ASX Announcement

28 February 2019

ASX: BOE

Optimisation Testwork Identifies Improvements to Honeymoon's Uranium Re-start

HIGHLIGHTS

- Optimisation testwork program highlights opportunities to simplify Honeymoon's production process flowsheet and reduce capital and operating costs
- Precipitation testwork shows existing installed precipitation circuit can deliver required production rate and thereby eliminate the need for an additional circuit as identified in PFS
- Further reduced capital expenditure identified from modifying the Ion exchange elution process
- Reductions to CAPEX & OPEX emanating from these testwork programs will reflect in the DFS
- Results of Phase 1 trade-off studies to be reported mid-March 2019

Boss Resources Limited (ASX: BOE) is pleased to announce the completion of the Phase 1 optimisation testwork program which forms part of the three-phase Re-Start Strategy for its 100% owned Honeymoon Uranium Project in South Australia. The successful optimisation testwork results have further defined the production process flowsheet for Honeymoon's expansion, identifying potential cost savings and process improvements.

ANSTO Minerals (ANSTO) completed optimisation testwork programs, and concentrated on the restart of Honeymoon's existing Solvent Extraction (SX) facility and addition of a new Ion Exchange (IX) process. Specifically, the testwork programs focussed on improving the resin elution process for the IX, nano-filtration testwork for reagent recycling, uranium precipitation and improved SX operations (impurity removal), and it identified several opportunities to reduce capital and operating expenditure to re-start operations at Honeymoon.

Results from the testwork will be included in a Definitive Feasibility Study examining the Honeymoon Re-start, which is due for completion in Q3 2019.

Boss Resources Managing Director Duncan Craib said, *"These initial Re-Start Strategy results are exceptional and a significant body of work which will enable us to develop an even more efficient flowsheet to deliver extra value to shareholders.*

"The considered approach undertaking this optimisation work has helped us better understand the process constraints and through a structured program of work optimise the process.

"The potential cost savings and process improvements emanating from these specific testwork programs will contribute positively towards the DFS."

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HONEYMOON RE-START STRATEGY

As previously announced[1] the Re-start Strategy is categorised into the below three key phases.

Final reporting of Phase 1 will occur this quarter, Phase 2 has commenced and expected to be released in Q3 2019 with Phase 3 following later in the year.

Phase 1: The generation of the final input data required for the Definitive Feasibility Study (DFS) including the drilling program to deliver the measured and indicated resource, an optimisation program to deliver further cost savings and/or process improvements and a preliminary execution plan, updated cost estimate and schedule for the re-start of the existing solvent extraction (SX) plant.

Phase 2: The second phase comprises the DFS and permitting updates. The DFS engineering works; process, engineering design and cost estimation, will use the results from the Phase 1 studies along with the outputs of the wellfield design, derived from the updated mineral resource, to deliver an independent feasibility study report.

Phase 3: The third phase covers the detailed execution planning, operational readiness inclusive of the SX plant recommissioning plan, in conjunction with the ion exchange plant detailed design.

On completion of the three-phase strategy, Boss will be in a position to proceed to mine, assuming a specified global uranium price has been achieved to satisfy the targeted IRR and NPV return to shareholders. Being an ISR mine in combination with IX production, the Honeymoon Uranium Project will operate in the lowest cost quartile of world-wide producers.

Stage 1: Restart of the existing operation; which will involve the use of existing wellfields, and restarting the existing SX plant with minor modifications to rectify identified operational issues. Construction of the ion exchange (IX) plant will commence;

Stage 2: Ramp up of plant capacity to 2Mlb/annum U_3O_8 equivalent using the combined SX / IX system;

Stage 3: Ramp up of plant capacity from 2Mlb/annum to ~3.2Mlb/annum U_3O_8 equivalent (after validating the IX technology) through the addition of further IX columns.

[1] Refer ASX announcements 2 July 2018, 9 October 2018

OPTIMISATION TESTWORK HIGHLIGHTS

The optimisation testwork results work show capital savings and process simplification in the targeted areas of SX, IX, uranium precipitation and nano-filtration, and highlights included:

- **Step-change in the elution process**: Testwork results show possible improvements to the resin elution process over what was achieved during the Field Leach Trail (FLT). Testwork also identified an alternate elution methodology that results in a performance step-change in the process and would allow exclusion of nano-filtration, resulting in capital savings and process simplification.
- **Increase in uranium grade:** Assuming the original elution process is maintained, the nano-filtration testwork identified a highly selective membrane with high fluxes (flowrates) that allows the majority of the reagents (NaCl) to be recovered while increasing the uranium grade in the precipitation feed by a factor of five. This results in a more efficient precipitation process, and should allow the existing precipitation circuit at Honeymoon to be used for the entire 2Mlb / annum production (i.e. further capital savings) without the need to install a second new circuit.
- **Continuous precipitation circuit:** Following this, uranium precipitation testwork was undertaken to demonstrate that the nano-filtration product liquor and the alternate eluate product could be combined with the existing SX strip liquor as feed to the precipitation. Both liquors were amenable to this and by converting the circuit from the current batch system to a continuous system the existing equipment could be used more effectively.

