~23 kg acid/kg Ni extracted to ~64 kg acid/kg Ni extracted, averaging ~40 kg acid/kg Ni (unweighted). Assuming an acid cost of ~US$176/t (based on a sulfur cost of ~US$539/t), this amounts to a cost of ~US$7,000/t Ni extracted in acid alone at the average value, and up to ~US$11,000/t Ni extracted at the higher end of this range). The Wamangola samples have shown acid consumption in the same generally range.

Acid consumptions in this range represent a major portion of the total payable metal value, without consideration of other reagent costs which vary largely in proportion to acid consumption. As such it is recommended results of the leaching work be reviewed in the context of the extent of leaching of acid consuming species in ratio to the extent of nickel leaching. This is expected to aid in highlighting the optimum end point for the leach, rather than simply focusing on nickel extraction.

Table 2 – Summary of Ngasamo Leach Test Data[2]

Sample	Ore Type	Acid Addition		Head Grade		Residual H_2SO_4, g/L	Extraction, Ni, %
		kg/t leach feed	kg H_2SO_4 / kg Ni extracted	Ni, %	Mg, %		
NG-03	Var. Trans - Bene.	860	61.8	1.55	11.3	81	89.7
NG-18	Var. FeSi - Bene.	726	45.1	1.69	7.5	46	95.4
NG-22	Var. FeSi - Bene.	649	47.6	1.58	5.3	81	86.3
NG-05	Var. FeSi - Bene.	672	33.8	2.13	4.6	30	93.2
NG-05	Var. FeSi - Bene.	490	27.3	2.16	4.6	26	83.1
NG-05	Var. FeSi - Bene.	350	25.6	2.11	4.5	29	65.0
NG-13	Var. FeSi - Bene.	619	29.2	2.27	2.8	53	93.3
NG-06	Var. FeSi - Bene.	700	29.8	2.47	7.3	30	95.0
NG-06	Var. FeSi - Bene.	535	25.4	2.47	7.3	25	85.3
NG-06	Var. FeSi - Bene.	370	23.2	2.39	7.1	20	66.8
NG-07	Var. Trans - Bene.	880	39.0	2.35	11.7	28	95.8
NG-07	Var. Trans - Bene.	690	34.0	2.33	11.5	19	87.0
NG-07	Var. Trans - Bene.	520	30.5	2.29	11.4	17	74.5
NG-FeSi02	Bulk FeSi - Bene.	750	63.9	1.39	7.1	60	84.4
NG-FeSi02	Bulk FeSi - Bene.	650	59.9	1.39	7.0	45	78.0
NG-FeSi02	Bulk FeSi - Bene.	550	63.6	1.38	7.1	33	62.8

Table 2. Summary of Ngasamo Leach Test Data[2]

A "sequential leach" in which beneficiated FeSi ore is fed to the head of the leach train and transition ore is introduced midway through the leach train is currently proposed. It is recommended the merits of this configuration be reviewed in more detail.

Further optimisation of the leach circuit configuration and operating conditions is required.

It is recommended to explore the trade-off in residence time, acid consumption and overall nickel recovery (including beneficiation losses). It is expected there is likely advantages in targeting lower leach residence times and acid concentrations. This would potentially yield saving in both CAPEX and OPEX per unit nickel recovered.

It is also recommended to investigate a counter current leach configuration. This may allow a reduction in acid and limestone consumptions, and gangue leaching to be achieved, for an equivalent nickel extraction.

2.4.2 Impact of grind size

Leach tests were carried out to assess the sensitivity of nickel extraction to grind size. This showed minimal sensitivity of nickel extraction over the range investigated. However, it is recommended to review the results of these tests to assess the impact of grind size on leach selectivity/the extent of leaching of gangue species. This will aid in assessing whether there is any impact of varying grind size on reagent consumptions.

