Appendix 11.

SLR Consulting Australia (2020b) *Rum Jungle Rehabilitation – Stage 2A Detailed Design – Waste Storage Facilities (WSF) Cover Options Analysis.* Report to the Department of Primary Industry and Resources, Northern Territory Government.

NORTHERN TERRITORY GOVERNMENT

Department of **Primary Industry and Resources**

RUM JUNGLE REHABILITATION - STAGE 2A DETAILED ENGINEERING DESIGN

Waste Storage Facilities (WSF)
Cover Options Analysis

Prepared for:

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CONTENTS

DOCUMENT REFERENCES

TABLES

1 Introduction

The Northern Territory Government (NTG), represented by the Department of Primary Industry and Resources (DPIR), proposes the rehabilitation of the former Rum Jungle Mine site (the Project), located 6 km north of Batchelor, Northern Territory (NT).

The rehabilitation strategy of the Project is outlined in detail in Draft Environment Impact Statement (EIS) (NT-DPIR, December 2019). The Stage 2A engineering design for the strategy has been undertaken by SLR and is reported in SLRs Detailed Engineering Design Report (SLR, 2020a). This report forms part of the Design Report and should be read in conjunction with it.

As part of the for the Project, a decision on the final rehabilitation cover system for the proposed new Waste Storage Facilities (WSFs) is required.

Detailed modelling of a proposed cover system was carried out in Stage 2 by O'Kane Consulting (OKC, 2016). The proposed cover system comprised:

- Top of WSFs (bottom up):
    - 0.5m barrier layer of compacted clay (low permeability) layer; and
    - 2m growth medium layer.
- Side slopes of WSFs (dimensions perpendicular to slope, bottom up):
    - 0.5m barrier layer of compacted clay layer;
    - 2m growth medium layer; and
    - 0.5m rock and growth medium mix layer.

The barrier layer is designed to inhibit oxygen and water infiltration into the underlying waste rock, which is potentially acid forming (PAF); the impact of oxygen and water infiltration is production of acid metalliferous drainage (AMD) from the waste rock.

In order to minimise risk and ensure the maximum life of the cover can be achieved, alternatives to the proposed option have been assessed using a Multi Criteria Analysis (MCA) approach. No detailed modelling or testing has been carried out as part of the options assessment, rather a qualitative approach to how the options may improve performance of the proposed cover has been adopted.

2 Scope

The options assessment process has involved:

1. Identification and summary of options. Three components of the cover have been assessed:
    - Cover materials on the plateau;
    - Cover material on the side slopes; and
    - Revegetation materials.
2. Preliminary (feasibility) level design of selected options;
3. MCA undertaken to score and rank each option, addressing the following factors:
    - Environmental;

- Financial; and
- Technical.

4. Selection of the preferred option for each of the three components.

3 Objectives

The objectives of the final rehabilitation cover system are as follows:

- Physical Stability—the landform must maintain integrity for a minimum of 500 years and should behave in a similar manner to natural analogues;
- Chemical Stability—the cover and landform must manage the processes of oxidation and infiltration to reduce solute loadings to downstream receptors to acceptable levels for a minimum of 500 years.
- Land-Use—the landform must present acceptable visual aesthetics and must support sustainable native vegetation communities.

4 Options

The cover material options chosen to be assessed are based on engineering judgement of the project team and are summarised in Table 1. Options were assessed individually and in composite.

