Chapter 8 Best Practicable Technology

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Appendices

APPENDIX 8.1: 2011-12 ITWC PFS BPT ASSESSMENT
8 Best Practicable Technology

8.1 Introduction

The identification and use of Best Practicable Technologies (BPTs) is a key component of the ERs for Ranger mine, which specify that:

12.1 All aspects of the Ranger Environmental Requirements must be implemented in accordance with BPT

12.2 Where there is ... agreement ... that the primary environmental objectives can be best achieved by ... (an) action which is contrary to the Environmental Requirements ... and which has been determined in accordance with BPT, that proposed action should be adopted

12.3 All environmental matters not covered by these Environmental Requirements must be dealt with by the application of BPT

The definition of BPT in the ERs effectively establishes a framework for assessment of currently available technology at any point during the operational and rehabilitation phases of mine life, rather than the ERs specifying particular technologies which may become obsolete (Supervising Scientist, 2000). A method to allow assessment of BPT was proposed by the Supervising Scientist and published in their 2000/2001 Annual report (SSD 2001). This has been historically used by ERA to support major proposals for amendment to the Ranger Authorisation. The current ER definition of BPT and an explanation of each BPT clause is presented in Table 8-1.

Table 8-1: Explanation of relevant matters/criteria to be included in BPT assessment (SSD 2001)

<table>
<thead>
<tr>
<th>Environmental Requirement Clause</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.4 BPT is defined as:</td>
<td>BPT</td>
</tr>
<tr>
<td>That technology from time to time relevant to the Ranger Project [Area] which produces the maximum environmental benefit that can be reasonably achieved having regard to all relevant matters including:</td>
<td>That technology that ranks highest when assessed against the factors below and is consistent with the Primary Environmental Objectives (Chapter 4).</td>
</tr>
<tr>
<td>(a) the environmental standards achieved by uranium operations elsewhere in the world with respect to (i) level of effluent control achieved; and (ii) the extent to which environmental degradation is prevented;</td>
<td>World’s Best Practice Options must be compared with the environmental standards set by world’s best practice in uranium mining and milling at the time they are to be implemented with respect to the level of effluent control achieved and the prevention of environmental degradation.</td>
</tr>
<tr>
<td>(b) the level of environmental protection to be achieved by the application or adoption of the technology and the resources required to apply or adopt the technology so as to</td>
<td>Cost-effectiveness Options should be assessed with respect to both the level of environmental protection achieved, and the cost of implementation.</td>
</tr>
<tr>
<td>Environmental Requirement Clause</td>
<td>Explanation</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>achieve the maximum environmental benefit from the available resources;</td>
<td></td>
</tr>
<tr>
<td>(c) evidence of detriment, or lack of detriment, to the environment;</td>
<td>Proven effectiveness Proposals for which there is practical evidence of their effectiveness should be favoured over proposals for which there is only experimental or theoretical evidence.</td>
</tr>
<tr>
<td>(d) the physical location of the Ranger Project</td>
<td>Location The Ranger mine is located in the Wet/Dry tropics, on Aboriginal land surrounded by Kakadu National Park, remote from high population density cities. Hence the level of protection required for the environment and community is very high and the technology chosen should be designed accordingly.</td>
</tr>
<tr>
<td>(e) the age of equipment and facilities in use on the Ranger Project and their relative effectiveness in reducing environmental pollution and degradation; and</td>
<td>Age of equipment Technology in use should be reviewed periodically to determine whether or not recent advances have been made that would result in enhanced environmental protection. Technology installed at Ranger in accordance with BPT should be reasonably allowed to fulfil its serviceable life with due consideration given to the advances in technology and the amount of serviceable life expended.</td>
</tr>
<tr>
<td>(f) social factors including the views of the regional community and possible adverse effects of introducing alternative technology.</td>
<td>Social factors The views of the regional community must be incorporated into BPT assessment. This includes where the introduction of new technology would improve the level of environmental protection but may also have negative social consequences. Benefits in environmental effectiveness may not necessarily result in greater social acceptability.</td>
</tr>
</tbody>
</table>

The determination of BPT for Ranger closure was primarily undertaken during the 2011/12 Integrated, Tailings, Water and Closure Prefeasibility Study (ITWC PFS) (Johnston and Iles, 2013), included as Appendix 8.1. Sections 8.2 and 8.3 present the outcomes of the ITWC study; the outcomes of the supplementary BPT assessment for additional tailings treatments conducted in September 2016 are provided in Section 8.4.

As outlined previously in Chapter 1, Section 1.4.3, several rehabilitation/closure activities were identified for standalone assessment via the Minesite Technical Committee (MTC). BPT assessments will accompany each Application submitted to the MTC for assessment, as per the provisions outlined in the Ranger Authorisation.
8.1.1 BPT Assessment Criteria

Early Ranger BPT assessments ranked technology alternatives against the criteria presented in Table 8-1. For the ITWC PFS, ERA wanted to ensure that the issue of BPT was considered from the outset by all members of the study team. Updates were presented to stakeholders at various stages throughout the study on progress of the assessment of BPT, details of these meetings are included in the stakeholder engagement register presented as Appendix 5.1 and included 9 presentations to ARRTC between 2011 and 2016 and a presentation to the CCWG in October 2016. It was ERA's intention that BPT would be a principal driver of the project and that adoption of this procedure would ensure that proposals emerging from the study would be demonstrably consistent with the requirements of BPT.

In considering the best procedure for ensuring that the BPT concept became a driver for the project as well as an assessment tool at its completion, ERA developed a more detailed assessment matrix than had been applied in the past. This detailed matrix is considered to be one that can more easily be used by technical staff in assessing individual components of the project as well as in assessing overall BPT for the final closure proposal.

The 25 criteria that were used in the ITWC PFS and subsequent September 2016 tailings assessment to rank technology alternatives for closure include:

**Traditional owner culture and heritage:**
- Would the adoption of the option have adverse impacts on the cultural practices, traditions and customs of the local Aboriginal communities?
- Would the option threaten in any way the integrity of sacred sites, rock art or any other aspect of the cultural heritage of the region?

**Protection of people and the environment – operational phase:**
- Would the option give rise to adverse impacts on the health and safety of Aboriginal or non-Aboriginal members of the local community?
- Would the option have any adverse socio-economic impacts on the communities in the town of Jabiru or in the broader Kakadu region?
- Would the option achieve protection of the natural World Heritage and Ramsar values of Kakadu National Park?
- While disturbance and environmental impact is inevitable on the project area, would adoption of the option minimise such on-site impacts?

**Fit for purpose:**
- Does the option being considered use proven technology? Proven and demonstrated technology would be ranked higher than very new, unproven or theoretical technology.
- How effective is the technology used in the option in meeting its desired output objective and how robust is it in response to variations in feed and consumables? Effective, highly robust options would rank highly.
• Does the standard of environmental protection achieved by the option meet the highest standards achieved in uranium mining elsewhere in the world?
• Does the capital cost of the option ensure that its adoption would contribute significantly to the overall project value?
• How robust is the option with respect to variations in rainfall and requirements on the timing of mill closure?

Operational adequacy:
• Would adoption of the practice ensure the ongoing health and safety of the workforce?
• Would the option require extensive control and support effort to ensure its continued viability?
• Is the process operationally reliable? That is, will it have high availability or will it be sensitive to the failure of single plant items?
• Would the option be difficult to maintain?
• Would the operating costs associated with the option have a large impact on overall project value?

Rehabilitation and closure:
• Would adoption of the option ensure the establishment of a revegetated site using local native species with a low maintenance regime?
• Would the option ensure the establishment of erosion characteristics on the site that, as far as can reasonably be achieved, do not vary significantly from those of comparable landforms in surrounding undisturbed areas?
• Would the option enable the establishment of stable radiological conditions on the rehabilitated site that will ensure that health risks to members of the public meet Australian standards and are as low as reasonably achievable?
• Would adoption of the option ensure that agreed water quality criteria are met in creeks draining the mine site and that appropriate ecosystem restoration standards are achieved for water bodies on the rehabilitated landform?
• Would adoption of the option ensure that all tailings produced at the Ranger site are physically isolated from the environment for a period of 10,000 years and that any contaminants arising from the tailings will not result in any detrimental environmental impact for at least 10,000 years?
• Would adoption of the option extend closure beyond traditional owner expectations and, in particular, beyond the requirements specified in the s41 Authority?
Constructability:

- Would adoption of the option introduce significant health and safety risks to the workforce during the project construction phase?
- Will the option give rise to the need for significant land disturbance during construction, significant off-site environmental impact or require construction work near sites of cultural significance?
- Would adoption of the option lead to high construction complexity through difficult scheduling, complex logistics or significant manpower requirements?

The new criteria remain consistent with the original six broad matters in the formal definition of BPT and continue to embed the principals and objectives of ecological sustainable development via the use of the National Strategy for Ecologically Sustainable Development to provide the national context for understanding best practicable technology as applied to the Ranger Project Area.

Implicit within the criteria for "Traditional Owner Culture and Heritage", "Protection of People and the Environment" and "Rehabilitation and Closure" is an assessment of the option against the Ranger closure criteria themes, and the various Matters of National Environmental Significance (MNES) protected by the controlling provisions of Part 3 of the EPBC Act – e.g., living cultural, world heritage and Ramsar values.

8.1.2 BPT Ranking, Weighting and Scoring

The BPT assessments incorporated a 5-level technology ranking system where a ranking of 3 meets industry standards (Table 8-2).

Table 8-2: BPT technology and ranking system

<table>
<thead>
<tr>
<th>Rank</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rank 1</td>
<td>Inadequate; the option does not meet current standards and it is unlikely that modifications could reverse this assessment.</td>
</tr>
<tr>
<td>Rank 2</td>
<td>Poor; the option does not meet current standards but options for modifications exist that could reverse this assessment.</td>
</tr>
<tr>
<td>Rank 3</td>
<td>Acceptable; the option meets current standards.</td>
</tr>
<tr>
<td>Rank 4</td>
<td>Good; the option exceeds current standards.</td>
</tr>
<tr>
<td>Rank 5</td>
<td>Excellent; the option exceeds current standards by a substantial margin and the option is recognised as international best practice.</td>
</tr>
<tr>
<td>UTE</td>
<td>Unable-to-Evaluate (UTE) - insufficient information available to allocate a rank to a criterion.</td>
</tr>
<tr>
<td>NA</td>
<td>Not applicable (NA) - the criterion was not applicable to the option being considered.</td>
</tr>
</tbody>
</table>
The final BPT score for each technology option was calculated using the rank of the option against the each of the criteria. The BPT score essentially summarises performance of the option against current international performance standards. The score for an option which achieves the highest rating for all criteria would be 100; an option that meets standards for all criteria would score 0, and an option that achieves the lowest rating for all criteria would score -100.

In addition, two types of showstopper results were possible. A hard showstopper was allocated to an option where it was clear from basic initial consideration that the option could not be accepted and there was no need to proceed further with assessment of the option. This might occur, for example, if an initial assessment demonstrated that adoption of an option could result in intrusion on a sacred site. A soft showstopper would be recorded against an option if a rank equal to 1 or 2 was attributed to the option for any criterion involving occupational health and safety issues, off-site environmental protection issues, or cultural issues. The recording of a soft showstopper against an option would not be considered to rule out that option but it would record that the performance of the option against the particular criterion would need to be reviewed and improved before the option could be considered acceptable. The recording of a significant number of soft showstoppers against an option would, however, be likely to rule the option out of further consideration.

8.2 ITWC PFS1 Technical Options Assessment

The focus of the ITWC PFS program was to evaluate the technology for reclamation, treatment and transfer of tailings from the tailings dam to the mined out Pit 3, and salt management technology to ensure physical containment of brine (from the brine concentrator treatment of process water) within Pit 3 with no detrimental impact to the environment for a period of 10,000 years.

The ITWC PFS was further divided into components, whereby PFS1 was the technical options review for the tailings management and salt management. PFS2 was the complete engineering study including, but not limited to, closure strategy options assessment and closure plan development.

In order to assess the available technical options, separate BPT workshops were conducted in PFS1 to assess the following project components:

- Tailings reclamation, transfer, treatment and deposition within Pit 3.
- Process water salt management and disposal within Pit 3.
- Final landform construction, revegetation and ecosystem reconstruction.

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1 BPT score = \(100 \sum_{i=1,N} \frac{(s_i - 3)}{N.2}\) where \(s_i\) is the score for criterion \(i\) and \(N\) is the total number of criteria for which a score was recorded. Only criteria for which a score was recorded (rather than a UTE or NA result) were included in the summation process.
8.2.1 Tailings Management

Options were considered for the reclamation, treatment and deposition of tailings for mine closure, which are described below, along with the key conclusions as a result of rating each option.

*Tailings reclamation*

Three categories were considered for reclamation of tailings from the tailings dam; excavation, hydraulic mining and dredging. Each with a subset of transfer options, giving a total of nine options taken into the BPT assessment:

- **Excavation:**
  - Dewater and truck.
  - Dewater and conveyor.
  - Surry and pump.

- **Hydraulic mining:**
  - Pump.
  - Thickener and pump.

- **Dredging:**
  - Pump.
  - Thickener and pump.
  - Thickener, filtration and truck.
  - Thickener, filtration and conveyor.

Of the reclamation and transfer options, excavation rated poorly compared with hydraulic mining and dredging. The principal deficiencies identified were the sensitivity of excavation techniques to extreme rainfall events, environmental protection and occupational health and safety issues arising from dust from the disturbed tailings, the considerable operational effort that would be required, and the drainage requirements required for successful implementation of the process. Hence excavation was rejected as a method for reclamation of tailings from the tailings dam.

Hydraulic mining and dredging emerged from the workshop with approximately equal BPT assessments. An overall assessment of the relative significance of the various advantages and disadvantages of the two options led to the conclusion that the disadvantages of the dredging option (operability, maintainability, radiation protection) are much more amenable to management than those associated with hydraulic mining (sensitivity to extreme rainfall, environmental protection, high capital costs). This is particularly the case for the issue of sensitivity to extreme rainfall events where management options are extremely limited and the occurrence of such events could have a major impact on the rehabilitation schedule. For this reason, dredging was considered to be the preferred option.
Tailings treatment

The principal technical advantage of filtration is that it reduces the time required for tailings consolidation. It thought to potentially have some advantages for long-term dispersal of contaminants in groundwater, but this had yet to be demonstrated and the advantage was considered to be small. On the other hand, it is a very expensive option to construct, install and operate and maintenance requirements would be high. The overall assessment of filtration at the tailings workshop was that the option should be retained for whole-of-project BPT assessment but that it appeared to be a very expensive option with limited advantages.

Cementation was considered as an option to potentially reduce dispersion of solutes in groundwater if required; however, it did not emerge as a viable treatment option. Further trials would be required, capital costs would be high because of the need to include filtration as a preliminary step and operational costs would be extremely high as a result of the high cement consumption implicit in the process.

Tailings deposition

Options assessed for deposition of tailings into Pit 3 considered either sub-aerial or sub-aqueous techniques for thickened tailings and dry-stacking or co-disposal with waste rock for filtered tailings.

The assessment for deposition of thickened tailings was that either option would be acceptable, however sub-aqueous deposition was preferred principally because it was rated more highly under the operability and operating costs criteria and it was assessed that Traditional Owners would have a distinct visual preference for tailings covered by water rather than an exposed tailings surface. Subsequent to this initial BPT workshop consolidation modelling demonstrated that sub aerial deposition would provide an advantage over sub aqueous deposition. Since both options were determined to be BPT, the method was changed without the need for an additional assessment.

With filtration of tailings being retained as an option, the deposition of tailings needed to be considered. Two options were considered; dry stacking and co-disposal with waste rock. It was determined that co-disposal of filter cake and waste rock led to higher maximum elevation of tailings in Pit 3, giving preference to dry stacking. There were, however, concerns expressed about the degree to which either technique had a proven track record and it was noted that both would be sensitive to rainfall (a dry pit would be required).

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2 The initial BPT workshop was conducted prior to the groundwater solute transport modelling from Pit 3; this option was assessed in case treatment of tailings was required in order to achieve the 10,000 year requirement for no detrimental environmental impact. Subsequent to this BPT assessment modelling has shown that additional tailings treatment is not required to mitigate solute transport.
Conclusions from rating options for tailings

The principal conclusions arising from the BPT workshop on tailings management were:

- Dredging is the preferred tailings reclamation technology.
- Cementation is not currently considered viable as a treatment method.
- Tailings filtration should be retained as a potential treatment method to be considered in the overall strategic workshops but it is a very expensive option that produces little benefit.

8.2.2 Salt Treatment and Disposal

The need to dispose of saline water is a common process in a number of industries and, as a result, 25 methods were identified as potential salt management options and were considered for the BPT assessment. Many of the options considered had fatal flaws and were hard show stopped prior to the workshop. A total of seven options were assessed in detail, these included:

- Brine injection:
  - Pit 3 underfill.
  - Underground silos.
  - Pit 3 underfill with rick screening.

- Crystallisation:
  - Pit 3 placement.
  - Underground silos placement.

- Thermal distillation:
  - Pit 3 underfill injection.
  - Underground silos injection.

The overall outcome of the BPT assessment was that brine injection to the underfill without rock screening was the highest ranked alternative. Brine injection to underground silos scored well but concerns were identified on occupational health and safety issues during both the construction and the operational phases of this option. Major problems were identified for the crystallisation and distillation options and it is considered unlikely that either would be viable. The only uncertainty remaining for the preferred option related to the potential for reactivity between the brine and the waste rock of the underfill and possible limitation on the volume available for the storage of brine.

It was concluded that this issue required further assessment prior to a final decision on the salt management option to be implemented. For this reason crystallisation was taken forward into the overall strategy assessment pending further test work to confirm on the brine injection option.
8.2.3 Final Landform Construction, Revegetation and Ecosystem Reconstruction

The assessment process adopted in the BPT workshop on landform construction, revegetation and ecosystem reconstruction was different to that adopted for tailings management and salt treatment and disposal. The landform reconstruction and revegetation program has gone through significant options analysis and refinement over several years and there are no longer major competing alternatives for their implementation.

Rather than assessing options and completing the ranking; each of the current plans for landform construction, revegetation and ecosystem reconstruction were reviewed against each criteria to identify possible options for improvement and to record any uncertainties. In particular, focus was given to closure schedule to determine the nature of any risks to completion of rehabilitation by 2026 as required under the s41 Authority.

8.3 PFS 2 Closure Strategy and Plan

After a thorough options review and the application of a detailed BPT assessment, available technical options were narrowed down to core technical options which relate to tailings management (dredged tailings with thickened tailings transferred to Pit 3 vs dredged tailings with thickened and filtered tailings transferred to Pit 3) and salt management (brine injection vs crystallisation). In all cases the option for transfer of tailings from the tailings dam to Pit 3 is by dredging, thickening then pumping.

The combination of the feasible tailings management options and the feasible salt management options resulting from PFS1 and the BPT assessment are provided below:

- Dredged tailings which are thickened and pumped to Pit 3 combined with injection of brine into the constructed base of Pit 3 (underfill).
- Dredged tailings which are thickened, then filtered, and pumped to Pit 3 combined with injection of brine into the constructed base of Pit 3 (underfill).
- Dredged tailings which are thickened and pumped to Pit 3 combined with crystallization of brine to be placed within Pit 3.
- Dredged tailings which are thickened, then filtered, and pumped to Pit 3 combined with crystallization of brine to be placed within Pit 3.

These options progressed through ITWC PFS2 and were assembled into closure strategies where the preferred technical options from PFS1 were combined with two possible processing cessation dates:

- Milling will cease in 2016. These options were given a "C" designation.
- Milling will cease at the end of 2020 consistent with the terms of the Ranger Authorisation. These options were given a "B" designation.

This provided a total of eight closure strategies that were assessed in two stages; these are shown in Table 8-3.
Table 8-3: Initial closure strategies to be assessed

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Brine strategy</th>
<th>Tailings strategy</th>
<th>Milling end</th>
</tr>
</thead>
<tbody>
<tr>
<td>1C</td>
<td>Injection</td>
<td>Thickened</td>
<td>2016</td>
</tr>
<tr>
<td>2C</td>
<td>Injection</td>
<td>Thickened and filtered</td>
<td>2016</td>
</tr>
<tr>
<td>3C</td>
<td>Crystallisation</td>
<td>Thickened</td>
<td>2016</td>
</tr>
<tr>
<td>4C</td>
<td>Crystallisation</td>
<td>Thickened and filtered</td>
<td>2016</td>
</tr>
<tr>
<td>1B</td>
<td>Injection</td>
<td>Thickened</td>
<td>2020</td>
</tr>
<tr>
<td>2B</td>
<td>Injection</td>
<td>Thickened and filtered</td>
<td>2020</td>
</tr>
<tr>
<td>3B</td>
<td>Crystallisation</td>
<td>Thickened</td>
<td>2020</td>
</tr>
<tr>
<td>4B</td>
<td>Crystallisation</td>
<td>Thickened and filtered</td>
<td>2020</td>
</tr>
</tbody>
</table>

8.3.1 Stage 1 Assessment

The BPT assessment of the eight identified strategies was divided into two stages. Stage 1, or the preliminary strategic assessment, was conducted soon after completion of the individual component assessments. The intention was to eliminate strategic options which clearly did not constitute BPT and also to identify more clearly information gaps in the remaining options that needed to be addressed prior to the final BPT assessment of the strategic options.

The key options that were eliminated in the stage 1 assessment were tailings filtration and brine crystallisation; results of the stage 1 assessment are shown in Figure 8-1.

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**Figure 8-1:** Outcomes of the stage 1 assessment, with strategy 1 being the preferred technology (in orange)
The tailings management workshop confirmed that filtration was a very expensive option with limited advantages and therefore it was decided that filtration of tailings (2C, 2B) should not be considered further in the development of the best practice strategy for rehabilitation and closure of the Ranger mine.

Further analysis and test work completed following the initial technical options BPT workshops confirmed that brine injection was the best option for management of salt. Further to this, the Stage 1 BPT confirmed that brine crystallisation was not a viable option, performing poorly under several criteria. As a result the strategies that included crystallisation (3B, 3C, 4B, 4C) of the brine stream from the water treatment plant were rejected.

8.3.2 Stage 2 Assessment

Based on the Stage 1 BPT assessment, all filtration and crystallization options were eliminated (this was further validated by programs conducted between the stage 1 BPT and the stage 2 BPT). As such, the closure strategies considered in the Stage 2 BPT workshop were limited to 1B and 1C, however, extended water treatment cases (5B and 5C) were considered as well. This was to allow for the scenario where process water volumes exceeded the brine concentrator treatment capacity; allowing for longer term treatment of process water if an extension beyond the 2026 closure date could be negotiated. Table 8-4 lists the options assessed in Stage 2.

Table 8-4: Final closure strategies assessed

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Brief description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1C</td>
<td>Brine injection, thickened tailings, milling until 2016</td>
</tr>
<tr>
<td>1B</td>
<td>Brine injection, thickened tailings, milling until 2020</td>
</tr>
<tr>
<td>5C</td>
<td>Strategy 1C with extended water treatment</td>
</tr>
<tr>
<td>5B</td>
<td>Strategy 1B with extended water treatment</td>
</tr>
</tbody>
</table>

The highest BPT score was recorded for Strategy 1B with a score of 19; the three other options scored 15. To put this result in perspective, changing the assessed score for any individual criterion by one unit would change the overall score for that option by about 2 units. Hence, these results imply that option 1B is the favoured option on the basis of the BPT assessment process but the result is marginal.

The criteria where differences were recorded were:

- Socio-economic impact on Jabiru and the region: the two extended options provide additional time for community partnerships to run and continued retention of services, the 5B case also provides additional royalty income.
- Technical performance: both 2020 options scored higher because the extended milling period enables the processing of lower grade ores that were previously assessed as not being commercially viable.
• Capital expenditure: the two extended options scored higher primarily because only one brine concentrator is required for these options.

• Maintainability: the 2020 milling option with extended water treatment results in the use of the brine concentrator for nine years beyond its planned lifetime.

• Operating costs: the operating costs of the extended 2020 option would be higher because replacement of major brine concentrator parts would almost certainly be required.

• Schedule: both extended options scored lower than the primary options under the schedule criterion.

8.4 Supplementary BPT Assessment

A review of the ITWC BPT assessment was conducted in August 2016; this determined that with the exception of tailings treatment, all technical options selected as BPT remained valid.

The initial PFS 1 BPT assessment for tailings treatment included thickening as part of all options assessed. At the time of the ITWC PFS thickening was considered to be the base case for two reasons:

• To remove process water from the tailings prior to pumping over to Pit 3, thereby reducing the costs of pumping this water back to the tailings dam.

• To assist in achieving final consolidation targets in Pit 3, to allow for backfill and completion of rehabilitation by 2026 as required under the s41 Authority.

Further test work, modelling and analysis undertaken since 2012 and the effective consolidation outcomes currently being achieved in Pit 1 has indicated that thickening may not be required. In order to determine if there were options without thickening that could be BPT; a supplementary workshop was conducted on 8 September 2016.

The primary additional treatments considered in the assessment were scenarios associated with unthickened tailings deposition into Pit 3, including: unthickened (A2); unthickened with prefabricated vertical drains (wicks) (A3); unthickened tailings with extended water treatment (A4); unthickened tailings, with inline agglomeration and wicks (A5) and unthickened tailings with neutralisation and wicks (A6). Tailings treatments brought forward from the previous ITWC BPT assessments include: thickened tailings (A1); thickened and filtered tailings (A7); and thickened, filtered and cemented tailings (A8). A summary description of each option is provided later in this section.

Several key assumptions were identified during the assessment, which were taken into consideration when ranking individual strategies, including:

• Processing to January 2021.

• Any additional process water treatment that may be required would be in the form of an additional brine concentrator or expansion of the existing infrastructure.

• Use of lime as the preferred neutralisation option.
8.4.1 Thickened Tailings (A1)

The ITWC treatment options analysis assumed as a base case that all tailings would be thickened. Under this option, tailings are to be reclaimed from the tailings dam by dredging and dewatered in a thickener prior to pumping the thickened tailings to the mined out Pit 3. A schematic of the thickening option is presented as Figure 8-2.

The rationale behind thickening of tailings was to reduce the volume of tailings deposited and thus the rate of rise, reducing time taken for consolidation and reduce the pumping costs associated with process water return from Pit 3. The plan was to implement thickening 12 months after the commencement of dredging.

The Ranger mill currently thickens the tailings stream to approximately 50 weight percent solids prior to deposition in Pit 3, while the proposed tailings dam reclamation dredge will progressively reclaim the sub-aqueous tailings producing a 28 weight percent solids stream. Thickening prior to transfer to Pit 3 will increase the solids content to approximately 60 weight percent.

Consolidation modelling has shown the thickened tailings will achieve consolidation targets.

![Figure 8-2 Thickened tailings flow sheet](image)

8.4.2 Unthickened Tailings (A2)

The unthickened tailings strategy involves the direct transfer of dredged tailings from the tailings dam to Pit 3, where it is allowed to naturally consolidate over time.

Dredged tailings have a solids density of approximately 28 weight percent. Following deposition in Pit 3, the tailings undergo sedimentation where they release water and achieve an initial settled density. Sedimentation testing has shown that unthickened mill tailings discharged at 28 percent solids rapidly settle to about 55 percent solids whilst thickened mill tailings discharged at 50 percent solids settle to 56 percent solids; indicating that unthickened tailings may be a viable option.
Consolidation modelling was conducted to determine if any unthickened options would be able to achieve the consolidation targets by the schedule date of January 2026. The results of this modelling demonstrated that consolidation could be achieved, but only if prefabricated vertical drains (wicks) were used to assist with the consolidation.

Based on this result, the option of unthickened tailings without further treatment was hard show stopped.

8.4.3 Unthickened Tailings with Wicks (A3)

As highlighted in Section 8.4.2, the unthickened tailings option with the installation of wicks can achieve the required amount of consolidation by 2026.

Pit 1 has provided a working demonstration of the effectiveness of tailings dewatering and consolidation via the installation of prefabricated vertical wick drains. In 2012, 7,554 wicks were installed into the pit to assist with dewatering, ahead of capping and rehabilitation (Figure 8-3). The wicks were installed within the top 40 metres of the tailings mass to dewater the upper level of the tailings and promote tailings consolidation, thus establishing a stable surface upon which to commence bulk backfill activities. A pre-load waste rock layer is placed over the tailings mass, designed to activate the vertical wicks by compressing the tailings and forcing the water in the pit to travel to the surface via the wicks and natural drainage patterns to decant towers located at the lowest points in the pit. Pumps located in the decant towers; pump the process water back to the process water system for treatment. Current consolidation modelling predicts that over 99 percent of the pore water in Pit 1 will be expressed within the first 6 years of consolidation. The installation of wicks in Pit 1 has proven to be an effective alternative technology to thickening and/or thickening with additional treatments.
8.4.4    Unthickened Tailings with Extended Water Treatment (A4)

This strategy is a variation on strategy A2 but includes extended water treatment past 2026, by way of construction and commissioning of an additional brine concentrator or expansion of the existing plant. Under this option, the landform over Pit 3 is surcharged and the tailings are allowed to complete consolidation. Process water expressed during consolidation would be captured and treated. This option is similar to the 5B and 5C in the ITWC PFS2 stage 2 BPT assessment.

The need for a second brine concentrator or expansion of the existing concentrator was based on the expected operational life span of the existing brine concentrator, not the volume requiring treatment.

8.4.5    Unthickened Tailings, with Inline Agglomeration and Wicks (A5)

Inline agglomeration involves the dosing of tailings with a flocculent, (i.e. a synthetic water-soluble polymer or aqueous liquid with dispersed particulate solids) that potentially reduces the dry density of tailings in the pit after consolidation (Figure 8-4).

A feasibility study was conducted in 2014 to quantify the costs and risks associated with inline agglomeration. The option was proposed as an alternative to the construction and operation of a high compression thickener. The feasibility study in 2014 followed laboratory scale testing.
(i.e. a scoping study) undertaken in May 2013, which demonstrated the viability of depositing flocculated tailings just above the floor of Pit 3 from a launder or pipe laid along the pit's haulage ramp. The study estimated that inline agglomeration could potentially reduce the tailings transfer costs, process infrastructure, flow sheet complexity and the risks associated with thickening the tailings from the tailings dam and managing foreign objects. However, if this option were to be adopted, the consolidation target would not be achieved without the installation of wicks.

Figure 8-4: Inline agglomeration flow sheet

8.4.6 Unthickened Tailings with Neutralisation and Wicks (A6)

Neutralised tailings are an alternative to cementation of tailings (Figure 8-5) and were thought to potentially be required to lock up contaminants in the tailings, preventing detrimental environmental impact for 10,000 years. This treatment involves adding a reagent to the tailings stream to bind (reduce mobility) or precipitate solutes and/or radionuclide. Two examples of this method are:

- The addition of lime, similar to the existing Ranger processing plant but to a higher pH target.
- The addition of spent liquor from the Gove Alumina Refinery – e.g. hydrotalcite \( \left[ (\text{Mg}_6\text{Al}_2(\text{CO}_3)_{16.4}(\text{OH}) \right] \) precipitates.

Test work an analysis of this option determined a number of advantages and disadvantages (Table 8-5).
Table 8-5: Tailings neutralisation advantages and disadvantages

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoids pipeline solidification issues associated with cementation.</td>
<td>Methods (i.e. hydrotalcite) not proven at Ranger.</td>
</tr>
<tr>
<td>Simpler process compared to cementation.</td>
<td>Medium – high opex costs.</td>
</tr>
<tr>
<td>Avoids capital in cement facility, mixing and tremie/pump.</td>
<td>10,000 year stability not known.</td>
</tr>
<tr>
<td>Lime neutralisation is proven technology at Ranger.</td>
<td>Impact of expressed water solute loading and composition on water treatment not known.</td>
</tr>
<tr>
<td></td>
<td>Tailings would be more permeable than cemented tailings.</td>
</tr>
<tr>
<td></td>
<td>Impact on consolidation not known.</td>
</tr>
</tbody>
</table>

Figure 8-5: Tailings neutralisation flow sheet

8.4.7 Thickened and Filtered Tailings (A7)

Thickening following by filtration was an option considered as part of the original BPT, therefore it was included as part of this supplementary assessment.

The primary purpose would be to ensure prompt consolidation of tailings in Pit 3 and thus effectively eliminate tailings settlement after deposition. The proposed filter plant would process both the reclaimed thickened tailings from the dam tailings and the mill tailings using pressure filters. The filter cake would then be transferred via a conveyor system to a truck load out bin, hauled to Pit 3 and spread by dozers (Figure 8-6). Tailings filtration studies established that:

- Pressure filtration was required to dewater mill tailings.
• Vacuum filtration was inappropriate technology for dewatering the whole tailings stream and was only suitable for dewatering the coarse size fractions.

The major advantages of filtered tailings over thickened tailings are:

• When placed and compacted the filtered tailings will reach a high overall density and a relatively low permeability. Thus filtered tailings will express a negligible quantity of process water after placement, reducing post-closure water treatment.

• Filtered tailings will produce negligible settlement allowing earlier access for backfilling, thus accelerating the overall closure schedule.

However, compared with thickened tailings the main disadvantage of filtering is that Pit 3 must be dry before the tailings can be placed. This requires the construction of another process water dam. Other disadvantages include higher capital and operating costs, and increased health, safety and environment risks during operations.

Figure 8-6: Tailings filtration flow sheet

8.4.8 Thickened, Filtered and Cemented Tailings (A8)

Cementation of tailings was an option considered as part of the original BPT, therefore it has been included as part of this supplementary assessment. Due to the high water content of tailings, the solids concentration would need to be raised by both thickening and filtration in an appropriate plant before cementation occurred. Otherwise cement consumption and the associated costs would be extraordinarily high and drying times would be long.
Tailings would be split with one fraction passing through a thickener and the other through a filtration plant and a hopper prior to combining both outputs in a mixer with a tailored mixture of cement and water. The mixer output would be held in a tank for conditioning prior to being pumped to Pit 3 (Figure 8-7).