2.5 Solids/Liquor Seperation

From the information reviewed, only limited preliminary solids/liquor separation testwork has been completed for the leach residue thickening and CCD duties. Results of this preliminary work show reasonable settling performance of the Dutwa leaches residues, and are within expectations for nickel laterite leach residues.

Additional testwork, including vendor testing, is required on representative leach residue pulps to define achievable performance, and support equipment sizing and selection.

It is noted the leach residue thickening and CCD train are capital intensive areas of the circuit, with performance here greatly impacting the overall mass balance and soluble losses from the circuit.

No solids/liquor separation testwork has been completed for the duties within the neutralisation, solution purification and product recovery circuits. Appropriate solids/liquor separation testing will be required for these duties once circuit configuration and operating conditions have been optimised.

2.6 Neutralisation, Solution Purification and Product Recovery

From the information reviewed, only limited preliminary testwork has been completed for the neutralisation, solution purification and product recovery circuits. Significant additional testwork is required in these areas to define achievable performance, reagent utilisations, product quality, confirm process design criteria and support equipment sizing and selection.

Such work should be carried out utilising solution compositions representative of the optimised upstream beneficiation and leaching flowsheets.

Significant amounts of Mg are expected to be leached into solution through the atmospheric leach train (Mg is the key driver of acid consumption). The build-up of high concentrations of Mg in solution can potentially lead to nickel losses, due to the formation of a nickel magnesium double salt and scale formation in various pieces of process equipment. Further consideration of the most appropriate means of Mg management is required.

2.7 Nickel Product Recovery

A trade-off study was previously completed to assess the merits of Mixed hydroxide product (MHP) production compared with mixed sulfide precipitation (MSP)[3]. Based on preliminary analysis of the revenue from the MHP and MSP products, it was concluded the difference between the nickel revenue and operating costs for the MSP and MHP options that economically there is no significant difference between the two options. However, health and safety risk was identified as (and is) one of the major differentiators between these options. (The risk for the MSP option is higher compared to the MHP option mainly due to the pyrophoric nature of the MSP product produced from NaHS precipitation and the possible generation of H_2S gas within the circuit).

The outcomes of this trade-off study appear reasonable. However, it is recommended the choice of product be reviewed in the context of a current marketing study (to better assess payment terms and marketability), and investor's/ potential off-take customer preferences.

From a technical perspective, both options provide a good fit with the atmospheric acid leach process, produce readily marketable intermediate products, and are relatively simple and lower capital compared with routes to produce final nickel products (e.g. Ni EW, hydrogen reduction, etc.). Both options are considered to be a good fit with the scale of operation under consideration, and project locality.

Refer Section 3.1.2 for brief comments on application of the CleanTeQ ion exchange process.

2.8 Other Areas

2.8.1 Limestone Characterisation

Limestone consumption is a significant contributor to operating cost for the process, with consumption expected of the order of 370 kt/y[1].

Testwork has been completed on limestone samples from two potential limestone sources, Tanga (Tanzania) and Koru (Kenya), to assess acid neutralisation capacity and comminution properties of these[2]. Although the limestones tested are technically suitable, it is noted these sources are a considerable distance from Dutwa, and as such must carry significant transport costs.

In order to reduce transport costs associated limestone supply it is recommended to investigate the potential for more local supply, including potential 'greenfields' deposits.

Preliminary testwork suggests there is potentially substantial benefit (20 to 12%) in decreasing limestone grind size from P80 ~75µm to ~45 µm. It is recommended to undertake further testwork to identify the optimum limestone grind size, and better quantify achievable limestone utilisation.

2.8.2 Evaporation Testwork

Solution evaporation testwork has been completed to aid in water balance modelling[2]. The work undertaken appears adequate. Not further work is recommended.

2.8.3 Geotechnical and Tailings Testwork

It is recommended the work undertaken be reviewed by a tailings disposal specialist to assess the adequacy of this work, and any required further work.