Based on this work, ANSTO made recommendations to move forward into further trade-off studies with two potential flowsheets: a single-stage IX circuit plus nanofiltration and a two-stage IX circuit.

Testwork was also undertaken with regard to impurity (iron, zinc and organics) removal within the SX circuit prior to feeding precipitation. Key areas that effect these impurities are the phase modifier used and the scrubbing circuit. Both were investigated with the scrubbing being identified as the more critical step. The results have provided a more detailed understanding of the scrubbing process allowing some simplification by eliminating reagents, but has identified the need for more targeted testing to be undertaken

Ion Exchange Testwork Results

The IX testwork examined the impact of acidity, flowrate, temperature and resin bead size on the elution of uranium using the hydrochloric acid / sodium chloride (HCl/NaCl) eluent used in the FLT. The optimised conditions from the test work demonstrated that 10.8 bed volumes (BV) of 1.4 M NaCl + 0.1 M HCl eluent is required if operated at 50 °C and 0.5 BV/h (fixed bed elution). This compares to ~15BV seen in the FLT. The eluate tenor in this case would then increase by ~30% i.e. ~2.7 g/L U_3O_8, reducing flowrates as a result.

An alternate elution method developed by ANSTO was found to show a significant improvement compared with the HCl + NaCl elution process. This approach uses two steps: in the first, uranium is converted on the resin. In the second step, the converted uranium is fully eluted but, in this scenario, only requires ~3 BV of eluent. The eluate produced would contain approximately 9.7g/L U_3O_8.

A summary of the elution performance for each method is shown in the table below. Eluent	Flowrate (BV/h)	Temperature (°C)	Bed Volumes Required*	Expected Eluate tenor (g/L U_3O_8)**
Standard elution process	0.5	50	10.8	2.7
Alternate elution process***	0.5	50	3.0	9.7

*Number of bed volumes required for elution to 1 g/L_{wsr} U_3O_8. **Eluate tenor for a fixed bed elution of a loaded resin containing 30 g/L_{wsr} U_3O_8. ***This test after first step treatment

Figure 1 Ion Exchange Bench-scale Unit

Both options appear feasible, but the alternate elution process requires an additional stage in the IX process i.e. two-stage elution. However, with higher eluate grades being produced, Boss can eliminate the nano-filtration step which is essential for the standard elution process.

Nano-filtration Testwork Results

ANSTO investigated nano-filtration of the IX eluate as a means of increasing the tenor of uranium prior to precipitation, and to recover NaCl for IX elution. The aim was to reject uranium and sulfate into the concentrate stream, and allow sodium chloride to pass through to the permeate, which would then be recycled back to the elution stage of the IX process. Rejection of sulfate is as important as uranium, as previous test work programs showed that the presence of sulfate in the eluent affects the efficiency of the elution process.

Figure 2 Nanofiltration Bench-scale Unit

Flat-sheet experiments were performed using a cross-flow filtration apparatus that mimics spiral wound modules. The membrane samples were sourced from Dow, TriSep and Nanostone.

The preliminary tests showed that nano-filtration of the 2017 FLT eluate as produced in the IX plant (i.e. at pH 1) would not be possible, as sulfur rejection was only ~75%. After neutralisation to pH 2.5 the sulphur rejection increased to 93-94%. A synthetic simulant of eluate and SX strip liquor (to mimic parallel operation of the SX and IX circuits) achieved a sulfur rejection of 90-91%. A final test using eluate neutralised to pH 3 and the Nanostone membrane revealed sulfur rejection of 98.6% and uranium rejection of 98.5%, which was the best result seen.

High recovery tests, using eluate neutralised to pH 3.0, targeted 80% recovery to permeate. The Nanostone membrane test again produced the best result. The measured sulfur rejection of 98-99% and uranium rejections of 96-99%, combined with volume weighted average permeate flux of 29L/m2h,

demonstrated the potential for nano-filtration of the neutralised eluate to both concentrate the uranium by a factor of five, and recover the majority of the NaCl.

