RUM JUNGLE REHABILITATION PROJECT

Potential Impact of Climate Change on Rehabilitation Design

Prepared for:

NTG Department of Industry, Trade & Tourism
Level 5, Paspalis Centrepoint, 48 Smith Street, Darwin NT 0800

SLR Ref: 623.30135.00100 -R01
Version No: -v1.1
January 2022

PREPARED BY

SLR Consulting Australia Pty Ltd
ABN 29 001 584 612
Unit 5, 21 Parap Road
Parap NT 0820 Australia
(PO Box 1300 Parap NT 0804)
T: +61 8 8998 0100
E: darwin@slrconsulting.com www.slrconsulting.com

BASIS OF REPORT

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
623.30135.00100 -R01-v1.1	20 January 2022	Peter Georgiou, Peter Cupitt, Augusto Riascos, Ben Tarrant	Danielle O'Toole	Danielle O'Toole
623.30135.00100 -R01-v1.0 Draft for Comment	14 January 2022	Peter Georgiou, Peter Cupitt, Augusto Riascos, Ben Tarrant	Danielle O'Toole	Danielle O'Toole

EXECUTIVE SUMMARY

SLR Consulting Australia Pty Ltd (SLR) was engaged to deliver the Rum Jungle rehabilitation strategy design works over the period 2020 to 2021 (Project Stage 2A). This was used to support the draft Environmental Impact Statement (EIS) submitted by Northern Territory Government Department of Industry, Tourism and Trade (DITT) to the Australian Government Department Agriculture, Water and the Environment (the Department) for approval of the rehabilitation project under the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act).

Based on the review of the EIS, the Department issued a request for additional information associated with climate change, specifically:

"1. *Please provide a climate change assessment demonstrating that all design components can withstand varied climatic conditions over the next, for example, 1000 years. The climate change assessment should include modelling for:*

> *a. A wide range of possible seasonal rainfall scenarios (e.g., between 45 per cent drier and 44 per cent wetter in the dry season and between 23 per cent drier to 19 per cent wetter in the wet season).*
>
> *b. The impacts of changing rainfall patterns (i.e., intensity, frequency and duration) including changes in individual event characteristics (e.g., increased intensity); and*
>
> *c. Potential impacts of increased evaporation on aspects of the design including:*
>
>> *i. Ground water levels and ground water quality.*
>>
>> *ii. Maintenance of the proposed Main Pit Lake, including the proposed 2 metre deep water cover.*
>>
>> *iii. Potential for erosion of the waste storage facility capping layer.*
>>
>> *iv. Potential for erosion of the Main Pit capping layer. The Department notes this potential could be exacerbated as settlement occurs within the pit, resulting in an undulating surface and varied rates of capping layer erosion, and that any erosion that occurs will impact downstream water quality.*
>>
>> *v. Flowrates in the proposed diversion/realignment through the pit pathway, including the effects of modelled change in the intensity, frequency and duration of rainfall events.*
>>
>> *vi. The Department notes that flooding is likely to cause erosion of the waste storage facility and Main Pit capping layer material. Please provide a flooding sensitivity analysis that investigate the impacts of more extreme flooding than a 1 per cent AEP event (the currently modelled scenario)."*

SLR has undertaken modelling to assess the likely impact of climate change influencers including:

- Climate change induced rainfall.
- A catastrophic fire decimating the vegetation throughout the catchment.
- The intense heat changing the structure of the soil resulting in hydrophobic conditions.

EXECUTIVE SUMMARY

The specific design elements for which the requests relate to are:

- Backfilling and capping of the Main mine pit with potentially acid forming (PAF) waste rock to a level below the currently predicted lowest pit water level.
- Realignment of the East Branch Finnis River (EBFR) to follow its original course back through the Main pit.
- Cover design and landform profile of the Waste Storage Facilities (WSFs).

The results are summarised in the following table.

Summary of Results

No.	Department Query	Response
1.	Please provide a climate change assessment demonstrating that all design components can withstand varied climatic conditions over the next, for example, 1000 years.	The design components that could be impacted by climate change include: • Backfilling and capping of the Main Pit. • Realignment of the EBFR through the Main Pit. • Capping and landform of the WSFs.
a) b) c) v.	The climate change assessment should include modelling for a wide range of possible seasonal rainfall scenarios (e.g., between 45 per cent drier and 44 per cent wetter in the dry season and between 23 per cent drier to 19 per cent wetter in the wet season). and The impacts of changing rainfall patterns (i.e., intensity, frequency and duration) including changes in individual event characteristics (e.g., increased intensity). and Flowrates in the proposed diversion/realignment through the pit pathway, including the effects of modelled change in the intensity, frequency and duration of rainfall events.	Climate change influencers relevant to the Rum Jungle region have been developed based on recommendations given in ARR, 2019 and ICCP, 2021. The following climate change influencers have been identified and the impact on rainfall scenarios, storm frequencies, temporal patterns, runoff factors and soil conditions, have been assessed: • Climate change induced rainfall patterns. • A catastrophic fire decimating the vegetation throughout the catchment. • The intense heat changing the structure of the soil resulting in hydrophobic conditions. Modelling results indicate: • Catastrophic fire which denudes the catchment of vegetation will have the greatest influence on runoff increases at the site. • The predicted rainfall increases will have a slightly greater influence than the hydrophobic soil conditions. • Overall, the peak runoff could increase by approximately 78% should all influencers occur at once. The impact on the rehabilitation design for the Main Pit is as follows: • The climate change influencers could increase bed velocities by up to 0.6m/s at the entrance and exit to the Main Pit. • The climate change influencers could increase bed velocities by up to 0.2m/s in the direct flow path in the Main Pit between the inlet and outlet. • The climate change influencers will not change the bed velocities over the remainder of the Main Pit floor.