Figure 8-7: Thickened, filtered and cemented tailings flow sheet

### 8.4.9 BPT Analysis of Tailings Treatment Options

The 8 options outlined in Section 8.4.1 were assessed using the same assessment criteria, scoring and weighting, as used in the ITWC PFS assessment; results are presented in Table 8-6. Of the 8 options assessed, one hard show stopper and four soft showstoppers were identified by workshop participants.

Table 8-6: Supplementary tailings treatment assessment

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Technology</th>
<th>Showstopper</th>
<th>Overall rank</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Hard</td>
<td>Soft</td>
</tr>
<tr>
<td>A1</td>
<td>Thickened tailings (ITWC base case)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A2</td>
<td>Unthickened tailings</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>A3</td>
<td>Unthickened tailings, with prefabricated vertical drains (wicks)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A4</td>
<td>Unthickened tailings, with extended water treatment</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>A5</td>
<td>Unthickened tailings, with inline agglomeration and wicks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A6</td>
<td>Unthickened tailings with neutralisation and wicks</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>A7</td>
<td>Thickened and filtered tailings (ITWC assessed)</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>
The full BPT matrix resulting from the September workshop is shown in Tables 8-7 to 8-9. Table 8-7 shows results for the criteria in the Traditional Owner Culture and Heritage and the Protection of People and the Environment categories; Table 8-8 shows results for criteria in the categories Fit for Purpose and Operational Adequacy; and Table 8-9 shows the results for criteria under the Rehabilitation and Closure and the Constructability categories.

A general comment to make about the results shown in Tables 8-7 to 8-9 is that for most of the detailed options assessed, a NA (not applicable) result was obtained for criteria in the Culture and Heritage, and Ecosystems and Natural World Heritage Values of Kakadu National Park categories. This was expected as the method of reclamation of tailings from the tailing dam has little association with cultural and heritage issues with all activities associated with all options occurring within the cultural heritage exemption zone. In addition, these methods do not have any impact on the surrounding ecosystems and world heritage values of Kakadu during the operational phase. Hence, the BPT assessment of the tailings treatment options was dominated by the criteria under the Fit for Purpose, Operational Adequacy and Constructability categories.

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Technology</th>
<th>Showstopper</th>
<th>Overall rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>A8</td>
<td>Thickened, filtered and cemented tailings (ITWC assessed)</td>
<td>✓</td>
<td>6.8</td>
</tr>
</tbody>
</table>
Table 8-7: BPT assessment matrix for tailings treatment for categories Culture and Heritage and Protection of People and the Environment during the operational phase

<table>
<thead>
<tr>
<th>Option ID</th>
<th>Option Description</th>
<th>Show stopper 1 Indicator</th>
<th>Show stopper 2 Indicator</th>
<th>Overall rank</th>
<th>Living culture (Closure)</th>
<th>Cultural heritage</th>
<th>Community Health &amp; Safety</th>
<th>Socio-economic Impact on Local Communities</th>
<th>Ecosystems &amp; Natural world heritage values of Kakadu National Park</th>
<th>Ecosystems of the Project Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Thickened (ITWC, base case)</td>
<td>0</td>
<td>0</td>
<td>12.6</td>
<td>4</td>
<td>NA</td>
<td>4</td>
<td>3</td>
<td>NA</td>
<td>3</td>
</tr>
<tr>
<td>A2</td>
<td>Unthickened</td>
<td>4</td>
<td>0</td>
<td>-100.0</td>
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<td>NA</td>
<td>4</td>
<td>3</td>
<td>NA</td>
<td>4</td>
</tr>
<tr>
<td>A3</td>
<td>Unthickened - wicks</td>
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<td>0</td>
<td>41.3</td>
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<td>NA</td>
<td>4</td>
<td>3</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>A4</td>
<td>Unthickened - extended water treatment</td>
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<td>1</td>
<td>-6.5</td>
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<td>NA</td>
<td>4</td>
<td>3</td>
<td>NA</td>
<td>3</td>
</tr>
<tr>
<td>A5</td>
<td>Unthickened - inline agglomeration and wicks</td>
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<td>0</td>
<td>10.0</td>
<td>3</td>
<td>NA</td>
<td>4</td>
<td>3</td>
<td>NA</td>
<td>3</td>
</tr>
<tr>
<td>A6</td>
<td>Unthickened - neutralisation and wicks</td>
<td>0</td>
<td>2</td>
<td>17.5</td>
<td>UTE</td>
<td>NA</td>
<td>4</td>
<td>4</td>
<td>NA</td>
<td>3</td>
</tr>
<tr>
<td>A7</td>
<td>Thickened &amp; filtered tailings</td>
<td>0</td>
<td>3</td>
<td>13.0</td>
<td>4</td>
<td>NA</td>
<td>4</td>
<td>3</td>
<td>NA</td>
<td>2</td>
</tr>
<tr>
<td>A8</td>
<td>Thickened, filtered &amp; cemented tailings</td>
<td>0</td>
<td>3</td>
<td>6.8</td>
<td>4</td>
<td>NA</td>
<td>4</td>
<td>3</td>
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</table>
### Table 8-8: BPT assessment matrix for tailings treatment for categories Fit for Purpose and Operational Adequacy

<table>
<thead>
<tr>
<th>Rank</th>
<th>Adequate</th>
<th>Poor</th>
<th>Acceptable</th>
<th>Good</th>
<th>Excellent</th>
<th>Unable to evaluate</th>
<th>Not applicable to the option</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>UTE</td>
</tr>
</tbody>
</table>

#### Fit for Purpose

<table>
<thead>
<tr>
<th>Option</th>
<th>Option Description</th>
<th>Show stopper 1 indicator</th>
<th>Show stopper 2 indicator</th>
<th>Overall rank</th>
<th>Proven technology</th>
<th>Technical performance</th>
<th>Robustness (closure only)</th>
<th>Environmental Protection</th>
<th>CAPEX</th>
<th>Occupational Health &amp; Safety</th>
<th>Operability</th>
<th>Inherent availability and reliability</th>
<th>Maintainability</th>
<th>OPEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Thickened (ITW/C base case)</td>
<td>0</td>
<td>0</td>
<td>32.6</td>
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<td>4</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>A2</td>
<td>Unthickened</td>
<td>4</td>
<td>0</td>
<td>-100</td>
<td>4</td>
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<td>4</td>
</tr>
<tr>
<td>A3</td>
<td>Unthickened - solids</td>
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<td>0</td>
<td>41.3</td>
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<td>3</td>
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<td>4</td>
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<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>A4</td>
<td>Unthickened - extended water treatment</td>
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<td>-6.6</td>
<td>5</td>
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<td>4</td>
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<td>Unthickened - onsite agglomeration and thickening</td>
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<td>0</td>
<td>10.9</td>
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<td>3</td>
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<tr>
<td>A6</td>
<td>Unthickened - neutralization and dewatering</td>
<td>0</td>
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<td>13.7</td>
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</tr>
<tr>
<td>A7</td>
<td>Thickened &amp; filtered tailings</td>
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<td>3</td>
<td>13.0</td>
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<td>3</td>
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<td>3</td>
<td>3</td>
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<td>2</td>
</tr>
<tr>
<td>A8</td>
<td>Thickened, filtered &amp; cemented tailings</td>
<td>0</td>
<td>3</td>
<td>6.8</td>
<td>4</td>
<td>UTE</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
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<td>2</td>
</tr>
</tbody>
</table>
Table 8-9: BPT assessment matrix for tailings treatment for categories Rehabilitation and Closure, and Constructability

<table>
<thead>
<tr>
<th>Rank</th>
<th>Adequate</th>
<th>Poor</th>
<th>Acceptable</th>
<th>Good</th>
<th>Excellent</th>
<th>Unable to evaluate</th>
<th>Not applicable to the option</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>UTE</td>
<td>NA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Option ID</th>
<th>Option Description</th>
<th>Show stopper 1 Indicator</th>
<th>Showstopper 2 Indicator</th>
<th>Overall rank</th>
<th>Rehabilitation (Closure only)</th>
<th>Constructability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Thicked (ITWC base case)</td>
<td>0</td>
<td>0</td>
<td>82.6</td>
<td>4</td>
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<td>Unthicked</td>
<td>4</td>
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<td>-100.0</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Unthicked - IRTC</td>
<td>0</td>
<td>0</td>
<td>43.3</td>
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<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Unthicked - extended water treatment</td>
<td>0</td>
<td>1</td>
<td>-6.3</td>
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<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Unthicked - online agglomeration and vicks</td>
<td>0</td>
<td>0</td>
<td>10.9</td>
<td>4</td>
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<td>6</td>
<td>Unthicked - neutralisation and vicks</td>
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<td>13.0</td>
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</tr>
<tr>
<td>8</td>
<td>Thicked - filtered &amp; cemented tailings</td>
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<td>6.8</td>
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<td>4</td>
</tr>
</tbody>
</table>
As indicated above, the base case for this assessment assumed that tailings would be unthickened, with three additional options being considered a) with wicks, b) with extended water treatment, and c) with inline agglomeration and wicks. These were subsequently assessed against the previous ITWC thickened tailings options.

The results of the BPT indicate that unthickened tailings with wicks (A3) has advantages over unthickened tailings and extended water treatment (A4) and unthickened tailings with inline agglomeration (A6). It was assessed that the use of wicks would be viewed more favourably by traditional owners under the Living Culture criterion compared to unthickened (A2). The unthickened tailings option (A2) was hard show stopped due to factors including: not all process water being removed during consolidation, subsidence and erosion of the landform, impacts on rehabilitation performance, impacts to water quality and the formation of visible salts in the landform surface, all of which could lead to an unwillingness for traditional owners to resume cultural practices on the site post closure.

Unthickened tailings with wicks (A3) has been demonstrated as proven technology through its application in Pit 1. Prefabricated vertical drains, or wicks, present a sound technical method of achieving increased consolidation and ensuring that the schedule requirements on rehabilitation on the RPA are met.

Inline agglomeration and wicks (A5) option fared less favourably across Fit for Purpose and Operational Adequacy categories, than options A1 and A3 predominantly based on less certainty around achieving consolidation targets and potential reliability issues related to inconsistent input densities. There was also a high uncertainty around the complexity of integration with existing dredging operations, high operational expenditure and complexities associated with construction of the plant on the pit access ramp.

Unthickened with extended water treatment (A4) was soft show stopped under category “Construction, Environmental and Cultural risks” because of the increased number of vehicles through Kakadu National Park, necessary to transport new infrastructure and the substantial increase in workforce required to construct a new water treatment plant. It emerged as the least favoured option, scoring “inadequate” to “poor” against the majority of categories under Fit for Purpose, Operational Adequacy, and Constructability. The low ranking against these criteria was strongly influenced by high sustaining capital and operating costs associated with the existing brine concentrator, long procurement lead times required to purchase a new plant or additional infrastructure to expand the existing plant, and the complex operational nature of the plant potentially leading to a high number of interruptions and downtime.

Strategies A6 through A8 all recorded soft showstoppers under Construction, Environmental and Cultural risks criterion, attributed to the effects of increased traffic volumes through Kakadu National Park associated with new infrastructure and increased construction workforce in Jabiru. These options also recorded soft showstoppers under Occupational Health and Safety, attributed to increased risks of vehicle incidents during tailings transfer to Pit 3. In addition to the above, concerns identified during the ITWC PFS around strategy A8 (thickened, filtered and cemented) still remain. These include; the extremely high operational costs as a result of high cement consumption, and uncertainty around the long term stability of Portland cement, which is susceptible to sulfate attack. Therefore significantly more development work would be
required before this would be considered a viable option when compared to strategies that were assessed.

8.4.10 Final Conclusions

The BPT assessment has considered viable thickened tailings options from the previous ITWC PFS and new, unthickened tailings treatments. Of the eight options assessed, one option was hard show stopped (unthickened A2) and 4 were soft show stopped.

Three options were considered viable; however inline agglomeration with wicks (A5) scored the lowest of the three with the assessment identifying some inherent issues around achieving consolidation targets, high operational costs and construction complexities, compared to the other two options (e.g. thickened and unthickened with wicks).

There was no material difference in the assessment scores for the thickened (A1) and unthickened with wicks (A3) options. However, ERA has extensive knowledge around strategy A3, based on the performance of the Pit 1 backfill strategy and subsequent tailings consolidation being achieved via this method. Further modelling indicates that tailings consolidation in Pit 3 can be achieved within the 2026 timeframe using this option.

Future BPT assessments are expected to be held as further decisions on technology arise, for example a BPT analysis will be conducted for alternative methods of treating contaminated soils.

The final closure strategy, and its implementation, is discussed in detail in Chapter 10.
8.5 References


APPENDIX 8.1: 2011-12 ITWC PFS BPT ASSESSMENT
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Executive Summary

From the first approvals for mining at the Ranger Uranium Mine, it has been a requirement that all operations are consistent with Best Practicable Technology (BPT). The manner in which BPT has been assessed has varied over time but usually Energy Resources of Australia (ERA) has provided a draft assessment of BPT with major proposals for amendment of the General Authorisation, often prepared towards the end of the assessment process, and this draft has formed the basis of a formal assessment by members of the Minesite Technical Committee (MTC) prior to making recommendations to the Minister for approval.

For the Integrated Tailings Water and Closure (ITWC) project at Ranger, ERA decided that BPT would be a principal driver of the project rather than a postscript to it. It was ERA’s intention that BPT would be considered from the outset by all members of the study team to ensure that proposals emerging from the study would be demonstrably consistent with the requirements of BPT.

To achieve this objective, ERA developed a more detailed assessment matrix than has been applied in the past. This matrix is one that can more easily be used by technical staff in assessing individual components of the project as well as in assessing overall BPT for the final closure proposal. The criteria used in the matrix were derived not only from the six broad criteria in the formal definition of BPT but also including the more specific requirements identified in the primary and secondary environmental protection objectives contained within the Ranger Environmental Requirements of the Commonwealth of Australia for the Ranger Uranium Mine issued following assessment of the Ranger Project under the Environment Protection (Impact of Proposals) Act 1974 and revised in 1999. Following an internal review process and feedback from members of the MTC, the criteria used in the BPT screening matrix were those listed in Table 1.

Table 1: BPT Options Screening Criteria

<table>
<thead>
<tr>
<th>BPT Criteria</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Owner Culture &amp; Heritage</td>
<td>Living culture, cultural heritage</td>
</tr>
<tr>
<td>Operational Environmental Protection</td>
<td>Community health and safety, socio-economic impact on local communities, ecosystems of Kakadu, and ecosystems of the Ranger Project Area</td>
</tr>
<tr>
<td>Fit for purpose</td>
<td>Proven technology, technical performance capability, robustness to rainfall variability and mill closure date, worldwide comparative environmental standard, and CAPEX</td>
</tr>
<tr>
<td>Operational Adequacy</td>
<td>Occupational health and safety, operability, inherent availability and reliability, maintainability and OPEX</td>
</tr>
<tr>
<td>Rehabilitation and Closure</td>
<td>Revegetation, erosion, radiation exposure, water quality, tailings containment, and schedule</td>
</tr>
<tr>
<td>Constructability</td>
<td>Construction occupational health &amp; safety, construction environmental and cultural risks, and construction complexity.</td>
</tr>
</tbody>
</table>

At the highest level of project definition, the principle variables that determine the characteristics of project options are:

• Mill closure date; the principal options considered were 2016 and 2020.

• Brine management method; the principal options considered were brine injection at depth or brine crystallisation and deposition.

• Tailings treatment; the principal options considered thickening of tailings and tailings filtration after thickening.

In all cases, tailings would be transferred from the existing Tailings Storage Facility (TSF) and deposited in Pit 3 and all tailings produced by the mill from 2015 onwards would be deposited in Pit 3 following treatment.

Thus, the four core options identified at the outset of the project, and noted in discussions with stakeholders, as potential strategies for assessment in the ITWC PFS were:

• Mill Close 2016/20, Backfill Pit 3, Brine Injection, Thickened Tailings Deposition.

• Mill Close 2016/20, Backfill Pit 3, Brine Crystallisation, Thickened Tailings Deposition.

• Mill Close 2016/20, Backfill Pit 3, Brine Injection, Filtered Tailings Deposition.

• Mill Close 2016/20, Backfill Pit 3, Brine Crystallisation, Filtered Tailings Deposition.

The primary objective, therefore, of the BPT assessment process in the ITWC project was to determine which of these strategy options constituted Best Practicable Technology for closure of the Ranger mine.

However, within each of these strategies there were a number of major competing options for individual components of the project. For example, the previous Order of Magnitude study had identified three methods for recovery of tailings from the TSF; these were excavation, hydraulic mining and dredging. And for each of these there could be sub-options; thus for tailings excavation, transfer to Pit 3 could be by road haulage, pumping or by a conveyor system. For this reason, the process adopted for the BPT assessment was to conduct three individual program assessments to determine BPT for individual components of the overall project prior to conducting the BPT assessment for the major strategic options.

Thus, three workshops were conducted to assess BPT for the following project components:

• Tailings reclamation, transfer, treatment and deposition;

• Salt treatment and disposal; and

• Final landform construction, revegetation and ecosystem reconstruction.

**Tailings Management**

Three options were considered for reclamation of tailings from the TSF; excavation, hydraulic mining and dredging.

The excavation option would require installation of additional brine concentrator capacity and a storage pond so that water could be removed from the TSF early after each wet season for storage and treatment and thus allow access to the tailings surface. Excavators would remove tailings onto low ground pressure haul trucks which would deposit tailings at a stockpile inside the TSF to allow them to drain. Stockpiled tailings would subsequently be excavated onto large haul trucks for transfer to Pit 3.
The hydraulic mining option would also require early access to the tailings surface after each wet season so that additional brine concentrator capacity and a storage pond would again be required. Remote controlled high pressure water monitors would be used to breakdown and slurry the tailings which would then flow under gravity to sumps excavated in the TSF. The resultant slurry would then be pumped to thickener prior to disposal in Pit 3.

Dredging options were reviewed by ERA in a PFS-level study in 2009 and the use of a bucket wheel cutter - spud dredge was recommended. It would be anchored using steel cables shackled to heavy duty poly rope that stretches from the dredge to two D7 dozers on the TSF embankment crest. The dredge would progressively reclaim sub-aqueous tailings and would produce a 28% by weight solids stream. This slurry would then be dewatered to a 60% by weight solids stream using a thickener located on a raised pad constructed beside the TSF embankment. The thickened slurry would then be pumped to Pit 3.

The primary additional treatment considered in the assessment was filtration whose primary purpose would be to ensure prompt consolidation of tailings in Pit 3 and thus effectively eliminate tailings settlement after deposition. Filtration might also reduce dispersion of solutes in groundwater to some extent through a reduction in tailings permeability but a much more effective method of reducing groundwater dispersion of solutes would be cementation.

For tailings filtration, reclaimed tailings from the TSF, thickened and then fed into a pressure filtration system and the filter cake produced would be hauled or conveyed to Pit 3. The filtrate would be returned to the TSF. Tailings from the mill would be cycloned. A pressure filtration system would be used for the fine fraction and a vacuum filtration system would be used for the coarse fraction.

The water content of tailings from the TSF or the mill is high and the solids concentration would need to be raised by both thickening and filtration before cementation in an appropriate plant. Otherwise cement consumption and the associated costs would be extraordinarily high and drying times would be long. Tailings from either source would be split with one fraction passing through a thickener and the other through a filtration plant and a hopper prior to combining both outputs in a mixer with a tailored mixture of cement and water. The mixer output would be held in a tank for conditioning prior to being pumped to Pit 3.

Deposition of thickened tailings in Pit 3 could use either sub-aerial or sub-aqueous techniques. For sub-aerial deposition, the tailings slurry would be discharged from single or multiple points around the pit crest or benches and the tailings would form a sloping beach. For sub-aqueous deposition, the slurry could be discharged at the water surface either from the pit perimeter or via a floating pipeline. Alternatively, the slurry could be delivered by pipeline to the underwater tailings surface. A third alternative would be to use a tremie system to inject the slurry under the surface of previously injected tailings.

If tailings filtration is adopted, the options for pit deposition include dry-stacking or co-disposal with waste rock. For dry-stacking, dry tailings in the form of filter cake would be hauled by truck or delivered by conveyor to the pit and hauled downhill to a dump point on an appropriate bench. In co-disposal, the same procedure would be adopted but waste rock would be dumped in the pit at the same time.

Thus, the principal options considered in the tailings management workshop were those listed in Table 2.
Table 2: Options assessed in the tailings management workshop

<table>
<thead>
<tr>
<th>Process</th>
<th>Options assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reclamation and transfer</td>
<td>Excavation – excavate, dewater and truck; excavate, dewater &amp; conveyor, excavate, slurry &amp; pump</td>
</tr>
<tr>
<td></td>
<td>Hydraulic Mining – hydraulic mine and pump, hydraulic mine, thickener, and pump</td>
</tr>
<tr>
<td></td>
<td>Dredging – Dredge and pump, dredge thicken and pump, dredge, thicken filter and truck, dredge thicken filter and conveyor</td>
</tr>
<tr>
<td>Treatment (in addition to thickening)</td>
<td>Filtration</td>
</tr>
<tr>
<td></td>
<td>Cementation</td>
</tr>
<tr>
<td>Deposition</td>
<td>Thickened sub-aerial</td>
</tr>
<tr>
<td></td>
<td>Thickened sub-aqueous</td>
</tr>
<tr>
<td></td>
<td>Filtered dry stacking</td>
</tr>
<tr>
<td></td>
<td>Filtered co-disposal</td>
</tr>
</tbody>
</table>

Of the reclamation and transfer options, excavation rated poorly compared with hydraulic mining and dredging. The principal deficiencies identified were the sensitivity of excavation techniques to extreme rainfall events, environmental protection and OHS issues arising from dust from the disturbed tailings, the considerable operational effort that would be required, and the drainage requirements required for successful implementation of the process. Hence excavation was rejected as a method for reclamation of tailings from the TSF.

Hydraulic mining and dredging emerged from the workshop with approximately equal BPT assessments. An overall assessment of the relative significance of the various advantages and disadvantages of the two options led to the conclusion that the disadvantages of the dredging option (operability, maintainability, radiation protection) are much more amenable to management than those associated with hydraulic mining (sensitivity to extreme rainfall, environmental protection, high capital costs). This is particularly the case for the issue of sensitivity to extreme rainfall events where management options are extremely limited and the occurrence of such events could have a major impact on the rehabilitation schedule. For this reason, dredging was considered to be the preferred option.

Cementation did not emerge as a viable treatment option. Further trials using the currently proposed process would be required, capital costs would be high because of the need to include filtration as a preliminary step and operational costs would be extremely high as a result of the high cement consumption implicit in the process.

The principal technical advantage of filtration is that it reduces the time required for tailings consolidation. It may have some advantages for long-term dispersal of contaminants in groundwater but this had not yet been demonstrated and it was considered that the advantage would probably be small. On the other hand, it is a very expensive option to construct, install and operate and maintenance requirements would be high. The overall assessment of filtration at the tailings workshop was that the option should be retained until whole-of-project assessment but that it appeared to be a very expensive option with limited advantages.

The overall assessment of the two options for deposition of thickened tailings was that either option would be acceptable but that sub-aqueous deposition was preferred principally because it was rated more highly under the operability and operating costs.
criteria and it was assessed that Traditional Owners would have a distinct visual preference for tailings covered by water rather than an exposed tailings surface.

For the deposition of filtered tailings, the higher maximum elevation of tailings in Pit 3 resulting from the adoption of co-disposal of filter cake and waste rock led to a preference for the use of dry stacking under the Living Culture criterion. There were, however, concerns expressed about the degree to which either technique had a proven track record. Dry stacking has been used successfully elsewhere but not in a mine pit. Similarly, co-disposal has been used in the coal industry with varying levels of success. Of greater concern, however, is that both techniques would be sensitive to wet conditions.

The principal conclusions arising from the BPT workshop on tailings management were:

- Dredging is the preferred tailings reclamation technology;
- Cementation is not currently considered viable as a treatment method;
- Tailings filtration should be retained as a potential treatment method to be considered in the overall strategic workshops but it is a very expensive option that produces little benefit; and
- Sub-aqueous deposition is the preferred option for thickened tailings.

**Salt Treatment and Disposal**

During operations at the Ranger mine, a large inventory of process water has accumulated. This water has high concentrations of salts, metals and radionuclides and is unsuitable for discharge to the surrounding environment unless it has been appropriately treated. Following a review of ERA’s process water strategy in 2010 ERA decided to use a brine concentrator as the principal method of treating process water prior to discharge.

In the early stages of process water treatment using the brine concentrator, the brine stream will be returned to the TSF, a procedure that will result in a gradual build-up of the concentration of dissolved solids in the process water stream. This is clearly not a sustainable practice and ERA will need to introduce a long-term program for the management and disposal of salts in the process water at Ranger. A number of options for such a program have been identified and a BPT analysis of these options was carried out at a workshop as part of the ITWC project.

The need to dispose of saline water is widespread in a number of industries and, as a result, 25 methods were identified as potential salt management options and were considered at the workshop. Of these, options that included disposal of highly saline water in the rivers, aquifers and sewers of the region, pumping to the ocean, or irrigation on the land application areas at Ranger were all rejected outright as practices that are clearly inappropriate for the region and would be considered unacceptable by ERA and by its stakeholders.

Thirteen of the remaining options were considered by the workshop team but, in each case, one or more fatal flaws were identified. The remaining seven options were assessed in detail in the workshop.

The options for salt management that were assessed in detail at the BPT workshop fall into the following three categories in terms of treatment of the brine stream from the Brine Concentrator:

- Brine Injection; no treatment, disposal by direct injection into a suitable repository,
- Distillation; reduce the total brine volume using additional brine concentrator stages. The resultant high concentration brine stream is then injected into a suitable repository, and

- Crystallisation; dry the brine using a thermal crystallisation plant, disposal by placement in a suitable repository.

The infrastructure required for the Brine Injection options would be relatively simple. To prevent boiling in the pumping and storage infrastructure, the temperature of the brine emerging from the concentrator would be reduced using a heat exchanger. The brine would then be pumped to the directionally drilled injection system. High pressure pumps would need to be available if the back pressure from the repository increases.

Two options for a suitable repository were considered. The first was the lowest region of Pit 3 which would have been backfilled with waste rock prior to the commencement of tailings disposal in the pit. In addition an underdrain would be placed above the waste rock underfill to enable pumping of expressed water to the TSF. Additional infrastructure required would include a ring main and injection wells around the perimeter of Pit 3.

The second repository considered in the case of direct brine injection was a custom excavated set of silos deep underground and accessed from the Ranger 3-Deeps decline. The conceptual design included six silos developed in the granite gneiss basement rock which is very competent, stable and impervious. Such a choice would almost certainly ensure that there would be no impact on the environment arising from dispersal of solutes in groundwater even in the very long-term; solute transport modelling would be carried out to confirm this. Injection wells would be drilled from the location of the brine concentrator into the silos. A ventilation rise would also be installed.

The third option considered for direct injection of brine again used the proposed Pit 3 underfill but was designed to address a potential problem that could arise in that option. The concern was that chemical reactions could occur when the brine interacts with the waste rock of the underfill, particularly the fines, resulting in reduced porosity and eventually reducing the void volume available for brine storage. A possible solution would be to screen all waste rock before placement in the pit to remove the fines and hence alleviate the problem.

The infrastructure required for salt crystallisation includes a thermal crystallisation plant, a large salt bagging facility to cope with the high throughput of salt and a truck transport system. The scope of these facilities should not be underestimated; nor should the associated OHS issues. A very provisional estimate of the capital cost of the crystallisation plant exceeded $100M. It would also be a very high energy consumer. The radiation hazards in the salt bagging facility would be much greater than those in the current product packing area at Ranger partly because gamma exposure would be a significant issue as well as dust inhalation and partly because the solubility of the some of the radioactive constituents (for example, actinium) would be much higher. In addition, the salt throughput would be orders of magnitude greater than that of product in the product packing area.

The two options for the salt repository were, as considered for brine injection, Pit 3 and underground silos. However, in the case of Pit 3 as a repository, the bags of salt would need to be placed in the pit with the tailings slurry or filter cake as the operation proceeds through the final milling stages and the transfer of tailings from the TSF. This would mean that dried salt in bags would be collocated with tailings up to the final height of tailings deposition. Crystallised salt produced after capping of the Pit would need to be stored in the Ranger 3-Deeps decline.
Transfer of crystallised salt to underground silos would need to be by conveyor or trucks but, in either case, placement would be required. This would give rise to a number of OHS issues.

In a manner similar to the crystallisation option, adoption of treatment of brine in a distillation plant would require significant investment in infrastructure in the form of an additional brine concentrator system and a distillation plant. The repository options would be the same as for brine injection, Pit 3 underfill and silos excavated for the purpose in the granite gneiss basement rock accessed from the Ranger 3-Deeps decline and the injection methods would be similar. However, the storage volumes required would be less since the method increases the concentration of salts in the brine stream.

In summary, the options that were assessed in detail at the Salt Management BPT workshop were those listed in Table 3:

**Table 3: Options assessed in the salt treatment and disposal workshop**

<table>
<thead>
<tr>
<th>Salt treatment process</th>
<th>Disposal options assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brine Injection</td>
<td>Pit 3 underfill injection</td>
</tr>
<tr>
<td></td>
<td>Underground silos injection</td>
</tr>
<tr>
<td></td>
<td>Pit 3 underfill injection with rock screening of underfill</td>
</tr>
<tr>
<td>Brine Crystallisation</td>
<td>Co-placement of dry salt with tailings in Pit 3</td>
</tr>
<tr>
<td></td>
<td>Placement of dry salt in underground silos</td>
</tr>
<tr>
<td>Brine Thermal Distillation</td>
<td>Pit 3 underfill injection</td>
</tr>
<tr>
<td></td>
<td>Underground silos injection</td>
</tr>
</tbody>
</table>

Under the cultural criteria, it was assessed that there were no heritage issues arising for any of the options because all activities would take place within the currently disturbed areas. From the living culture perspective, those options that involve injection to the Pit 3 underfill were rated highly because the material would be being returned to the pit from which it had been taken in the mining phase of operations. Nevertheless, the Pit 3 option for the dried salt product from crystallisation was assessed as being a poor option because the much higher elevation for placement of the material in the pit would receive a negative community reaction.

All options performed well against the criteria under the Protection of People and Environment category since all identified risks to health of the community or the environment were considered to be low and manageable.

All of the brine injection options were rated highly in the Fit for Purpose category of criteria. However, the pit placement option for crystallisation was rated poorly under the proven technology criterion because there is no known case in uranium mining anywhere in the world where this procedure has been adopted. Technical performance was also rated as poor for three of the four crystallisation and distillation options. From the capital costs perspective, the construction of a crystallisation plant is an expensive option and for the corresponding silo option costs would be very high because of the compounding costs associated with mining the silos. Thus, the overall assessment of the crystallisation and distillation options against the Fit for Purpose criteria was poor.
A similar picture emerged in the consideration of options against the criteria in the Operational Adequacy category. The crystallisation and distillation options were only rated as acceptable in three of the twenty assessments in this category; all other rankings were poor or unacceptable. Reliability and maintainability concerns were particularly high for the distillation options arising from the use of two brine concentrators in series to achieve much higher brine stream concentrations. There were also significant OH&S concerns associated with the salt bagging facility where operations similar in nature to the current product packing area at Ranger would be carried out on a much larger scale. For the brine injection options, some manageable OH&S issues were identified but, otherwise, these options performed reasonably well against the criteria in the Operational Adequacy category.

Most of the salt management options were assessed as not being very relevant to the standard of rehabilitation to be achieved at the site in the revegetation, radiation, erosion and water quality criteria. Among the exceptions were the assessments that (a) in a relative sense, storing dried salt in silos would be much less of a radiation risk in the long term than placement near the surface in the pit, and (b) modelling might be necessary to provide assurance that the deposition of fines from the rock screening plant near the surface of the pit would not risk a deterioration in surface water quality.

The risks of long-term dispersion of solutes from the salt repository were assessed under the Tailings criterion in the Rehabilitation and Closure category because the salts arise from the tailings through treatment of process water. The results of solute transport modelling were presented to the workshop for the case of brine injection to the underfill and enabled the conclusion to be drawn that solutes from the underfill repository would not be expected to reach surface waters in less than ten thousand years. Similar conclusions were reached for the injection of a higher concentration brine stream into the Pit 3 underfill for the distillation option. Similarly, the assessment against this criterion for injection into silos was good. The only option for which was assessed poorly under this criterion was thermal crystallisation with pit placement because the location of dried salt in bags within the tailings mass would pose much greater risks than the other alternatives considered.

Meeting the requirements on rehabilitation schedule specified in the S41 Authority is expected to be straightforward for brine injection in the Pit 3 underfill. Some scheduling risks were identified for some other options but it was assessed that these could be managed.

For the constructability criteria, the best performing option was brine injection in the underfill for which infrastructure requirements are simple and safety and environmental issues are, therefore, minimised. The underground silo options all had some OHS concerns and complexity issues but in most cases options were assessed as being acceptable against the Constructability criteria.