Uranium Precipitation Testwork Results

A batch UO_4 precipitation testwork program was performed using synthetic SX strip liquor and combinations of the strip liquor with various synthetic IX eluates and nanofiltration concentrates. The program initially defined the optimum conditions for precipitation from SX strip liquor. Under the current plan for the re-start of Honeymoon this will be the feed to precipitation during Stage 1. The program then determined the impact of the addition of IX eluate and/or nanofiltration product to the uranium precipitation feed. One of these combined streams will effectively be the Stage 2 feed for the process

In addition to the precipitation tests, settling and pressure filtration tests were performed on all final slurries (as well as determination of the particle size distribution by laser sizing) to determine if the various process conditions tested impacted the precipitates physical characteristics.

Following an extensive series of tests, the optimum conditions for UO_4 precipitation were determined. Testwork was then undertaken with these optimum conditions on combinations of synthetic SX strip liquor and three samples; IX eluate from the Honeymoon FLT trial, synthetic eluate based on the two-stage alternate elution process developed in this program, and also a synthetic nanofiltration concentrate, again based on the results from this test-work program. The liquors were combined in ratios based upon the relative flows anticipated in practice. All three combinations were significantly higher in chloride concentration than the straight SX strip liquor, with concentrations of 41.7, 28.0 and 43.0 g/L for the FLT eluate, alternate eluate and nanofiltration concentrates, respectively, compared to 5.3 g/L in the SX strip liquor. The tests with the two highest chloride concentrations displayed slower rates of uranium precipitation with a 6-hour ageing time required to achieve a >99.9% precipitation. Significantly, the test using the alternate eluate displayed a similar rate of uranium precipitation to the test using straight SX strip, indicating that the Cl concentration of 28.0 g/L in this test did not impede precipitation. The results show that if the base case IX eluate and/or nanofiltration concentrate is to be fed to the precipitation circuit, a residence time greater than 2 h, probably ~6 h, would be required.

The particle sizes for the precipitates from the blended feeds were variable, with the FLT eluate sample very fine and the alternate eluate and nanofiltration concentrate solids significantly coarser, with P80s of 68 and 38µm, respectively. These coarser particle sizes were reflected accordingly in the filtration rates.

The testwork would indicate that the existing circuit at Honeymoon can successfully treat combined liquors from both the SX and nanofiltration or the two-stage alternate eluant, but that the alternate eluant may be more efficient.

Solvent Extraction Testwork Results

The SX testwork focused on improving the existing process. Initially the test work looked at determining if an alternative third phase modifier (less aqueous soluble) than the previously used TBP (tributyl phosphate) could be used to improve phase separation. Both Cyanex 923 and isodecanol were considered. While both were found to suppress third phase formation at lower concentrations than

TBP, Cyanex 923 was found to inhibit the phase disengagement in the stripping section, and isodecanol had a significant negative impact on uranium loading compared with TBP.

The existing solvent composition (2% Alamine 336, 2% DEHPA and 3% TBP) therefore appears to be the best option.

Scrubbing tests were undertaken on this mix to determine strategies to minimise iron (III) transfer to the stripping section, where it was previously found to precipitate as a crud at the alkaline conditions. Scrubbing with H_2SO_4 was effective but when the O:A was increased, as would be the case in the plant, the scrubbing performance decreased significantly. It is thought that this was due to chloride transfer to the aqueous phase, forming extractable iron (III) chloride complexes. Sodium metabisulfite did not appear to have a significant impact on the scrubbing efficiency and it is recommended that this is removed in the future operation. Further work is planned on the scrubbing stage to address the chloride problem.

IX and SX Process Flowsheet Options

Based on this testwork program a number of options for the integration of the IX process with the existing SX and precipitation circuits at Honeymoon were considered. A summary of the advantages and disadvantages of each is outlined in the table below.

A high-level operating cost estimate for the SX, IX, nanofiltration and precipitation stages of the process was prepared using the estimated annual reagent costs for each of the options to help guide some of the decision making. The results indicate that

- Nanofiltration of the NaCl/HCl eluate after mixing with the SX strip solution results in a lower reagent cost (A$1.6 per lb U3O8, Option 2b) than if nanofiltration is performed on the eluate prior to mixing with strip solution (A$2.1 per lb U3O8, Option 2a). This is due to the reduction in NaOH required to neutralise the eluate to pH 3.
- Option 4, the two-stage alternate elution process, resulted in a lower reagent cost than the NaCl/HCl elution with nanofiltration (A$1.5 per lb U3O8).
- The HCl/distillation flow sheet (Option 3) had a low reagent cost (A$1.4 per lb U3O8). This was a further alternate process defined due to the improved elution at low pH. This option is considered high risk due to the high temperature reagent recovery system required and the energy requirements associated with this.
- The use of nanofiltration in the two-stage alternate elution (Option 5) resulted in the lowest overall reagent cost (A$1.3 per lb U3O8), although that flowsheet is also the most complex and would have the highest capital costs as both the additional IX and the nanofiltration are assumed.
- For comparison the reagents costs determined in the Pre-feasibility Study were ~A$1.80 per lb U3O8