EXECUTIVE SUMMARY

No.	Department Query	Response
		The impact to design changes for the Main Pit and the EBFR realignment are as follows: • To maintain the design safety factor, it will be necessary to enhance the erosion protection immediately upstream and downstream of the Main Pit. • The larger flows are resulting in values within the "line of site" between the inlet and outlet of the Main Pit which exceed the mobilization velocity. This can be alleviated by minor modifications (i.e., widening) to the inlet design to ensure flow moves in an anti-clockwise direction around the pit rim, i.e., increasing the flow path and reducing the velocity. It is recommended that as the backfilling of the Main Pit is nearing end of construction, i.e., when the final profile of the Pit and capping is better understood, that the modelling be redone with the correct profile and the inlet redesigned as appropriate. • No other modifications are necessary to the remediation design to mitigate the effects of climate change.
c) i. c) ii.	*Potential impacts of increased evaporation on aspects of the design including ground water levels and ground water quality.* *and* *Maintenance of the proposed Main Pit Lake, including the proposed 2 metre deep water cover*	The level of the Main Pit Lake will be dictated by the permanent groundwater table, however it is acknowledged evaporation can exceed groundwater inflow during dry seasons and lower the standing water level in the Pit. Should the capping layer be exposed however there will be no ongoing environmental impact as the capping is inert material. Additionally, ongoing geomorphic processes will result in deposition of natural sediments from upstream over the capping. However, given the long-term settlement of up to 6m over the first 100 years, it is unlikely the capping layer will be exposed. It is recommended this topic be discussed with RGC.

EXECUTIVE SUMMARY

No.	Department Query	Response
c) iii.	*Potential for erosion of the waste storage facility capping layer*	It is important to note that the WSF landforms are draft, and the final landform, materials and vegetation will be determined as construction progresses. The results indicate that the erosional performance is acceptable, however it is important to understand that modelling relies on assumptions and/or simplifications in order to obtain results. Modelling has shown that even with 500 years of no vegetation on the WSF, erosion is as follows: • Gully depths are not likely to exceed 1.0 m over 99% of the WSFs, with a maximum expected of 1.45 m, which is less than the growth medium depth of 2 m. • Erosion rates are likely to be of the order of 1.75 t/ha/yr, significantly below industry acceptable guidelines Regardless of these results, an adaptive management approach to erosion monitoring is proposed and it is considered that these measures will account for climate changes. Key approaches include: • Rock armouring of areas of high susceptibility to erosion, as identified after construction is complete. • Long term erosion monitoring (up to 20 years). • Detail of actions to identify causes of erosion based on monitoring after 20 years to allow for remediation and future erosion protection.
c) iv.	*Potential for erosion of the Main Pit capping layer. The Department notes this potential could be exacerbated as settlement occurs within the pit, resulting in an undulating surface and varied rates of capping layer erosion, and that any erosion that occurs will impact downstream water quality*	It is certain that there will be differential settlement across the pit resulting in an undulating surface and this cannot be ‘engineered’ out. The natural geomorphic processes, including deposition of upstream sediments and meandering of the EBFR will, with time, ‘even out’ these surfaces, i.e., the Main Pit will be a “sink” - it is more likely that deposition will occur within the Main Pit that erosion.
c) vi.	*The Department notes that flooding is likely to cause erosion of the waste storage facility and Main Pit capping layer material. Please provide a flooding sensitivity analysis that investigate the impacts of more extreme flooding than a 1 per cent AEP event (the currently modelled scenario).”*	Modelling of climate change influencers indicates that the flood level increase over the site would vary between 50mm and 600mm. The greatest level increase would occur at the channel necking upstream of the entry to the Main Pit. The flow path between the Main and Intermediate Pits would increase by approximately 400mm with the remainder of the catchment 300mm and less. • Hydraulic modelling has confirmed that the climate influencers would increase flood levels within the EBFR and Fitch Creek flow paths between 50 and 600mm with the average increase approximately 350mm. • The flood level increase would not exceed the defined channel and inundate the proposed waste storage facility (WSF) areas. • The modified Main Diversion Channel will not be activated.

CONTENTS

CONTENTS

DOCUMENT REFERENCES

TABLES

CONTENTS

1 Introduction

The former Rum Jungle Uranium Mine, located approximately 100 km south of Darwin, operated between 1954 and 1971 and underwent rehabilitation from 1983 to 1986. The rehabilitation addressed significant environmental impacts caused by acid metalliferous drainage and achieved objectives related to aesthetic improvements and reducing public health hazards. Recent studies documented a gradual deterioration of the original rehabilitation works meaning further rehabilitation work would be required for site closure and relinquishment.