Table 1 Barrier Layer Options Assessed

Barrier Type	Description
0.5m Compacted Clay Liner	The ability of clay to retard water movement and absorb exchangeable cations makes it a suitable natural material for a low-permeability liner. A compacted clay liner (CCL) provides an effective barrier to contaminant migration.
1.5mm HDPE	A 1.5 mm thick high-density polyethylene (HDPE) geomembrane to provide a low permeability barrier to rainfall ingress. The HDPE liner is specified in the design to prevent migration of rainfall into the WSF subsurface. The HDPE is a very low permeability material specified for its combination of low permeability, mechanical properties and its resistance to chemical attack and breakdown as a result of exposure to any leachate. It has the advantages of: • Chemical resistance: The chemical resistance of the liner is considered one of the most critical aspects of the lining system. A HDPE liner is the most chemically resistant of all geomembranes. • Low permeability: The low permeability of a HDPE liner reduces the likelihood of leachate migration through the lining system.
1.5mm LLDPE	Linear low-density polyethylene (LLDPE) is similar to HDPE and is also made from polyethylene resin, carbon black and additives. The key differences from HDPE are that LLDPE has a lower crystallinity, lower stiffness and lower density, which make it more flexible and less susceptible to stress cracking
Geosynthetic Clay Liner (Coated)	A needle-punched non-woven geosynthetic clay liner (GCL) provides a very low permeability layer consisting of appropriate mechanical properties and its resistance to chemical attack and breakdown as a result of exposure to leachate. The upper surface of the non-woven geotextile is coated with a textured polymer to enhance interface friction. The advantages of a coated GCLs are as follows: • Very low hydraulic conductivity; • Relatively low cost; • Limited thickness; and • Good compliance with differential settlements.

Barrier Type	Description
Bituminous Geomembrane (BGM)	An alternative to the traditional and more commonly used polymeric geomembranes. Modern bitumen products are less viscous and more flexible than traditional bitumen and can be used as flexible membranes. Bituminous geomembranes are reinforced with a nonwoven geotextile. BGMs are relatively heavy.
0.30m Compacted Sand-Bentonite Mixture	Sand-bentonite mixtures have been utilized as a liner/barrier material in several engineering applications such as: landfills, cutoff walls, earth dams, buffer/backfill materials of radioactive nuclear waste containments and also reservoirs. Some advantages of sand-bentonite mixtures are: • Provide a very low permeability because of the ability of bentonite to swell and then fill the voids between sand particles; • Low compressibility which is provided by sand framework; • The mixture has less susceptible to frost damage comparing with natural clays; • Low shrinkage potential in terms of wetting or drying processes which lead to better volume stability and higher strength; and • Economical solution for applications in places where clay availability is limited.

Note that rock mulching is not considered as part of the capping system, and has been assessed as part of the revegetation works.

The capping options were assessed in the combinations defined in Table 2.

Table 2 Capping Options

Option	Cover systems
1	Topsoil 2m Growth Medium 1.5mm HDPE 0.5m Compacted Clay Liner
2	Topsoil 2m Growth Medium 1.5mm LLDPE 0.5m Compacted Clay Liner
3	Topsoil 2m Growth Medium GCL (coated) 0.5m Compacted Clay Liner
4	Topsoil 2m Growth Medium Bituminous Geomembrane 0.5m Compacted Clay Liner
5	Topsoil 2m Growth Medium Compacted Sand-Bentonite mixture

The revegetation options chosen to be assessed are based on ecological and agronomical knowledge of the area by the project team and are summarised in Table 3. Options were assessed individually and in composite.

Table 3 Revegetation Options Assessed

Revegetation Option	Description
Rock mulch layer	Depending on seeding and planting schemes, this material may be placed on the surface and / or admixed to the upper 100-200 mm of the cover system.
Hydro-mulch	Hydro-mulch includes a heat-treated straw and seed mixed with mineral fertiliser and a polymer binder. The binder temporarily protects exposed soils from erosion by water and wind.
Hydro-seeding	Applying a slurry of water, wood fibre mulch, seed and fertilizer to prevent soil erosion and provide an environment conducive to plant growth.
Jute Blanket	Jute mesh is a biodegradable open weave erosion control blanket suitable for short to medium term erosion protection. It is a natural product designed to offer short-term erosion control in low to moderate flow areas.
Japanese millet	Grown principally as a forage grass, needs shallow sowing, establish quickly, early growth is rapid and performs well for erosion protection.

The revegetation option combinations were assessed as defined in Table 4.