2.8.4 Further Testwork and Site Based Piloting

In our discussions with Blackdown Resources it is understood there have been some thoughts of building a pilot plant on site including an acid plant to provide sulphuric acid for the pilot plant.

On site piloting on the fully integrated flowsheet would be an extremely costly exercise, with significant logistical challenges, particularly given the lack of existing infrastructure, technical support services and technical personnel on site. In addition to being costly, without adequate technical supervision and support, such a pilot may become a protracted exercise, with potentially compromised technical outcomes.

If site based piloting of the full flowsheet was undertaken it would be significantly more cost effective to import concentrated sulfuric acid to site, rather than build an acid plant, unless considering a semi-commercial scale “demonstration” plant, which is not considered necessary or warranted for the atmospheric acid leach route.

WorleyParsons consider the most effective way forward is:

1. Further bench scale laboratory batch testing to:
   - Optimise the flowsheet, understand ore variability and further define process design criteria
2. Semi continuous/integrated batch testing:
   - An integrated testwork campaign to produce residues closely replicating those of the commercial plant would allow more accurate assessment of the overall circuit balance and confirmation of flowsheet configuration ahead of the pilot plant operation, allowing a more focused pilot plant exercise to be undertaken
3. Integrated pilot testing of the hydromet flowsheet:
   - This should integrate atmospheric leaching, solid-liquid separation, solution purification, product precipitation, conditioning, and all other integrated processes
     - The aim of this is to confirm process design criteria and process performance determined as outcomes of both bench and semi-continuous testing
   - This would likely require pilot scale testing of the beneficiation flowsheet to produce sufficient feed sample for the hydromet flowsheet. However, this could (and would be best) be conducted as a separate “stand alone exercise”

Typically such work would be best undertaken at competent and reputable commercial laboratory. WorleyParsons can assist in the selection of a laboratory to effectively and efficiently complete the test work required. We can also assist in the set-up of a laboratory to assist Curzon Resources if this option is of interest.

There may be some advantages to piloting of the beneficiation flowsheet on site at larger scale, if this were considered necessary. This would allow larger scale, more representative testing of various ore types to confirm achievable beneficiation results. However, at this stage this is not considered necessary, pending the outcomes of further more detailed analysis of the beneficiation results and assessment of further testing requirements.

3. Key Opportunities

Key opportunities identified are summarised below:

- Optimisation of mine plan:
  - This should consider options for high grading/selective mining to minimise acid consumption per unit nickel recovered
  - This should be done in conjunction with beneficiation and leaching outcomes. That is, the mine plan should be aimed at delivering an "optimised" feed to the leach circuit post beneficiation, aimed at minimising acid consumption per unit nickel recovered
  - The impact of widely varying comminution properties and beneficiation response also needs careful consideration in the mine plan, to smooth potential impacts on production
- Optimisation of beneficiation cut point:
  - Further work is required to optimise the beneficiation cut point, and strategy for treating various ore types
- Common ore preparation circuit (comminution and beneficiation circuits):
  - The current block flow diagram (refer Figure 2-1) proposes separate comminution and beneficiation circuits for the FeSi and Transition ores. It is recommended the merits of separate circuits be reviewed. Installation of a common circuit would simplify the overall circuit and reduce CAPEX
- Optimisation of the leach circuit configuration:
  - It is recommended to explore the trade-off in residence time, acid consumption and overall nickel recovery (including beneficiation losses)
    - It is expected there is likely advantages in targeting lower leach residence times and acid concentrations. This would potentially yield saving in both CAPEX and OPEX per unit nickel recovered.
  - It is recommended to explore a counter current leach configuration, which may allow a reduction in acid and limestone consumptions, and gangue leaching to be achieved.
- Acid plant; Some consideration for an plant with the capability of burning either sulfur or sulfide concentrate may be warranted:
  - If a suitable sulfide concentrate can be sourced this may offer considerably savings in acid costs, compared to import of elemental sulfur
- Co-treatment of Ni sulfide concentrates:
  - The project summary (7) mentions some potential for nickel sulfide exploration. Co-treatment of nickel sulfide concentrate could offer substantial upside for the project due to both providing 'free on board' sulfur units for acid production, and additional nickel units