Since 2009, the Northern Territory and Australian Governments have undertaken investigative works to develop an improved rehabilitation strategy consistent with the views and interests of stakeholders and contemporary environmental and mined-land rehabilitation standards.

SLR Consulting Australia Pty Ltd (SLR) was engaged to deliver the rehabilitation strategy design works over the period 2020 to 2021 (Project Stage 2A). This was used to support the draft Environmental Impact Statement (EIS) submitted by Northern Territory Government Department of Industry, Tourism and Trade (DITT) to the Australian Government Department Agriculture, Water and the Environment (the Department) for approval of the rehabilitation project under the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act).

Based on the review of the EIS, the Department issued a request for additional information associated with climate change, specifically:

"1. *Please provide a climate change assessment demonstrating that all design components can withstand varied climatic conditions over the next, for example, 1000 years. The climate change assessment should include modelling for:*

> *a. A wide range of possible seasonal rainfall scenarios (e.g., between 45 per cent drier and 44 per cent wetter in the dry season and between 23 per cent drier to 19 per cent wetter in the wet season).*
>
> *b. The impacts of changing rainfall patterns (i.e., intensity, frequency and duration) including changes in individual event characteristics (e.g., increased intensity); and*
>
> *c. Potential impacts of increased evaporation on aspects of the design including:*
>
> > *i. Ground water levels and ground water quality.*
> >
> > *ii. Maintenance of the proposed Main Pit Lake, including the proposed 2 metre deep water cover.*
> >
> > *iii. Potential for erosion of the waste storage facility capping layer.*
> >
> > *iv. Potential for erosion of the Main Pit capping layer. The Department notes this potential could be exacerbated as settlement occurs within the pit, resulting in an undulating surface and varied rates of capping layer erosion, and that any erosion that occurs will impact downstream water quality.*
> >
> > *v. Flowrates in the proposed diversion/realignment through the pit pathway, including the effects of modelled change in the intensity, frequency and duration of rainfall events.*
> >
> > *vi. The Department notes that flooding is likely to cause erosion of the waste storage facility and Main Pit capping layer material. Please provide a flooding sensitivity analysis that investigate the impacts of more extreme flooding than a 1 per cent AEP event (the currently modelled scenario)."*

This report has been prepared to address the above requests.

The specific design elements for which the requests relate to are:

- Backfilling and capping of the Main (mine) Pit with potentially acid forming (PAF) waste rock to a level below the currently predicted lowest pit water level.
- Realignment of the East Branch Finnis River (EBFR) to follow its original course back through the Main Pit.
- Cover design and landform profile of the Waste Storage Facilities (WSFs).

2 Climate Changes Influencers

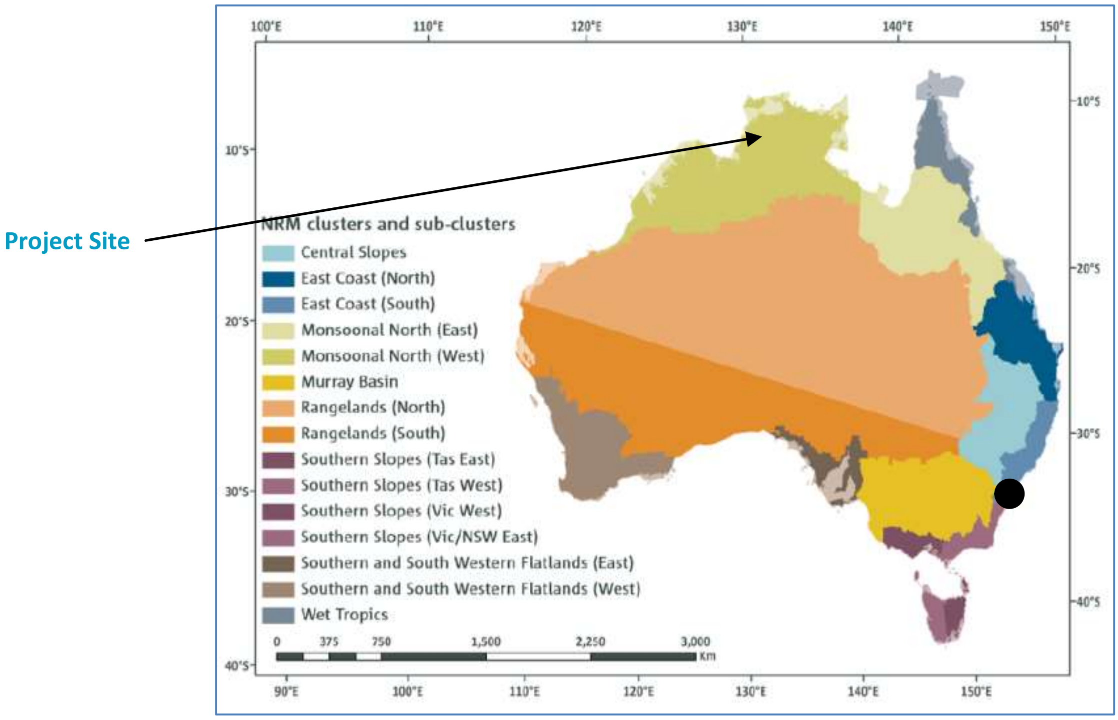
2.1 Australia's NRM Clusters and Sub-Clusters