The overall BPT assessment was that brine injection to the underfill without rock screening was the highest ranked alternative. Brine injection to underground silos scored well but concerns were identified on OHS issues during both the construction and the operational phases of this option. Major problems were identified for the Crystallisation and Distillation options and it is considered unlikely that either would be viable. The only uncertainty remaining for the preferred option related to the potential for reactivity between the brine and the waste rock of the underfill and possible limitation on the volume available for the storage of brine. It was concluded that this issue required further assessment prior to a final decision on the salt management option to be implemented.
Final landform construction, revegetation and ecosystem reconstruction

The assessment process adopted in the BPT workshop on landform construction, revegetation and ecosystem reconstruction was different to that adopted in the previous two workshops. A different approach was considered necessary for several reasons:

- The activities of landform formation, revegetation and ecosystem reconstruction will not start for many years and BPT for these programs will not be fully assessed until a time closer to implementation;
- These programs, particularly those on landform reconstruction and revegetation, have gone through significant options analysis and refinement over many years and there are no longer major competing alternatives for their implementation – ongoing refinement of these programs within a BPT context is a better description of what will occur in future; and
- There will be no major differences in the implementation of these programs within the major strategy alternatives identified for the overall ITWC project.

For these reasons, the approach adopted in the workshop was twofold:

- The current plans for each of these programs were assessed for the Schedule criterion under Rehabilitation to determine the nature of any risks to completion of rehabilitation by 2026 as required under the S41 Authority.
- All other criteria were assessed for each of the current programs to identify, where possible, options for improvement and to record any uncertainties that remain to be assessed.

The principal scheduling issues identified from consideration of the landform construction, revegetation and ecosystem reconstruction programs were:

- The timetable for completion of the landform construction program will be determined by process water expression at the surface of Pit 3; current estimates indicate that this is a major risk for completion of rehabilitation of the Ranger site by 2026.
- Alternatives to the current proposals need to be considered to enhance tailings settlement; these should include horizontal wicks, multistage wicks, and electrostatic flocculation. Electrostatic flocculation is the process of passing strong currents through a colloidal fluid. This has the effect of causing the suspended particles to come together and settle more rapidly.
- For all of the strategies currently under consideration, water treatment and decant systems will probably be needed after 2026 to manage process water expression from Pit 3.
- Sediment control traps may also need to operate for many years after 2026.
- Under the current alternative strategies, the most optimistic schedule for the revegetation program restricts commencement of planting on the land surface above Pit 3 (an area of about 200 ha) until October 2025. The revegetation program requires infill planting 1 year after the initial planting program and understory planting required after a period of 2 – 3 years. Thus, under the most optimistic schedule, revegetation could not be completed by January 2026.
It should be noted that most of these concerns were diminished during the project as further information became available. However, a specific issue that arose from the workshop was the identification of the potential for ecological impact arising from the drainage of rainwater through the waste rock that will form the final above-surface landform.

Such concerns arise from the current expectation that the closure criterion that will be set for magnesium in Magela Creek could be based on the current provisional trigger value that has been derived from ecotoxicological testing of aquatic animals when exposed to waters with enhanced concentrations of magnesium. It is known that the presence of calcium, even at fairly low concentrations, ameliorates magnesium-induced toxicity to some extent so this effect needs to be taken into account.

The solute transport modelling program had yet to be completed at the time of landform construction, revegetation and ecosystem re-construction BPT workshop. Nevertheless, results obtained in preliminary modelling were presented to the workshop and these results demonstrated that concentrations of magnesium in Magela Creek may well exceed the provisional trigger value unless management actions are implemented. While water treatment would be an option for some period after completion of the final landform, such treatment could not be a permanent or long-term activity after rehabilitation.

For this reason, the need was identified for a thorough review of the basis of any recommendations on the closure criterion for magnesium in the waters of Magela Creek to ensure that assessment of any potential impact would be realistic.

**Overall Strategy for the ITWC Project – Preliminary Assessment**

Following the BPT workshops on individual components of the ITWC project, the overall project strategies were refined on the basis of the workshop outcomes and were then assessed in two stages. Even although it was recognised that the information dataset was incomplete in some areas (for example, the solute transport modelling program was only partially complete), the preliminary strategic assessment was conducted soon after completion of the individual component assessments. The intention was to eliminate strategic options which clearly did not constitute BPT and also to identify more clearly information gaps in the remaining options that needed to be addressed prior to the final BPT assessment of the strategic options.

The options assessed in the preliminary BPT analysis of alternative strategies are listed in Table 4. The first four strategies are those identified at the outset of the project with a mill closure date of 2016. The fifth strategy with water treatment was introduced following identification of the possible water quality issue during the workshop on final landform formation, revegetation and ecosystem reconstruction. The sixth strategy was introduced to test the advantages and disadvantages of a later mill closure date.

The overall BPT scores recorded in the assessment of the preliminary strategic options confirmed the conclusions drawn in the salt management workshop that the options that include crystallisation of the brine stream from the water treatment plant are not viable strategic options for the ITWC project.

These options performed poorly in a number of criteria including living culture, technical performance, the standard of environmental protection achieved in an international comparison framework, occupational health and safety, maintainability and costs. For the combined crystallisation and filtration option, both operating costs and capital costs were assessed as being unacceptably high. Following the workshop, a re-examination of the radiological safety issues that would arise in a brine crystallisation plant concluded that the significance of these issues had
probably been underestimated and that it was unlikely that such a plant would receive regulatory approval. Comparison of the overall BPT scores of the crystallisation options with those using brine injection clearly demonstrated that crystallisation of the brine stream is not a process that could be included in a best practice strategy for rehabilitation and closure of the Ranger Mine.

**Table 4: Options assessed in the preliminary assessment of alternative strategies**

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Brief Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1C</td>
<td>Brine injection, Thickened tailings, Milling until 2016</td>
</tr>
<tr>
<td>2C</td>
<td>Brine injection, Thickened and filtered tailings, Milling until 2016</td>
</tr>
<tr>
<td>3C</td>
<td>Brine crystallisation, Thickened tailings, Milling until 2016</td>
</tr>
<tr>
<td>4C</td>
<td>Brine crystallisation, Thickened and filtered tailings, Milling until 2016</td>
</tr>
<tr>
<td>5C</td>
<td>Strategy 1C with water treatment 2026 - 2030</td>
</tr>
<tr>
<td>1B</td>
<td>Strategy 1C with milling until 2020</td>
</tr>
</tbody>
</table>

The remaining strategy that includes the treatment of tailings by filtration (Strategy 2C with filtration and brine injection) achieved an overall BPT rating that was acceptable. However, it was ranked as inferior to the thickened tailings base case, Strategy 1C, in the criteria on capital expenditure, maintainability and operating costs and its overall BPT ranking was significantly poorer than that for Strategy 1C. The conclusion drawn in the tailings management workshop that filtration was a very expensive option with limited advantages was confirmed and it was decided that filtration of tailings should not be considered further in the development of the best practice strategy for rehabilitation and closure of the Ranger Mine.

Summarising the issues related to salt management, an extensive analysis has been carried out of options for disposal of the salts in the brine stream. This analysis clearly demonstrated that BPT for disposal of the salts is to inject the concentrated brine into the underfill at the base of Pit 3 and to cover this with the tailings from the TSF and the mill. This procedure will ensure that the salts, metals and radionuclides contained in the brine stream will be isolated from the surface water environment for about ten thousand years. The only issue that has been identified that could threaten the viability of the brine injection technology is the potential for chemical reactivity between the brine and the waste rock of the underfill. This issue would need review prior to the final BPT workshop.

From the tailings treatment perspective, the BPT analysis has shown that cementation is not a viable option. The overall assessment was that if, by the time the final BPT assessment workshop is carried out, long-term dispersal of contaminants from thickened tailings is demonstrated to be a serious issue, consideration of alternative neutralisation methods would be required rather than implementation of the full cementation process. The BPT analysis has also shown that tailings filtration would be inferior to the thickened tailings base case in the criteria on capital expenditure, maintainability and operating costs. The cost differential would not be small; for example, the capital cost would be expected to be
about $200M. It was assessed that the costs of filtration could not be justified on the basis of the limited environmental gains to be made.

Areas identified at the workshop for which additional information would be needed before the conduct of the final workshop included:

- Expected workforce numbers in later years to enable social impact assessment;
- Radiation dose assessment for people accessing the rehabilitated landform;
- Modelling of erosion of the rehabilitated landform;
- The effect of solute transport on off-site surface water quality;
- Long-term dispersion of solutes in groundwater;
- Scheduling details for some aspects of individual strategies; and
- Ongoing assessment and testing of brine reactivity with waste rock of the underfill.

The absence of the above information had no impact on the decision to exclude filtration and crystallisation options from further consideration because most of the above issues are common to all options and the rankings allocated to each option against these criteria would be the same.

**Overall Strategy for the ITWC Project – Final Assessment and Conclusions**

In the five month period between the preliminary BPT assessment of the strategic options and the final workshop, a number of projects were carried out to complete the modelling required in radiation exposure for those accessing the rehabilitated landform, erosion of the landform, and the effects of solute dispersion on both surface waters and groundwater. In addition, more precise specification of the flowsheets and schedules of the remaining strategic options was carried out to ensure that all criteria could be fully assessed in the final BPT assessment. (Recent brine reactivity testwork conducted with Ranger waste rock samples and synthetic brine has not identified any fatal flaws for the brine injection proposal. Additional work on cooling, compressibility and hydraulic conductivity has confirmed sufficient storage exists within the Pit 3 underfill to contain the forecast life of mine brine production (2GL). However, the total brine storage capacity within the underfill is proving to be less than the theoretical value (3GL) determined during the PFS.)

The strategies considered in the final workshop are those listed in Table 5. There was a significant change in the description of strategy 5C between the version described for the preliminary strategic workshop and the final workshop. The primary reason for the inclusion of a second brine concentrator in the flowsheet for strategy 1C was that it was considered impossible to meet the closure completion deadline of 2026 without additional treatment capacity for process water. However, it was recognised that if an extension beyond the 2026 deadline could be negotiated the introduction of a second brine concentrator could be avoided at a very significant savings to the Capital budget of over $200M. Hence, for the final strategic BPT workshop, the scope of strategy 5C was revised to exclude the purchase and implementation of a second brine concentrator.
Strategy 5B was very similar to strategy 1B except that it included an extension of water treatment until 2033, only one brine concentrator would be used for process water treatment, and there would be a significant reduction in the volumes required for water storage.

Table 5: Options assessed in the final assessment of alternative strategies

<table>
<thead>
<tr>
<th>Strategy</th>
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</tr>
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<tbody>
<tr>
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<td>Strategy 1C with water treatment 2026 – 2030</td>
</tr>
<tr>
<td>1B</td>
<td>Strategy 1C with milling until 2020</td>
</tr>
<tr>
<td>5B</td>
<td>Strategy 1B with water treatment 2026 – 2033</td>
</tr>
</tbody>
</table>

The difference between the options assessed in the final BPT workshop was much smaller than those in previous workshops and the number of criteria where differences were recorded is few. All strategies achieved an overall BPT assessment in the range acceptable to good. Strategy 1B achieved a higher overall rating than the other strategies but the difference was small.

The criteria where differences were recorded were:

- Socio-economic impact on Jabiru and the region: the two extended options provide additional time for community partnerships to run and continued retention of services and strategy 5B also provides additional royalty income.
- Technical performance: both 2020 mill closure options scored better because the extended milling period enables the processing of lower grade ores that were previously assessed as not being commercially viable. The precise value of this advantage will be evident in the overall financial analysis.
- Capital Expenditure: the two extended options scored better primarily because only one Brine Concentrator is required for these options. Again, comparison of overall financial estimates will enable a better assessment of the significance of this advantage.
- Maintainability: the 2020 milling option with extended water treatment results in the use of the Brine Concentrator for nine years beyond its planned lifetime resulting in higher maintenance costs.
- Operating Costs: the operating costs of the extended 2020 option would also be higher because replacement of major parts would almost certainly be required.
- Schedule: Both extended options scored lower than the primary options under the schedule criterion.

A significant outcome is that, on the basis of this BPT assessment, the final choice of option will not alter the cultural or environmental significance since all options performed equally against the cultural and environmental criteria; all rankings against these criteria were either acceptable or good. Dispersal of solutes was, however, an issue of concern for all strategies and this issue is addressed below. The significance of four of the six issues listed above on which there were differences in the
assessment of the options will be effectively incorporated in the detailed financial analysis of the options. The remaining two issues, regional socio-economic impact and the ability of options to meet expectations on the timing of closure, will undoubtedly be issues on which the Traditional Owners will provide significant input.

At the final BPT workshop, a presentation was given on the three dimensional modelling of groundwater in the vicinity of Pit 3, its integration into a surface water flow model, and the dispersion of conservative solutes from both tailings and waste rock to Magela Creek. A key hydrogeological feature of the Pit 3 region is the existence of a sand lens between Pit 3 and Magela Creek at the north east corner of the Pit. Recent drilling has confirmed that this lens extends to a depth of about 30m and modelling has now shown that this sand lens would provide the main pathway for the transport of solutes originating in both the waste grade-2 rock in the Pit 3 cover and in the tailings.

Potential mitigation measures to address these solute transport issues were identified at the workshop. These included a cut-off wall within the sand zone, an impermeable barrier above the grade-2 material in the Pit, the introduction of reactive material in the sand zone and the rock cap to attenuate radionuclides, the removal of the proposed replacement Djalkmarra Billabong from the landform design and the implementation of engineering measures to ensure that any drainage of the subsurface region above Pit 3 occurs during the wet season rather than during the recessional period. While it was recognised that the full assessment of these measures will take some time to complete, it was concluded that some of the measures considered (for example, bentonite slurry walls) are well established and proven techniques and that there is a reasonable probability that a solution can be implemented at reasonable cost. These issues, as well as the modelling of the transport of solutes from the tailings mass to the surface environment through the deep aquifer, are being addressed in the Tailings and Brine Management Feasibility Study now underway.

The overall conclusion of the BPT assessments carried out for the ITWC project is that the principal stages in the rehabilitation and closure program at Ranger should be:

- Establishment of a waste rock “underfill” at the base of Pit 3 with sufficient void space to accommodate all of the brine produced from treatment of process water at Ranger using a brine concentrator based water treatment system; waste rock would not be screened prior to placement in Pit 3.
- Following assessment of the potential mitigation measures for solute dispersion, mitigation measures that need to be implemented prior to tailings placement in Pit 3 (for example a cut-off wall within the sand zone) will be carried out.
- Prior to the commencement of tailings deposition in Pit 3, an underdrain will be established above the underfill to enable the pumping of expressed process water to the TSF.
- Tailings will be excavated from the Ranger TSF by dredging, will be dewatered in a thickener, and will be deposited in Pit 3 using sub-aqueous disposal methods.
- Tailings from the Ranger Mill will also be deposited in Pit 3 by sub-aqueous deposition until the date of mill closure. This will probably be in 2020 following the processing of lower grade ore in stockpiles at Ranger.
• To prevent boiling in the pumping and storage infrastructure, the temperature of the brine emerging from the concentrator will be reduced using a heat exchanger. The brine will then be pumped to a directionally drilled injection system around the periphery of Pit 3. Injection points near the centre of the underfill via the underdrain will be installed if necessary. High pressure pumps would be available if the back pressure from the repository increases. Until the final brine management system is commissioned, the brine stream from the water treatment system will be directed to the TSF.

• On completion of all tailings disposal in Pit 3, the tailings will be capped using grade-2 material covered by grade-1 material to form the final cap on Pit 3. These works will include the installation of those mitigation measures (for example, impermeable layers over the tailings or grade-2 material) assessed as being essential to protect surface waters and groundwater from adverse impact arising from solute transport.

• Completion of the final landform, revegetation and ecosystem reconstruction, and ongoing water treatment as necessary.
1. Introduction

From the first approvals for mining at Ranger it has been a requirement that all operations are consistent with Best Practicable Technology (BPT). The manner in which BPT has been assessed has varied over time but usually Energy Resources of Australia (ERA) has provided a draft assessment of BPT with major proposals for amendment of the General Authorisation and this draft has formed the basis of a formal assessment by members of the Minesite Technical Committee (MTC) prior to making recommendations to the Minister for approval of the amendment.

For the Integrated Tailings Water and Closure (ITWC) project at Ranger, ERA decided to ensure that the issue of BPT was considered from the outset by all members of the study team and also to brief members of the MTC at various stages throughout the study on progress on the assessment of BPT. It was ERA’s intention that BPT would be a principal driver of the project and that adoption of this procedure would ensure that proposals emerging from the study would be demonstrably consistent with the requirements of BPT. It was also expected that this approach would result in minimisation of delays in obtaining final regulatory approval.

In considering the best procedure for ensuring that the BPT concept became a driver for the project as well as an assessment tool at its completion, ERA developed a more detailed assessment matrix than has been applied in the past. This detailed matrix is considered to be one that can more easily be used by technical staff in assessing individual components of the project as well as in assessing overall BPT for the final closure proposal.

This report provides a detailed description of the process that has been followed in assessing BPT for the ITWC project and summarises the results obtained.

2. Best Practicable Technology

The concept of Best Practicable Technology in uranium mining in Australia was first developed in the second report of the Ranger Uranium Environmental Inquiry in 1977 (Fox et al. 1977). It was further developed in the initial approvals process for the Ranger mine and the definition that was eventually adopted was that specified in the Environmental Requirements of the Commonwealth of Australia for the Ranger Uranium Mine following assessment under the Environment Protection (Impact of Proposals) Act 1974.

The definition of BPT remained unchanged until the Commonwealth Government decided, following the Environmental Impact Statement (EIS) and Public Environment Report (PER) processes for the proposed Jabiluka development and the subsequent inquiry carried out by the World Heritage Committee in the late 1990s, that a revision was required. This revision was formally required of ERA for the Ranger project in 1999 within the context of a revised set of Environmental Requirements (ERs) for the Ranger Project and it was anticipated that a similar revision would apply to any subsequent approval process for the Jabiluka project.

The ERs now specify a number of Primary Environmental Objectives, a set of Secondary Environmental Objectives and the definition of BPT.
2.1 Primary environmental objectives

The primary environmental protection objectives defined in the ERs are as follows:

- Maintain the attributes for which Kakadu National Park was inscribed on the World Heritage list;
- Maintain the ecosystem health of the wetlands listed under the Ramsar Convention on Wetlands (i.e. the wetlands within Stages I and II of Kakadu National Park);
- Protect the health of Aboriginals and other members of the regional community; and
- Maintain the natural biological diversity of aquatic and terrestrial ecosystems of the Alligator Rivers Region, including ecological processes.

For rehabilitation, the overall rehabilitation goal is stated in the ERs as follows:

- The company must rehabilitate the Ranger Project Area to establish an environment similar to the adjacent areas of Kakadu National Park such that, in the opinion of the Minister with the advice of the Supervising Scientist, the rehabilitated area could be incorporated into the Kakadu National Park.

The ERs go on to define specific major objectives for rehabilitation to achieve this goal as follows:

- Revegetation of the disturbed sites of the Ranger Project Area using local native plant species similar in density and abundance to those existing in adjacent areas of Kakadu National Park, to form an ecosystem the long term viability of which would not require a maintenance regime significantly different from that appropriate to adjacent areas of the park;
- Stable radiological conditions on areas impacted by mining so that the health risk to members of the public, including traditional owners, is as low as reasonably achievable; members of the public do not receive a radiation dose which exceeds applicable limits recommended by the most recently published and relevant Australian standards, codes of practice, and guidelines; and there is a minimum of restrictions on the use of the area;
- Erosion characteristics which, as far as can reasonably be achieved, do not vary significantly from those of comparable landforms in surrounding undisturbed areas.

In addition, there are specific requirements on tailings. All tailings at Ranger must be returned to the mined out pits and final disposal of tailings must be undertaken in such a way as to ensure that:

- The tailings are physically isolated from the environment for at least 10,000 years;
- Any contaminants arising from the tailings will not result in any detrimental environmental impacts for at least 10,000 years; and
- Radiation doses to members of the public will comply with relevant Australian law and be less than limits recommended by the most recently published and relevant Australian standards, codes of practice, and guidelines effective at the time of the final tailings disposal.

\(^2\) On 12 May 2010, the Kakadu Ramsar sites were merged into one site and expanded to incorporate the entire area of Kakadu National Park.
2.2 Best Practicable Technology

Best practicable technology, as defined in the ERs, is that technology from time to time relevant to the Ranger Project which produces the maximum environmental benefit that can reasonably be achieved having regard to all relevant matters including:

a. the environmental standards achieved by uranium operations elsewhere in the world with respect to
   i. level of effluent control achieved; and
   ii. the extent to which environmental degradation is prevented;

b. the level of environmental protection to be achieved by the application or adoption of the technology and the resources required to apply or adopt the technology so as to achieve the maximum environmental benefit from the available resources

c. evidence of detriment, or of lack of detriment, to the environment;

d. the physical location of the Ranger Project;

e. the age of equipment and facilities in use on the Ranger Project and their relative effectiveness in reducing environmental pollution and degradation; and

f. social factors including the views of the regional community and possible adverse social effects of introducing alternative technology

3. Assessment of BPT for Ranger Projects

For the Ranger ITWC Project, it was decided that a BPT assessment should be carried out for all procedures and practices considered for the project throughout its development to ensure that a record is kept of all alternatives considered, their environmental advantages and disadvantages, their relative costs and the potential community concerns. The intention was to ensure that:

- An extensive BPT database would be developed that could be used to carry out the overall BPT assessment towards the end of the project;

- Members of the technical team conducting the project would be required to address the environmental, cultural and safety issues arising from their proposals throughout the project;

- The people who contribute the technical data required for the BPT assessment would be those who know most about the technical issues;

- ERA staff would have ownership of, and confidence in, the BPT assessment of the project; and

- A high level of assurance would be provided to Traditional Owners, local Stakeholders and the ERA Board that the closure design finally adopted is indeed fully consistent with BPT.
To assist in this process, a BPT matrix was been developed that is to be used by all program leaders in the assessment of options considered for the practices possibly appropriate to achieve outcomes in their project design areas.

The matrix was developed in two stages. First, a detailed matrix was derived that could be applied in the development of any significant future proposal for a change in the Ranger Authorisation; for example, any proposal for underground mining of uranium in the Ranger 3 Deeps. The second stage was the revision of this general BPT matrix to the more restricted consideration of the closure of existing operations at Ranger.

3.1 BPT for possible future development projects at Ranger

Taking into account the generic operational requirements of any development and the specific issues raised in the definition of BPT, it was considered that the BPT analysis of all proposed development projects at Ranger should address the following issues:

**Traditional Owner Culture & Heritage:**
- Would the adoption of the option have adverse impacts on the cultural practices, traditions and customs of the local Aboriginal communities?
- Would the option threaten in any way the integrity of sacred sites, rock art or any other aspect of the cultural heritage of the region?

**Protection of People and the Environment – Operational phase:**
- Would the option give rise to adverse impacts on the health and safety of Aboriginal or non-Aboriginal members of the local community?
- Would the option have any adverse socio-economic impacts on the communities in the town of Jabiru or in the broader Kakadu region?
- Would the option achieve protection of the natural World Heritage and Ramsar values of Kakadu National Park?
- While disturbance and environmental impact is inevitable on the project area, would adoption of the option minimise such on-site impacts?
- Would the option ensure long-term protection of the health of members of the local community and of the natural World Heritage and Ramsar values of Kakadu National Park?

**Fit for Purpose:**
- Does the option being considered use proven technology? Proven and demonstrated technology would be ranked higher than very new, unproven or theoretical technology.
- How effective is the technology used in the option in meeting its desired output objective and how robust is it in response to variations in feed and consumables? Effective, highly robust options would rank highly.
- Does the standard of environmental protection achieved by the option meet the highest standards achieved in uranium mining elsewhere in the world?
- Does the capital cost of the option ensure that its adoption would contribute significantly to the overall project value?
Operational Adequacy:

- Would adoption of the practice ensure the ongoing health and safety of the workforce?
- Would the option require extensive control and support effort to ensure its continued viability?
- Is the process operationally reliable? That is, will it have high availability or will it be sensitive to the failure of single plant items?
- Would the option be difficult to maintain?
- Would the operating costs associated with the option have a large impact on overall project value?

Rehabilitation and Closure:

- Would the option give rise to impacts that would make it difficult to rehabilitate the site to the standards required for incorporation of the site into Kakadu National Park following closure?
- Would the option require extensive rehabilitation actions before closure could be achieved and hence extend closure beyond stakeholder expectations?
- Would adoption of the option result in closure costs that significantly detract from overall project value?

Constructability:

- Would adoption of the option introduce significant health and safety risks to the workforce during the project construction phase?
- Will the option give rise to the need for significant land disturbance during construction, significant off-site environmental impact or require construction work near sites of cultural significance?
- Would adoption of the option lead to high construction complexity through difficult scheduling, complex logistics or significant manpower requirements?

3.2 BPT for the Ranger ITWC Project

The ITWC project is a Major Project in the Rio Tinto context and as such is conducted in a number of stages with each stage building on the information needed to assess the best options and strategies to employ. The Pre-Feasibility Study (PFS) stage will identify the best options to take to the Feasibility Study (FS) and Implementation stages. The range and depth of BPT assessments need to match the scope of the particular stage of the project.

The scope of the Pre-Feasibility Study includes the Ranger mine site and associated infrastructure on the Ranger Project Area and the time scale of the programs considered in the study is subject to the requirements of the Section 41 Authority issued under the Atomic Energy Act. The scope for the PFS stage excludes decisions on the airport, ongoing power supply and the withdrawal of ERA from Jabiru town and the region. These aspects of closure will be subjected to parallel studies once the high level socio-political issues, strategy and options are evaluated with key stakeholders. Notwithstanding this, some impacts on town and regional communities will be considered as outlined below.
In considering the application of BPT to the Ranger ITWC Project, it was concluded that more emphasis needs to be placed on the assessment of the adequacy with which the rehabilitation requirements in the ERs are likely to be met and less emphasis on any construction issues involved. Initially it was thought that any construction issues that arose could be considered as operational but it has been decided to retain constructability as a separate issue for consideration because, once the options for closure were examined, it became clear that all likely options will involve some significant construction of plant and some of the issues specific to constructability warrant separate attention. An increased focus on rehabilitation was been achieved by expanding the number of rehabilitation criteria based upon the detailed content of the ERs.

The cessation of all milling operations and the completion of rehabilitation have legal deadlines specified in the Section 41 Authority issued under the Atomic Energy Act; the consistency of the schedule for any option with these requirements has been addressed under the Rehabilitation criteria. It is essential that the robustness of options is tested against their possible impact on achieving the planned date on which milling will cease. The severe impact on operations that can result from the occurrence of high rainfall events is well known and, given the existence of legally required deadlines for completion of rehabilitation activities, the robustness of options in the face of extreme rainfall events will also be an important issue to address. For this reason, an additional criterion on robustness of design with respect to these two issues was added to the Fit for Purpose issues.

For these reasons, therefore, the list of issues addressed in the ITWC Project included those listed in section 3.1 with the amendments listed below:

Protection of People and the Environment – Operational phase:

Noting the increased emphasis on rehabilitation criteria, in particular, the specific reference to erosion, radiation, water quality and dispersal of solutes from tailings, it was decide that the question on the potential long-term environmental consequences of operational activities would be redundant. Hence the following question was deleted:

- Would the option ensure long-term protection of the health of members of the local community and of the natural World Heritage and Ramsar values of Kakadu National Park?

Fit for Purpose:

Following the second issue on effectiveness and robustness in achieving the technical objective, a new criterion on general robustness was added:

- How robust is the option with respect to variations in rainfall and requirements on the timing of mill closure?

Rehabilitation and Closure:

The first issue listed in section 3.1 on rehabilitation, which reflects the broad rehabilitation goal defined in the ERs, was replaced by a number of specific issues that reflect the major rehabilitation objectives and the requirements on tailings management. It was considered that if these specific objectives are met then the overall goal would be achieved. Thus the issues for rehabilitation are listed below.

- Would adoption of the option ensure the establishment of a revegetated site using local native species with a low maintenance regime?
Would the option ensure the establishment of erosion characteristics on the site that, as far as can reasonably be achieved, do not vary significantly from those of comparable landforms in surrounding undisturbed areas?

Would the option enable the establishment of stable radiological conditions on the rehabilitated site that will ensure that health risks to members of the public meet Australian standards and are as low as reasonably achievable?

Would adoption of the option ensure that agreed water quality criteria are met in creeks draining the mine site and that appropriate ecosystem restoration standards are achieved for water bodies on the rehabilitated landform?

Would adoption of the option ensure that all tailings produced at the Ranger site are physically isolated from the environment for a period of 10,000 years and that any contaminants arising from the tailings will not result in any detrimental environmental impact for at least 10,000 years?

Would adoption of the option extend closure beyond Traditional Owner expectations and, in particular, beyond the requirements specified in the S41 Authority?

It should be noted that the criterion on closure costs has been deleted from the rehabilitation criteria in section 3.1. It was considered that, at this stage in the BPT assessment process for the ITWC project, the CAPEX, OPEX and technical effectiveness criteria would adequately cover cost issues and that the overall Net Present Cost (NPC) of closure would be a major issue to be considered in the final overall assessment of BPT by ERA and the other members of the MTC.

### 3.3 Ranking System

The breadth of the ranking system proposed for BPT assessments is dependent on the stage of project development. For an Order of Magnitude project study a simple 3-level ranking system is proposed as follows.

- Rank 1 – Inadequate; the option does not meet current standards
- Rank 2 – Acceptable; the option meets current standards
- Rank 3 – Excellent; the option exceeds current standards

In the detailed BPT assessment matrix, a specific descriptor is given for the meaning of “meets current standards” for each criterion.

However, for PFS and FS stages of project development, it is considered appropriate that the BPT assessment would incorporate a 5-level system. The 5-level system adopted for the ITWC project was as follows:

- Rank 1 – Inadequate; the option does not meet current standards and it is unlikely that modifications could reverse this assessment
- Rank 2 – Poor; the option does not meet current standards but options for modifications exist that could reverse this assessment
- Rank 3 – Acceptable; the option meets current standards
- Rank 4 – Good; the option exceeds current standards
- Rank 5 – Excellent; the option exceeds current standards by a substantial margin and the option is recognised as international best practice.
If insufficient information was available to allocate a rank to a criterion in the early stages of the BPT process, the criterion was given an Unable-to-Evaluate (UTE) assessment. This prompted the development of actions to address the lack of knowledge to ensure that sufficient information became available for the “whole-of-project” evaluation later in the project. Where it was assessed that the criterion was not applicable (NA) to the particular option being considered, a “NA” result was recorded. NA results could occur in the individual program assessments but, for the overall assessment of the project, it was expected that each criterion would be assessed for each option.

The final BPT score for an option, S, was calculated as follows:

\[ S = 100 \sum_{i=1,N} (s_i - m)/(N.F) \]

where \( s_i \) is the score for criterion \( i \), \( m \) is 2 for a 3-rank system and is 3 for a 5-rank system, \( N \) is the total number of criteria for which a score was recorded and the factor \( F \) is 1 for a 3-rank system and 2 for a 5-rank system. Only criteria for which a score was recorded (rather than a UTE or NA result) were included in the summation process. The BPT score essentially summarises performance of the option against current international performance standards. Thus, for either a 3 or a 5 rank system, the score that would be recorded for an option which achieves the highest rating for all criteria would be 100; an option that simply meets standards for all criteria would score 0, and an option that achieves the lowest rating for all criteria would score -100.

In the assessment process, two types of Showstopper result were recorded for an option. A Hard Showstopper was allocated to an option where it was clear from basic initial consideration that the option could not be accepted and there was no need to proceed further with assessment of the option. This might occur, for example, if an initial assessment demonstrated that adoption of an option could result in intrusion on a sacred site.

A Soft Showstopper would be recorded against an option if a rank equal to 1 was attributed to the option in a 3-rank system (1 or 2 in a 5-rank system) for any criterion involving OHS issues, off-site environmental protection issues, or cultural issues. The recording of a Soft Showstopper against an option would not be considered to rule out that option but it would record that the performance of the option against the particular criterion would need to be reviewed and improved before the option could be considered acceptable. The recording of a significant number of Soft Showstoppers against an option would, however, be likely to rule the option out of further consideration.

An Excel spreadsheet was developed for the BPT assessment process. It contains three principal sheets. The first contains the detailed description of the above assessment matrix with a specific definition of the issues to be addressed under each criterion and, for each potential rank, a description of the performance expected to be met for the criterion being considered. The second sheet contains the BPT database in which each option considered is allocated a rank (or score) by the assessment team for each of the criteria. The third sheet contains an identical data base but, instead of recording a rank for each criterion, a record is made of the principal reasons for the team’s assessment of the option against that criterion and the reason for its allocation of the recorded rank. The full list of the criterion descriptors and the ranking definitions is given in Appendix 1.
3.4 Weighting Factors

The BPT assessment matrix spreadsheet contains the option of allocating weighting factors to each criterion but the default value for each factor is one. Consideration was given to allocating weighting factors but it was decided to keep all factors equal in the assessment process for the following reasons:

- The introduction of weighting factors could, and probably would, lead to endless arguments among stakeholder groups on the actual value to be attributed to the factor for each criterion. Since there are more than 25 criteria, there is potential for endless debate and the final outcome would probably be a decision to have all criteria equal.

- The extended BPT assessment used in the ITWC project replaces the original six-issue matrix in which all criteria were considered equal. In arriving at the current list of criteria, ERA has attempted to retain a balance between technical and cost related criteria and those related to cultural, social and environmental issues that is similar to the balance present in the original list. On this basis, equal weighting factors should be retained.

- The allocation of weighting factors could be taken to imply that the BPT score arising from the assessment matrix would be the final determinant of what constitutes BPT. ERA considers that the result obtained from the assessment matrix should inform the decision making process rather than be the final assessment. This view is supported by other members of the MTC.

Effective weighting of criteria could occur through double counting for which there is potential in carrying out a BPT assessment using the proposed criteria. For example, adverse water quality impacts could be scored low in both the environmental and the cultural criteria; or a low scoring tailings containment rank might also score low in both water quality and cultural areas.