Option	Advantages	Disadvantages	Assessment
Option 1: (Mix eluate and strip liquor without nanofiltration and proceed to precipitation)	Least complex process.	No recovery of NaCl. Peroxide precipitation is not efficient	Not worthy of further consideration – insufficient residence time in the precipitation circuit to cope with the full flow of eluate.
Option 2: (2a: Nanofiltration of eluate at pH 3, mix with SX strip liquor. 2b: mix strip liquor and eluate, then nanofiltration)	Recovery of ~80 % of NaCl. Smaller volume of liquor to precipitation.	Additional unit operation. Energy input in nanofiltration. Capital/Operating cost of membranes Large volume of eluate must be neutralised prior to nanofiltration (additional tank?)	**Consider as 'base case' option (see Figure 3)**
Option 3: (HCl elution, evaporate and recovery HCl, mix concentrate with SX strip liquor)	Recover ~80-90 % of HCl. ~ 95 % volume reduction prior to precipitation	Materials of construction associated with hot HCl solutions. Energy input to evaporate eluate	Not considered further
Option 4: (Two stage elution without nanofiltration)	Considerably less reagent used. Smaller eluate volume	Uncertainties about equipment to be used for conversion step. Eluent has not been piloted	**Considered as "alternate case" option (see Figure 4)**
Option 5: (Two stage elution with nanofiltration)	Recovery of NaCl. Further reduction in eluate volume	Additional unit operation	Consider as future upgrade.

Two clear processing options have been identified from this work for the integration of the ion exchange process with the solvent extraction and uranium precipitation circuits; nanofiltration of the HCl/NaCl eluate after combining with SX strip liquor and neutralising to pH 3, and the two-stage alternate elution process without nanofiltration. The basic process flowsheets for these are shown below. These two options will be investigated further as part of the trade-off studies currently underway with the intention to select one option for the final Definitive Feasibility Study work.