In recognition of the impact of climate change on the management of Australia's natural resources, the Australian Government developed the **Regional Natural Resource Management (NRM) Planning for Climate Change Fund**, to provide projections of the likely impact of climate change on Australia's natural resources. The Fund (which operates within the Commonwealth Department of Environment) was also charged with reviewing adaptation opportunities for protecting and managing our land, soil, water, plants and animals.

Australia has **54 NRM regions**, defined by catchments and bioregions. Many aspects of the activities of both human activity and ecosystems within these regions are vulnerable to impacts of climate change.

- For the purposes of climate change impacts, NRM regions were originally grouped into so-called **"clusters"**, which were delineated on the basis of the broad-scale climate and biophysical regions of Australia. These eight clusters were broadly consistent in terms of history, population, resource base, geography and climate, and therefore had a unique set of priorities for responding to climate change.
- Following ongoing Australian research studies, further sub-division was deemed appropriate for some clusters to better capture the important patterns of projected change for specific climatic variables. Accordingly, five of the eight clusters were sub-divided into so-called **"sub-clusters"**, more useful for impact assessment and adaptation planning – refer **Figure 1**.
- The location of the project site is shown in the sub-cluster diagram – it lies within the **Monsoonal North (West)** sub-cluster.

Figure 1 Australia's Natural Resource Management (NRM) Clusters & Sub-Clusters



2.2 Northern Territory – Climate Sub-Zones

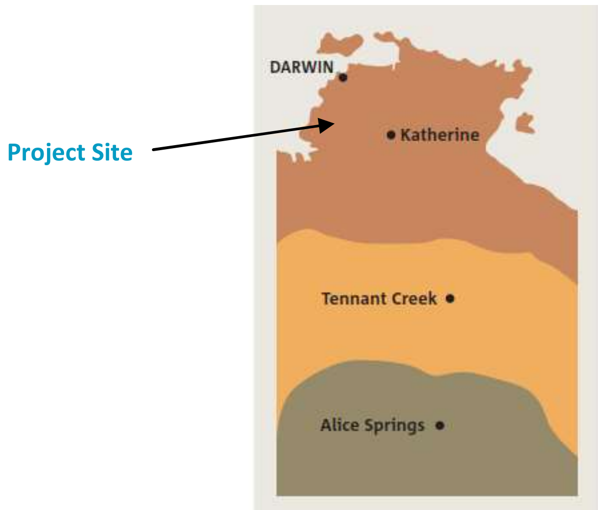
The Northern Territory's climate is shaped by a number of types of weather systems and large-scale drivers that operate over a range of time scales.

- The **monsoon** is responsible for much of the wet season rainfall in the north of the Territory. Around late December each year easterly trade winds reverse and become moisture-laden westerlies. The monsoon persists until around April. Likely changes to the monsoon in a changing climate are somewhat uncertain.
- The **El Niño Southern Oscillation** (ENSO) influences rainfall, temperatures and tropical cyclones. During an El Niño, there is reduced cloud cover leading to cooler minimum temperatures, reduced rainfall in the monsoon build-up and fewer tropical cyclones. El Niño years tend to have lower rainfall totals overall. During the alternative La Niña phase, there are higher minimum temperatures in near-coastal areas due to higher sea surface temperatures, and increased rainfall in the build-up months. El Niño events are projected to become more frequent and severe in the future, the same is the case for extreme La Niña events.
- The **Indian Ocean Dipole** (IOD) also influences rainfall and temperatures. In a positive IOD phase, the Top End experiences dry build-up months. In a negative IOD phase, there is higher rainfall over the central Northern Territory in spring, and the increased cloud results in higher minimum temperatures. There is also higher rainfall in the north during the early wet season, and temperatures are warmer due to increased sea surface temperatures near Australia.

Due to these large-scale influences and geography, the Northern Territory can also be delineated into three distinct climate zones, refer **Figure 2**, which align with the NRM clusters shown in **Figure 1.**

- The project site lies within the "Top End" tropical north sub-zone, experiencing a hot, humid wet season from November to April and a cooler dry season from May to October.

Figure 2 Northern Territory Climate Sub-Zones (based on Temperature and Humidity)



2.3 IPCC AR5 and AR6 Climate Change Projections

2.3.1 IPCC Fifth Assessment Report (2013) & CSIRO/BOM NRM Projections

The UN's IPCC (Intergovernmental Panel on Climate Change) Fifth Assessment Report, AR5, provided climate change projections based on a series of future climate change scenarios encompassing a plausible range of likely outcomes. These scenarios noted the uncertainty that would be posed by trends in population and economic growth, technological developments and transfer, and in particular, **political and social changes**. The changes to national commitments that have occurred between the December 2015 Paris Climate Change Agreement and the recent Glasgow Climate Pact (2021, COP26) are indicative of the uncertainties governing the pathway of actual future greenhouse gas emissions.