BPT assessment teams in the ITWC project attempted to avoid double counting as described in these examples. For example, issues like water quality were only addressed in the environmental criteria. The cultural criteria addressed specific living cultural and cultural heritage issues and excluded broad issues such as the TOs perception of water quality. In making assessments, it was acknowledged that such perceptions should already be taken into account in setting the water quality criteria against which the predicted water quality was being judged.

Nevertheless, it was recognised that apparent double counting may actually arise for different reasons. Superficially it may appear that a low score in tailings containment might also rank poorly under water quality. However, the tailings issue would be assessed against water quality in the very long-term, thousands of years, while other water quality issues would relate to the short-term impact. These are, therefore, quite separate issues and need to be considered separately.

However, one area was identified where double counting is probably intrinsic to the assessment process. Under the radiation protection criterion associated with rehabilitation, an option may be assessed as acceptable if doses received by members of the public are expected to be adequately below the public dose limit even if this can only be achieved with limited restrictions on access to sections of the rehabilitated landform. This would be consistent with the ERs. Under the cultural heritage criterion, an acceptable option could be one that does not have any impact upon a sacred site but for which normal routes to such a site may be subject to limited access restrictions arising from radiation exposure considerations. This would appear to constitute double counting. Even here, however, while the cause of the restriction is the same in both cases, the impact is different. In the first case the
impact is a human health issue while in the second it would result in discouragement of Traditional Owner access to sites of cultural significance.

3.5 **Scope of socio-economic issues in the ITWC BPT assessment**

Clarification was necessary for the scope of issues to be considered when assessing the potential for socio-economic effects on the people of Jabiru and the surrounding region.

As indicated earlier, the scope for the PFS stage excludes decisions on the airport, ongoing power supply and the withdrawal of ERA from Jabiru town and the region. For this reason, issues such as town governance and infrastructure were not addressed in BPT assessments for the project.

However, the various options considered in the project could have social and economic impacts in a number of ways. For example, the size of the workforce would vary between options and this would have consequences for the availability of accommodation in the town, pressures on health services etc. Similarly, increased heavy vehicle traffic on the Arnhem Highway, which may be a feature of some options, could have an impact on the local tourism industry. Or there could be significant variations in the business opportunities available to local businesses under different options. These issues were addressed in the BPT process by conducting a comparative assessment between options using current internal ERA resources; it was not considered necessary to use external resources to assess these issues at this stage.

Effects in this category that could arise during construction of plant and equipment for different options were addressed under the appropriate Constructability criterion. Non-construction related effects were addressed under the socio-economic criterion for the operational phase.

4. **BPT Assessment Process for the Ranger ITWC Project**

Following an internal ERA review process, a draft BPT discussion paper and assessment matrix, based upon the above analysis, were submitted by ERA to the MTC for assessment and comment by committee members. The overall response of MTC members was very positive and some specific comments and suggestions were received. These comments were taken into account in the final revision of the discussion paper and the BPT matrix prior to the conduct of a series of workshops to assess BPT for the ITWC project.

At the highest level of project definition, the principle variables that determine the characteristics of project options are:

- Mill closure date; the principal options considered were 2016 and 2020.
- Brine management method; the principal options considered were brine injection at depth or brine crystallisation and deposition.
- Tailings treatment; the principal options considered thickening of tailings and tailings filtration after thickening.

In all cases, tailings would be transferred from the existing Tailings Storage Facility (TSF) and deposited in Pit 3 and all tailings produced by the mill from 2015 onwards would be deposited in Pit 3 following treatment.
Thus, the four core options identified at the outset of the project, and noted in discussions with stakeholders, as potential strategies for assessment in the ITWC PFS were:

- Mill Close 2016/20, Backfill Pit 3, Brine Injection, Thickened Tailings Deposition.
- Mill Close 2016/20, Backfill Pit 3, Brine Crystallisation, Thickened Tailings Deposition.
- Mill Close 2016/20, Backfill Pit 3, Brine Injection, Filtered Tailings Deposition.
- Mill Close 2016/20, Backfill Pit 3, Brine Crystallisation, Filtered Tailings Deposition.

The primary objective, therefore, of the BPT assessment process in the ITWC project was to determine which of these strategy options constituted Best Practicable Technology for closure of the Ranger mine.

However, within each of these strategies there were a number of major competing options for individual components of the project. For example, the previous Order of Magnitude study had identified three methods for recovery of tailings from the TSF; these were excavation, hydraulic mining and dredging. And for each of these there could be sub-options; thus for tailings excavation, transfer to Pit 3 could be by road haulage, pumping or by a conveyor system. For this reason, the process adopted for the BPT assessment was to conduct three individual program assessments to determine BPT for individual components of the overall project prior to conducting the BPT assessment for the major strategic options.

Thus, three workshops were conducted to assess BPT for the following project components:

- Tailings reclamation, transfer, treatment and deposition;
- Salt treatment and disposal; and
- Final landform construction, revegetation and ecosystem reconstruction.

The outcomes of these workshops were then used to define the specifications of the major strategic options to be assessed in a preliminary BPT workshop on strategic options. The options considered in this preliminary workshop on strategic options were:

- Brine injection, thickened tailings, mill closure 2016
- Brine injection, thickened & filtered tailings, mill closure 2016
- Brine crystallisation, thickened tailings, mill closure 2016
- Brine crystallisation, thickened & filtered tailings, mill closure 2016
- Brine injection, thickened tailings, mill closure 2016, with water treatment 2026 – 2030
- Brine injection, thickened tailings, mill closure 2020

It was known that certain key studies such as the surface water and ground water solute transport project would not be completed before this preliminary workshop but it was considered important to make early progress on the overall BPT assessment to ensure that (a) other areas of uncertainty were identified at an early stage and rectified, if possible, before the final assessment and (b) the scope of options considered in the final assessment could be broadened or refined as necessary.
A complete assessment of all of the above options was, as expected, not possible at the preliminary workshop on strategic options but the areas of uncertainty were more clearly delineated and actions were agreed to fill the knowledge gaps before the final strategic BPT workshop. In addition, sufficient information was available at the time of the preliminary workshop to reach the following conclusions:

- Filtration of tailings after thickening would not be justified, and
- Brine injection technology is superior to brine crystallization for which a number of significant deficiencies were identified.

As a result of the conclusions reached in the preliminary strategic BPT workshop, the list of options brought forward to the final BPT workshop was as follows:

- Brine injection, thickened tailings, mill closure 2016
- Brine injection, thickened tailings, mill closure 2020
- Brine injection, thickened tailings, mill closure 2016 with water treatment until 2029
- Brine injection, thickened tailings, mill closure 2020 with water treatment until 2034

A full description of the BPT workshops, their outcomes and the underlying rationale for conclusions reached is provided in subsequent chapters of this report.

5. **Tailings reclamation, transfer, treatment and deposition**

5.1 **Description of options for rehabilitation of tailings**

The first BPT workshop examined a number of options for the reclamation, transfer, treatment and deposition of tailings.

5.1.1 **Tailings Reclamation and Transfer**

Three options were considered for reclamation of tailings from the TSF; excavation, hydraulic mining and dredging.

The excavation option would require installation of additional brine concentrator capacity and a storage pond so that water could be removed from the TSF early after each wet season for storage and treatment and thus allow access to the tailings surface. Excavators would remove tailings onto low ground pressure haul trucks which would deposit tailings at a stockpile inside the TSF to allow them to drain. Stockpiled tailings would subsequently be excavated onto large haul trucks for transfer to Pit 3.

The hydraulic mining option would also require early access to the tailings surface after each wet season so that additional brine concentrator capacity and a storage pond would again be required. Remote controlled high pressure water monitors would be used to breakdown and slurry the tailings which would then flow under gravity to sumps excavated in the TSF. The resultant slurry would then be pumped to thickener prior to disposal in Pit 3.

Dredging options were reviewed by ERA in a PFS-level study in 2009 and the use of a bucket wheel cutter - spud dredge was recommended (Coghill 2010). It would be anchored using steel cables shackled to heavy duty poly rope that stretches from the
dredge to two D7 dozers on the TSF embankment crest. The dredge would progressively reclaim sub-aqueous tailings and would produce a 28% by weight solids stream. This slurry would then be dewatered to a 60% by weight solids stream using a thickener located on a raised pad constructed beside the TSF embankment. The thickened slurry would then be pumped to Pit 3.

For each of these reclamation options, a number of alternative transfer options were considered as follows:

- **Excavation**
  - Excavate, dewater and truck
  - Excavate, dewater and conveyor
  - Excavate, slurry and pump

- **Hydraulic mining**
  - Hydraulic mine, pump
  - Hydraulic mine, thickener, pump

- **Dredging**
  - Dredge, pump
  - Dredge, thickener, pump
  - Dredge, thickener, filtration, truck
  - Dredge, thickener, filtration, conveyor

A detailed description of each of these options was presented and discussed at the workshop prior to the conduct of the BPT assessment.

### 5.1.2 Tailings Treatment

With the thickening option being considered as a base case, the tailings treatment options considered were:

- Filtration
- Cementation

The base case considered for tailings treatment was thickening to about 60% solids water content which is similar to the settled density achieved in the TSF. The primary additional treatment considered in the assessment was filtration whose primary purpose would be to ensure prompt consolidation of tailings in Pit 3 and thus effectively eliminate tailings settlement after deposition. Filtration might also reduce dispersion of solutes in groundwater to some extent through a reduction in tailings permeability but a much more effective method of reducing groundwater dispersion of solutes would be cementation.

For tailings filtration, reclaimed tailings from the TSF, thickened and then fed into a pressure filtration system and the filter cake produced would be hauled or conveyed to Pit 3. The filtrate would be returned to the TSF. Tailings from the mill would be cycloned. A pressure filtration system would be used for the fine fraction and a vacuum filtration system would be used for the coarse fraction.

The water content of tailings from the TSF or the mill is high and the solids concentration would need to be raised by both thickening and filtration before cementation in an appropriate plant. Otherwise cement consumption and the
associated costs would be extraordinarily high and drying times would be long. Tailings from either source would be split with one fraction passing through a thickener and the other through a filtration plant and a hopper prior to combining both outputs in a mixer with a tailored mixture of cement and water. The mixer output would be held in a tank for conditioning prior to being pumped to Pit 3.

5.1.3 Tailings Deposition

Deposition of thickened tailings in Pit 3 could use either sub-aerial or sub-aqueous techniques.

For sub-aerial deposition, the tailings slurry would be discharged from single or multiple points around the pit crest or benches and the tailings would form a sloping beach. Water would be pumped from the lower end of the beach for water management purposes.

For sub-aqueous deposition, the slurry could be discharged at the water surface either from the pit perimeter or via a floating pipeline. Alternatively, the slurry could be delivered by pipeline to the underwater tailings surface. A third alternative would be to use a tremie system to inject the slurry under the surface of previously injected tailings.

If tailings filtration is adopted, the options for pit deposition include dry-stacking or co-disposal with waste rock. For dry-stacking, dry tailings in the form of filter cake would be hauled by truck or delivered by conveyor to the pit and hauled downhill to a dump point on an appropriate bench. In co-disposal, the same procedure would be adopted but waste rock would be dumped in the pit at the same time.

Thus the four tailings disposal options considered at the workshop were:

- Thickened sub-aerial
- Thickened sub-aqueous
- Filtered dry stacking
- Filtered co-disposal

5.2 BPT assessment of tailings rehabilitation options

5.2.1 Reclamation and transfer of tailings from the TSF

The BPT matrix resulting from the first workshop is shown in Tables 1(a), 1(b) and 1(c). Table 1(a) shows results for the criteria in the Traditional Owner Culture and Heritage and the Protection of People and the Environment categories; table 1(b) shows results for criteria in the categories Fit for Purpose and Operational Adequacy; and table 1(c) shows the results for criteria under the Rehabilitation and Closure and the Constructability categories.

A general comment to make about the results shown in Table 1 is that for most of the detailed options assessed, a NA (not applicable) result was obtained for criteria in the Culture and Heritage, People & Environment (during the operational stage), and Rehabilitation and Closure categories. This was not unexpected. For example, the method of reclamation of tailings from the TSF has little association with cultural and heritage issues. Nor do these methods have any impact on achieving the revegetation, radiation exposure or erosion standards for the final landform. Hence, the BPT assessment of the tailings rehabilitation options was dominated by the criteria under the Fit for Purpose, Operational Adequacy and Constructability categories.
Of the reclamation and transfer options, excavation rated poorly compared with hydraulic mining and dredging. The sensitivity of excavation techniques to extreme rainfall events led to poor ratings for robustness; dust arising from disturbance of the tailings surface gave rise to concerns on both environmental protection and OHS grounds; and excavation was assessed as a method of reclamation that would be require considerable operational effort because of the variable ground conditions that would be experienced, the expected variability in tailings density and substrate strength and the drainage requirements required for successful implementation of the process. The scores obtained for the three excavation options ranged from -7 to -21 and these can be compared to scores of up to +19 and +21 for hydraulic mining and dredging respectively. Hence excavation was rejected as a method for reclamation of tailings from the TSF.

Hydraulic mining and dredging emerged from the workshop with approximately equal BPT assessments with scores of about +20 for the reclamation and pumping options and about +11 for reclamation, thickening and pumping options. Significant disadvantages of hydraulic mining were the need to remove overlying water, sensitivity to extremes rainfall events, higher capital expenses because of the brine concentrator and additional pond and potential environmental protection issues arising from tailings mist dispersal. It rated better than dredging in the operational OHS assessment where, although radiation exposure of dredge operators is lowered by the shielding effect of water, risks associated with operating on water resulted in a poorer risk rating. Dredging was also ranked slightly lower on the operability and maintainability criteria.

An overall assessment of the relative significance of the various advantages and disadvantages of the two options led to the conclusion that the disadvantages of the dredging option are much more amenable to management than those associated with hydraulic mining. This is particularly the case for the issue of sensitivity to extreme rainfall events where management options are extremely limited and the occurrence of such events could have a major impact on the rehabilitation schedule. For this reason, dredging is considered the preferred option.

The results of the BPT analysis presented in Table 1 show, however, that one soft show-stopper was recorded for the dredging options. This arose from the allocation of a rank of 2 for the OHS criterion under Operational Adequacy. The issue of concern was, as noted above, the risks associated with working over water. The assessment of the workshop team was that, with the application of engineered safety controls the practice would satisfy Rio Tinto occupational health requirements. However, it would only be considered safe with the application of multiple safety controls from lower in the hierarchy of preferred risk controls (eg procedures and PPE). This issue should receive further assessment later in the PFS study.
Table 1 (a) BPT assessment matrix for tailings reclamation, transfer, treatment and deposition for categories Culture & Heritage and Protection of People and the Environment during the Operational Phase

<table>
<thead>
<tr>
<th>BPT ASSESSMENT</th>
<th>Inadequate</th>
<th>Poor</th>
<th>Acceptable</th>
<th>Good</th>
<th>Excellent</th>
<th>Unable to evaluate</th>
<th>Not applicable to this option</th>
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<tr>
<td>BPT Ranking Database</td>
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<td></td>
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<td></td>
</tr>
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<td>NA</td>
<td>UTE</td>
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Legend:
- Yes
- No
- UTE
- NA

Rank weighting: 1 1 1 1 1 1 1
Table 1 (b) BPT assessment matrix for tailings reclamation, transfer, treatment and deposition for categories Fit for Purpose and Operational Adequacy

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<th>BPT ASSESSMENT</th>
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<th>Poor</th>
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<tr>
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<tbody>
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<th>Option Description</th>
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<th>Robustness (rainfall and mill closure)</th>
<th>Environmental Protection</th>
<th>CAPEX</th>
<th>Safety Occupational Health</th>
<th>Operability</th>
<th>Inherent availability and reliability</th>
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<th>Erosion</th>
<th>Water Quality</th>
<th>Tailings</th>
<th>Schedule</th>
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</tr>
<tr>
<td>BPT Ranking Database</td>
<td>1</td>
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</table>

| Excavation | NA | NA | NA | NA | NA | 1 | 4 | 3 | 3 |
| NA | NA | NA | NA | NA | NA | 1 | 4 | 3 | 3 |
| NA | NA | NA | NA | NA | NA | 1 | 4 | 3 | 3 |

| Hydraulic Mining | Inadequate | Poor | Acceptable | Good | Excellent | Unable to evaluate | Not applicable to this option |
| BPT ASSESSMENT | 1 | 2 | 3 | 4 | 5 | UTE | NA |

| Hydraulic mining, pump | NA | NA | NA | NA | NA | UTE | 4 | 3 | 3 |
| Hydraulic mining, thickener, pump | NA | NA | NA | NA | NA | UTE | 4 | 3 | 3 |

| Dredging | Inadequate | Poor | Acceptable | Good | Excellent | Unable to evaluate | Not applicable to this option |
| BPT ASSESSMENT | 1 | 2 | 3 | 4 | 5 | UTE | NA |

| Dredge, pump | NA | NA | NA | NA | NA | 3 | 3 | 3 | 3 |
| Dredge, thickener, pump | NA | NA | NA | NA | NA | 3 | 3 | 3 | 3 |
| Dredge, thickener, filtration, truck | NA | NA | NA | NA | NA | 3 | 3 | 3 | 3 |
| Dredge, thickener, filtration, conveyor | NA | NA | NA | NA | NA | 3 | 3 | 3 | 3 |

| Tailings Treatment | Inadequate | Poor | Acceptable | Good | Excellent | Unable to evaluate | Not applicable to this option |
| BPT ASSESSMENT | 1 | 2 | 3 | 4 | 5 | UTE | NA |

| Filtered Tailings | NA | NA | NA | NA | NA | 3 | 3 | 3 | 3 |
| Filtered & cemented Tailings | NA | NA | NA | NA | NA | 3 | 3 | 3 | 3 |

| Pit 3 Deposition | Inadequate | Poor | Acceptable | Good | Excellent | Unable to evaluate | Not applicable to this option |
| BPT ASSESSMENT | 1 | 2 | 3 | 4 | 5 | UTE | NA |

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<thead>
<tr>
<th>Thickened Tailings only</th>
<th>Sub-aerial</th>
<th>Sub-aqueous</th>
<th>Filtered tailings</th>
<th>Dry stacking</th>
<th>Co-Disposal</th>
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<td>UTE</td>
</tr>
<tr>
<td>Sub-aqueous</td>
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<td>NA</td>
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<td>UTE</td>
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<tr>
<td>Filtered tailings</td>
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<td>NA</td>
<td>4</td>
<td>UTE</td>
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<tr>
<td>Dry stacking</td>
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<td>NA</td>
<td>4</td>
<td>UTE</td>
</tr>
<tr>
<td>Co-Disposal</td>
<td>4</td>
<td>NA</td>
<td>NA</td>
<td>4</td>
<td>UTE</td>
</tr>
</tbody>
</table>
5.2.2 Tailings treatment

As indicated above, the base case assumed for tailings treatment is that all tailings will be thickened. The two additional options being considered were (a) filtration and (b) cementation.

The results of the BPT assessment shown in Table 1 indicate that filtration does have some advantages over basic thickening. It was assessed that the use of filtration would be viewed more favourably by Traditional Owners under the Living Culture criterion because the solid product being deposited in the pit more closely represents the original material that was removed from the pit during the mining stage of the Ranger project. Filtration was assessed as being a technique that is proven technology worldwide and that it is a sound technical way of achieving increased consolidation in Pit 3 and hence ensuring that the schedule requirements on rehabilitation of the site are met.

Thus the prime technical advantage of filtration is that it reduces the time required for tailings consolidation. It may have some advantages for long-term dispersal of contaminants in groundwater but this had not yet been demonstrated and it is considered that the advantage will probably be small. On the other hand, it is a very expensive option to construct, install and operate and maintenance requirements would be high. Increased traffic on the Arnhem highway and an increased workforce in Jabiru during the construction phase were also recorded as slight negatives compared to the base case. The overall assessment of filtration at the tailings workshop was that the option should be retained until at least the preliminary workshop on overall strategies for the ITWC project but that it appeared to be a very expensive option with limited advantages.

Cementation did not emerge as a favoured option. Although it is anticipated, based upon earlier trials, that cementation would result in a significant reduction in the long-term transport of solutes from the tailings repository, this had not yet been demonstrated for the currently proposed process and further trials would be required. Capital costs would, however, be high because of the need to include filtration as a preliminary step and operational costs would be extremely high as a result of the high cement consumption implicit in the process. The overall assessment was that if, by the time the final BPT assessment workshop is carried out, long-term dispersal of contaminants from thickened tailings is demonstrated to be a serious issue, consideration of alternative neutralisation methods would be required rather than implementation of the full cementation process. It was decided to implement a desktop study on this possibility.

5.2.3 Tailings deposition

As was noted above, the options for sub-aqueous deposition of thickened tailings include discharge of the slurry at the water surface, at the underwater tailings surface or by using a tremie system to inject the slurry under the surface of previously injected tailings. At the workshop, there was some discussion on the relative advantages of these three options and it was noted that, while the tremie system has been used elsewhere, it’s use in Pit 3 could be problematic because of issues such as access to the tremie barge, operator radiation exposure etc. It was decided that a full relative assessment of these alternatives need not be carried out at that stage and that the current assessment would be limited to a higher level comparison of sub-aerial and sub-aqueous techniques.

From the Living Culture perspective, it was assessed that Traditional Owners would have a distinct visual preference for tailings covered by water rather than an exposed
tailings surface. It was expected that this would not be considered to be a major issue and, therefore, that the sub-aerial option would be assessed as acceptable but since the sub-aqueous option would be preferred it should be assessed as good under this criterion. The criteria under the Protection of People and the Environment category were not considered relevant to the comparison of these options.

Sub-aerial deposition was rated slightly better than sub-aqueous under the Fit for Purpose criteria. While both techniques are applied successfully around the world, the sub-aerial method is probably used more extensively and it is likely to achieve a higher settled density. However, the sub-aqueous method is not sensitive to extreme rainfall events whereas the sub-aerial deposition technique requires dry beaches to achieve optimum density and is sensitive to flooding and evaporation rates.

This slight advantage was reversed in the Operational Adequacy criteria where, based upon previous experience at Ranger, sub-aqueous deposition was rated more highly under the operability and operating costs criteria.

The ratings for all other criteria were equal and the overall conclusion was there is a preference for the adoption of sub-aqueous deposition for deposition of thickened tailings but that both options for disposal would be acceptable.

Both options for the deposition of filtered tailings involve the use of a solid product but filter cake does not, apparently, produce the type of negative reaction from Traditional Owners as occurs for beached tailings. For this reason, both techniques were considered acceptable. However, the higher maximum elevation of tailings in Pit 3 resulting from the adoption of co-disposal of filter cake and waste rock led to a preference for the use of dry stacking under the Living Culture criterion.

Under the Fit for Purpose category of issues, there were concerns expressed about the degree to which either technique had a proven track record. Dry stacking has been used successfully elsewhere but not in a mine pit. Similarly, co-disposal has been used in the coal industry with varying levels of success. Of greater concern, however, is the sensitivity of both techniques to wet conditions. Both options require the maintenance of dry conditions and their use, therefore, would be limited to the dry season. Both techniques were, therefore, rated as unacceptable under the Robustness criterion.

A number of other disadvantages were identified for these techniques in other areas such as capital costs, OHS, maintainability and operational costs and the overall BPT scores obtained were -3 for Dry Stacking and -9 for Co-disposal. These results on tailings disposal options simply compound the earlier conclusion on the options for tailings treatment that the adoption of tailings filtration would not be justified.

6. **Salt treatment and disposal**

During operations at the Ranger mine, a large inventory of process water has accumulated. This water has high concentrations of salts, metals and radionuclides and is unsuitable for discharge to the surrounding environment unless it has been appropriately treated. Following a review of ERA’s process water strategy in 2010 (Prebble et al. 2010) and a BPT analysis of potential treatment options for process water (Coghill 2011), ERA decided to use a brine concentrator as the principal method of treating process water prior to discharge.

In the early stages of process water treatment using the brine concentrator, the brine stream will be returned to the TSF, a procedure that will result in a gradual build-up of the concentration of dissolved solids in the process water stream. This is clearly not a sustainable practice and ERA will need to introduce a long-term program for the
management and disposal of salts in the process water at Ranger. A number of options for such a program have been identified and a BPT analysis of these options was carried out at a workshop as part of the ITWC project.

Table 2 Salt management options rejected with hard show-stoppers

<table>
<thead>
<tr>
<th>Option Description</th>
<th>Reason for rejection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blend brine with tailings, Deposited in Pit 3</td>
<td>Could not manage brine over the life of mine because run out of tailings; could not manage high TDS tailings water expressed when backfilling Pit 3</td>
</tr>
<tr>
<td>Thermal Calcination - Storage Placement</td>
<td>Excessive capital cost (i.e. need to raise solids concentration prior to calcination using a crystalliser) and high energy demand. Dust / gas (SO₂) scrubbing issues. High fuel demand.</td>
</tr>
<tr>
<td>Cementation - Pit 3 Placement</td>
<td>Unproven technology on a commercial scale. Excessive cost and high risks associated with supply of specialised cement. Requires a high capital cost dewatering step to raise the brine concentration to reduce cement consumption.</td>
</tr>
<tr>
<td>Cementation - Underground Silos Placement</td>
<td>Technically feasibility not proven on a commercial scale. Excessive cost and high risks associated with supply of specialised cement. Require a high capital cost dewatering step (i.e. brine crystalliser - centrifuge) to raise the brine concentration to reduce cement consumption.</td>
</tr>
<tr>
<td>Chemical Precipitation - Storage Placement</td>
<td>Excessive cost and high risks associated with supply of precipitation agent. Previous review ruled out this option due to lime supply issues.</td>
</tr>
<tr>
<td>Membrane Concentration - Storage Injection</td>
<td>Membrane dewatering technology is constrained by feed TDS; brine TDS is much higher than maximum feasible values for current membranes.</td>
</tr>
<tr>
<td>Spray Dry - Storage Placement</td>
<td>Inadequate technology to scrub dust and control radiation. Operator and environment exposure to dust and radiation.</td>
</tr>
<tr>
<td>Eutectic Freeze Crystallisation - Storage Placement</td>
<td>Eutectic freeze crystallisation is not commercial and only demonstrated in laboratory and small scale pilot plants using simpler salt systems. It is unlikely that this technology will be developed/demonstrated in time to meet Ranger's closure schedule.</td>
</tr>
<tr>
<td>Freeze Distillation (Desalination) - Storage Placement / Injection</td>
<td>Technology demonstrated using pilot plants. Freeze desalination has not been successfully proven on a large commercial scale for brine treatment. It is unlikely that this technology will be developed/demonstrated in time to meet Ranger's closure schedule.</td>
</tr>
<tr>
<td>Produce Salt - Commercial Scale</td>
<td>While technically feasibility to selectively precipitate, high cost to ensure the product is free of other process water components and radionuclides. Large solar pond size required. Selling a 'waste product' unacceptable to ERA / Stakeholders.</td>
</tr>
<tr>
<td>Produce Salt - Purpose Built Onsite Repository</td>
<td>Shallow water table across site. While used in dry regions this technology is unproven for wet / tropical location. Require a large storage footprint.</td>
</tr>
<tr>
<td>Produce Salt - Purpose Built Offsite Repository</td>
<td>Storage of high concentration brine / salt off site is an unacceptable option for ERA / Stakeholders. Potential adverse impact on environment, local communities etc.</td>
</tr>
</tbody>
</table>
The need to dispose of saline water is widespread in a number of industries and, as a result, 25 methods were identified as potential salt management options and were considered at the workshop. Of these, options that included disposal of highly saline water in the rivers, aquifers and sewers of the region, pumping to the ocean, or irrigation on the land application areas at Ranger were all rejected outright as practices that are clearly inappropriate for the region and would be considered unacceptable by ERA and by its stakeholders.

Thirteen of the remaining options were considered by the workshop team but, in each case, one or more hard showstoppers were identified. These options and a brief description of the issues that led to their rejection are described in Table 2 and they received no further consideration. The remaining seven options are described below and were assessed in detail in the workshop.

6.1 Description of options for salt management

The options for salt management that were assessed in detail at the BPT workshop fall into the following three categories in terms of treatment of the brine stream from the Brine Concentrator:

- **Brine Injection**: no treatment, disposal by direct injection into a suitable repository
- **Distillation**: reduce the total brine volume using additional brine concentrator stages. The resultant high concentration brine stream is then injected into a suitable repository
- **Crystallisation**: dry the brine using a thermal crystallisation plant, disposal by placement in a suitable repository, and

The infrastructure required for the Brine Injection options would be relatively simple. To prevent boiling in the pumping and storage infrastructure, the temperature of the brine emerging from the concentrator would be reduced using a heat exchanger. The brine would then be pumped to the directionally drilled injection system. High pressure pumps would need to be available if the back pressure from the repository increases.

Two options for a suitable repository were considered. The first was the lowest region of Pit 3 which would have been backfilled with waste rock prior to the commencement of tailings disposal in the pit. In addition an underdrain would be placed above the waste rock underfill to enable pumping of expressed water to the TSF. This process is illustrated in figure 1. Additional infrastructure required would include a ring main and injection wells around the perimeter of Pit 3.

For the Pit 3 underfill injection option, the brine would fill the cavities in the waste rock of the underfill and estimates of the void volume required at the time of the workshop was about 2 GL. The estimated storage volume within the voids of the underfill is ~3GL.

The second repository considered in the case of direct brine injection was a custom excavated set of silos deep underground and accessed from the Ranger 3-Deeps decline. The conceptual design included six silos developed in the granite gneiss basement rock which is very competent, stable and impervious. Such a choice would almost certainly ensure that there would be no impact on the environment arising from dispersal of solutes in groundwater even in the very long-term; solute transport modelling would be carried out to confirm this. Injection wells would be drilled from the location of the brine concentrator into the silos. A ventilation rise would also be installed.
The third option considered for direct injection of brine again used the proposed Pit 3 underfill but was designed to address a potential problem that could arise in that option. The concern was that chemical reactions could occur when the brine interacts with the waste rock of the underfill, particularly the fines, resulting in reduced porosity and eventually reducing the void volume available for brine storage. A possible solution would be to screen all waste rock before placement in the pit to remove the fines and hence alleviate the problem.

The infrastructure required for salt crystallisation includes a thermal crystallisation plant, a large salt bagging facility to cope with the high throughput of salt and a truck transport system. The scope of these facilities should not be underestimated; nor should the associated OHS issues. A very provisional estimate of the capital cost of the crystallisation plant exceeded $100M. It would also be a very high energy consumer. The radiation hazards in the salt bagging facility would be much greater than those in the current product packing area at Ranger partly because gamma exposure would be a significant issue as well as dust inhalation and partly because the solubility of the some of the radioactive constituents (for example, actinium) would be much higher. In addition, the salt throughput would be orders of magnitude greater than that of product in the product packing area.

The two options for the salt repository were, as considered for brine injection, Pit 3 and underground silos. However, in the case of Pit 3 as a repository, the bags of salt would need to be placed in the pit with the tailings slurry or filter cake as the operation proceeds through the final milling stages and the transfer of tailings from the TSF. This would mean that dried salt in bags would be collocated with tailings up to the final height of tailings deposition. Crystallised salt produced after capping of the Pit would need to be stored in the Ranger 3-Deeps decline.
Transfer of crystallised salt to underground silos would need to be by conveyor or trucks but, in either case, placement would be required. This would give rise to a number of OHS issues.

In a manner similar to the crystallisation option, adoption of treatment of brine in a distillation plant would require significant investment in infrastructure in the form of an additional brine concentrator system and a distillation plant. The repository options would be the same as for brine injection, Pit 3 underfill and silos excavated for the purpose in the granite gneiss basement rock accessed from the Ranger 3-Deeps decline and the injection methods would be similar. However, the storage volumes required would be less since the method increases the concentration of salts in the brine stream.

In summary, the options to be assessed in detail at the Salt Management BPT workshop were:

- Brine injection to the Pit 3 underfill
- Brine injection to underground silos
- Brine injection to the Pit 3 underfill with rock screening for the underfill
- Brine crystallisation with co-placement of dry salt within tailings in Pit 3
- Brine crystallisation with placement of dry salt in underground silos
- Brine thermal distillation with injection to the Pit 3 underfill
- Brine thermal distillation with injection to underground silos

6.2 BPT analysis of the salt management options

The results obtained in the Salt Management BPT workshop are shown in table 3(a) for the Culture & Heritage criteria and for Protection of People and the Environment during the Operational Phase, in table 3(b) for the Fit for Purpose and Operational Adequacy criteria and in table 3(c) for the Rehabilitation, Closure and Constructability criteria.

Under the cultural criteria, it was assessed that there were no heritage issues arising for any of the options because all activities would take place within the currently disturbed areas. From the living culture perspective, those options that involve injection to the Pit 3 underfill were rated highly because the material would be being returned to the pit from which it had been taken in the mining phase of operations. Nevertheless, the Pit 3 option for the dried salt product from crystallisation was assessed as being a poor option because the much higher elevation for placement of the material in the pit would receive a negative community reaction. The underground silos options for placement were recorded as UTE rankings because no underground options have yet been discussed with the community. This would need to be addressed if an underground option emerges as a favoured option in the BPT process.