- Limestone:
  - Limestone represents at major operating cost. In order to reduce transport costs associated limestone supply it is recommended to investigate the potential for more local supply, including acquisition/development of potential 'greenfields' deposits
- Final product:
  - It is recommended the choice of product, MHP or MSP, be reviewed in the context of a current marketing study (to better assess payment terms and marketability), and investor's/ potential off-take customer preferences
  - It is also recommended some consideration (informed by appropriate marketing study) be given to production of nickel sulfate

3.1 Alternative Technologies

3.1.1 Direct Nickel Process

The Direct Nickel process (DNi™) is a nitric acid based atmospheric leaching process developed for treating nickel laterite.

Although the proponents claim considerably benefits compared to established technologies, particular with respect to reagent consumptions, it is an emerging technology which is yet to be commercialised. As such significant development effort would be required, to implement the technology.

A full and thorough trade-off study, supported by substantial additional testwork, would be required to properly assess the claimed potential benefits, and merits relative to the atmospheric sulfuric acid leach route which has been considered to date.

Potential areas of concern which would need further consideration for this route include:

- Technical novelty and technical risk
- Required development effort and development time frame
- Energy requirements
  - it is expected the process is energy intensive
  - this potentially offsets savings in reagent costs
- Issues in handling and recycle of NO_2 and potential environmental, health and safety risks
- Nitric acid losses and make-up costs
- Saleability of by-products

It is noted being a nitrate based leaching system, this would be a significant departure for the sulfate based route which has been considered to date. The development effort required to move forward would be a "re-start", as opposed to building on the substantial amount of work which has been completed to date on the atmospheric sulfuric acid leach route. As such consideration of this route would be associated with a considerable schedule and study cost impact.

At this point in time it is not recommended to consider this route for Dutwa.

3.1.2 CleanTeQ/Ion Exchange

Clean TeQ is focused on applying its proprietary ion exchange (IX) processes to the recovery of metals from various process streams, in addition to various water treatment applications. CleanTeQ's continuous resin-in-pulp (cRIP) and elution processes extract and concentrate nickel and cobalt directly from acidic lateritic pulps. This allows the purification and production of saleable nickel and cobalt sulphates direct at the mine site, potentially eliminating the need for further refining required.

The CleanTeQ (and other ion exchange) technology is compatible with the atmospheric sulfuric acid leach route, and represents an alternative solution purification and nickel recovery (from solution) route to the mixed hydroxide product (MHP) which has been considered by the project to date.

Ion exchange represents a convenient means to produce nickel sulfate as a saleable product, rather than the mixed hydroxide product which has been considered by the project. Alternatively, IX can be used as an alternative solution purification method ahead of metal production by electrowinning. This is a readily scalable technology, and which would fit with the scale of project under consideration.

To evaluate the CleanTeQ IX route and its merits compared to the MHP route, an appropriate trade-off study would be required, including marketing study for nickel sulfate product.

3.1.3 Atmospheric Chloride Leaching

Atmospheric chloride leaching of nickel laterites is considered a developing technology, which is yet to be commercialised. As such significant development effort would be required, to implement the technology.

Potential areas of concern which would need further consideration for this route include:

- Technical novelty and technical risk
- Required development effort and development time frame
- Energy requirements
  - it is expected the process is energy intensive
  - potentially offsets savings in reagent costs
- Chloride losses and make-up costs
- Materials of construction
- Chloride contamination of products and residues

At this point in time it is not recommended to consider this route for Dutwa.

4. References

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4. OMC, “High Level Review of Continuous Open Circuit metal Removal Tests at Varying Magnesium Solute Concentration Dutwa Nickel Project”, Rev A, Nov 2012
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