The various climate change scenarios coalesced into a spectrum of **"Representative Concentration Pathways"** (RCPs) able to explore credible future options, expressed in terms of future carbon emissions and associated radiative forcing.

- The RCPs were developed taking into account expertise in areas spanning atmospheric modelling, chemistry and the carbon cycle as well as the work of social scientists in economics, policy and impacts [Moss et al. 2010].
- Each RCP prescribed internally self-consistent 'representative' concentrations of greenhouse gases and aerosols, as well as land use changes.
- Four standard RCPs were commonly adopted in most global climate studies (**and adopted for use in the Australian context**). They represented the distillation of a much larger number of potential futures discussed in the literature [van Vuuren et al. 2011, Meinshausen et al. 2011] and, at the time, spanned the range of plausible global warming scenarios, providing a range of options for the world's governments and other institutions for decision making.
- These RCPs were used in the **Fifth Climate Model Intercomparison Project (CMIP5)** and associated **AR5 IPCC Assessment Report (2013)**.

The standard RCPs were as follows:

- **RCP8.5** was chosen to represent a future with little curbing of emissions, with CO_2 concentrations continuing to rapidly rise, reaching 940 ppm by 2100.
- **RCP6.0** represented lower emissions, achieved by application of some mitigation strategies and technologies. CO_2 concentrations rise less rapidly than RCP8.5, but still reach 660 ppm by 2100 with total radiative forcing stabilising shortly after 2100.
- **RCP4.5** concentrations were set slightly above those of RCP6.0 until after mid-century, but emissions peak earlier (around 2040). CO_2 concentrations reach 540 ppm by 2100.
- **RCP2.6** represented the most ambitious mitigation scenario, with emissions peaking rapidly (around 2020), then rapidly declining. At the time, it was recognised that RCP2.6 would require early and aggressive carbon emission controls from all emitters, including developing countries, combined with advanced technologies for actively removing carbon dioxide from the atmosphere.

The projected temperature and sea level increases associated with the above RCPs are summarised in **Table 1**.

Table 1 Projected Temperature and Sea Level Change with AR5 RCPs (Baseline: 1986-2005).

RCP	GHG Concentration in 2100 ($CO_{2,eq}$ ppm)	Projected Average Temperature Change in 2100 (°C)	Projected Average Sea Level Rise in 2100 (m)
2.6	490	0.3 to 1.7	0.26 to 0.55
4.5	650	1.1 to 2.6	0.32 to 0.63
6.5	850	1.4 to 3.1	0.33 to 0.63
8.5	1370	2.6 to 4.8	0.45 to 0.82

When the standard RCPs were first promulgated, no particular scenario was deemed more likely than the others.

- Given that the earth has (as of 2021) already experienced an increase in average temperature of just over 1°C, the lowest radiative forcing scenario, RCP2.6, would clearly require "heroic" changes in carbon emissions patterns on a global scale, changes that would appear politically unattainable.
- Post-COP26 (the recent Glasgow Climate Summit) however, there is a reasonable expectation that we may yet avoid the worst impacts associated with the RCP8.5 pathway (average temperature increase of over 3.5°C).

In response to the UN IPCC AR5 Report, Australia's CSIRO and Bureau of Meteorology (BOM) prepared tailored climate change projections for each of Australia's eight NRM clusters (as well as their sub-clusters) to be considered in planning and adaptation option assessments.

Appendix A contains the detailed CMIP5 climate change projections for the Monsoonal North Cluster.

Appendix A also contains detailed selected climate change projections for the Monsoonal North (West) Sub-Cluster.

Further details regarding climate change projections relevant to the project site can be found in:

- *"Climate Change in the Northern Territory - State of the Science and Climate Change Impacts"*, Earth Systems and Climate Change Hub, September 2020.

Highlights for the NT's "Top End" (which includes the project site):

Average Temperature:

- By 2030, warming of around 0.5°C to 1.4°C will occur compared to the average for the period 1986–2005, with very little difference between RCP scenarios.
- By 2050, warming will range from 0.7°C to 1.6°C (low emissions RCP) to 1.4°C to 2.4°C (high emissions RCP).
- By 2090, warming will range from 0.6°C to 1.8°C (low emissions RCP) to 2.8°C to 5.1°C (high emissions RCP).

Maximum Temperatures:

- The hottest days in the NT will be hotter and more frequent, and warm spells will be longer.
- By the middle of the century, the number of days a year over 35°C will at least double in many places across the Territory. For Batchelor for example, the number of days a year over 35°C is projected to increase from 86 (1981-2010 historical average) to 199 by 2050 and 291 by 2090 under the RCP8.5 pathway.