All criteria under the Protection of People and Environment category were assessed as either acceptable or good. In all cases, any risks to health or the environment were considered to be low and manageable; for such cases a rank of 3 was allocated. In some cases it was assessed that risks would be so low that management action would not be necessary; these options were given a rank of 4.
Table 3(a) BPT assessment matrix for salt treatment and disposal under categories Culture & Heritage and Protection of People and the Environment during the Operational Phase

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<tr>
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## Table 3(b) BPT assessment matrix for salt treatment and disposal under categories Fit for Purpose and Operational Adequacy

<table>
<thead>
<tr>
<th>BPT ASSESSMENT</th>
<th>Inadequate</th>
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<th>Good</th>
<th>Excellent</th>
<th>Unable to evaluate</th>
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<td>Robustness</td>
<td>Environmental Protection</td>
<td>CAPEX</td>
<td>Safety Occupational Health</td>
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Table 3(c) BPT assessment matrix for salt treatment and disposal under categories Rehabilitation & Closure and Constructability

<table>
<thead>
<tr>
<th>BPT ASSESSMENT</th>
<th>BPT Ranking Database</th>
<th>Salt Management</th>
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<th>Constructability</th>
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<table>
<thead>
<tr>
<th>Option Description</th>
<th>Revegetation</th>
<th>Radiation</th>
<th>Erosion</th>
<th>Water Quality</th>
<th>Tailings</th>
<th>Schedule</th>
<th>Construction Occupational Health &amp; Safety</th>
<th>Construction Environmental and Cultural risks</th>
<th>Construction Complexity</th>
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All of the brine injection options were rated highly in the Fit for Purpose category of criteria. The option using the underground silos as a repository was assessed as excellent because (a) it is very well established technology that would certainly meet the technical objective of secure storage with no uncertainties on available volume and (b) the timing of storage availability would have no constraints. Similarly, this option has no sensitivity to climate extremes during operations and storage in a deep, impervious rock would ensure a very high standard of long-term environmental protection. The capital cost of this option would, however, be very high. Brine injection to the underfill was not ranked as highly with respect to the proven technology criterion because, although deep well injection is a very well established technique for disposal of water treatment brines and other waste streams, uncertainties still remain about the possible impact on performance from rock reactivity with the brine. Underfill injection rated almost as highly as silo injection for technical performance, robustness and environment protection standard but it was rated as excellent under the capital expenditure criterion because of its extremely low establishment costs compared to other options. Injection in the underfill with prior rock screening would probably alleviate the proven technology concerns associated with unscreened injection but capital costs were estimated to be very high to establish a screening plant of the size that would be required.

The crystallisation and distillation options were rated acceptable or good for the proven technology and robustness criteria and, with one exception, of pit placement for crystallisation, for the standard of environmental protection achieved compared to internationally accepted standards. The exception was the crystallisation with pit placement option which was assessed as unacceptable under this criterion because there is no known case in uranium mining anywhere in the world where this procedure has been adopted. In other industries where this technique has been applied for the storage of hazardous wastes, it has only been adopted when the repository is lined with an impermeable barrier and subject to monitoring. Technical performance was also rated poorly for three of the four crystallisation and distillation options. The capital costs associated with a crystallisation plant led to a rating of poor under the CAPEX criterion and this rating was downgraded to unacceptable for the corresponding silo option because of the compounding costs associated with mining the silos. Thus, the overall assessment of the crystallisation and distillation options against the Fit for Purpose criteria was poor.

A similar picture emerged in the consideration of options against the criteria in the Operational Adequacy category. The crystallisation and distillation options only rated a ranking of acceptable in three of the twenty assessments in this category. All other rankings were poor or unacceptable. Particularly negative assessments of unacceptable were given to the distillation options under the Inherent Availability and Reliability criterion and the related Maintainability criterion. These assessments arose from concerns expressed about the use of two brine concentrators in series in an attempt to achieve much higher brine stream concentrations; this was considered likely to result in a high risk of infrastructure scaling causing relatively frequent shutdowns and high level maintenance requirements. While the crystallisation plant options were assessed as being slightly more reliable in these areas with a poor assessment, these options were ranked as unacceptable against the operating costs criterion because of the very high energy demands of the process and also because of the high personnel costs in running the bagging facility.

At the workshop, radiation safety concerns were expressed about the risks of exposure in the salt bagging plant where operations similar in nature to the current product packing area at Ranger would be carried out on a much larger scale. A rank of poor was allocated at the workshop but further health safety advice was sought
later and it was agreed that this ranking should be reduced to unaccepta-ble in further assessments. It is considered unlikely that such a bagging facility would receive regulatory approval.

The brine injection options performed reasonably well against the criteria in the Operational Adequacy category. The inherent OHS risks associated with backfilling underground stopes with liquid were noted for the silos option and some uncertainties were recorded on the potential for a higher level of maintenance needed in the injection wells. Otherwise, operational performance was assessed as good and operating costs were considered to be very low for the two brine injection underfill options.

Most of the salt management options were assessed as not being very relevant to the standard of rehabilitation to be achieved at the site in the revegetation, radiation, erosion and water quality criteria. Among the exceptions were the assessments that (a) in a relative sense, storing dried salt in silos would be much less of a radiation risk in the long term than placement near the surface in the pit, and (b) modelling might be necessary to provide assurance that the deposition of fines from the rock screening plant near the surface of the pit would not risk a deterioration in surface water quality.

The risks of long-term dispersion of solutes from the salt repository were assessed under the Tailings criterion in the Rehabilitation and Closure category because the salts arise from the tailings through treatment of process water. The results of solute transport modelling were presented to the workshop for the case of brine injection to the underfill. Current modelling provides strong evidence that solutes from the underfill repository would not be expected to reach surface waters in less than ten thousand years. Further modelling would be carried out to confirm this conclusion and the assessment made at the workshop was that the underfill option, for both the screened rock and the unscreened alternatives, was acceptable against this criterion. Similar conclusions were reached for the injection of a higher concentration brine stream into the Pit 3 underfill. The assessment against this criterion for injection into silos was increased to good because of the lower permeability of the rocks in which the silos would be developed. For the thermal crystallisation options, the risk of long-term dispersal of solutes from the salts was assessed as being unacceptable for the pit placement alternative because the location of dried salt in bags within the tailings mass much nearer the surface would pose much greater risks than the other alternatives considered. The corresponding risk for dried salt disposal in silos was considered to be very low.

Meeting the requirements on rehabilitation schedule specified in the S41 Authority is expected to be straightforward for brine injection in the Pit 3 underfill. Some scheduling risks were identified for some other options but it was assessed that these could be managed.

For the constructability criteria, the best performing option was brine injection in the underfill for which infrastructure requirements are simple and safety and environmental issues are, therefore, minimised. The underground silo options all had some OHS concerns and complexity issues but in most cases options were assessed as being acceptable against the Constructability criteria.

The overall BPT assessment was that brine injection to the underfill without rock screening was the highest ranked alternative with a score of +30 and no soft showstoppers were identified for this option. Brine injection to underground silos scored well at +24 but 2 soft showstoppers were identified for this option; they arose from a poor assessment for OHS issues during both the construction and the operational phases of this option. Major problems were identified for the
Crystallisation and Distillation options and it is considered unlikely that either would be viable. The only question mark about the preferred option appears to be on the potential for reactivity between the brine and the waste rock of the underfill and possible limitation on the volume available for the storage of brine. It was concluded that this issue requires further assessment prior to a final decision on the salt management option to be implemented.

7. **Final landform construction, revegetation and ecosystem reconstruction**

The assessment process adopted in the BPT workshop on landform construction, revegetation and ecosystem reconstruction was different to that adopted in the previous two workshops. A different approach was considered necessary for several reasons:

- The activities of landform formation, revegetation and ecosystem reconstruction will not start for many years and BPT for these programs will not be fully assessed until a time closer to implementation;
- These programs, particularly those on landform reconstruction and revegetation, have gone through significant options analysis and refinement over many years and there are no longer major competing alternatives for their implementation – ongoing refinement of these programs within a BPT context is a better description of what will occur in future; and
- There will be no major differences in the implementation of these programs within the major strategy alternatives identified for the overall ITWC project.

For these reasons, the approach adopted in the workshop was twofold:

- The current plans for each of these programs were assessed for the Schedule criterion under Rehabilitation to determine the nature of any risks to completion of rehabilitation by 2026 as required under the S41 Authority.
- All other criteria were assessed for each of the current programs to identify, where possible, options for improvement and to record any uncertainties that remain to be assessed.

The outcomes from the workshop are summarised in each of the following sections.

7.1 **Scheduling risks in the programs**

The principal scheduling issues identified from consideration of the landform construction, revegetation and ecosystem reconstruction programs were:

- The timetable for completion of the landform construction program will be determined by process water expression at the surface of Pit 3; current estimates indicate that this is a major risk for completion of rehabilitation of the Ranger site by 2026.
- Alternatives to the current proposals need to be considered to enhance tailings settlement; these should include horizontal wicks, multistage wicks, and electrostatic flocculation. Electrostatic flocculation is the process of passing strong currents through a colloidal fluid. This has the effect of causing the suspended particles to come together and settle more rapidly.
• For all of the strategies currently under consideration, water treatment and
decant systems will probably be needed after 2026 to manage process water
expression from Pit 3.

• Sediment control traps may also need to operate for many years after 2026.

• Under the current alternative strategies, the most optimistic schedule for the
revegetation program restricts commencement of planting on the land surface
above Pit 3 (an area of about 200 ha) until Oct 2025. The revegetation
program requires infill planting 1 year after the initial planting program and
understory planting required after a period of 2 – 3 years. Thus, under the
most optimistic schedule, revegetation could not be completed by Jan 2026.

Following further consideration of these issues, options will need to be discussed
with the TOs and the regulatory agencies.

7.2 Landform construction

Consideration of the currently planned landform construction program led to the
following issues identified against the various BPT criteria. Only those criteria are
listed for which one or more issues were identified.

Living culture

Height of landform and Mt Brockman visibility - TO expectations
appear to be achievable for the current plans (FLv2) for
placement of material within the disturbed footprint.

Slopes & erosion – TO expectations on landform slopes appear
to be met in the current landform design (FLv2); expectations
on erosion rates would be met if the performance of the
landform under the Erosion criterion is rated as acceptable or
better.

Residual rock size – Under current plans, less than 1% of rock
is expected to be greater than 50 cm; this outcome should be
acceptable to TOs; consultation required on this topic.

Aesthetic blending with the surrounding landscape; the current
planned landform (FLv2) appears to be acceptable from the
TOs perspective on this topic.

Permanent waterbodies: TO expectation is that only pre-
existing waterbodies should form part of the landscape. Thus
any proposal to reinstate Djalkmarra billabong should be for
cultural purposes and should have cultural attributes. This
contrasts with any proposal to use a reinstated Djalkmarra as a
sink for collection of expressed poor quality water from Pit 3. A
strategy to address both set of requirements would be needed.

Removal of rubbish from the final landform is a TO expectation;
this is currently being planned.

Cultural heritage

Previously quarantined rock from Pit 3 needs to be placed
appropriately in the landscape; consultation will be needed to
identify a suitable location.

Established land disturbance procedures should be followed to
ensure Cultural Heritage clearance is obtained for areas
outside of "disturbance boundary"; ie the LAA, drainage corridors, RP1 catchment, Corridor Creek etc.

Sensitive areas should be mapped to compare with all plans and all plans should be discussed with the Communities team for clearance.

Community health & safety
Pathways for radiation exposure during landform establishment include water, dust and radon. These pathways need to be modelled and management plans implemented. This refers to tourists as well as local communities.

Town/Region
A large construction workforce will be employed in landform construction. This will have the potential for positive (e.g. business opportunities) and negative (pressure on accommodation, alcohol issues etc) impacts. These will need to be assessed and management plans implemented. The FIFO versus residential issue should be assessed.

Ecosystems of Kakadu
During landform construction, there will be a need to manage solute generation and sediment transport offsite to protect ecosystems.

In decommissioning contaminated sites (LAAs, mill site etc), controls will be needed when scraping sediments or soils close to creeks or billabongs to protect water quality. TO views should be sought on what constitutes "contamination" and adequate decontamination.

Ecosystems of Project Area
Refer to Ecosystems of Kakadu comment - the same issues apply to the Project Area.

Proven technology
There may be a need to manage seepage from the landform and water expressed from Pit 3 in the long term. The technology to employ for this purpose is unclear since there is currently no proven technology for passive treatment of water with high concentrations of $\text{MgSO}_4$.

Robustness
The timing of plant decommissioning is dependent on mill closure. A management plan is needed to ensure that contaminated plant items (eg density gauges, calciner etc) can be placed in appropriate long-term repositories (e,g within the tailings layer or in the R3-Deeps decline etc.).

Environmental Protection
With respect to best international practice, compacted backfill and geotextile layers were used in pits at Wismuth to manage subsidence through the underdrain. Are such practices appropriate for Ranger and, if so, do current plans comply with international standards?

Revegetation
It is understood that the currently planned landform will provide a substrate that is suitable for appropriate plant community establishment.
Radiation Contracts for modelling human radiation exposures across landform are underway. It was noted that ERICA modelling will also be required to assess radiation exposure impacts on non-human biota.

Erosion Erosion modelling is underway for the currently proposed landform (FLv2) to address both short-term and long-term erosion. This is an iterative process of design, modelling, assessment and redesign as required. Erosion arising from creek migration as well as rainfall runoff is being considered in the surface water modelling project and by SSD.

Water Quality Note the water quality issues related to runoff and seepage under the Kakadu and Project Area criteria. This is potentially one of the biggest risks to water quality and there will be a need to derive a management and communication strategy to address reality and perception.

Location of seepage expression. The rehabilitated landform is designed to be within RP1 interception trench, part of the active seepage management system. Continued poor quality water may express from the stockpiles. Need to assess the need for continued water management and develop a strategy to address this considering the lag period associated with seepage generation, the potential quality and quantity of the seepage.

Tailings The issue of expression of water of process water quality water from tailings in Pit 3 has been covered in the Tailings BPT.

These issues need to be addressed as the Landform Construction program is developed in the future.

7.3 Revegetation

Consideration of the currently planned Revegetation program led to the following issues identified against the various BPT criteria.

Living culture TOs wish to ensure consideration is given to the establishment of plant species that are of economic value. These species could possibly include weeds. Consultation is required to identify appropriate species and build them into the revegetation and weed management plans.

Traditional burning practices should be included in the revegetation management plan.

TOs have expressed a desire to ensure that habitat re-establishment on the landform will support both iconic and bush Tucker species. This will need to be assessed under Rehabilitation & Closure (Water) and under Health (radiological issues) criteria.
A large construction workforce will be employed in the revegetation. This will have the potential for positive (e.g. business opportunities) and negative (pressure on accommodation, alcohol etc.) impacts. These will need to be assessed and management plans implemented. The FIFO versus residential issue should be assessed.

Local people should be given the opportunity to work on this program.

Weed introduction will be an issue for imported nursery products (eg tubestock from Darwin). A weed control program will be essential.

Any use of fertilisers in the establishment of vegetation will need to be managed to ensure protection of waterways from excess nutrients.

Potential OHS issues that may need to be managed include:
- Heat exhaustion for planting teams.
- Meliodosis for planting team.
- Bites and stings; also applies to ecosystem re-establishment
- Risks arising from the use of mechanised planting equipment

Issues that require assessment include:
- Is the proposed species diversity considered appropriate by the TOs?
- Provenance issues such as genetic diversity and provenance zone need to be addressed. Broadening of the provenance zone has been assessed as appropriate by ARRTC but the views of the TOs should be sought.
- Seed & tubestock supply; contracts for supply need to be established and alternative suppliers need to be identified.
- Selection of species and previous trials indicate maintenance will be acceptably low.

Note the radiation exposure issue (planting of bushtucker species) identified under the Living Culture criterion.

These issues need to be addressed as the Revegetation program is developed in the future.
7.4 Ecosystem Reconstruction

Consideration of the currently planned Revegetation program led to the following issues identified against the various BPT criteria; criteria are only listed where one or more issues were identified.

**Proven technology**
- Trial landform, seeding studies etc have demonstrated technology for aspects of terrestrial ecosystem establishment.
- There is no proven technology for re-establishing aquatic ecosystems.

**Environmental Protection**
- Prepare a comparison with practices in other industries - most are not re-establishing high conservation value ecosystems.

**Water Quality**
- Water quality needs to sustain ecological systems (traditional knowledge and western science based), including food and cultural species.
- Need to ensure that any aquatic fauna or flora that are dietary items (e.g. mussels or water lily rhizomes) are safe to eat.
- Regional and local water bodies need to be used to achieve a characterisation scheme for water bodies to determine the range of parameters that will support desired habitats and important species. A collaborative review by SSD & ERA is planned; a program is needed to include TO views.

These issues need to be addressed as the Ecosystem Reconstruction program is developed in the future.

7.5 Emerging water quality issues

As recorded above, concerns about meeting water quality closure criteria arose on a number of occasions in the consideration of aspects of the landform and ecosystem re-construction programs. Some of these concerns were related to the potential for dispersion of solutes from tailings or salt repositories and these will be addressed once the solute modelling program is complete. However, a specific issue that is not tailings or salt related is the potential for ecological impact arising from the drainage of rainwater through the waste rock that will form the final above-surface landform.

Such concerns arise from the current expectation that the closure criterion that will be set for Mg in Magela Creek could be based on the current provisional trigger value of approximately 3 mg/L. This value has been derived from ecotoxicological testing of aquatic animals when exposed to waters with enhanced concentrations of magnesium. It is known that the presence of calcium, even at fairly low concentrations, ameliorates magnesium-induced toxicity to some extent so this effect needs to be taken into account. The current provisional Mg trigger value is based upon species sensitivity distributions at the 99% protection level for chronic exposures of at least 5 local species of aquatic animals with Mg:Ca ratios of less than 9.

The solute transport modelling program had yet to be completed at the time of landform construction, revegetation and ecosystem re-construction BPT workshop. Nevertheless, results obtained in preliminary modelling were presented to the workshop and these results demonstrated that concentrations of Mg in Magela Creek
may well exceed 3 mg/L unless management actions are implemented. While water treatment would be an option for some period after completion of the final landform, such treatment could not be a permanent or long-term activity after rehabilitation. Hence, if future modelling demonstrates that enhanced concentrations of Mg in Magela Creek could be expected in the long term, this issue could emerge as a significant one for ERA and its stakeholders because there are currently no known techniques for the passive treatment of MgSO₄ in effluent waters.

For this reason, the need has been identified for a thorough review of the potential impacts of elevated Mg under different flow conditions and the basis of the current recommendations on the closure criterion for Mg in the waters of Magela Creek. Issues that need to be considered include:

- The appropriateness of chronic or pulsed tests
- The need to take into account field observations as well as laboratory based data
- The relevance of the possible exposure time in the annual flow cycle to the choice of species and/or endpoints.
8. **Overall Strategy for the ITWC Project – Preliminary Assessment**

8.1 **Strategic options in the preliminary assessment**

There are four core closure strategies being investigated in the ITWC project. These strategies vary in relation to the treatment of the waste products, i.e. salts within the process water and mill tailings in the TSF. The characteristics of these four strategies were refined on the basis of the conclusions reached in first two BPT workshop on tailings excavation, treatment and deposition methods and on salt management options. Despite poor overall assessments for tailings filtration and brine crystallisation, these options were retained for the first strategy workshop to ensure that the conclusions reached when considered in isolation were tested again in the context of the complete project. However, the only repository for tailings and salt retained for consideration in the first strategy workshop was Pit 3.

Strategy 1, titled Brine Injection and Thickened Tailings, is to inject the concentrated brine, which is produced by the brine concentrators when they treat the process water, into the underfill at the base of Pit 3 and to cover this with the tailings from the TSF and the mill. The tailings will be excavated from the TSF by dredging and will be dewatered in a thickener before pumping to Pit 3 where they will be deposited using a sub-aqueous disposal method. The main benefit of Strategy 1 is the placement of the salts from the process water into the deepest part of Pit 3 and then covering them with a near-imperVIOUS layer of approximately 60 metres of tailings. A variation on this option that was considered in the salt management BPT workshop included the screening of waste rock prior to dumping as underfill in Pit 3. On the basis of the previous assessment, this option was not carried forward to the first strategy workshop. An overview of the Variation 1C of Strategy 1 is provided in Appendix 2 (C strategies cease milling in 2016) along with summaries of the other strategies. A summary of the timing of key events for each of the strategies is given in Table 4. To highlight differences in timing, entries for options other than 1C are only shown if they differ from the 1C entry.

Strategy 2 is very similar to Strategy 1 except that the tailings are filtered before being trucked into Pit 3. Strategy 2 is titled Brine Injection and Filtered Tailings. The benefit of filtering of the tailings is that, once in place, they do not express water. This allows the tailings to be covered with waste rock immediately after placement and may allow waste rock to be placed simultaneously with the tailings. This latter option was, however, rejected on the basis of assessment in the tailings BPT workshop. The main disadvantage of this method is the fact that Pit 3 must be dry before the tailings can be placed, which will require the construction of another process water dam (RP7) before October 2014, much earlier than would otherwise be necessary.

Strategy 3, titled Crystallisation and Thickened Tailings, treats the brine from the Brine Concentrators until it is crystallised. This salt would then be bagged and placed into Pit 3 where the bags would be covered with tailings. An alternative could be to prepare clay-lined alcoves in the pit walls which would be used as repositories for the crystallised salt. Where possible, these alcoves could be placed so that the rising tailings cover the salt. It was decided that any consideration of this alternative would only be explored in detail if the crystallisation option emerged as a genuine front-line option for salt management. The disadvantage of the crystallisation methodology is that salt would still be produced after tailings deposition had ceased and an alternative repository would be required late in the process.
Table 4  The timing of key events in the strategies considered in the preliminary strategies BPT workshop; entries same as 1C unless specified otherwise

<table>
<thead>
<tr>
<th>Key Event</th>
<th>Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction of additional pond water storages known as RP5 and RP6 &amp; 2.3m raise of TSF</td>
<td>2012</td>
</tr>
<tr>
<td>Completion of mining activities within Pit#3</td>
<td>2012</td>
</tr>
<tr>
<td>Commence backfill of Pit#3 through placement of ~30Mt of waste rock within the void</td>
<td>2013</td>
</tr>
<tr>
<td>Commission the brine concentrator for treatment of process water from the TSF at distillate capacity of 1.83 GL/annum</td>
<td>2013</td>
</tr>
<tr>
<td>Commission the brine injection bores to deliver brine to the Pit#3 underfill, thus removing this stream from the TSF</td>
<td>2015, N/A, N/A</td>
</tr>
<tr>
<td>Commission the TSF dredge and tailings thickener to deliver thickened tailings stream to Pit#3</td>
<td>2015</td>
</tr>
<tr>
<td>Commission the Mill to Pit#3 / Filtration unit tailings system, thus removing this stream from the TSF</td>
<td>2015</td>
</tr>
<tr>
<td>Milling operations cease</td>
<td>2016, 2015</td>
</tr>
<tr>
<td>Decommission and rehabilitate Mill</td>
<td>2017, 2020</td>
</tr>
<tr>
<td>Commission the incremental brine concentrator with process water feed from the TSF</td>
<td>2017</td>
</tr>
<tr>
<td>Pit#1 backfill complete with revegetation activity underway on the Pit#1 landform</td>
<td>2017</td>
</tr>
<tr>
<td>Revegetation of Mill area</td>
<td>2019, 2023</td>
</tr>
<tr>
<td>Dredging of the TSF, and thus all tailings transfers to Pit#3, ceases</td>
<td>2020, 2021, 2021</td>
</tr>
<tr>
<td>RP6 converted from a pond water storage to a process water storage</td>
<td>2020</td>
</tr>
<tr>
<td>Construct and commission RP7 as process water storage and feed source for the brine concentrators</td>
<td>2021, 2014, 2014</td>
</tr>
<tr>
<td>Installation of prefabricated vertical drains (wicks) within Pit#3 to promote consolidation through removal of entrained water</td>
<td>2021, N/A, N/A</td>
</tr>
<tr>
<td>Decommission and demolition of filtration plant &amp; infrastructure and/or crystallisation plant &amp; infrastructure</td>
<td>N/A, 2022, 2025, 2025, N/A, N/A</td>
</tr>
<tr>
<td>Commence backfilling of Pit 3</td>
<td>2024, 2023, 2023, 2023</td>
</tr>
<tr>
<td>Decommission and rehabilitate RP6</td>
<td>2025</td>
</tr>
<tr>
<td>Decommission and rehabilitate RP2 and RP7</td>
<td>2025, 2029</td>
</tr>
<tr>
<td>Decommission &amp; demolition of brine concentrators, MF/ROs and infrastructure</td>
<td>2025</td>
</tr>
<tr>
<td>Final landfill shaping and revegetation of Pit 3</td>
<td>2025, 2026</td>
</tr>
<tr>
<td>Cessation of closure activities</td>
<td>2026, 2026, 2026, 2026, 2030, 2026</td>
</tr>
</tbody>
</table>
Strategy 4 combines the crystallisation of the salts with tailings filtration and is titled Crystallisation and Filtered Tailings.

Each of these strategies was assessed within the BPT framework in the preliminary strategic BPT workshop. However, two other strategies were also assessed.

Strategy 5C was very similar to Strategy 1C except that it included an extension of water treatment until 2030. The key differences from the 1C Strategy are:

- Water is treated until 2029 by microfiltration reverse osmosis and the brine concentrator.
- Pond and process water storage ponds, power supply and some offices (at reduced size/capacity) remain until the end of 2029.
- Remaining facilities are buried in the ponds and the ponds reshaped and re-vegetated in 2030.
- Pit 3 earthworks take place as in 1C. Revegetation of Pit 3 can occur over 2026.

Strategy 1B was a second variation of Strategy 1 in which milling would continue until 2020. To accommodate this later mill closure date, activities associated with decommissioning and dismantling the mill, removal and burial of soils and revegetation in the plant area are moved from 2017, 2018 and 2019 to 2021, 2022 and 2023 respectively.

Thus the strategic options assessed at the preliminary strategy workshop were:

- Option 1C: brine injection, thickened tailings, milling until 2016
- Option 2C: brine injection, thickened & filtered tailings, mill to 2016
- Option 3C: brine crystallisation, thickened tailings, mill to 2016
- Option 4C: brine crystallisation, thickened & filtered tailings, mill to 2016
- Option 5C: Option 1C with water treatment 2026 – 2030
- Option 1B: Option 1C with milling to 2020.

8.2 Preliminary BPT analysis of the strategic options

The results obtained in the preliminary BPT analysis of the strategic options are shown in table 5(a) for the cultural criteria and for protection of people and the environment during the operational phase, in table 5(b) for the fit for purpose and operational adequacy criteria and in table 5(c) for the rehabilitation, closure and constructability criteria.

Traditional Owner Culture and Heritage

Some of the living culture issues that were raised in discussion, such as accessibility to the site after closure and the visibility of Mount Brockman from various locations around the site, were assessed as being similar for all options and acceptable. Similarly, although the proposed location of some injection wells may be close to heritage sites, it is believed that this issue can be managed through existing controls and ongoing consultation.

It was assessed that the Traditional Owners would prefer the filtration option for which there would be no expressed process water from the tailings and, therefore, they would be comfortable visiting the riparian sites and accessing aquatic ecosystems within the Ranger Project Area. The cultural expectations for Djalkmarra
Billabong would be more easily achieved. Option 2C, therefore, was ranked as *good* against the Living Culture criterion. However, for the filtered option with crystallisation of salt, option 4C, this advantage is more than counteracted by the disadvantage, from the TO’s perspective, of salt being deposited close to the surface in Pit 3 and this option was ranked as *poor*.

The brine injection and thickened tailings options 1C and 5C would have associated with them higher volumes of process water expression after 2026 than the filtered tailings option but the issue was considered manageable (for example, by extended water treatment) and that it would be assessed as *acceptable*. In the 5C case, however, the much longer use of water treatment was thought to significantly reduce the risk to Djalkmarra Billabong cultural values as well as the riparian and aquatic ecosystems. Hence this option was assessed as *good* against the Living Culture criterion.

**Protection of People and the Environment during the Operational Phase**

For the criteria on protection of people and the environment up until 2026, all of the options received equal rankings.

For community health and safety, dispersion of radionuclides in dust is an issue that is common to all options but it was assessed that the risks should be readily managed using normal operational controls. For radon emanation from the tailings, literature values indicate that the emanation rate would be much higher for filtered tailings. Nevertheless, the resulting radiation exposure rates in areas where members of the public visit would be very low. All options were ranked as *good* from the community health perspective.

There is potential for significant social impacts on the communities of Jabiru and the region during the closure operational phase. For the options that involve mill closure in 2016, royalty payments would cease at that time and there would be potential for a reduction in community partnerships and contributions. The latter include the supply of power to local communities, subsidy of management and maintenance of Jabiru Airport, and a number of cultural and educational programs that are currently supported by ERA. Some options (e.g. those involving filtration or crystallisation) have significantly higher workforce requirements and there would be accommodation issues, FIFO/residential issues etc that would have an impact on the local community. Similarly, these options would have higher fuel demands and consequently more truck traffic on the Arnhem highway. It was considered that allocation of rankings to the options under this category could not be carried out reliably without better estimates of workforce numbers, potential social impacts and revenue profile information. A UTE ranking was, therefore, recorded against the Town/region criterion for all options and responsibility was allocated to obtain the required information before the final BPT assessment workshop.

During the closure operational phase, the pathways for potential impact on the ecosystems of Kakadu National Park and the risks associated with these pathways would be very similar to those that are present during current operations. Hence, with similar management procedures and practices, it was assessed that the high level of environmental protection currently being achieved, as demonstrated in all of the ERA and SSD monitoring programs, should continue until closure is complete. A ranking of *good* was attributed to all options. Impact on ecosystems of the Project Area during the closure operational phase should also be similar to that occurring now because there are no greenfield disturbances planned for any option and disturbance within the disturbed area would be similar for all options. A rank of *acceptable* was recorded for all options.
Table 5(a) BPT assessment matrix for the preliminary assessment of strategic options under categories Culture & Heritage and Protection of People and the Environment during the Operational Phase

<table>
<thead>
<tr>
<th>Option Description</th>
<th>Show stopper 1 Indicator</th>
<th>Show stopper 2 Indicator</th>
<th>Overall rank</th>
<th>Living culture</th>
<th>Cultural heritage</th>
<th>Community Health &amp; Safety</th>
<th>Town/Region</th>
<th>Ecosystems of Kakadu</th>
<th>Ecosystems of Project Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPTION 1C: Brine injection; thickened tailings Mill to 2016</td>
<td>0</td>
<td>0</td>
<td>15.0</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>UTE</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>OPTION 2C: Brine injection; thickened &amp; filtered Mill to 2016</td>
<td>0</td>
<td>0</td>
<td>5.3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>UTE</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>OPTION 3C: Brine crystallisation; thickened tailings Mill to 2016</td>
<td>0</td>
<td>3</td>
<td>-5.0</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>UTE</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>OPTION 4C: Brine crystallisation; thickened &amp; filtered Mill to 2016</td>
<td>0</td>
<td>3</td>
<td>-18.4</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>UTE</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>OPTION 5C: Brine injection; thickened tailings Mill to 2016; water treatment 2026 - 2030</td>
<td>0</td>
<td>0</td>
<td>18.4</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>UTE</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>OPTION 1B: Brine injection; thickened tailings Mill to 2020</td>
<td>0</td>
<td>0</td>
<td>22.5</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>UTE</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>
Table 5(b) BPT assessment matrix for the preliminary assessment of strategic options under categories Fit for Purpose and Operational Adequacy

<table>
<thead>
<tr>
<th>Option Description</th>
<th>Proven technology</th>
<th>Technical performance</th>
<th>Robustness</th>
<th>Environmental Protection</th>
<th>CAPEX</th>
<th>Safety Occupational Health</th>
<th>Operability</th>
<th>Inherent availability and reliability</th>
<th>Maintainability</th>
<th>OPEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPTION 1C: Brine injection; thickened tailings</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>M1 to 2016</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPTION 2C: Brine injection; thickened &amp; filtered tailings</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>3</td>
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<tr>
<td>M1 to 2016</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPTION 3C: Brine crystallisation; thickened tailings</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>M1 to 2016</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>OPTION 4C: Brine crystallisation; thickened &amp; filtered</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>M1 to 2016</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPTION 5C: Brine injection; thickened tailings</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>M1 to 2016, water treatment 2026 - 2030</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPTION 1B: Brine injection; thickened tailings</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>4</td>
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<tr>
<td>M1 to 2020</td>
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<td></td>
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</tr>
</tbody>
</table>
Table 5(c) BPT assessment matrix for the preliminary assessment of strategic options under categories Rehabilitation & Closure and Constructability

<table>
<thead>
<tr>
<th>BPT ASSESSMENT</th>
<th>Inadequate</th>
<th>Poor</th>
<th>Acceptable</th>
<th>Good</th>
<th>Excellent</th>
<th>Unable to evaluate</th>
<th>Not applicable to this option</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>UTE</td>
<td>NA</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>ITWC Project</th>
<th>Rehabilitation and Closure</th>
<th>Constructability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Option Description</th>
<th>Revegetation</th>
<th>Radiation</th>
<th>Erosion</th>
<th>Water Quality</th>
<th>Tailings</th>
<th>Schedule</th>
<th>Construction Occupational Health &amp; Safety</th>
<th>Construction Environmental and Cultural Risks</th>
<th>Construction Complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPTION 1C: Brine injection; thickened tailings Mill to 2016</td>
<td>4</td>
<td>UTE</td>
<td>UTE</td>
<td>UTE</td>
<td>UTE</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>OPTION 2C: Brine injection; thickened &amp; filtered Mill to 2016</td>
<td>4</td>
<td>UTE</td>
<td>UTE</td>
<td>UTE</td>
<td>UTE</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>OPTION 3C: Brine crystallisation; thickened tailings Mill to 2016</td>
<td>4</td>
<td>UTE</td>
<td>UTE</td>
<td>UTE</td>
<td>UTE</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>OPTION 4C: Brine crystallisation; thickened &amp; filtered Mill to 2016</td>
<td>4</td>
<td>UTE</td>
<td>UTE</td>
<td>UTE</td>
<td>UTE</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>OPTION 5C: Brine injection; thickened tailings Mill to 2016; water treatment 2026 - 2030</td>
<td>4</td>
<td>UTE</td>
<td>UTE</td>
<td>UTE</td>
<td>UTE</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>OPTION 1B: Brine injection; thickened tailings Mill to 2020</td>
<td>4</td>
<td>UTE</td>
<td>UTE</td>
<td>UTE</td>
<td>UTE</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>
**Fit for Purpose**

Some individual components of all of the strategies have residual uncertainties when assessed against the Proven Technology criterion. For example, for the brine injection options, uncertainties remain about the possible impact on performance arising from reactivity between the brine and the rocks of the underfill, particularly with the fines. Similarly, deposition of filter cake by dry stacking has been used successfully elsewhere but not in a mine pit and co-disposal has been used in the coal industry but with varying levels of success. Nevertheless, all of the technologies of tailings thickening, filtration, salt crystallisation and brine injection are well proven technologies and all options were assessed as being acceptable at the strategic level against this criterion.