Table 4 Revegetation Combinations

Option	Rehabilitation method
1	Rock mulch layer
2	Hydro-mulch with native cover
3	Hydro-seed with native cover
4	Hydro-seed native cover with jute blanket
5	Hydro-seed native cover with Japanese millet

5 Multiple Criteria Analysis

5.1 Methodology

The selected options were evaluated against each other using an MCA system. The general objective of the MCA is to provide the means by which evaluators (stakeholders) can select the most suitable option from a list of alternatives by weighing the relative benefits and costs (i.e. negative impact) of each. This involves three basic steps:

1. Identify the impacts (benefits and costs) to be included in the evaluation;
1. Quantify the impacts (benefits and costs); and
2. Assess the combined or accumulated impacts for each option and compare these with other alternatives to develop a preference list (ranking, scaling and weighting) of the options.

Identification of the impacts will generally fall into the following indicator topics:

- Environmental, Social and Cultural
- Financial; and
- Technical.

Each indicator topic is divided into sub-indicators, and for each sub-indicator, the options are then assigned a relative score (Ssi) based on comparison with the other options. The Ssi ranges from 0 (worst) to 9 (best), and values in between assigned based on the relativity of each option.

Weightings (Wsi) are then applied to each sub-indicator to introduce a value bias between the individual sub-indicators. The value bias is based on the importance of one sub-indicator versus another (i.e. a higher weighting factor reflects a perceived greater value or importance than a sub indicator with a lower weighting). The value bias is applied objectively where possible (i.e. where numerical values are available for sub-indicators), or subjectively where numerical values are unavailable.

Weighted scores are calculated for each sub-indicator by multiplying the relative score (Ssi) by the weighting factor (Wsi). Indicator scores are determined by summing the weighted scores of the sub-indicators. The final (baseline) score for each option is taken as the sum of the indicator scores, as shown by:

$$Option\ Score = \sum_{environmental\ and\ social} (W_{si} \times S_{si}) + \sum_{financial} (W_{si} \times S_{si}) + \sum_{technical} (W_{si} \times S_{si}) + \sum_{general} (W_{si} \times S_{si})$$

5.2 Evaluation Criteria

The evaluation criteria, i.e. the indicators and sub-indicators, were identified between SLR and DPIR. Table 5 lists all indictors and their sub-indicators that were identified and included in the MCA.

Table 5 Evaluation criteria identified

Indicator	ID	Sub-Indicator
Environmental, Social and Cultural	1.1	Environmental Impact
Financial	2.1	Cost
Technical	3.1	Failure probability
	3.2	Stability
	3.3	Constructability ease
	3.4	Lifespan
	3.5	Permeability
	3.6	In-service repair ease

5.3 Criteria Weighting

With the sub-indicators identified, the next step was to assign weightings to them relative to each other. Individual stakeholders at DPIR and SLR (management, environment, designers etc.) assigned a level of importance from 0 (least) to 9 (most) to each sub-indicator, and the average score of all stakeholders was then calculated. To assist with assigning the level of importance, the criteria were related back to cost where possible; otherwise the likely range of impact was provided. The results are presented in Table 6. Note that the scores are presented as a rounded figure, but the actual value without rounding is used in the calculations.

Table 6 Criteria Weighting Average

Indicator	ID	Sub-Indicator	Average Weighting
Environmental, Social and Cultural	1.1	Environmental Impact	9
Financial	2.1	Cost	8
Technical	3.1	Failure probability	5
	3.2	Stability	9
	3.3	Constructability ease	7
	3.4	Lifespan	7
	3.5	Permeability	5
	3.6	In-service repair ease	4

5.4 Criteria Ratings

With the sub-indicators weighted, the next step was to quantify and then score each sub-indicator for each option. Quantification involves:

- Applying numerical values (i.e. haulage costs) where available; **OR**
- Rating on a scale of very low through to very high.

A score of 0 through to 9 must be assigned to each option. Where numerical values are applied, numerical scaling (i.e. cost of option versus maximum cost) was used to calculate the score. For the rating from very low to very high, the score scale as shown in Table 7 was applied:

Table 7 Score Scale

Rating	Score
None/Very Low	0
Low	1
Medium	5
High	7
Very high	9
Unknown	1
Sufficient	9
Not Sufficient	0
Positive	9
Neutral	5
Negative	0

The scoring process was undertaken by the DPIR and SLR stakeholders. Key assumptions and considerations applied in the assignment of scores are outlined in the following sections.