Rainfall:

- For the near future, natural variability will cause greater year-to-year changes in rainfall than the effects of climate change.
- Near-future projections (compared to the 1986-2005 average) for the dry season range from 35% drier to 29% wetter, depending on RCP scenario. For the west season, projected changes range from 8% wetter to 7% drier.
- By 2090, the projected dry season changes range from 45% drier to 44% wetter, depending on RCP scenario. For the wet season, the projected range is 23% drier to 19% wetter.
- These large ranges and the lack of a clear over-riding direction suggest that planning needs to consider both a drier and wetter future, in terms of rainfall averages.
- In general, as the air becomes warmer, it has a greater capacity to hold water vapour. This means that, even though changes to average rainfall may be unclear, the intensity of heavy rainfall events will likely increase in the future.
- While there is high confidence that heavy rainfall events will become more intense, the percentage change in intensity is not clear and judgement must be used in assigning future potential "peak" storm events.

Fire Weather:

- Over the past 30 years or so, the number of days with severe fire weather has increased during the dry season (winter and spring).
- Under all future RCP scenarios, fire weather will become more frequent and harsher.

2.4 Recent Projections – AR6 and CMIP6

The most recent climate change data can be found in the UN's IPCC Sixth Assessment Report, AR6.

AR6 Working Group I - The Physical Science Basis, states the following:

- *"It is indisputable that human activities are causing climate change, making extreme climate events, including heat waves, heavy rainfall, and droughts, more frequent and severe."*
- *"Recent changes in the climate are widespread, rapid, and intensifying, and unprecedented in thousands of years."*
- *"Unless there are immediate, rapid, and large-scale reductions in greenhouse gas emissions, limiting warming to 1.5°C will be beyond reach."*

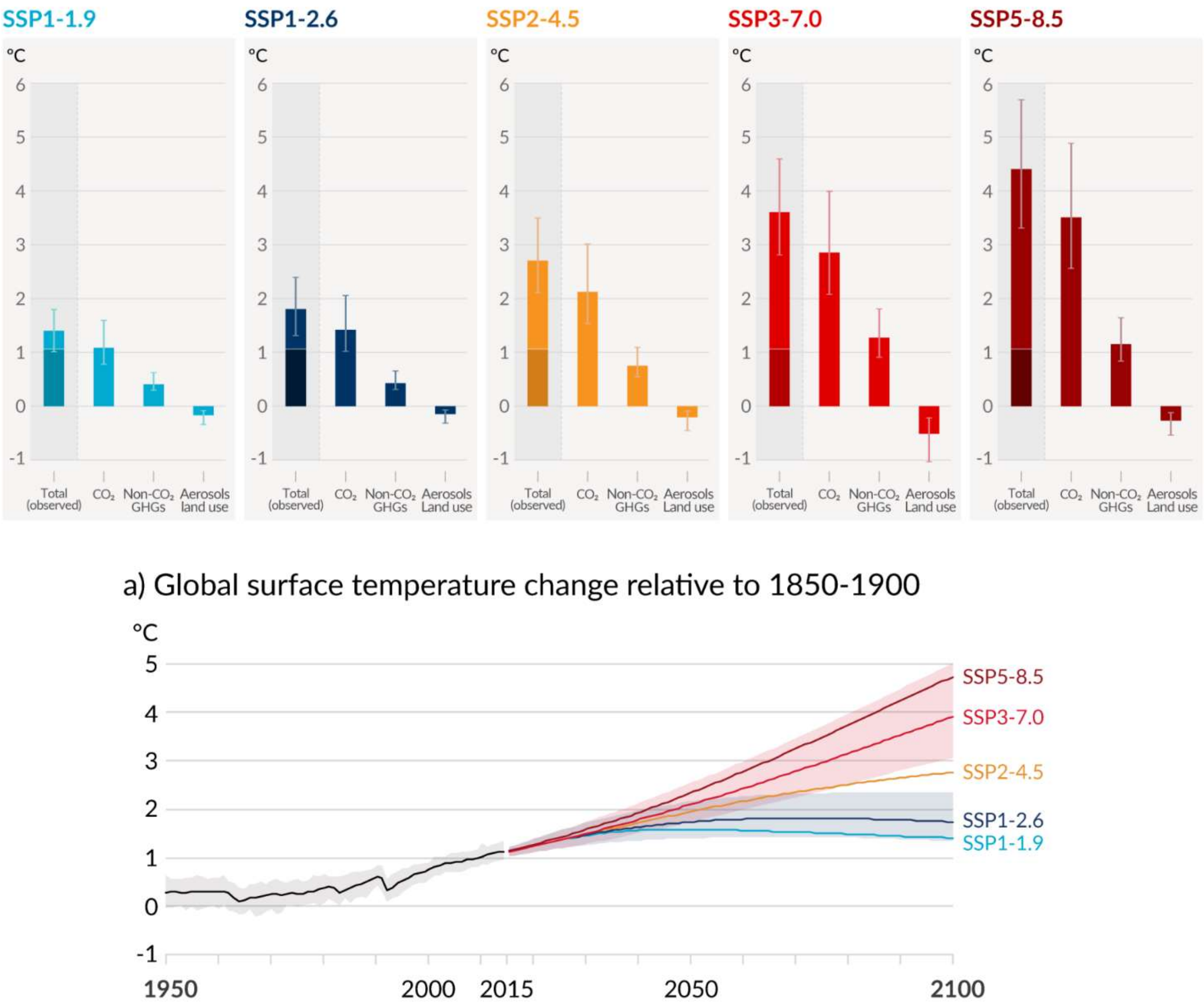
Comment on CMIP6 / IPCC Sixth Assessment Report – Climate Change Scenarios

The climate change scenarios covered in the IPCC AR6 Report cover a broader range of emissions futures, so-called "SSPs", than considered in AR5.