As noted in the ranking definitions for individual program assessments, the Technical Performance of an option is to be judged against the effectiveness of the option in achieving its technical objective and its robustness to variations in feed and consumables but, for the overall project assessment, performance is to be judged against effectiveness of the option in maximising the uranium processed at Ranger in the remaining years before closure while still meeting all closure requirements. Adoption of any of the options that include cessation of milling in 2016 would result in a significant loss of uranium production. For this reason, all of these options were ranked as poor against this criterion. Option 1B, however, was ranked as good since its adoption would enable milling until 2020.

Most of the options were assessed as being robust with respect to the mill closure date but for the Crystallisation options (3C and 4C) some water storage infrastructure changes would be needed and additional salt storage would need to be identified if milling were to be extended beyond 2016.

With respect to sensitivity to rainfall extremes, Brine Injection and Thickening (1C) is very robust until about 2021 because contingency storage for both pond and process water has been included in the design of the strategy but sensitivity increases after 2021 when recovery of process water arising from consolidation of tailings in Pit 3 commences. Management options include increased storage or additional treatment. The situation would be similar for options 5C and 1B but with minor variations.

The adoption of tailings filtration would certainly introduce considerable sensitivity to extremes of rainfall since the pit would need to be kept dry and it may be necessary to stop placement during rainfall. This could result in cessation of upstream operations. However, it was assessed that management options would be available and an acceptable rating was recorded.

This assessment was reviewed after the workshop. At the earlier tailings management BPT workshop, filtration options were considered unacceptable against the robustness criterion because they were assessed as requiring the maintenance of dry conditions and, therefore, their use would be limited to the dry season. At the preliminary strategies workshop it was noted that the TSF would be available while the filter plant is in operation and, therefore, all the water in the pit that could not be placed into RP2, RP5 or RP6 could be directed to the TSF. In this way Pit 3 could be be returned to a dry condition rapidly after rain. It was on this basis that the assessment was revised to acceptable. On review, it was assessed that the availability of the TSF implies that the sensitivity of filtration options to extremes of rainfall could be managed to some extent but that sensitivity still remains and these options would remain less robust that the brine injection options. A revised rating as poor would be appropriate rather than acceptable. The rating allocated at the
workshop has not been changed but this issue should be taken into account in the decision making process.

The crystallisation options were similarly assessed with respect to rainfall sensitivity. The overall assessment was that all options would be rated as acceptable under the Robustness criterion.

Deposition of thickened tailings in pits is considered to be standard practice elsewhere in the world so option 1C would be rated as acceptable against the Environment Protection criterion on this basis. However, the standard brine management practice adopted elsewhere is precipitation and placement of insoluble salt within the tailings mass. Hence the use of brine injection to a geologically tight repository below the tailings and effectively isolating the salts from the environment for about 10,000 years would be considered best practice. The overall assessment of the Brine Injection and Thickened Tailings option (1C) was therefore assessed as good. The same rank was allocated to options 5C and 1B for similar reasons.

The use of tailings filtration prior to placement is considered to be best practice in general mining. However, in uranium mining it has been considered best practice to retain a level of moisture to control the radiation hazard but Europe is moving towards the adoption of tailings filtration in uranium mining. Overall the combination of Brine Injection and Tailings Filtration in option 2C was assessed as good for this criterion.

The use of brine crystallisation in options 3C and 4C led to an assessment of poor against the Environment Protection criterion because the location of crystallised salts at high elevations in Pit 3 is not considered to be consistent with standard environmental protection practice.

Under the CAPEX criterion, the three options that incorporate thickened tailings and brine injection (1C, 5C and 1B) were all rated as good because the additional infrastructure required for their implementation would be relatively minor. The adoption of either filtration or crystallisation with thickened tailings would, however, require a substantial capital commitment and hence these options (2C and 3C) were allocated a poor ranking. The adoption of both filtration and crystallisation (option 4C) would require a very high level of capital investment and was ranked as unacceptable against this criterion.

Operational Adequacy

Potential OHS risks had been identified for a number of components of each strategy during the previous workshops on tailings management and salt management options. Dredging, for example, is common to all strategies being considered and the risks associated with operating on water had resulted in a poorer risk rating in the earlier assessment; this is an issue that can be managed. Overall, the radiation exposure risks associated with filtered tailings are higher than those arising from the use of thickened tailings but it was assessed that these additional risks are manageable using standard safety practices and procedures. Hence all of the options that use brine injection and either thickened or filtered tailings (1C, 2C, 5C and 1B) were allocated a ranking of acceptable for OHS risks.

Options involving the use of brine crystallisation, however, were assessed as having additional risks arising from the radionuclide rich salt product, dust, and the very large number of vehicle movements. For these reasons, these options (3C and 4C) were ranked as poor. This ranking is recorded in figure 5(b). However, as noted in section 6.2, further health safety advice was sought later and it was agreed that this ranking should be reduced to unacceptable in further assessments. It is considered
unlikely that the bagging facility required for such an operation would receive regulatory approval.

For all strategic options under consideration, Operability was assessed as being an area that would not be problematic. Dredging, thickening and materials movement is common to all strategies and no abnormal operational issues have been identified for these programs. Brine injection has a relatively simple flowsheet. On balance, the brine injection and thickened tailings options (1C, 5C and 1B) are the least difficult to operate and they were assessed as being good against this criterion. The options involving filtration and/or crystallisation (2C, 3C and 4C) have more systems in operation, greater interdependence between system components and more complex scheduling requirements but these require normal levels of control in a mining operation. These options were assessed as acceptable.

Brine injection and thickened tailings processes have multiple redundancies built into their systems as do brine crystallisation processes. Filtration plants, however, have more interdependencies; they do have a degree of built-in redundancy through the use of multiple units but there is a sensitivity to the continuity of upstream processes such as the thickener or dredging system. These issues are subject to normal controls so the filtration options (2C and 4C) were assessed as being acceptable against the Availability and Reliability criterion and the other options were assessed as being good.

The principal maintenance issues for brine injection and thickened tailings options would be the ongoing maintenance of the vehicle fleet, the milling plant and water treatment plant. More trucks would be needed during the Pit 3 final fill than are currently available to move stockpiled material so the current aging fleet would be supplemented with additional new trucks. This increased demand for maintenance will be offset to a considerable extent by the reduction in maintenance of the plant after cessation of milling in 2016 or 2020. This maintenance demand is considered normal for a mining operation and the 1C and 5C options were assessed as acceptable under this criterion. Although the significance of these issues would be greater for the 1B option in which the plant and the fleet would need to operate until 2020, this would be assessed as an operational issue rather than a closure issue so a rank of acceptable was also attributed to the 1B option. Maintenance issues would be more significant if a crystalliser plant is established under options 3C and 4C but the team’s assessment was that the increased maintenance load would not be very significant and that a reduced ranking would not be justifiable on that basis. However, the increased maintenance load would be much more significant for a filtration plant because an additional trucking fleet would be required to haul the filter cake. If a conveyor is used it will still need to augment the existing trucking fleet rather than replace it since a conveyor does not have the flexibility to load and dump and reach the range of locations required. For these reasons, both options that include filtration (2C and 4C) were ranked as poor for this criterion.

In the assessment of options against the Operating Costs criterion, Option 1C was considered as the base case expenditure on the fleet, plant and personnel and it was allocated a ranking of acceptable. Additional costs associated with filtration options include those for replacement of cloths in the filter plant, running costs for the additional fleet and additional power expenditure. For option 2C, there could be a reduction in running costs if it is established that a second brine concentrator would not be needed but, it was assessed that this would not produce sufficient savings to prevent an allocation of poor for this option. A Crystalliser has associated with it large power requirements and higher personnel costs for trucking the salt to the pit; overall the operating costs would be higher than for option 2C but they were assessed as being roughly on a par with 2C compared to the other C options and it
was ranked equal to 2C. The combined additional costs associated with both filtration and crystallisation in option 4C led to a ranking allocation of unacceptable. Extension of water treatment until 2030 in option 5C would introduce ongoing operator costs for water treatment and power costs; this option was therefore ranked as poor compared to option 1C. Under option 1B, however, there would be a significant saving in the costs of water treatment since, under this scenario, water treatment costs up until 2020 would be attributed to the running costs of the milling operation rather than a closure cost. Option 1B was therefore, ranked as good under the OPEX criterion.

Rehabilitation and Closure

In assessing the options against the Revegetation criterion, it was noted that the revegetation trials have been carried out successfully at Ranger and that they provide a high degree of confidence that an ecosystem based upon local native species can be established. There is also confidence that, once the vegetation on the landform has been fully established, the long-term demands on maintenance will be low. The revegetation program will be common to all options so a ranking of good was recorded for each option, noting that there are concerns on scheduling that will be addressed under the appropriate criterion.

Modelling is underway to determine radiation exposure estimates for both members of the public and non-human biota. For both surface water and terrestrial exposure pathways, all options will have similar outcomes but differences in dose estimates are likely for the groundwater pathway since the differences in treatment and disposal of both tailings and salt will produce significantly different dispersion results for radionuclides contained in Pit 3. The results of all of the modelling programs will be required before assessments of radiation exposure can be completed. A UTE ranking was attributed to all options for the radiation criterion.

Similar comments apply to the assessments of the Erosion, Water Quality and Tailings criteria. A UTE ranking was allocated for all options for each of these criteria but a number of observations were made on extent to which differences may arise in the assessment of the various options against these criteria.

- The landform will be very similar for all options and, therefore, the erosion of the landform from both rainfall runoff and drainage and from stream flow will be similar for all options. This issue should therefore not affect the BPT assessment of options.

- Similarly, since the shape of the landform and its above grade constitution (i.e. grade-1 material) will be very similar in all options, there will, for most of the landform, be little difference in the water quality in nearby streams and water bodies for the various options. However, for surface water emerging from the vicinity of Pit 3, the options with thickened tailings will have greater short-term movement of water through the waste rock capping over the tailings and hence it is likely that poorer water quality may occur for these options.

- Consolidation modelling has shown that it is likely that there will be a significantly higher volume of water expressed from the tailings after 2026 for options with thickened tailings only than for the other options. This implies that continuation of process water treatment after 2026 would very probably be necessary if no treatment of tailings is applied after thickening.

It is clear from the above comments and earlier discussion, there will be difficulty in meeting the S41 scheduling requirement of completion of all rehabilitation and closure work by January 2026.
For option 1C, 6 years will be required for transfer of tailings from the TSF and about 5 years is required for settlement. Since transfer cannot commence until completion of the underfill in Pit 3 in 2015 at the earliest, it will be difficult to complete capping of Pit 3 by 2026 and there will be significant revegetation work required after capping is complete. There is also no advantage to be gained from compression of the timeline for tailings transfer from the TSF since consolidation would then take longer to achieve. Hence, Option 1C was assessed as *poor* under the Schedule criterion. Since the commissioning of the crystalliser does not have a significant impact on the schedule, Option 3C was similarly assessed as *poor* under the Schedule criterion.

The primary advantage arising from the adoption of tailings filtration would be that consolidation of tailings would not be required and this should assist considerably in meeting the 2026 requirement on completion of rehabilitation. Current scheduling estimates indicate that the filtration plant would need to be commissioned by 2015 but the schedule has not yet been confirmed and a UTE ranking was considered necessary until this work is complete. A similar conclusion was reached for Option 4C because it relies on use of tailings filtration.

The schedule assumptions for option 5C differ from those of 1C and are not directly comparable. A detailed schedule would need to be developed so a UTE assessment was recorded. It is clear that, to implement this option, permission would be required to operate a water treatment facility after 2026, but there would be significant environmental protection advantages if this were obtained.

Option 1B can be assessed as *poor* against the Schedule criterion because the scheduling problems associated with Option 1C would apply and there would also be a delay in revegetation of the Mill area of the site as well as the Pit area.

**Constructability**

The OHS risks associated with the construction phase of all of the options were assessed as being normal and a ranking of *acceptable* was recorded for each option.

For Option 1C, construction activities would be sequential and would, therefore, reduce the intensity of truck movements on the Arnhem Highway and the size of the transient workforce compared to other options. The intensity of construction activities would be similar to those currently (2012) underway. Construction of brine injection wells is expected to be inside the bund but injection sites need to be cleared through consultation to ensure that culturally significant zones are avoided. Cultural subsurface values (e.g. the dark rock area on the southern pit wall) will need to be managed. Overall, an assessment of *good* was recorded for the environmental and cultural risks associated with construction of Option 1C. Construction activities for Options 5C and 1B would be very similar to those for Option 1C so they were also ranked as *good*.

While there would be an increase in the construction workforce with the inclusion of a filtration plant in Option 2C, it was not considered to be very significant and all other construction activities would be similar to Option 1C. A ranking of *good* was allocated to Option 2C.

For Option 3C construction of a crystallization plant, filtration plant and an extra power station would be required. Other construction aspects are common to all strategies. However, the construction workforce and truck movements would be higher than for other strategies and an increase in community concern would be expected. A ranking of *acceptable* was allocated.
The complexity of the construction activities required for most options were assessed as normal for a mining operation and a ranking of acceptable was recorded for all options. However, the multiple construction requirements of Option 4C were assessed as being more complex and likely to introduce risks of schedule overrun and possible budget overrun. Option 4C was ranked as poor against the Construction Complexity criterion.

8.3 Overall assessment of the preliminary strategic options

The overall BPT scores recorded in the assessment of the preliminary strategic options confirmed the conclusions drawn in the salt management workshop that the options that include crystallisation of the brine stream from the water treatment plant are not viable strategic options for the ITWC project.

These options performed poorly in a number of criteria including living culture, technical performance, the standard of environmental protection achieved in an international comparison framework, occupational health and safety, maintainability and costs. For the combined crystallisation and filtration option, both operating costs and capital costs were ranked as unacceptable.

The overall BPT scores were -5 for crystallisation of salt and thickened tailings and -18 for crystallisation of salt and filtration of tailings. Following the workshop, a re-examination of the radiological safety issues that would arise in a brine crystallisation plant concluded that the significance of these issues had probably been underestimated and that it was unlikely that such a plant would receive regulatory approval. Hence, it is likely that the overall scores could have been even lower. Compared to the overall results for the various brine injection strategies, which scored up to a ranking of +22, the conclusion has to be drawn that crystallisation of the brine stream could not be considered to be a process that could be included in a best practice strategy for rehabilitation and closure of the Ranger Mine.

The remaining option that includes the treatment of tailings by filtration (Option 2C with filtration and brine injection) had an overall score that was positive; that is, it achieved an overall assessment that was better slightly better than acceptable. However, it was ranked as inferior to the thickened tailings base case, Option 1C, in the criteria on capital expenditure, maintainability and operating costs. The comparison of overall scores achieved by options 1C and 2C shows that brine injection and thickened tailings is preferred over brine injection with both thickened and filtered tailings by a margin of +15 to +5. If permission could be obtained to treat expressed process water after 2026 (Option 5C) the use of filtration to prevent tailings settlement would not be necessary. It was concluded that filtration of tailings should not be considered further in the development of the best practice strategy for rehabilitation and closure of the Ranger Mine.

For these reasons, the options to be brought forward to the final BPT assessment workshop should be:

- Option 1C; brine injection, thickened tailings, milling until 2016
- Option 5C: Option 1C with water treatment 2026 – 2030
- Option 1B: Option 1C with milling to 2020

However, it would be logical to then consider the extension of water treatment for the case of milling until 2020.
Areas identified at the workshop for which additional information would be needed before the conduct of the final workshop included:

- Expected workforce numbers in later years to enable social impact assessment;
- Radiation dose assessment for people accessing the rehabilitated landform;
- Modelling of erosion of the rehabilitated landform;
- The effect of solute transport on off-site surface water quality;
- Long-term dispersion of solutes in groundwater;
- Scheduling details for some aspects of individual strategies; and
- Ongoing assessment and testing of brine reactivity with waste rock of the underfill.

The absence of the above information had no impact on the decision to exclude filtration and crystallization options from further consideration because most of the above issues are common to all options and the rankings allocated to each option against these criteria would be the same.
9. **Overall Strategy for the ITWC Project – Final Assessment**

9.1 **Status of the BPT assessment**

Prior to the final assessment workshop on BPT for the ITWC, a summary was prepared of the major conclusions drawn from the BPT assessment process to that point. The intention was to clarify the principal issues that would need to be addressed in the final workshop to ensure that participants could reach an informed conclusion on the best strategy for rehabilitation and closure of the Ranger Mine.

The BPT assessment process has demonstrated that the principal issues that need to be addressed in a successful rehabilitation strategy are:

- Disposal of the salts contained in the brine stream from the water treatment plant
- Transfer, treatment and disposal of tailings from the TSF and from the mill to Pit 3

An extensive analysis has been carried out of options for disposal of the salts in the brine stream. This analysis clearly demonstrated that BPT for disposal of the salts is to inject the concentrated brine into the underfill at the base of Pit 3 and to cover this with the tailings from the TSF and the mill. This procedure will ensure that the salts, metals and radionuclides contained in the brine stream will be isolated from the surface water environment for about ten thousand years.

The only issue that has been identified that could threaten the viability of the brine injection technology is the potential for chemical reactivity between the brine and the waste rock of the underfill. This could result in reduced porosity and could eventually reduce the void volume available for brine storage. Screening of all waste rock before placement in the pit was identified as possible solution but was rejected partly because it was considered unnecessary but also because its adoption would result in the placement of fines at a high level in the Pit. (Recent brine reactivity testwork conducted with Ranger waste rock samples and synthetic brine has not identified any fatal flaws for the brine injection proposal. Additional work on cooling, compressibility and hydraulic conductivity has confirmed sufficient storage exists within the Pit 3 underfill to contain the forecast life of mine brine production (2GL). However, the total brine storage capacity within the underfill is proving to be less than the theoretical value (3GL) determined during the PFS.)

The ‘base case’ that has emerged from the BPT assessment of options for the transfer, treatment and disposal of tailings from the TSF and from the mill to Pit 3 is deposition of thickened tailings in Pit 3 above the brine repository. The main issues that arose from consideration of thickened tailings option were:

- The time required for transfer of tailings from the TSF and tailings settlement imply that, if no further ameliorative measures are possible after January 2026, it is highly likely that surface water criteria will not be met as a result of process water expression from the settling tailings and from the movement of water through the waste rock cap above the tailings in Pit 3.
- Capping of Pit 3 will only be completed in 2025 under that scenario and, as a result, there will be significant revegetation work required after January 2026.
- The potential for long-term environmental and human impact arising from the dispersion of tailings constituents (including salts, metals and radionuclides) from the tailings mass to the surface water system remains to be fully
assessed. Final groundwater modelling results were expected to be available at the final BPT workshop.

At the time of the workshop, it was considered that the adoption of tailings filtration would have an impact on the first two of these issues. However, the BPT analysis has shown that it was ranked as inferior to the thickened tailings base case in the criteria on capital expenditure, maintainability and operating costs. The cost differential would not be small; for example, the capital cost would be expected to be about $200M. It was assessed that the costs of filtration could not be justified on the basis of the limited environmental gains to be made if there is an alternative solution to the process water expression issue. (Detailed solute transport modelling subsequently demonstrated that filtration has a small environmental benefit that diminishes very quickly.) The conclusion reached was that the best outcome for surface water quality was likely to emerge from the use of process water treatment for as long as proves to be necessary. (This conclusion was not supported by the outcomes of the final assessment as discussed in the following section.)

The issue of possible long-term impact arising from dispersion of contaminants in groundwater was assessed in the first BPT workshop in which options for tailings treatment were assessed. It was assessed that filtration might limit dispersion of solutes in groundwater to some extent through a reduction in tailings permeability but that the advantage would be small. However, a much more effective method of reducing groundwater dispersion of solutes was considered to be cementation. Earlier trials had demonstrated that cementation could result in a significant reduction in the long-term transport of solutes from the tailings repository but this had not been demonstrated for the currently proposed process and further trials would be required. Moreover, capital costs would be high because of the need to include filtration as a preliminary step and operational costs would be extremely high as a result of the high cement consumption implicit in the process. The overall conclusion reached was that if, when completed, the groundwater solute transport modelling demonstrated that there would be a risk of environmental and human impact arising from dispersal of contaminants from thickened tailings, consideration of alternative neutralisation methods would be required rather than implementation of the full cementation process. It was decided to implement a desktop study on this possibility.

An issue that emerged during the BPT assessment process is the potential for ecological impact arising from the drainage of rainwater through the waste rock that will form the final above-surface landform and by the movement of water through the waste rock cap on Pit 3 resulting from settlement of the tailings. This issue arises from the expectation that the closure criterion for Mg in Magela Creek could be as low as 3 mg/L. Preliminary solute transport modelling demonstrated that concentrations of Mg in Magela Creek will probably exceed this value at times of very low flow after the wet season unless management actions are implemented. While water treatment would be an option for some period after completion of the final landform, such treatment could not be a permanent or long-term activity after rehabilitation.

It was concluded that this issue would require further assessment if the final solute transport modelling confirmed these early results. A thorough review of the potential for impacts arising from elevated Mg concentrations during recessional flows and the basis of the current provisional trigger values for Mg in the waters of Magela Creek would be required and an assessment would be needed of what measures could be taken to minimise environmental detriment within the context of BPT.
9.2 Strategic Options in the Final Assessment

As summarised in section 8.3, the conclusion at the end of the preliminary strategic BPT workshop was that the options to be addressed in the final workshop would be:

- Option 1C; brine injection, thickened tailings, milling until 2016
- Option 5C: Option 1C with water treatment 2026 – 2030
- Option 1B: Option 1C with milling to 2020, and
- Option 5B: Option 1B with water treatment 2026 – 2034.

Options 1C and 1B have been fully described in section 8.3, table 4 and Appendix 2. Option 5C has also been described in these sections but there was a significant change in its description between the version described for the preliminary strategic workshop (Appendix 2 and Table 4) and the final workshop. The primary reason for the inclusion of a second brine concentrator in the flowsheet for option 1C was that it was considered impossible to meet the closure completion deadline of 2026 without additional treatment capacity for process water. However, it was recognised that if an extension beyond the 2026 deadline could be negotiated the introduction of a second brine concentrator could be avoided at a very significant savings to the Capital budget of over $200M.

Hence, for the final strategic BPT workshop, the scope of option 5C was revised to exclude the purchase and implementation of a second brine concentrator. The key events for the revised version of option 5C remain as shown in table 4 but the process water storage volume required in RP7 would need to be increased substantially.

Strategy 5B was very similar to Strategy 1B except that it included an extension of water treatment until 2033. The key differences from the 1B Strategy are:

- Water is treated until 2033 by microfiltration reverse osmosis and the brine concentrator.
- Only one Brine Concentrator system is used for process water treatment and the process water storage volume in RP7 is increased substantially
- Pond and process water storage ponds (RP2 and RP7), power supply and some offices (at reduced size/capacity) remain until the end of 2033.
- Remaining facilities are buried in the ponds and the ponds reshaped and re-vegetated in 2034.
- Pit 3 earthworks take place as in 1B. Revegetation of Pit 3 can occur over 2026.

9.3 Final BPT Analysis of the Strategic Options

The results obtained in the final BPT analysis of the strategic options are shown in table 6(a) for the cultural criteria and for protection of people and the environment during the operational phase, in table 6(b) for the fit for purpose and operational adequacy criteria and in table 6(c) for the rehabilitation, closure and constructability criteria.

An initial general comment on the assessment outcomes is that there was found to be little difference between the options for many of the criteria. This is not surprising
because the most significant differences between potential rehabilitation and closure options (for example tailings filtration, salt crystallisation and salt distillation) were eliminated in the preliminary strategic BPT workshop. The strategies that remained for assessment in the final workshop differed only in the date for cessation of milling and the time period over which water treatment would be carried out.

**Traditional Owner Culture and Heritage**

The criteria for Living Culture were assessed under the following three broad issues:

- Economic value of the land to Traditional Owners
- Timing of access to land, and
- Extent of contamination or degradation

The economic value of the land is considered to include its use for traditional economic purposes such as the growing of traditional food species, the harvesting of plants for traditional medical practice, and the use of plants for the fabrication of fibres, tools, art and dyes.

It is our understanding that the TOs do not currently believe that the land will return to a condition that would enable them to use land for cultural activities. If that were to be the final outcome, the economic value of the land would be reduced.

Steps that are being taken to address this issue include:

- Species for revegetation are being chosen in consultation with TOs to ensure that they will support traditional cultural practices while still being suitable on ecological grounds.
- While it is recognised that certain food species may be need to be excluded to reduce the potential for radiation exposure, any reduction in such species will be optimised based on radiation dose assessments.
- The development of closure criteria (sediment and water quality) will include assessments to ensure protection of the economic value of the aquatic foods and plants.

It is believed that the above actions should ensure an *acceptable* outcome can be achieved for all currently considered options for the economic value issue.

With respect to the timing of access to the land by Traditional Owners, cessation of milling in 2016 would provide confidence that the site is entering a genuine closure period. This could make access to the peripheral areas of the site (e.g. riparian zones) more attractive. It is ERA’s impression that, from this perspective, the TOs would prefer options that include cessation of milling in 2016 to those that involve mill closure in 2020. However, the reality is that this perception is not likely to affect traditional practices and it is likely that access will not occur for many years. For this reason, all options were assessed equally and were rated as *acceptable* for this issue.
Table 6(a) BPT assessment matrix for the final assessment of strategic options under categories Culture & Heritage and Protection of People and the Environment during the Operational Phase

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<tr>
<th>BPT FINAL ASSESSMENT</th>
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<td>Option Description</td>
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<td>Community Health &amp; Safety</td>
<td>Town/Region</td>
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Table 6(b) BPT assessment matrix for the final assessment of strategic options under categories Fit for Purpose and Operational Adequacy

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Table 6(c) BPT assessment matrix for the final assessment of strategic options under categories Rehabilitation & Closure and Constructability

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<tr>
<td>Option Description</td>
<td>Revegetation</td>
<td>Radiation</td>
<td>Erosion</td>
<td>Water Quality</td>
<td>Tailings</td>
<td>Schedule</td>
<td>Construction Occupational Health &amp; Safety</td>
<td>Construction Environmental and Cultural risks</td>
<td>Construction Complexity</td>
</tr>
<tr>
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<td>3</td>
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<tr>
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The quantity of tailings left at the site and the quality of water on and near the site are the issues that dominate the perception of TOs on the extent to which the site is contaminated.

Currently, the perception of TOs is that less milling leads to less tailings being left behind and therefore a lower risk to the environment. This in turn would lead to a higher likelihood of accessing the land. The reality is, however, that contamination associated with grade-2 waste rock is likely to be more significant than that associated with tailings. Since more grade-2 material would be milled under a 2020 mill closure scenario, the 2020 mill closure options should be favoured by TOs from this perspective. This perception issue can be addressed through consultation.

The volume of process water left in Pit 3 under all options will be the same but the timing of water expression is different. The perceptions associated with the process water as a source remaining in the pit are (a) that it creates a hazard for the riparian zone, and (b) there is more volume in the 1C & 1B cases compared to the extended water treatment cases (the 5C & 5B cases). This (as described later in the discussion under the Water Quality and Tailings criteria) is no longer forecast to be the case. These perceptions need to be addressed through consultations with the TOs.

Under both 1C and 1B options no pond water treatment would be available to treat poor quality water from the landform seepage post 2025. Poor quality water discharging from the landform will reduce the TOs comfort with accessing and using the riparian zones. Therefore the 1C and 1B options would be less favoured from this perspective.

The TOs expectation is that Djalkmarra Billabong will be reinstated to a condition allowing beneficial use. Therefore, reinstatement of the billabong will score favourably but this is common to all options in their current form. (It should be noted that removal of the reinstatement of Djalkmarra Billabong from the final landscape design is raised as one of the possible measures to address water quality issues in the discussion on Solute Transport later in this section.)

The overall assessment under the Living Culture criterion was that traditional practices and ceremonies or for the collection of bush tucker, bush medicines and similar practices would generally be available with limited restrictions on places to visit and length of stay. There would be little variation between the different options considered in the final assessment except those that enable extended pond water treatment would be favoured. However the advantages gained from extended pond water treatment were not considered to be sufficient to change the relative ranking of the options. All options were assessed as acceptable.

In assessing the Cultural Heritage criterion, it was noted that there are no sites of significance or heritage items in the footprint of the reconstructed landform and rehabilitated areas. All activities will be within the cultural heritage exemption zone and this is common to all options. All options were rated as acceptable. In reaching this conclusion, it was noted that agreement has been reached with the GAC for the management of the previously excavated "dark" material during backfilling of the pit. This issue is also common to all options.

**Protection of People and the Environment during the Operational Phase**

For community health and safety during closure operations, dispersion of radionuclides in dust is an issue that is common to all options but it was assessed that the risks should be readily managed using normal operational controls as practiced under current operations. For radon emanation from the tailings, the high
water content will ensure that emanation rates are low. All options were ranked as good from the community health perspective.

In the relative assessment of the potential for socio-economic impacts on Jabiru and the region, Strategy 1C was considered the base case and was allocated a rating of acceptable. Both extended milling options (1B and 5B) are considered to have positive benefits to the community and region arising from royalty streams (payment amount and extended time over which royalties would be paid), additional time for community partnerships to run, and the extended period over which the local population remains high will lead to continued retention of services (private businesses, health services, power supply etc.). The benefits are considered significant enough for the allocation of a rank of good for both options 1B and 5B. Extension of the period over which water treatment occurs does not have any socio-economic impact and does not affect the ranking. An estimate has been made of workforce numbers required during closure operations and, for all options, they are smaller than current construction force. Hence, there should be no resulting adverse socio-economic impact.

During the closure operational phase, the pathways for potential impact on the ecosystems of Kakadu National Park and the risks associated with these pathways would be very similar to those that are present during current operations. Hence, with similar management procedures and practices, it was assessed that the high level of environmental protection currently being achieved, as demonstrated in all of the ERA and SSD monitoring programs, should continue until closure is complete. A ranking of good was attributed to all options. Impact on ecosystems of the Project Area during the closure operational phase should also be similar to that occurring now because there are no greenfield disturbances planned for any option and disturbance within the disturbed area would be similar for all options. A rank of acceptable was recorded for all options.

**Fit for Purpose**

The technology associated with the major components (dredging, pumping, thickening, and brine injection into sub-surface repositories, landform reconstruction) of each of the options is well proven technology and would clearly be assessed as acceptable against the proven technology criterion. Indeed, in many cases the technology has been proven at a range of sites. Thus, the underground injection of highly saline fluids is common in the oil and gas industries, tailings reclamation by dredging has been carried out at many mine sites (including at Ranger on a small scale), and tailings thickening is common practice at mine sites including at Ranger in current operations. For these reasons, each option was assessed as good against this criterion. The potential for reactivity between brine and waste rock is one area where proven technology could be questioned but this issue is no longer considered to be of great significance because the available void volume in the underfill is much greater than the total projected brine volume.

For the overall project assessment, the Technical Performance of an option is to be judged in terms of its effectiveness in maximising the uranium processed at Ranger in the remaining years before closure. The original choice of 2016 as the date for mill closure was made because it was expected that all economically viable ore would have been processed by this date. Thus both options with this closure date should be ranked as good against this criterion. Any decision to continue milling until 2020 would only be made if the processing of lower grade ores is now considered to be economically viable. Hence, the two options that involve milling until 2020 were ranked as excellent against this criterion.
(It should be noted that the current rankings for Option 1C against the Proven Technology and Technical Performance criteria are higher than that recorded for option 1C in the preliminary workshop. The current rankings were reviewed after the workshop and were considered to be appropriate. Since the previous lower ranking disadvantaged Option 1C relative to other options, there is no need to revisit the rejection of the other options in the preliminary workshop assessment.)

As recorded during the preliminary strategy workshop, Strategy 1C (Brine Injection and Thickening) is very robust in its sensitivity to high rainfall extremes until about 2021 because contingency storage for both pond and process water has been included in the design of the strategy but sensitivity increases after 2021 when recovery of process water arising from consolidation of tailings in Pit 3 commences. Management options include increased storage or additional treatment and the risk of exceeding storage capacity will be low. The situation would be similar for Strategy 1B but with minor variations.

For the extended water treatment options 5B and 5C, process and pond water ponds would operate over a much longer period and this would give rise to an increased risk of exceeding storage capacity. This risk can be managed through forecasting and appropriate design and choice of both storage and treatment capacity and it was assessed that the robustness of the extended options would not be significantly different from that of options 1B and 1C. It was assessed that all strategies are robust to very low rainfall extremes since management options such as cessation of treatment would be readily available. All options were ranked as acceptable against the robustness criterion.