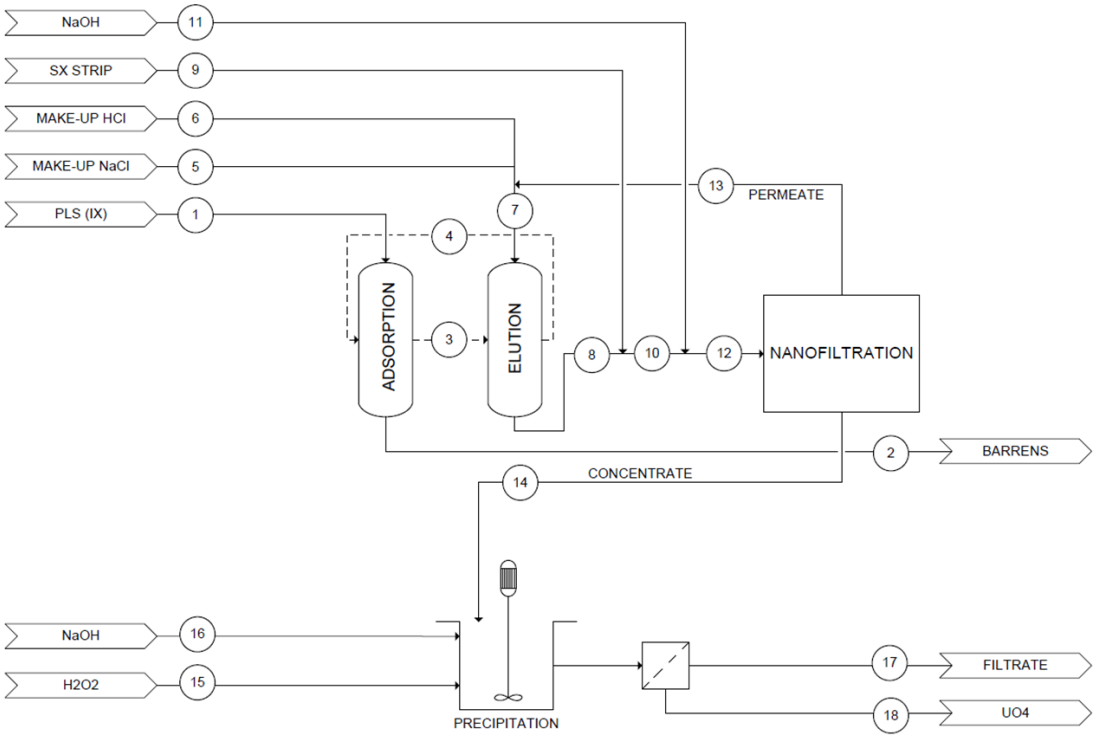

Figure 3 Base Case Option

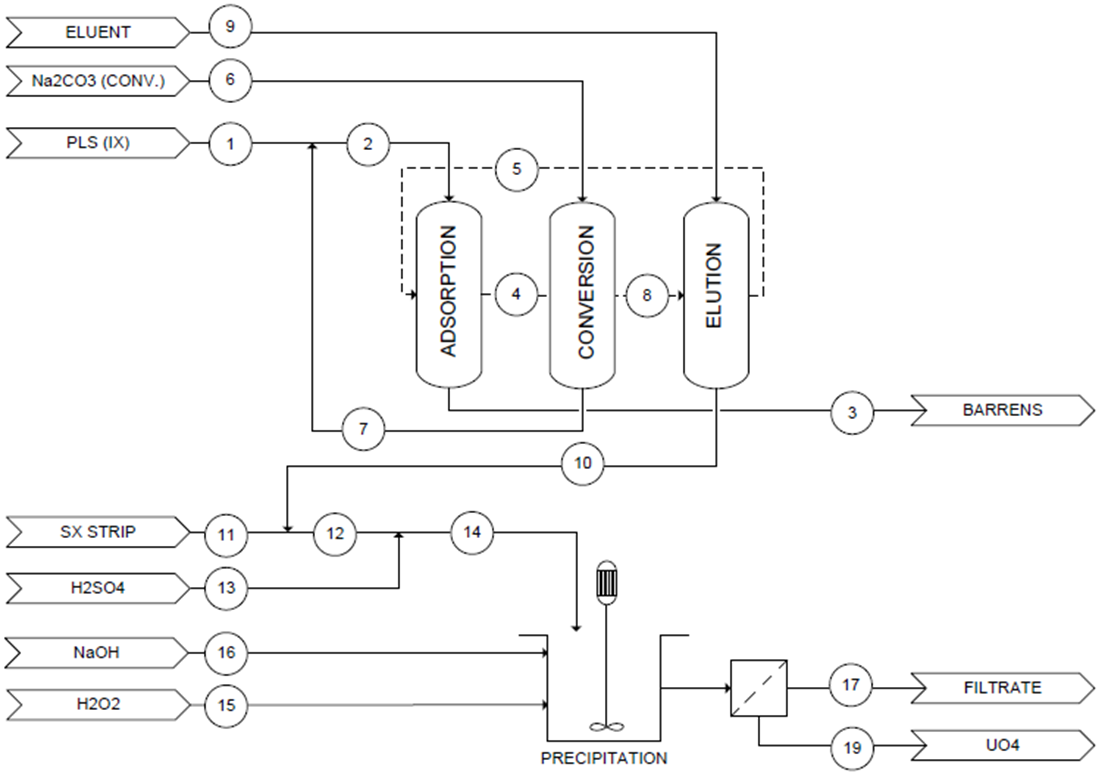

Figure 4 Base Case Option

FUTURE TESTWORK PROGRAMS

The testwork highlighted areas for further attention, and recommendations for the next phase of testwork are to:

- Conduct lock-cycle tests of the two-stage elution process using a fixed bed lead/lag/elute apparatus or moving bed arrangement;
- Further nanofiltration testing in a combination of continuous bench testing and at pilot scale (using commercially available spirally wound modules) should be undertaken using the selected membrane. The tests should be operated for an extended period to quantify membrane life and fouling rates.; and
- It is recommended that a continuous uranium precipitation process is trialled to validate the batch results seen here for the combined liquors. Recycling should be tested as this would likely produce particles of larger size and more favourable morphology, which would improve the solid/liquid separation and drying characteristics.

Regarding solvent extraction, the work showed that the current phase modifier (TBP) is the preferred reagent. Further work is required to fully understand and optimise the scrubbing circuit, in particular:

- Impact of chloride on the scrubbing of iron and zinc;
- Use of uranium to scrub iron (III) and zinc at several acidities.

The results from the current work and testwork recommended above will support the trade-off studies currently in progress and these can then define the optimal flowsheet for the project.

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