- A core set of five illustrative SSP scenarios is emerging for use in exploring climate change impacts over the 21st century and beyond. They are labelled SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5.
- These span a wide range of radiative forcing levels in 2100 and include scenarios with high and very high GHG emissions (SSP3-7.0 and SSP5-8.5), scenarios with intermediate GHG emissions (SSP2-4.5) and scenarios with very low and low GHG emissions (SSP1-1.9 and SSP1-2.6).

The change in global surface temperature for each of these new AR6 climate change scenarios is shown in **Figure 3**.

Figure 3 Change in Global Surface Temperature (°C)in 2018-2100 (relative to 1850-1900)



Selected Climate Change Projections - NT

To date, the CMIP5 projections for Australia's NRM Clusters and Sub-Clusters have not yet been updated to reflect the updated AR6 climate change scenarios.

Nevertheless, the climate change projections in AR6 are wholly consistent with the AR5 projections.

In particular, the following overall climate change impacts relevant to this study are noted in AR6 for Australia's "Northern Australian" (NAU) Region, which covers the northern part of Australia down to 20°south.

And, as in the case of the CMIP5 projections, the above report notes that these impacts are already being observed in climate observations gathered over the past several decades.

Heat & Cold

- Mean Surface Temperature will INCREASE HIGH confidence
- Extreme Heat will INCREASE HIGH confidence
- Cold Spells will DECREASE HIGH confidence

West & Dry

- River Flooding will INCREASE MEDIUM confidence
- Heavy Precipitation & Pluvial Flooding will INCREASE MEDIUM confidence
- Fire Weather will INCREASE HIGH confidence