Deposition of thickened tailings in pits is considered to be standard practice elsewhere in the world. There are, however, examples where above ground disposal of tailings is adopted and there are few places where a requirement for the containment of contaminants from tailings for 10,000 years applies. For brine management, the standard practice adopted elsewhere is precipitation and placement of insoluble salt within the tailings mass. Hence the use of brine injection to a geologically tight repository below the tailings and effectively isolating the salts from the environment for about 10,000 years would be considered best practice. The overall assessment of the long-term brine and tailings management practices adopted in all of the options being considered in the final workshop was that they are of a similar environmental protection standard to the best examples adopted elsewhere in the world and they were, therefore, assessed as good for the Environment Protection criterion.

In the preliminary strategy workshop, the additional infrastructure demands of option 1C were assessed as relatively minor compared to those required for filtration and crystallisation and it was allocated a rank of acceptable under the CAPEX criterion. The same ranking was allocated to options 1C and 1B in the final workshop. Nevertheless, in a comparative sense, adoption of either of the extended water treatment options, 5B and 5C, would result in a very significant net saving ($100M - $200M) since, although capital expenditure on enhanced storage capacity would be required, this would be more than counteracted by the savings associated with one less brine concentrator system. These options were, therefore, ranked as good under this criterion.

**Operational Adequacy**

Potential OHS risks had been identified for a number of components of each strategy during the previous workshops on tailings management, and salt management and the preliminary strategies. It was noted, for example, that dredging is common to all strategies being considered and the risks associated with operating on water had
resulted in a poorer risk rating in the earlier assessment; this is an issue that can be managed. The radiation exposure risks associated with thickened tailings are low and are manageable using standard safety practices and procedures. Overall, the OH&S risks associated with all of the options are considered normal for any mining operation and can be managed by the adoption of standard practices. Hence all of the options were allocated a ranking of acceptable for OHS risks.

Operability was assessed as being an area that would not be problematic for any of the strategic options being considered. Dredging, thickening and materials movement is common to all strategies and no abnormal operational issues have been identified for these programs. Brine injection has a relatively simple flowsheet. All options were assessed as readily controlled and stable and were, therefore, ranked as good.

As noted in the preliminary strategies workshop, brine injection and thickened tailings processes have multiple redundancies built into their systems and hence performance would not be unduly affected by single plant item failures. This also applies to the process water management systems in all options, including those with only one brine concentrator system. All options were ranked as good against the Availability and Reliability criterion.

The principal maintenance issues for all options would be the ongoing maintenance of the vehicle fleet, the milling plant and water treatment plant. Any increased demand for maintenance compared to current levels will, on the whole, be offset to a considerable extent by the reduction in maintenance of the plant after cessation of milling in 2016 or 2020. Thus, for operations until 2026, maintenance demands have been assessed as normal for a mining operation and options 1B and 1C were ranked as acceptable under this criterion. However, for the extended water treatment options, maintenance demands for the brine concentrator systems will become an issue. For the 5C option, the extension of operation of the BC system over normal expectations will be about four years. While increased maintenance is likely, the increase was not assessed as being highly significant and the rank remained as acceptable. For option 5B, however, the expected operational life of the brine concentrator system would be extended by about nine years. The maintenance demands of such an extension would probably be highly significant including the replacement of major components, and the 5B option was assessed as poor under the Maintainability criterion.

In the assessment of options against the Operating Costs criterion, option 1C was considered as the base case for expenditure on the fleet, plant and personnel and it was allocated a ranking of acceptable. For option 1B, the additional operational costs associated with running the mill until 2020 were considered as being attributable to uranium mining operations rather than closure costs; these costs would be included in the assessment of the viability of processing lower grade ores. Hence, option 1B was allocated a ranking of acceptable under the OPEX criterion. The increased human resource costs associated with operating a second brine concentrator in options 1B and 1C would be offset to a considerable extent by the increased maintenance costs associated with the extended operating life of the brine concentrators in options 5B and 5C. However, it was assessed that the increased costs associated with replacement parts for the brine concentrator during the nine year extended operation of the brine concentrator in option 5B required a downgrading of its rank under this criterion to poor.
Rehabilitation and Closure

Revegetation

In assessing the options against the Revegetation criterion, it was noted in the preliminary strategies workshop that the revegetation trials have been carried out successfully at Ranger and that they provide a high degree of confidence that an ecosystem based upon local native species can be established. There is also confidence that, once the vegetation on the landform has been fully established, the long-term demands on maintenance will be low. From an ecological perspective, therefore, current options were ranked as good against the Revegetation criterion.

It is also worth noting that the specific concerns of Traditional Owners on aspects of the revegetation program are also being addressed through measures outlined in the discussion on the Living Culture criterion. In the ongoing development of the revegetation program, it will also be necessary to address some of the other issues raised in section 7 of this report. These include ensuring a high level of weed control, the need to broaden the provenance of species included in the program, and social issues including the provision of employment opportunities to members of the local community. In the context of weed control, an issue not previously captured is the potential for gamba grass invasion from the park and related fire risks that could result in a reduction of plant diversity. Management plans will be needed for these issues.

Radiation

Estimates of radiation exposure from the rehabilitated landform were not sufficiently advanced at the time of the preliminary strategies workshop to enable an assessment to be made against the Radiation criterion. For the current assessment, ERA prepared a semi-quantitative estimate of radiation exposure based upon an assumed occupancy model involving persons who live at a camp located about 2 km from the rehabilitated site and who spend about eight hours each day in hunter gatherer activities on the site. These occupancy assumptions are considered very conservative. The model provided an estimated dose of about 2 mSv per annum to members of such a group. If this estimate were to be confirmed by detailed modelling, doses received by members of the public could be adequately maintained below the public dose limit with limited restrictions on access to sections of the rehabilitated landform. Hence, while noting that more detailed modelling will be required, a rank of acceptable was recorded against the Radiation criterion for all options.

It is understood that estimates of radiation exposure from the rehabilitated landform at Ranger will shortly be published by the Supervising Scientist Division (SSD) and that these estimates are well below the public dose limit of 1 mSv per annum.

Erosion

At the time of the preliminary strategies workshop, no results were available from the SSD project, commissioned by ERA, on erosion of the final landform at the Ranger site. At the final strategy workshop, results were presented (Lowry et. al. 2012) on the first stages of this project in which modelling of the erosion of the landform in the region of Pit 1 has been carried out. These results enabled an initial assessment to be made of the significance of erosion for the currently proposed final landform for the whole site.

The modelling has shown that while denudation rates will probably be an order of magnitude greater than natural rates in the early years following rehabilitation, they are expected to decrease gradually to values that are comparable with natural rates provided a good vegetation cover is present. Also, while gully formation could be...
significant in areas of the landform where high gradients are present initially, gully formation should not occur on a well vegetated, low gradient landform. While recognising that much more extensive modelling is required, the current assessment is that erosion of the final landform should, for all options considered, rank as acceptable against the Erosion criterion.

**Solute Transport**

At the final BPT workshop, a presentation was given on the three dimensional modelling of groundwater in the vicinity of Pit 3, its integration into a surface water flow model, and the dispersion of conservative solutes from both tailings and waste rock to Magela Creek. Full details on these modelling results will be presented elsewhere; only the key outcomes are summarised here.

The key hydrogeological feature of the Pit 3 region is the existence of a sand lens between Pit 3 and Magela Creek at the north east corner of the Pit. Recent drilling has confirmed that this lens extends to a depth of about 30m Modelling has now shown that this sand lens would provide the main pathway for the transport of solutes originating in both the waste grade-2 rock in the Pit 3 cover and in the tailings.

Throughout most of the period of flow in Magela Creek, the pressure gradient is from the surface to the groundwater and hence there is no dispersion of solutes to the creek from underground sources. However, in the months of recessional flow after the annual wet season there is a short period before cease-to-flow during which the flow gradient is reversed; it is during this period that solutes arising from subsurface sources can reach the Creek.

Results obtained from solute transport modelling indicate that concentrations of Mg in Magela Creek during this recessional period are expected to gradually increase during the first few hundred years following rehabilitation and reach a plateau after about 300 years. From 300 years onwards, the maximum concentration of Mg in creek waters each year is expected to be in the range 10-100mg/L and the peak monthly average concentration is expected exceed 10mg/L about once in five years.

At the time of the final BPT workshop, full results were not yet available on transport of radionuclides and other non-conservative solutes. However, it is expected that there will be little or no attenuation of non-conservative solutes in the sand lens and initial estimates on the transport of uranium indicate that concentrations of uranium in Magela Creek may reach values around 1mg/L during the recessional period after about 300 years.

Potential mitigation measures to address these solute transport issues were identified at the workshop. These included a cut-off wall within the sand zone, an impermeable barrier above the grade-2 material in the Pit, the introduction of reactive material in the sand zone and the rock cap to attenuate radionuclides, the removal of the proposed replacement Djalkmarra Billabong from the landform design and the implementation of engineering measures to ensure that any drainage of the subsurface region above Pit 3 occurs during the wet season rather than during the recessional period. While it was recognised that the full assessment of these measures will take some time to complete, it was concluded that some of the measures considered (for example, bentonite slurry walls) are well established and proven techniques and that there is a reasonable probability that a solution can be implemented at reasonable cost.
Water Quality

The Water Quality criterion refers to the potential impact on the surface waters of the region arising from the dispersal of solutes from the rehabilitated landform except from tailings. The latter issue is addressed under the tailings criterion. For the conservative solutes, the modelling shows that the contribution to concentrations in Magela Creek from waste rock is expected to be greater than that from tailings by a factor of about 3. Hence most of the Mg (and also the U) loads referred to above are relevant to this criterion.

The peak concentrations expected in Magela Creek during the recessional period are considerably higher than current uranium and provisional magnesium water quality objectives. These objectives are based on High Reliability Toxicity Values derived from chronic tests on Magela Creek species and are, therefore, considered to be highly appropriate. However, the flow in the creek during periods when the current objectives would be exceeded would be extremely low, less than 0.1 m$^3$/s, and connectivity to the downstream environment would be limited. The opportunity for exposure of aquatic animals of Kakadu National Park would, therefore, be limited and the predicted toxicity effects may not actually occur.

The closure criteria that will apply to rehabilitation of the Ranger Mine have not yet been agreed with the regulatory authorities. These criteria will be designed to meet the primary objectives specified in the Environmental Requirements; that is, maintenance of biodiversity and ecosystem health. The results obtained in the solute transport modelling highlight the need to ensure that the derived criteria are appropriate to the types of impact that could occur late in the recessional period of flow in Magela Creek.

The quality of water in Magela Creek and the billabongs on the Project Area will be determined by solute flows from the entire above-grade landform, not just the region of the landform above Pit 3. The solute transport model has yet to be applied to the entire landform and, given the results obtained from the modelling of the Pit 3 region, there may be significant management issues to be addressed. Water treatment could be an option in the short term but seepage may occur over many years. Metals may be attenuated through discharge pathways but there is no known passive management option for Mg.

In the light of all of these uncertainties, it was necessary to record a rank of UTE for all options under the Water Quality criterion. This was not a desirable outcome but, since the same assessment is likely to apply to all options when finally completed, this decision should not affect the outcome of the overall BPT assessment.

The decision to record a UTE ranking for all options against this criterion is considered to be technically correct but it should not be taken to imply that ERA does not consider the water quality issue to be a serious one. It is clear that, if no successful ameliorative measures are implemented to reduce solute transport through the sand lens, the impact on the environment would be unacceptable.

Tailings

In assessing the potential impact on the environment from tailings, the discussion focused on three potential transport pathways:

- expression of tailings pore water during the period of tailings settlement and its subsequent dispersal to the surrounding environment,
- shallow aquifer transport to the Creek through the sand lens between Pit 3 and Magela Creek, and
deep aquifer transport through bedrock to Magela Creek.

For pore water under the 1C and 1B strategies, recovery of expressed tailings water from Pit 3 will cease in April 2025 when the Brine Concentrators cease operation. Under this scenario the expression of water down into the underfill drain will quickly cease as the hydraulic gradient changes. Expression of tailings pore water upward into the waste rock backfill will continue for a few years but it has been demonstrated to have little impact on solute transport. The 1C and 1B scenarios assume two brine concentrators are present to treat all existing process water inventories.

Scenarios 5C and 5B assume that recovery of expressed water from Pit 3 continues until 2029 (5C) and 2034 (5B). The recovery of expressed water is required because the 5C and 5B scenarios use a single Brine concentrator to treat the existing inventory of process water. To continue to inject brine into the underfill, water must be extracted off the under bed drain. Modelling shows that expressed water has little impact on solute transport over the long term so both scenarios rank equally in that regard.

The existing volume of process water is treated in all scenarios. The 5C and 5B scenarios require recovery of tailings expressed water in Pit 3 to allow for brine injection. All Scenarios have the same environmental benefit in terms of treatment of the process water inventory. However, options 5C and 5B provide an opportunity to extend the duration of pond water treatment.

From this analysis it is clear that the potential for impact on the external environment from expressed pore water will be negligible in all scenarios. Hence the concern expressed previously (summarised in section 9.1) that water treatment facilities might be needed over an extended period to treat expressed pore water is no longer considered to be significant. This provides additional confirmation that the adoption of filtration as a treatment for tailings could not be justified.

The potential for impact on the environment arising from the transport of solutes contained in tailings water through the sand lens was discussed above. Although tailings would only be the source for about 25% of the concentration of conservative solutes in Magela Creek, the impact of magnesium is expected to increase gradually over the first few hundred years and would then continue for an extended period. The lack of radionuclide attenuation through the sand lens would lead to unacceptable surface water quality. In the absence of any viable options for modifications of option design to reverse this assessment, the rank allocated to the Tailings criterion would be unacceptable.

As discussed above, potential mitigation measures (a cut-off wall within the sand zone, an impermeable barrier above the grade-2 material in the Pit, the introduction of reactive material in the sand zone, etc) have been identified to address these solute transport issues. It was recognised that the full assessment of these measures will take some time to complete but it was concluded that there is a reasonable probability that a solution can be implemented at reasonable cost.

At the time of the workshop, modelling of the transport of solutes from the tailings mass to the surface environment through the deep aquifer had not been completed. However, as described in section 6, such modelling had been completed for dispersion of solutes through the deep aquifer from brine in the underfill and it was found that no impact would be expected over the next ten thousand years, even for conservative solutes. While it is recognised that there are a number of differences in the transport process from the tailings, these results provide a significant level of confidence that a similar assessment will be made for solutes, particularly radionuclides, originating in the tailings.
Hence, the principal risk to the environment from contaminants in the tailings was considered to be dispersion of solutes through the sand lens between Pit 3 and Magela Creek. Since a number of measures have been identified that could ameliorate the potential adverse effects and these measures have been demonstrated to be effective elsewhere, a rank of poor rather than unacceptable was recorded for the tailings criterion. This assessment applies to each of the options 1C, 5C, 1B and 5B.

Schedule

For Strategy 1C, all closure activities other than revegetation will be completed well in advance of the deadline of 9 January 2026. Initial revegetation of most of the site will also be completed on time but there will be an area of about 100 ha over Pit 3 for which the revegetation program will only begin in approximately October 2025. Initial planting of 1,000 stems/ha can be completed by end of 2025. However, infill planting will only be complete across the whole site by end of 2026 and understory planting of about half of the disturbed footprint needs is currently scheduled to occur over the period 2026 – 2027 and the whole program will be completed by 2028. Option 1C was ranked as poor against the Schedule criterion.

In the flowsheet for Strategy 1B, the timeline for rehabilitation of plant and the administration area is compressed compared to the 1C timeline and, as a result, there is not a significant difference in the revegetation timelines for the two options. Continued processing in the mill until 2020 is expected to produce an additional 10M tonnes of tailings compared to option 1C. The timing of tailings delivery to Pit 3 is not extended as tailings transfer from the TSF is still occurring. The timing for tailings consolidation and the date by which the tailings surface strength reaches the value required for backfilling is not significantly altered. The rank allocated under the Schedule criterion for option 1B was poor.

For both of the extended water treatment options, 5C and 5B, the infrastructure remaining on the site after January 2026 would be significant. It would include substantial water storage dams, a water treatment plant and a power station. Revegetation of areas already decommissioned would not be affected but, clearly, revegetation of the areas occupied by this infrastructure could not take place until 2030 and 2034 for options 5C and 5B respectively. Both of these options were, therefore ranked as unacceptable under the Schedule criterion. It was noted, however, that agreement to retain the required infrastructure on site after 2026 could possibly be negotiated under Clause 2.3 of the Environmental Requirements rather than requiring an amendment of the Atomic Energy Act. Legal advice would be required on this issue and it would need to be discussed with the Traditional Owners and the regulatory authorities.

Constructability

The OHS risks associated with the construction phase of all of the options were assessed as being normal and a ranking of acceptable was recorded for each option.

For Option 1C, construction activities would be sequential and would, therefore, reduce the intensity of truck movements on the Arnhem Highway and the size of the transient workforce compared to other options. The intensity of construction activities would be similar to those currently (2012) underway. Construction of brine injection wells is expected to be inside the bund but injection sites need to be cleared through consultation to ensure that culturally significant zones are avoided. Cultural subsurface values (e.g. the dark rock area on the southern pit wall) will need to be managed. Overall, an assessment of good was recorded for the environmental and cultural risks associated with construction of Option 1C. Construction activities for
Options 5C, 1B and 5B would be very similar to those for Option 1C so they were also ranked as good.

The complexity of the construction activities required for most options was assessed as normal for a mining operation and a ranking of acceptable was recorded for all options.

9.4 Overall assessment of strategic options and conclusion

As noted earlier, the difference between the options assessed in the final BPT workshop is much smaller than those in previous workshops and the number of criteria where differences were recorded is few.

The highest BPT score was recorded for Strategy 1B with a score of 19; the three other options scored 15. To put this result in perspective, changing the assessed score for any individual criterion by one unit would change the overall score for that option by about 2 units. Hence, these results imply that option 1B is the favoured option on the basis of the BPT assessment process but the result is marginal.

The criteria where differences were recorded were:

- Socio-economic impact on Jabiru and the region: the two extended options provide additional time for community partnerships to run and continued retention of services and the 5B case also provides additional royalty income.
- Technical performance: both 2020 options scored better because the extended milling period enables the processing of lower grade ores that were previously assessed as not being commercially viable.
- Capital Expenditure: the two extended options scored better primarily because only one Brine Concentrator is required for these options. (It should be noted that at the time of the preliminary strategies workshop, it was thought that these options would have the significant advantage of enabling the treatment of a greater volume of expressed pore water and hence would enable a higher degree of environmental protection. This is now known not to be the case.)
- Maintainability: the 2020 milling option with extended water treatment results in the use of the Brine Concentrator for nine years beyond its planned lifetime.
- Operating Costs: the operating costs of the extended 2020 option would also be higher because replacement of major parts would almost certainly be required.
- Schedule: Both extended options scored lower than the primary options under the schedule criterion.

A significant outcome is that, on the basis of this BPT assessment, the final choice of option will not alter the cultural or environmental significance since all options performed equally against the cultural and environmental criteria; all rankings against these criteria were either acceptable or good. There was, of course, one soft showstopper that was common to all options considered. This arose from the assessment that there could be significant environmental impact arising from dispersal of solutes, including radionuclides, from the tailings mass in Pit 3 unless the ameliorative measures identified at the workshop can be determined to be effective in preventing the dispersal of these solutes. This issue is being addressed in the Tailings and Brine Management Feasibility Study now underway.
The significance of four of the six issues listed above on which there were differences in the assessment of the options will be effectively incorporated in the detailed financial analysis of the options. The remaining two issues, regional socio-economic impact and the ability of options to meet expectations on the timing of closure, will undoubtedly be issues on which the Traditional Owners will provide significant input.

The overall conclusion of the BPT assessments carried out for the ITWC project is that the principal stages in the rehabilitation and closure program at Ranger should be:

- Establishment of a waste rock “underfill” at the base of Pit 3 with sufficient void space to accommodate all of the brine produced from treatment of process water at Ranger using a brine concentrator based water treatment system; waste rock would not be screened prior to placement in Pit 3.

- Following assessment of the potential mitigation measures for solute dispersion, mitigation measures that need to be implemented prior to tailings placement in Pit 3 (for example a cut-off wall within the sand zone) will be carried out.

- Prior to the commencement of tailings deposition in Pit 3, an underdrain will be established above the underfill to enable the pumping of expressed process water to the TSF.

- Tailings will be excavated from the Ranger TSF by dredging will be dewatered in a thickener, and will be deposited in Pit 3 using sub-aqueous disposal methods.

- Tailings from the Ranger Mill will also be deposited in Pit 3 by sub-aqueous deposition until the date of mill closure. This will probably be in 2020 following the processing of lower grade ore in stockpiles at Ranger.

- To prevent boiling in the pumping and storage infrastructure, the temperature of the brine emerging from the concentrator will be reduced using a heat exchanger. The brine will then be pumped to a directionally drilled injection system around the periphery of Pit 3. Injection points near the centre of the underfill via the underdrain will be installed if necessary. High pressure pumps would be available if the back pressure from the repository increases. Until the final brine management system is commissioned, the brine stream from the water treatment system will be directed to the TSF.

- On completion of all tailings disposal in Pit 3, the tailings will be capped using grade-2 material covered by grade-1 material to form the final cap on Pit 3. These works will include the installation of those mitigation measures (for example, impermeable layers over the tailings or grade-2 material) assessed as being essential to protect surface waters and groundwater from adverse impact arising from solute transport.

- Completion of the final landform, revegetation and ecosystem reconstruction, and ongoing water treatment as necessary.
10. References


Coghill 2010, “ERA Ranger tailings storage facility reclamation and transfer prefeasibility engineering study”, Rio Tinto Technology and Innovation report number 13309-6 Version 3.1, Coghill M., 16th April

Lowry, J., Coulthard, T., and Hancock, G., 2012. *Initial assessment of the geomorphic stability of the conceptual rehabilitated Ranger landform – Pit1,* Supervising Scientist Division, Darwin

Appendices

Appendix 1: BPT Criterion Descriptors and Ranking Definitions
<table>
<thead>
<tr>
<th>Ranking</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>Inadequate</td>
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<tr>
<td></td>
<td>Does not meet current standards &amp; modifications unlikely to affect this result</td>
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<tr>
<td>2</td>
<td>Poor</td>
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<tr>
<td></td>
<td>Does not meet current standards but modifications might reverse this conclusion</td>
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<tr>
<td>3</td>
<td>Acceptable</td>
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<td>Meets Current standards</td>
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<td>4</td>
<td>Good</td>
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<td></td>
<td>Option exceeds current standards</td>
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<tr>
<td>5</td>
<td>Excellent</td>
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<td></td>
<td>Option is Best Practice</td>
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</table>
# BPT Aspect Description

## Traditional Owner Culture & Heritage

<table>
<thead>
<tr>
<th><strong>Living culture</strong></th>
<th>Cultural practices, traditions and customs are an important part of life for Aboriginal people and communities; this is the living culture. This aspect considers the Traditional owners cultural practices and how these might be impacted by the option being considered. Included is access to country and the ongoing care of country including considerations such as bush tucker, bush medicine, flora and fauna, habitation sites, traditional ceremonies, dreaming sites. Note: health aspects of all members of the public including Aboriginal people are assessed under Community Health &amp; Safety.</th>
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<tr>
<td><strong>Option 1</strong></td>
<td>Under this option access to the rehabilitated landform would be severely restricted and would impair traditional practices and ceremonies, the collection of bush tucker, bush medicine and similar practices. Opportunities for ameliorating this assessment appear to be very unlikely.</td>
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<tr>
<td><strong>Option 2</strong></td>
<td>Under this option access to the rehabilitated landform would be significantly restricted and would impair traditional practices and ceremonies or for the collection of bush tucker, bush medicine and similar practices. However, opportunities for ameliorating this assessment have been identified and could be explored further.</td>
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<tr>
<td><strong>Option 3</strong></td>
<td>Under this option access to the rehabilitated landform for traditional beliefs, traditional practices and ceremonies or for the collection of bush tucker, bush medicines and similar practices would be available with limited restrictions on places to visit and length of stay.</td>
</tr>
<tr>
<td><strong>Option 4</strong></td>
<td>Under this option access to the rehabilitated landform for traditional beliefs, traditional practices and ceremonies or for the collection of bush tucker, bush medicines and similar practices would be available with no restrictions on places to visit or length of stay.</td>
</tr>
<tr>
<td><strong>Option 5</strong></td>
<td>Under this option access to the rehabilitated landform for traditional beliefs, traditional practices and ceremonies or for the collection of bush tucker, bush medicines and similar practices would be available with only minor restrictions on places to visit and length of stay.</td>
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<tr>
<th><strong>Cultural heritage</strong></th>
<th>Ranger Project Area contains sacred and archaeological places, sites and objects of significance. These form an important part of Aboriginal culture that has been practised for over 50,000 years. This aspect concerns the impact on such important cultural items.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Option 1</strong></td>
<td>The option disturbs or is perceived to disturb sacred and archaeological places, sites and sites of significance. The option interferes with access to these sites. Adoption of the option would be considered unacceptable to Traditional Owners and could result in legal challenge under heritage legislation.</td>
</tr>
<tr>
<td><strong>Option 2</strong></td>
<td>Adoption of the option could be perceived to disturb sacred and archaeological places, sites, and sites of significance and/or result in interference with access to these sites. Options have been identified that could ameliorate this assessment and are being investigated with Traditional Owners.</td>
</tr>
<tr>
<td><strong>Option 3</strong></td>
<td>The option does not disturb sacred or archaeological places, sites or objects of significance. The option provides for ongoing access to cultural sites by Traditional Owners.</td>
</tr>
<tr>
<td><strong>Option 4</strong></td>
<td>The option does not disturb sacred or archaeological places, sites and objects of significance and any disturbance associated with the option is remote from such sites. However normal routes to some sites may be subject to limited access restrictions resulting in discouragement of Traditional Owner cultural sites of significance.</td>
</tr>
<tr>
<td><strong>Option 5</strong></td>
<td>The option does not disturb sacred and archaeological places, sites and objects of significance and any disturbance associated with the option is remote from such sites. The option provides for ongoing access to cultural sites by Traditional Owners.</td>
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## Protection of People and the Environment during the Operational Phase
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<th>BPT Aspect Description</th>
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<td>Community Health &amp; Safety</td>
<td>This aspects assess potential impacts on the health and safety of Aboriginal and non-Aboriginal members of the local community. Such impacts could arise through radiation exposure or chemical exposure as a result of dispersion of contaminants through the atmosphere, surface water or ground water. All such exposures must comply with national and internationally accepted standards.</td>
<td>Estimates of the likely impacts on the health and/or safety of members of the local community show that internationally accepted standards will probably not be met. No options have been identified for appropriate modification of option design to ensure standards are met.</td>
<td>Estimates of the likely impacts on the health and/or safety of members of the local community show that internationally accepted standards will probably be met but the margin for error is small. Options have been identified for appropriate modification of option design that could ensure standards are met.</td>
<td>Estimates of the likely impacts on the health and/or safety of members of the local community show that internationally accepted standards will be met and options for additional control are available if needed in practice. The option will satisfy health and safety standards for members of the public.</td>
<td>The option poses no significant risk for the health and safety of members of the public and is established as best practice (from a health and safety perspective) in mines or other industries around the world.</td>
</tr>
<tr>
<td>Socio-economic Impact on Local Communities</td>
<td>This aspect considers the socio-economic impacts of the option in relation to: - social impacts on the region and Jabiru (including lifestyle, alcohol and drug, health and educational, regional demographics) - economic impacts (including employment, business opportunities and taxes)</td>
<td>The option would probably result in unacceptable negative social or economic impact on Jabiru and the regional community. Options for amending this assessment have not been identified.</td>
<td>The option could result in unacceptable negative social and economic impact on Jabiru and the regional community. Options for amending this assessment have been identified and would probably be successful.</td>
<td>The option has a neutral socio-economic impact on Jabiru and the surrounding region relative to the current situation</td>
<td>No negative socio-economic impact on Jabiru and the regional community have been identified for this option and there are some probable positive outcomes that would be welcomed by the community.</td>
</tr>
<tr>
<td>Ecosystems of Kakadu National Park</td>
<td>This aspect assesses potential impacts during the operational period on: - scale and integrity of landscapes and ecosystems - flora and fauna species diversity. The very highest environmental protection standards apply to Kakadu National Park to reflect its World Heritage and Ramsar status. Minimal impact ranks highest.</td>
<td>Assessment of the potential environmental impact arising from the adoption of the option demonstrates significant risk to some of the world heritage values of Kakadu National Park or its Ramsar status. There appear to be no viable options for reducing this risk significantly.</td>
<td>Assessment of the potential environmental impact arising from the adoption of the option demonstrates that some of the world heritage values of Kakadu National Park or its Ramsar status could be at risk. Viable options for modifying the option to reduce the risk to an acceptable low level have been identified.</td>
<td>Assessment of the potential environmental impact arising from the adoption of the option demonstrates a low risk to the World Heritage or Ramsar values of Kakadu National Park. In addition, management options are available to ensure low impact should unexpected events occur.</td>
<td>Assessment of the potential environmental impact arising from the adoption of the option demonstrates a very low risk to the World Heritage or Ramsar values of Kakadu National Park. While contingency action should not be necessary, management options for additional control have been identified.</td>
</tr>
<tr>
<td>Ecosystems of the Project Area</td>
<td>This aspect considers the impact of the environment of the Project Area. While it is clear that environmental impact is inevitable on the Project Area during the operational period, such impact should be minimised. Minimal impact rank highest.</td>
<td>The option results in significant environmental disturbance on the Project Area that could be avoided by the adoption of alternative options. There appear to be no viable options for reducing this impact significantly.</td>
<td>The option results in significant environmental disturbance on the Project Area that could be avoided by the adoption of alternative options. However, viable options for reducing this impact have been identified.</td>
<td>The option results in environmental disturbance on the Project Area comparable with that caused by the adoption of alternative options.</td>
<td>The option results in a lower level of environmental disturbance on the Project Area than that caused by the adoption of most alternative options.</td>
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<tr>
<td>Fit for Purpose</td>
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<td>Aspect Description</td>
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<tr>
<td><strong>Proven technology</strong></td>
<td>Unproven, theoretical support only, evaluation or historical performance proven inadequate. Further testing unlikely to improve confidence.</td>
<td>Unproven but further practicable testing could improve confidence and, if successful, could yield significant benefits.</td>
<td>Proven operation at a small number of sites and history of successful application of the technology.</td>
<td>Proven operating performance at multiple sites with demonstrated results being achieved.</td>
<td>Proven operating performance at multiple sites with results demonstrating high performance and reliability.</td>
</tr>
<tr>
<td><strong>Technical performance</strong></td>
<td>For individual discipline assessments, the option considered is assessed as a standard of performance that is inadequate compared with the other options and is considered inappropriate in achieving a sound business case. For the overall project assessment, adoption of the option is likely to result in either cessation of mining before the extraction of the full resource is achieved or milling before processing of all ore is complete. Modifications of option design are not expected to achieve a significantly better outcome.</td>
<td>For individual discipline assessments, the option considered is assessed as a standard of performance that is inferior to that of most other options and is considered poor in achieving a sound business case. For the overall project assessment, adoption of the option is likely to result in either cessation of mining before the extraction of the full resource is achieved or milling before processing of all ore is complete. However, viable modifications of option design have been identified that should reverse this assessment.</td>
<td>For individual discipline assessments, the option considered is assessed as a standard of performance that is comparable with other options and is considered appropriate in achieving a sound business case. For the overall project assessment, adoption of the option is likely to achieve extraction and processing of the full uranium resource before cessation of activities is required to complete closure in the time legally required.</td>
<td>For individual discipline assessments, the option considered is assessed as a standard of performance that is better than most other options considered and is considered appropriate in achieving a good business case. For the overall project assessment, there is a high probability that adoption of the option would achieve extraction and processing of the full uranium resource before cessation of activities is required to complete closure in the time legally required.</td>
<td>For individual discipline assessments, the option considered is assessed as a standard of performance that is the best of all options considered and is considered appropriate in achieving an excellent business case. For the overall project assessment, adoption of the option would almost guarantee extraction and processing of the full uranium resource before cessation of activities is required to complete closure in the time legally required.</td>
</tr>
<tr>
<td><strong>Robustness</strong></td>
<td>Successful implementation highly dependent on occurrence of normal climatic conditions and/or date of implementation is highly sensitive to the planned mill closure date. Management options limited.</td>
<td>Successful implementation dependent on occurrence of normal climatic conditions or successful implementation could be affected by the planned mill closure date but potential management options may be available.</td>
<td>Successful implementation has some dependence on occurrence of normal climatic conditions or date of implementation is potentially sensitive to the planned mill closure date but management options have been identified and assessed as being viable.</td>
<td>Successful implementation does not appear to be dependent on occurrence of normal climatic conditions or the planned mill closure date.</td>
<td>Successful implementation highly independent of either the occurrence of normal climatic conditions or the planned mill closure date.</td>
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<td>BPT Aspect Description</td>
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<tr>
<td>Environmental Protection</td>
<td>The option achieves a very poor standard of environmental protection compared to other options adopted in uranium mining elsewhere in the world.</td>
<td>The option achieves a standard of environmental protection comparable with that achieved in uranium mining elsewhere in the world.</td>
<td>The option achieves a standard of environmental protection comparable with that achieved in uranium mining elsewhere in the world with minor exceptions for which viable management options have been identified.</td>
<td>The option achieves a standard of environmental protection that is on a par with the best performance achieved in uranium mining elsewhere in the world.</td>
<td>The option achieves a standard of environmental protection that is significantly higher than that achieved in any other uranium mining operation elsewhere in the world.</td>
</tr>
<tr>
<td>CAPEX</td>
<td>The option has associated capital costs that would make the project economically prohibitive.</td>
<td>The option has higher capital costs than alternative viable options.</td>
<td>The option has expected capital requirements that are comparable with other viable alternatives.</td>
<td>The option has expected capital requirements that are lower than those of other viable alternatives.</td>
<td>The option has very low capital cost requirements and contributes significantly to the overall project value</td>
</tr>
<tr>
<td>Operational Adequacy</td>
<td>Occupational Health &amp; Safety</td>
<td>The option is inherently unsafe and safe operation is very dependent on non-engineered controls. Health: The option results in unacceptable health impacts on the workforce.</td>
<td>The option is safe when control actions are implemented but controls are from lower in the control hierarchy. The option will satisfy Rio Tinto occupational health requirements.</td>
<td>The option is safe when normal levels of control actions are implemented. The option will satisfy Rio Tinto occupational health requirements.</td>
<td>Safety: The option is inherently safe and only minor aspects require safety controls. Health: The option will satisfy Rio Tinto occupational health requirements and is best practice relative to other mines.</td>
</tr>
<tr>
<td>Operability</td>
<td>This aspect considers how much effort is required to operate the equipment or process. Lower effort and simpler operations rank high.</td>
<td>The option is difficult to operate requiring extensive control and support effort to achieve results.</td>
<td>Some operational aspects of the option have been identified that could require limited control and support effort to achieve desired results.</td>
<td>The option is controllable to normal levels.</td>
<td>The option has been assessed as being readily controlled and stable.</td>
</tr>
<tr>
<td>Inherent availability and reliability</td>
<td>This aspect considers the inherent availability associated with the option. Some options are simple by design or have features that make them highly reliable resulting in high availability. Such options rank high. Longevity of an option should be considered under this criterion.</td>
<td>The option is very sensitive to a single plant item failure and major disruptions could result from such failures.</td>
<td>The option is intolerant of single plant item failures but major disruptions are unlikely.</td>
<td>The option can tolerate single plant item failures with minor disruptions experienced.</td>
<td>The option is robust and performance is not unduly impacted with single plant item failures.</td>
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<td>BPT Aspect Description</td>
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<tr>
<td>Maintainability</td>
<td>This aspect considers the effort required for maintenance of the plant and equipment. Some options will require less effort and cost to maintain as the access is adequate, parts are readily available and skill and repair equipment levels match those readily available. If maintenance costs are high as a result of the plant being old or because the arrangement of plant makes maintenance costly then this aspect would rank low.</td>
<td>The option is difficult to maintain and/or requires high levels of maintenance given the equipment age and/or load placed on equipment (duty levels). Aspects include plant age, duty levels, difficult access, inadequate level of spares, high levels of skills and equipment required for maintenance.</td>
<td>The option is likely to require a moderate level of maintenance and commensurate costs to ensure an adequate level of operability.</td>
<td>The option is maintainable with normal levels of maintenance input. The age of plant and duty placed on equipment results in normal levels of maintenance effort.</td>
<td>The option is readily maintained and maintenance effort is low. Aspects include equipment age and/or duty placed on equipment, easy access, available spares, normal skill levels and maintenance equipment.</td>
</tr>
<tr>
<td>OPEX</td>
<td>Operating costs have a large impact on project value. Options with low operating costs rank high.</td>
<td>Adoption of the option would result in very high operating costs (consumables, people, maintenance, power) compared to alternative options and would have a very significant impact on overall project costs.</td>
<td>The option has higher operating costs than some of the alternatives in terms of consumables, people, maintenance, power.</td>
<td>The option has normal levels of operating costs</td>
<td>The option has lower operating costs than most alternatives in terms of consumables, people, maintenance, power.</td>
</tr>
<tr>
<td>Rehabilitation &amp; Closure</td>
<td>This aspect considers the need to rehabilitate the site to the standards required to enable its incorporation into Kakadu National Park following closure. Options that avoid the need for significant rehabilitation measures would rank highly.</td>
<td>Option would result in significant rehabilitation measures and closure criteria are difficult to meet.</td>
<td>Rehabilitation measures to meet closure criteria are as expected for equivalent mine and processing operation</td>
<td>Minimal rehabilitation measures required to meet closure criteria.</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>This aspect considers the cost associated with closure and whether or not the option would significantly detract from overall project value.</td>
<td>The option has high closure costs significantly reducing overall project value</td>
<td>Normal closure cost as expected for similar operations</td>
<td>Low cost offering significant increase in project value</td>
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<td>BPT Aspect Description</td>
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<tr>
<td><strong>Schedule</strong></td>
<td>This aspect addresses the need to achieve closure within a period that meets stakeholder expectations and any legal requirements. The principal legal requirements are (a) cessation of milling by January 2021 and (b) completion of all rehabilitation works and relinquishment of the site by January 2026. However, there are operational deadlines that must be met to achieve these legal deadlines. These operational deadlines need to be carefully specified and options need to be assessed against their suitability for meeting the required schedule.</td>
<td>The detailed schedule for implementation of the option predicts that the operational deadlines will not be met. Hence there is very low confidence that adoption of the option would ensure that legal requirements on cessation of activities on the Ranger Project Area will be met. Modifications of option design are not expected to achieve a significantly better outcome.</td>
<td>The detailed schedule for implementation of the option predicts that there will be difficulties in meeting the operational deadlines. Hence confidence is poor that adoption of the option would ensure that legal requirements on cessation of activities on the Ranger Project Area will be met. However, viable modifications of option design have been identified that could achieve a significantly better outcome.</td>
<td>The detailed schedule for implementation of the option predicts that the operational deadlines will be comfortably met and the schedule has been assessed as robust. Hence there is reasonable confidence that adoption of the option would ensure that legal requirements on cessation of activities on the Ranger Project Area will be met. An action plan is in place to monitor activities on the critical path and introduce active additional management if required but it is not expected to be required.</td>
<td>The detailed schedule for implementation of the option predicts that the operational deadlines will be met with considerable ease and the schedule has been assessed as robust. Hence there is a very high level of confidence that adoption of the option would ensure that legal requirements on cessation of activities on the Ranger Project Area will be met. An action plan is in place to monitor activities on the critical path and introduce active additional management if required but is very unlikely to be required.</td>
</tr>
<tr>
<td><strong>Constructability</strong></td>
<td>This aspect contrasts how inherently safe any option with a major construction component is to construct. Occupational health and safety (including radiation safety) of the workforce is of paramount importance. Options requiring least controls to ensure safety rank high.</td>
<td>Safety: Construction aspects of the option are inherently unsafe and safe operation is very dependent on non-engineered controls. Health: Construction aspects of the option result in unacceptable health impacts on the workforce.</td>
<td>Construction aspects of the option are safe when control actions are implemented but controls are from lower in the control hierarchy. The option will satisfy Rio Tinto occupational health requirements.</td>
<td>Construction aspects of the option are safe when normal levels of control actions are implemented. The option will satisfy Rio Tinto occupational health requirements.</td>
<td>Safety: Construction aspects of the option are inherently safe and only minor aspects require safety controls. Health: Construction aspects of the option will satisfy Rio Tinto occupational health requirements and are best practice relative to other mines.</td>
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<td>BPT Aspect Description</td>
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<tr>
<td>Construction Environmental and Cultural risks</td>
<td>This aspect addresses the likely environmental and cultural risks arising from the option during project construction. On-site disturbance needs to be minimised, Kakadu National Park must be protected and construction work needs to avoid sites of cultural significance. Risks associated with logistics such as the number and frequency of truck movements through Kakadu National Park must be considered as does work force numbers and the social impacts from transient construction workforce numbers.</td>
<td>The option would give rise to significant on-site disturbance or would threaten the ecosystems of Kakadu National Park or would require construction activity near culturally significant sites. Or the option would result in high numbers or high frequency of truck movements through Kakadu National Park. Or the option has negative social impacts associated with the construction workforce. Modifications of option design are not expected to achieve a significantly better outcome.</td>
<td>The option would give rise to significant on-site disturbance or would threaten the ecosystems of Kakadu National Park or would require construction activity near culturally significant sites. Or the option would result in high numbers or high frequency of truck movements through Kakadu National Park. Or the option has negative social impacts associated with the construction workforce. However, viable modifications of option design have been identified that should reverse this assessment.</td>
<td>Environmental and cultural risks associated with construction aspects of the project are relatively low and transient. Truck movements through Kakadu National Park are limited and the social impact arising from a relatively small transient construction workforce is not expected to be of concern to the local community.</td>
<td>The option has low environmental and cultural risks during the project construction phase and has features that could significantly reduce such risks even further. The construction workforce numbers are very low as are the social impacts from the construction workforce.</td>
</tr>
<tr>
<td>Construction complexity</td>
<td>This aspect addresses the project cost risks arising from uncertainty in schedule due to complexity, construction complexity and/or manpower effort required during project construction. Note construction CAPEX is included in CAPEX aspect.</td>
<td>The option has high or less certain construction costs, high work effort and/or construction complexity. Costs are relatively high and there is a high chance of cost over runs and delayed completion of the project. Modifications of option design are not expected to result in a significantly better assessment.</td>
<td>The option has higher or less certain construction costs than other options, higher work effort and/or construction complexity. Costs are relatively high and there is a chance of cost over runs and delayed completion of the project. However, viable options for modifications of option design have been identified that should result in a significantly better assessment.</td>
<td>The option has normal levels of construction costs, complexity and/or work effort resulting in normal levels of cost and schedule uncertainty. Costs over runs are less likely and would be less than that allowed for in normal contingency allowances. It is likely that the project would be completed as originally scheduled.</td>
<td>The option has relatively low construction costs, low complexity and/or the costs are reasonably predictable with relatively low chance of cost over runs. The work effort is medium for the option under consideration and the project will most likely be completed ahead of original schedule.</td>
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Appendix 2: Strategy Summaries