5.5 Environmental, Financial and Technical Factors

The rationale for the scores assigned to each option are detailed in the MCA spreadsheet provided separately to DPIR and summarised in Table 8, Table 9 and Table 10.

Table 8 Environmental, Financial and Technical Assessment – Capping Options (Crest)

ID	Criteria	Option 1 HDPE/CLAY	Option 2 LLDPE/CLAY	Option 3 LLDPE,GCL /CLAY	Option 4 BGM/CLAY	Option 5 CLAY
1.1	Environmental impact	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM
2.1	Cost	MEDIUM	MEDIUM	HIGH	HIGH	LOW
3.1	Failure Probability	HIGH	MEDIUM	MEDIUM	LOW	HIGH
3.2	Stability	HIGH	HIGH	HIGH	HIGH	HIGH
3.3	Constructability Ease	MEDIUM	MEDIUM	LOW	LOW	HIGH
3.4	Lifespan	HIGH	HIGH	HIGH	HIGH	LOW
3.5	Permeability	LOW	LOW	LOW	LOW	MEDIUM
3.6	In-service repair Ease	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH

Table 9 Environmental, Financial and Technical Assessment – Capping Options (Batter)

ID	Criteria	Option 1 HDPE/CLAY	Option 2 LLDPE/CLAY	Option 3 LLDPE, GCL /CLAY	Option 4 BGM/CLAY	Option 5 CLAY
1.1	Environmental impact	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW
2.1	Cost	HIGH	HIGH	VERY HIGH	VERY HIGH	LOW
3.1	Failure Probability	MEDIUM	MEDIUM	LOW	LOW	HIGH
3.2	Stability	LOW	LOW	LOW	LOW	HIGH
3.3	Constructability Ease	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH
3.4	Lifespan	MEDIUM	MEDIUM	HIGH	HIGH	MEDIUM
3.5	Permeability	LOW	LOW	LOW	LOW	MEDIUM
3.6	In-service repair Ease	LOW	LOW	LOW	LOW	HIGH

Table 10 Environmental Financial and Technical Assessment – Revegetation Options

ID	Criteria	Option 1 Gravel (Originally Proposed by O'Kane)	Option 2 Hydro-mulch Native Cover	Option 3 Hydroseed Native Cover	Option 4 Hydroseed Native Cover with Jute Blanket	Option 5 Broadcast native cover
1.1	Environmental impact	HIGH	HIGH	HIGH	MEDIUM	LOW
2.1	Cost	LOW	MEDIUM	MEDIUM	HIGH	MEDIUM
3.1	Failure Probability	VERY HIGH	HIGH	HIGH	MEDIUM	LOW
3.2	Stability	LOW	MEDIUM	MEDIUM	HIGH	VERY HIGH
3.3	Constructability Ease	HIGH	VERY HIGH	VERY HIGH	LOW	VERY HIGH
3.4	Lifespan	LOW	LOW	MEDIUM	HIGH	VERY HIGH
3.5	Permeability	LOW	LOW	LOW	LOW	LOW
3.6	In-service repair Ease	HIGH	MEDIUM	MEDIUM	HIGH	MEDIUM

5.6 Financial Factors

The numeric estimates and relative ratings for the barrier system unit rates (this excludes the clay liner (and by association Option 5 – Clay only, as it is common to all options) are discussed in Table 11.