Strategy 1, Variation 1C, Flowsheet Rev B2

The 1C strategy, known as ‘Brine Injection and Thickened Tailings’, is intended to inject the concentrated brine produced by the Brine Concentrator into the Pit3 underfill and to cover the underfill with tailings from the TSF and the Mill. The tailings are to be excavated from the TSF by dredging, dewatered in a new thickener, then pumped to Pit3 for permanent storage. Mill tailings will report directly to Pit3, in conjunction with TSF reclaimed tailings, from Q1 2015 through to the Mill cessation date of December 2016. The main benefit of Strategy 1 is the placement of the salts from process water treatment into the deepest part of Pit3 and covering the salts with a near-impervious layer of tailings. Solute transport modelling of the brine indicates that the brine will be contained within the underfill, with only minor diffusion into the surrounding rock mass.

A year by year summary of activities undertaken as part of the 1C Strategy is provided below. This is to be read in conjunction with the year by year flowsheet and together they form the basis of the 1C strategy reviewed as part of the May Preliminary Strategy BPT workshop.

2012

- Installation of prefabricated vertical drains (wicks) within the upper 40m of the Pit1 tailings mass to affect release of entrained tailings water, thus promoting the development of a trafficable surface upon which to commence backfill operations
- Construction of additional pond water storages known as RP5 and RP6 to allow for reduction of pond water reporting to Pit3 during the wet season
- Construction of a 2.3m raise to the Ranger tailings dam clay core to crest level RL60.5m to enable containment of process water and tailings until Pit3 is prepared to receive tailings in Q1 2015
- Completion of mining activities within Pit3 by the end of 2012 to enable backfill operations to commence in Q1 2013
- Construction of the brine concentrator for commissioning in H2 2013

2013

- Commence stockpile mining operations to feed the Mill with Mill tailings reporting to the TSF
- Commence backfill of Pit3 in Q1 2013 through placement of ~30Mt of waste rock within the void via a tall dump at RL-100m
- Commission the brine concentrator in H2 2013 for treatment of process water from the TSF at distillate production capacity of 1.83 GL/annum with distillate reporting to Corridor Creek wetland system for polishing prior to release to Magela Creek, and brine reporting to the TSF
- Commission a new power station (non-integrated) to provide required power to the brine concentrator
• Exploration Decline construction commences (this is noted although the Exploration Decline and R3D are out of scope of the ITWC)

2014
• Complete the Pit#3 underfill construction in Q4 2014 with placement of ~30Mt of waste material
• Completion of the underfill drainage layer in Q4 2014
• Installation of brine injection bores surrounding Pit#3 to intersect the base of the Pit#3 underfill
• Installation of water extraction bores intersecting the Pit#3 underfill drainage layer to dewater the underfill and transfer extracted water to the TSF or RP2 dependent on quality
• Construction of the TSF dredge and tailings thickener
• Construction of the Mill to Pit#3 tailings delivery system

2015
• Commission the brine injection bores to deliver brine concentrator brine to the Pit#3 underfill, thus removing this stream from the TSF
• Commission the TSF dredge and tailings thickener to deliver thickened tailings stream to Pit#3 from Q1 2015
• Commission the Mill to Pit#3 tailings system to deliver Mill tailings direct to Pit#3 from Q1 2015, thus removing this stream from the TSF
• Magela LAA and Magela Ext LAA closure works commence with removal of contaminated soils and transfer to Pit#3

2016
• Commence stage 2 of Pit#1 closure with the placement of geotextile layer, 1m of crushed rock, decant structures, and 3m rockfill layer
• Contaminated soil removed from Magela LAA and Magela Ext LAA, allowing for rehabilitation and revegetation of these areas
• Milling operations cease at end of 2016
• Commence construction of the incremental brine concentrator with distillate output capacity of 1.83 GL/annum

2017
• Commission the incremental brine concentrator with process water feed from the TSF, distillate reporting to the Corridor Creek wetland system, and brine to the Pit#3 underfill
• With load shedding from cessation of Milling operations, the current power station available to meet the power demands of the incremental brine concentrator

• Commence demolition of the Mill and associated infrastructure, with placement within Pit#3

• Pit#1 backfill complete with revegetation activity underway on the Pit#1 landform

2018

• Recover contaminated material from the Mill footprint and surrounding areas with placement in Pit#3

• Designated LAA closure works commence with removal of contaminated soils and transfer to Pit#3

• RP1WLF contaminated sediment and soils transported to Pit#3

2019

• Rehabilitation and revegetation of RP1WLF, Mill area and surrounds

2020

• Dredging of the TSF, and thus all tailings transfers to Pit#3, ceases in Q4 2020

• Designated LAA closure works commence with removal of contaminated soils and transfer to Pit#3

• RP6 converted from a pond water storage to a process water storage

2021

• Rehabilitation and revegetation of Coonjimba Billabong, DLAA and DLAA extension

• Construct and commission RP7 as process water storage and feed source for the brine concentrators

• Recovery of groundwater plume beneath the TSF and transfer to RP6/RP7

• Removal of contaminated soils beneath the TSF and transport to Pit#3

• Removal of TSF wall and shaping of TSF final landform

• Installation of prefabricated vertical drains (wicks) within Pit#3 to promote consolidation through removal of entrained water
2022
- Designated LAA closure works commence with removal of contaminated soils and transfer to Pit#3 from JELAA, RP1LAA and RP1LAA extension
- TSF reshaping continues

2023
- Designated LAA closure works commence with removal of contaminated soils and transfer to Pit#3 from RP1, CCWLF and CCLAA
- Rehabilitation and revegetation of JELAA, RP1LAA, RP1LAA extension and CCLAA
- Rehabilitation and revegetation of the TSF
- Commence backfilling of Pit 3

2024
- Rehabilitation and revegetation of RP1, CCWLF, and GCMBL
- Removal and rehabilitation of RP5
- Continue backfilling of Pit 3

2025
- Decommission and demolition of brine concentrators, MF/ROs and all associated infrastructure with placement within RP2 and exploration decline for final disposal
- Backfill of RP2
- Final landform shaping and revegetation

2026
- Cessation of closure activities in Q1 2026

Key notes:
- Airport and related infrastructure out of scope of the ITWC
- Jabiru infrastructure out of scope of the ITWC
- Post 2025, no infrastructure available to treat the expressed water from Pit#3

Strategy 2, Variation 2C, Flowsheet Rev A6
The 2C strategy, known as 'Brine Injection and Thickened and Filtered Tailings', is intended to inject the concentrated brine produced by the Brine Concentrator into the Pit 3 underfill and to cover the underfill with tailings from the TSF and the Mill. The
tailings are to be excavated from the TSF by dredging, dewatered in a new thickener, then pumped to a filtration plant, filtered to 80% solids by weight and trucked to Pit#3 for permanent storage. Mill tailings will also be sent to the filtration plant before reporting to Pit#3 from Q1 2015 through to the Mill cessation date of December 2016. The additional benefit of Strategy 2, compared to Strategy 1, is the removal of the water early and prevention of post deposition consolidation and process water expression.

A year by year summary of activities undertaken as part of the 2C Strategy is provided below. This is to be read in conjunction with the year by year flowsheet and together they form the basis of the 2C strategy reviewed as part of the May Preliminary Strategy BPT workshop.

2012
- Installation of prefabricated vertical drains (wicks) within the upper 40m of the Pit#1 tailings mass to affect release of entrained tailings water, thus promoting the development of a trafficable surface upon which to commence backfill operations
- Construction of additional pond water storages known as RP5 and RP6 to allow for reduction of pond water reporting to Pit#3 during the wet season
- Construction of a 2.3m raise to the Ranger tailings dam clay core to crest level RL60.5m to enable containment of process water and tailings until Pit#3 is prepared to receive tailings in Q1 2015
- Completion of mining activities within Pit#3 by the end of 2012 to enable backfill operations to commence in Q1 2013
- Construction of the brine concentrator for commissioning in H2 2013

2013
- Commence stockpile mining operations to feed the Mill with Mill tailings reporting to the TSF
- Commence backfill of Pit#3 in Q1 2013 through placement of ~30Mt of waste rock within the void via a tall dump at RL-100m
- Commission the brine concentrator in H2 2013 for treatment of process water from the TSF at distillate production capacity of 1.83 GL/annum with distillate reporting to Corridor Creek wetland system for polishing prior to release to Magela Creek, and brine reporting to the TSF
- Commission a new power station (non-integrated) to provide required power to the brine concentrator
- Exploration Decline construction commences (this is noted although the Exploration Decline and R3D are out of scope of the ITWC)

2014
- Complete the Pit#3 underfill construction in Q4 2014 with placement of ~30Mt of waste material
• Completion of the underfill drainage layer in Q4 2014
• Installation of brine injection bores surrounding Pit#3 to intersect the base of the Pit#3 underfill
• Installation of water extraction bores intersecting the Pit#3 underfill drainage layer to dewater the underfill and transfer extracted water to the TSF or RP2 dependent on quality
• Construction of the TSF dredge and tailings thickener
• Construction of the filtration plant commences
• Construct and commission RP7 as process water storage and feed source for the brine concentrators (constructed earlier than in 1C to enable Pit 3 to be kept dry for filtered tailings placement)

2015
• Commission the brine injection bores to deliver brine concentrator brine to the Pit#3 underfill, thus removing this stream from the TSF
• Commission filtration plant and power supply (new station) by Q3 2015
• Commission the TSF dredge and tailings thickener to deliver thickened tailings stream to the filtration plant from Q3 2015
• Commission the Mill to deliver Mill tailings to the filtration plant from Q3 2015, thus removing this stream from the TSF
• Magela LAA and Magela Ext LAA closure works commence with removal of contaminated soils and transfer to Pit#3

2016
• Commence stage 2 of Pit#1 closure with the placement of geotextile layer, 1m of crushed rock, decant structures, and 3m rockfill layer
• Contaminated soil removed from Magela LAA and Magela Ext LAA, allowing for rehabilitation and revegetation of these areas
• Milling operations cease at end of 2016
• Commence construction of the incremental brine concentrator with distillate output capacity of 1.83 GL/annum

2017
• Commission the incremental brine concentrator with process water feed from the TSF, distillate reporting to the Corridor Creek wetland system, and brine to the Pit#3 underfill
• With load shedding from cessation of Milling operations, the current power station available to meet the power demands of the incremental brine concentrator
• Commence demolition of the Mill and associated infrastructure, with placement within Pit#3
• Pit#1 backfill complete with revegetation activity underway on the Pit#1 landform

**2018**
• Recover contaminated material from the Mill footprint and surrounding areas with placement in Pit#3
• Designated LAA closure works commence with removal of contaminated soils and transfer to Pit#3
• RP1WLF contaminated sediment and soils transported to Pit#3

**2019**
• Rehabilitation and revegetation of RP1WLF, Mill area and surrounds

**2020**
• Designated LAA closure works commence with removal of contaminated soils and transfer to Pit#3
• RP6 converted from a pond water storage to a process water storage

**2021**
• Dredging of the TSF, and thus all tailings transfers to Pit#3, ceases in Q4 2021 (delayed one year from the 1C case to allow time to filter tailings)
• Rehabilitation and revegetation of Coonjimba Billabong, DLAA and DLAA extension

**2022**
• Designated LAA closure works commence with removal of contaminated soils and transfer to Pit#3 from JELAA, RP1LAA and RP1LAA extension
• Removal of contaminated soils beneath the TSF and transport to Pit#3
• Recovery of groundwater plume beneath the TSF and transfer to RP6/RP7
• Commence final waste rock backfill of Pit#3 (commences earlier than 1C as no delay required for in-pit consolidation to occur; finish date is similar to 1C)
• Decommission and demolition of filtration plant and associated power supply

**2023**
• Designated LAA closure works commence with removal of contaminated soils and transfer to Pit#3 from RP1, CCWLF and CCLAA
• Rehabilitation and revegetation of JELAA, RP1LAA, RP1LAA extension and CCLAA
- Reshaping of TSF walls to final landform

2024
- Rehabilitation and revegetation of RP1, CCWLF, and GCMBL
- Removal and rehabilitation of RP5
- Rehabilitation and revegetation of the TSF
- Continue backfilling of Pit 3

2025
- Decommission and demolition of brine concentrators, MF/ROs and all associated infrastructure with placement within RP2 and exploration decline for final disposal
- Backfill of RP2
- Final landform shaping and revegetation

2026
- Cessation of closure activities in Q1 2026

**Strategy 3, Variation 3C, Flowsheet Rev A2.**

The 3C strategy, known as ‘Brine Crystallisation and Thickened Tailings’, is intended to solidify the concentrated brine produced by the Brine Concentrator in a thermal crystalliser plant and bag the salts for placement in Pit 3. Tailings are treated as in the 1C Strategy. The 3C Strategy was developed in case brine injection (Strategy 1C) proved impractical.

A year by year summary of activities undertaken as part of the 3C Strategy is provided below. This is to be read in conjunction with the year by year flowsheet and together they form the basis of the 3C strategy reviewed as part of the May Preliminary Strategy BPT workshop.

2012
- Installation of prefabricated vertical drains (wicks) within the upper 40m of the Pit#1 tailings mass to affect release of entrained tailings water, thus promoting the development of a trafficable surface upon which to commence backfill operations
- Construction of additional pond water storages known as RP5 and RP6 to allow for reduction of pond water reporting to Pit#3 during the wet season

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3 Placement in underground silos of the exploration decline was also assessed.
• Construction of a 2.3m raise to the Ranger tailings dam clay core to crest level RL60.5m to enable containment of process water and tailings until Pit#3 is prepared to receive tailings in Q1 2015

• Completion of mining activities within Pit#3 by the end of 2012 to enable backfill operations to commence in Q1 2013 to provide a working surface for the tailings consolidation

• Construction of the brine concentrator for commissioning in H2 2013

2013

• Commence stockpile mining operations to feed the Mill with Mill tailings reporting to the TSF

• Commence backfill of Pit#3 in Q1 2013 through placement of ~30Mt of waste rock within the void via a tall dump at RL-100m

• Commission the brine concentrator in H2 2013 for treatment of process water from the TSF at distillate production capacity of 1.83 GL/annum with distillate reporting to Corridor Creek wetland system for polishing prior to release to Magela Creek, and brine reporting to the TSF

• Commission a new power station (non-integrated) to provide required power to the brine concentrator

• Exploration Decline construction commences (this is noted although the Exploration Decline and R3D are out of scope of the ITWC)

2014

• Complete the Pit#3 underfill construction in Q4 2014 with placement of ~30Mt of waste material

• Completion of the underfill drainage layer in Q4 2014

• Installation of water extraction bores intersecting the Pit#3 underfill drainage layer to dewater the underfill and transfer extracted water to the TSF or RP2 dependent on quality

• Construction of the TSF dredge and tailings thickener

• Construction of the Mill to Pit#3 tailings delivery system

2015

• Commission the TSF dredge and tailings thickener to deliver thickened tailings stream to Pit#3 from Q1 2015

• Commission the Mill to Pit#3 tailings system to deliver Mill tailings direct to Pit#3 from Q1 2015, thus removing this stream from the TSF

• Magela LAA and Magela Ext LAA closure works commence with removal of contaminated soils and transfer to Pit#3

2016
• Commence stage 2 of Pit#1 closure with the placement of geotextile layer, 1m of crushed rock, decant structures, and 3m rockfill layer
• Contaminated soil removed from Magela LAA and Magela Ext LAA, allowing for rehabilitation and revegetation of these areas
• Milling operations cease at end of 2016
• Commence construction of the incremental brine concentrator with distillate output capacity of 1.83 GL/annum
• Commence construction of the crystallisation plant and power plant

2017
• Commission the crystallisation plant, and bagging station and power supply. Commence trucking bagged salt to Pit 3.
• Commission the incremental brine concentrator with process water feed from the TSF, distillate reporting to the Corridor Creek wetland system and brines reporting to the crystallisation plant
• With load shedding from cessation of Milling operations, the current power station available to meet the power demands of the incremental brine concentrator
• Commence demolition of the Mill and associated infrastructure, with placement within Pit#3
• Pit#1 backfill complete with revegetation activity underway on the Pit#1 landform

2018
• Recover contaminated material from the Mill footprint and surrounding areas with placement in Pit#3
• Designated LAA closure works commence with removal of contaminated soils and transfer to Pit#3
• RP1WLF contaminated sediment and soils transported to Pit#3

2019
• Rehabilitation and revegetation of RP1WLF, Mill area and surrounds

2020
• Dredging of the TSF, and thus all tailings transfers to Pit#3, ceases in Q4 2020
• Designated LAA closure works commence with removal of contaminated soils and transfer to Pit#3
• RP6 converted from a pond water storage to a process water storage
2021
- Rehabilitation and revegetation of Coonjimba Billabong, DLAA and DLAA extension
- Construct and commission RP7 as process water storage and feed source for the brine concentrators
- Recovery of groundwater plume beneath the TSF and transfer to RP6/RP7
- Removal of contaminated soils beneath the TSF and transport to Pit#3
- Reshaping of TSF walls for final landform
- Installation of prefabricated vertical drains (wicks) within Pit#3 to promote consolidation through removal of entrained water

2022
- Designated LAA closure works commence with removal of contaminated soils and transfer to Pit#3 from JELAA, RP1LAA and RP1LAA extension
- TSF reshaping continues

2023
- Designated LAA closure works commence with removal of contaminated soils and transfer to Pit#3 from RP1, CCWLF and CCLAA
- Rehabilitation and revegetation of JELAA, RP1LAA, RP1LAA extension and CCLAA
- Rehabilitation and revegetation of the TSF
- Commence backfilling of Pit 3

2024
- Rehabilitation and revegetation of RP1, CCWLF, and GCMBL
- Removal and rehabilitation of RP5
- Continue backfilling of Pit 3

2025
- Decommission and demolition of brine concentrators, MF/ROs and all associated infrastructure with placement within RP2 and exploration decline for final disposal
- Backfill of RP2
- Final landform shaping and revegetation

2026
- Cessation of closure activities in Q1 2026
Strategy 4, Variation 4C, Flowsheet Rev A6

The 4C strategy is known as ‘Brine Crystallisation and Thickened and Filtered Tailings’. This strategy was considered as it combined the potential benefits of brine crystallisation (see Strategy 3C) and tailings filtration (see Strategy 2C).

A year by year summary of activities undertaken as part of the 4C Strategy is provided below. This is to be read in conjunction with the year by year flowsheet and together they form the basis of the 4C strategy reviewed as part of the May Preliminary Strategy BPT workshop.

2012

- Installation of prefabricated vertical drains (wicks) within the upper 40m of the Pit#1 tailings mass to affect release of entrained tailings water, thus promoting the development of a trafficable surface upon which to commence backfill operations
- Construction of additional pond water storages known as RP5 and RP6 to allow for reduction of pond water reporting to Pit#3 during the wet season
- Construction of a 2.3m raise to the Ranger tailings dam clay core to crest level RL60.5m to enable containment of process water and tailings until Pit#3 is prepared to receive tailings in Q1 2015
- Completion of mining activities within Pit#3 by the end of 2012 to enable backfill operations to commence in Q1 2013
- Construction of the brine concentrator for commissioning in H2 2013

2013

- Commence stockpile mining operations to feed the Mill with Mill tailings reporting to the TSF
- Commence backfill of Pit#3 in Q1 2013 through placement of ~30Mt of waste rock within the void via a tall dump at RL-100m (optional)
- Commission the brine concentrator in H2 2013 for treatment of process water from the TSF at distillate production capacity of 1.83 GL/annum with distillate reporting to Corridor Creek wetland system for polishing prior to release to Magela Creek, and brine reporting to the TSF
- Commission a new power station (non-integrated) to provide required power to the brine concentrator
- Exploration Decline construction commences (this is noted although the Exploration Decline and R3D are out of scope of the ITWC)

2014

- Construction of the TSF dredge and tailings thickener
- Construction of the filtration plant and power station commences
• Construct and commission RP7 as process water storage and feed source for the brine concentrators (constructed earlier than in 1C to enable Pit 3 to be kept dry for filtered tailings placement)

2015
• Commission filtration plant and power supply by Q3 2015
• Commission the TSF dredge and tailings thickener to deliver thickened tailings stream to the filtration plant from Q3 2015
• Commission the Mill to deliver Mill tailings to the filtration plant from Q3 2015, thus removing this stream from the TSF
• Magela LAA and Magela Ext LAA closure works commence with removal of contaminated soils and transfer to Pit#3

2016
• Commence stage 2 of Pit#1 closure with the placement of geotextile layer, 1m of crushed rock, decant structures, and 3m rockfill layer
• Contaminated soil removed from Magela LAA and Magela Ext LAA, allowing for rehabilitation and revegetation of these areas
• Milling operations cease at end of 2016
• Commence construction of the incremental brine concentrator with distillate output capacity of 1.83 GL/annum
• Commence construction of the crystallisation plant and power plant

2017
• Commission the crystallisation plant, and bagging station and power supply. Commence trucking bagged salt to Pit 3.
• Commission the incremental brine concentrator with process water feed from the TSF, distillate reporting to the Corridor Creek wetland system and brines reporting to the crystallisation plant
• With load shedding from cessation of Milling operations, the current power station available to meet the power demands of the incremental brine concentrator
• Commence demolition of the Mill and associated infrastructure, with placement within Pit#3
• Pit#1 backfill complete with revegetation activity underway on the Pit#1 landform

2018
• Recover contaminated material from the Mill footprint and surrounding areas with placement in Pit#3
• Designated LAA closure works commence with removal of contaminated soils and transfer to Pit#3
• RP1WLF contaminated sediment and soils transported to Pit#3

2019
• Rehabilitation and revegetation of RP1WLF, Mill area and surrounds

2020
• Designated LAA closure works commence with removal of contaminated soils and transfer to Pit#3
• RP6 converted from a pond water storage to a process water storage

2021
• Dredging of the TSF, and thus all tailings transfers to Pit#3, ceases in Q4 2021 (delayed one year from the 1C case to allow time to filter tailings)
• Rehabilitation and revegetation of Coonjimba Billabong, DLAA and DLAA extension

2022
• Designated LAA closure works commence with removal of contaminated soils and transfer to Pit#3 from JELAA, RP1LAA and RP1LAA extension
• Removal of contaminated soils beneath the TSF and transport to Pit#3
• Recovery of groundwater plume beneath the TSF and transfer to RP6/RP7
• Commence final waste rock backfill of Pit#3 (commences earlier than 1C as no delay required for in-pit consolidation to occur; finish date is similar to 1C)
• Decommission and demolition of filtration plant and associated power supply

2023
• Designated LAA closure works commence with removal of contaminated soils and transfer to Pit#3 from RP1, CCWL and CCLAA
• Rehabilitation and revegetation of JELAA, RP1LAA, RP1LAA extension and CCLAA
• Reshaping of TSF walls to final landform

2024
• Rehabilitation and revegetation of RP1, CCWL, and GCMBL
• Removal and rehabilitation of RP5
• Rehabilitation and revegetation of the TSF
2025

- Decommission and demolition of brine concentrator and crystalliser, MF/ROs and all associated infrastructure with placement within RP2 and exploration decline for final disposal
- Backfill of RP2
- Final landform shaping and revegetation

2026

- Cessation of closure activities in Q1 2026

Strategy 5C: Option 1C with water treatment 2026 – 2030

Strategy 5C was developed ahead of the Preliminary Strategies assessment workshop to assess the 1C Strategy with water treatment continuing to 2030 rather than ceasing in 2025.

This summary is to be read in conjunction with the year by year flowsheet and together they form the basis of the 5C strategy reviewed as part of the May Preliminary Strategy BPT workshop.

The key differences from the 1C Strategy are:

- Water is treated until 2029 by MF/RO and the brine concentrator.
- Pond and process water storage ponds, power supply and some offices (at reduced size/capacity) remain until the end of 2029.
- Remaining facilities are buried in the ponds and the ponds reshaped and re-vegetated in 2030.

- Pit 3 earthworks take place as in 1C. Revegetation of Pit 3 can occur over 2026.

For the BPT assessment it was assumed that approval for remaining facilities could be sought under ER 2.3.

Strategy 1B: Option 1C with milling to 2020

This is to be read in conjunction with the year by year flowsheet and together they form the basis of the 1B strategy reviewed as part of the May Preliminary Strategy BPT workshop.
Key dates for 1B are as for 1C with the following exceptions:

- Milling continues to 2020

- Activities associated with decommissioning and dismantling the mill, removal and burial of soils and revegetation in the plant area are moved from 2017, 2018 and 2019 by three years to 2021, 2022 and 2023 respectively.