Table 11 Barrier Financial Assessment

Options	Membranes and Layers	Material Supply Price ($/m²)	Installation Price ($/m²)	Sub Total ($/m²)	Total
Option 1 high-density polyethylene geomembrane (HDPE)	Protection Geotextile	$1.00	$1.70	$2.70	$10.30
	HDPE	$4.60	$3.00	$7.60	
Option 2 Linear low-density polyethylene geomembrane (LLDPE)	Protection Geotextile	$1.00	$1.70	$2.70	$10.20
	LLDPE	$4.50	$3.00	$7.50	
Option 3 Coated Geosynthetic Clay Liner (GCL)	Protection Geotextile	$1.00	$1.70	$2.70	$14.50
	Coated GCL	$8.80	$3.00	$11.80	
Option 4 Bituminous Geomembrane (BGM)	BGM	$12.70	$4.40	$17.10	$17.10

6 Results

6.1 MCA Analysis

The general weightings applied to the criteria were used to calculate the total scores for each of the options. The option that scores the highest total score generally is indicated as the preferred option. However, as noted before, some of the ratings and weightings are subjective and it is possible that one option may be selected over another due to a bias in the assessment of the ratings or weightings. For this reason, the evaluation analysis was used to determine whether there would be a shift in the preferred option if, for example, a higher emphasis was placed on any given set of criteria, i.e. environmental, financial or technical. To this end, five cases were assessed for each barrier system and revegetation and are discussed in the following section.

6.2 Preferred Option

The calculated total points and rankings of each option are summarised in Table 12, Table 13 and Table 14.

Table 12 Summary of MCA Results – Capping Crest

ID	Criteria	Option 1 HDPE/CLAY	Option 2 LLDPE/CLAY	Option 3 LLDPE, GCL /CLAY	Option 4 BGM/CLAY	Option 5 CLAY
1.1	Environmental impact	35	35	35	35	35
2.1	Cost	21	21	4	4	29
3.1	Failure Probability	9	45	45	63	9
3.2	Stability	56	56	56	56	56
3.3	Constructability Ease	24	24	5	5	34
3.4	Lifespan	62	62	62	62	9
3.5	Permeability	51	51	51	51	36
3.6	In-service repair Ease	26	26	26	26	37
TOTAL SCORE		284	320	284	302	245

Table 13 Summary of MCA Results – Capping Batter

ID	Criteria	Option 1 HDPE/CLAY	Option 2 LLDPE/CLAY	Option 3 LLDPE, GCL /CLAY	Option 4 BGM/CLAY	Option 5 CLAY
1.1	Environmental impact	35	35	35	35	49
2.1	Cost	4	4	0	0	29
3.1	Failure Probability	45	45	63	63	9
3.2	Stability	8	8	8	8	56
3.3	Constructability Ease	24	24	24	24	34

ID	Criteria	Option 1 HDPE/CLAY	Option 2 LLDPE/CLAY	Option 3 LLDPE, GCL /CLAY	Option 4 BGM/CLAY	Option 5 CLAY
3.4	Lifespan	44	44	62	62	44
3.5	Permeability	51	51	51	51	36
3.6	In-service repair Ease	5	5	5	5	37
TOTAL SCORE		217	217	249	249	295

Table 14 Summary of MCA Results – Rehabilitation Options

ID	Criteria	Option 1 Gravel (Originally Proposed by O'Kane)	Option 2 Hydro mulch Native Cover	Option 3 Hydroseed Native Cover	Option 4 Hydroseed Native Cover with Jute Blanket	Option 5 Broadcast native cover
1.1	Environmental impact	7	7	7	35	49
2.1	Cost	29	21	21	4	21
3.1	Failure Probability	0	9	9	45	63
3.2	Stability	8	40	40	56	72
3.3	Constructability Ease	34	44	44	5	44
3.4	Lifespan	9	9	44	62	80
3.5	Permeability	51	51	51	51	51
3.6	In-service repair Ease	37	26	26	37	26
TOTAL SCORE		175	207	242	295	406

In summary, the results indicate:

- Recommendation of Capping Option 2 for the crest as:
  - Topsoil; overlying
  - 2m growth medium; then
  - 1.5mm LLDPE; then
  - 0.5m compacted clay liner.
- Recommendation of Capping Option 5 for batter slopes as:
  - Topsoil; overlying
  - 2m growth medium; then
  - 0.5m compacted clay liner.
- Recommendation of Rehabilitation Option 5:
  - Broadcast native cover

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