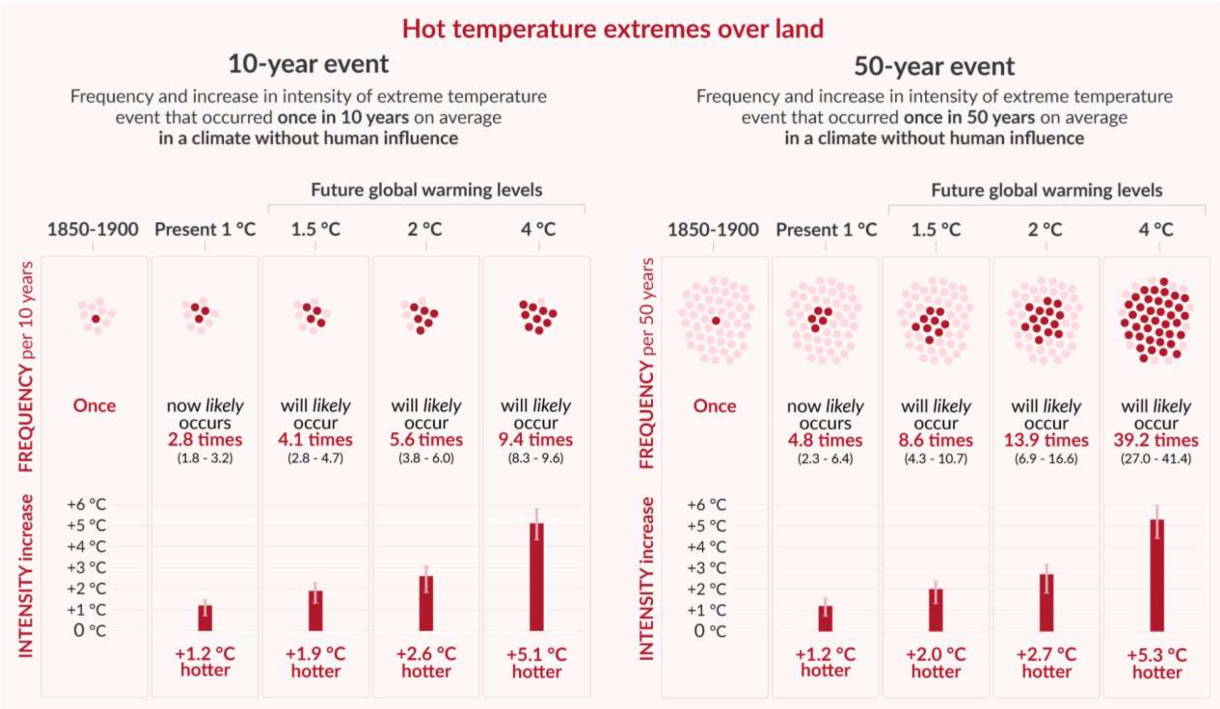
Wind

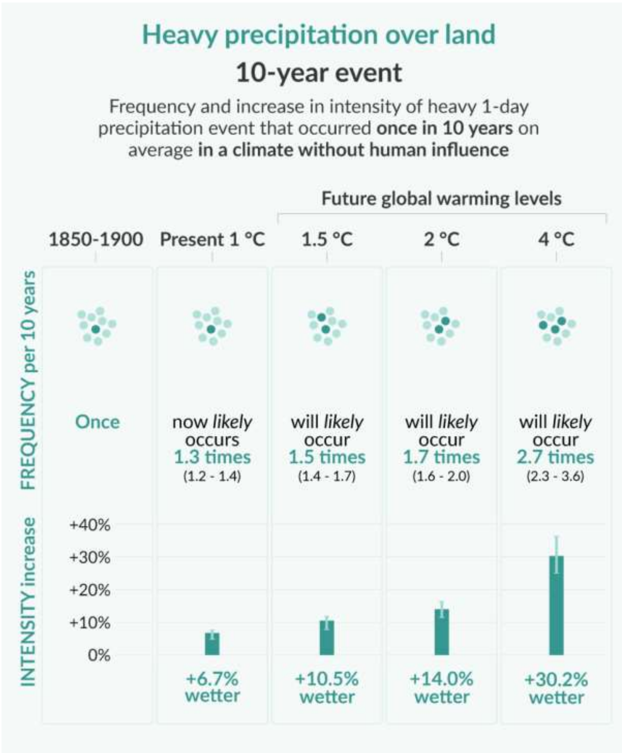
- Sand & Dust Storms will INCREASE MEDIUM confidence

An appreciation of what the above overall impacts may mean in terms of the occurrence of severe weather events, eg extreme heat, extreme rainfall, can be seen in **Figure 4**.

- 10-year return period extreme temperature events are already occurring almost 3 times as often compared to the 1850-1900 period. Under a 2°C future global warming scenario (which would appear to be potentially optimistic following the outcomes of the recent COP26 Glasgow Climate Summit), this will increase to almost 6 times as often.
- 10-year return period extreme 1-day precipitation events are already occurring about 1.3 times as often compared to the 1850-1900 period. Under a 2°C future global warming scenario, this will increase to about 1.7 times as often.

Figure 4 IPCC Sixth Assessment Report – Predicted Changes in Extreme Temperatures and Rainfall





3 Climate Change Influencers on Rehabilitation Design

SLR has considered the ways that key climate change indicators, eg temperature, rainfall, etc, might influence the Rum Jungle Rehabilitation Design, with a focus on:

- Climate change impacts on rainfall: especially peak intensity rainfall events;
- Climate change impacts on fire weather I: we have considered the potential for a catastrophic fire decimating the vegetation throughout the project site catchment; and
- Climate change impacts on fire weather II: we have considered how the intense heat from an extreme bush fire might change the structure of the soil resulting in hydrophobic conditions.

Table 2 summarises the potential climate change influencers that could impact the design, which includes topics of interest requested by the Department, and the potential impact on the design works undertaken to date.

Table 2 Climate Change Influencers and Potential Impact

Influencer	Impact on modelling equations	Impact on modelling results	Impact on Rum Jungle rehabilitation design	Potential influence on the integrity of the rehabilitation design	Requires further investigation
Increase in rainfall intensity i.e., a 1 in 100 AEP event in say 2050 will contain more rainfall with a greater intensity than a 1 in 100 AEP today.	- rainfall depth increased - steepness of temporal pattern increased	- flood depth increased - greater surface velocities	- flooding exacerbated - surface erosion potential increased - flood hazard increased - velocities in Main Pit increased	Moderate	Yes
Droughts and fire	- hydrophobic soil conditions generated - the sorpitivity (initial loss) reduced however would be partially compensated by storages developed from deep surface cracking in clays - the hydraulic conductivity (continuing loss) will reduce due to hydrophobic soil conditions	- will increase runoff rate - will decrease infiltration - will increase surface velocities	- will increase flood depth and velocity during small/frequent storms - will marginally increase flood depth and velocity during large/rare storms - will increase erosion	Moderate	Yes
More intense and widespread fires within the contributing catchment	- A change to the modelled surface roughness due to loss of cover exposing bare earth rather than vegetation	- an increase in runoff rate - an increase in flood depths - an increase in surface velocities	- greater flowrate through Main Pit and diversion channel - greater potential for erosion - deposition of silt and debris in the Main Pit - could agitate/erode Main Pit capping	Major	Yes

Influencer	Impact on modelling equations	Impact on modelling results	Impact on Rum Jungle rehabilitation design	Potential influence on the integrity of the rehabilitation design	Requires further investigation
Rainfall frequency reduced	- not modelled	- not modelled	- frequency for fish migration reduced - fish likely to reside longer in Main and Intermediate Pits	Minor	No
Reduced groundwater levels	- lower starting water level in Main Pit	- minor during small/frequent events - insignificant during large/rare events	- unlikely to expose capping in Main Pit as historic groundwater levels have not shown a significant downward trend	Minor	No
Increased average soil temperatures	- reduced antecedent moisture conditions	- major during small/frequent events - minor during large/rare events	- none	Minor	No

4 Climate Change and Effect on Rainfall

4.1 Climate Change and Flood Projections – Comments from IPCC AR6

Floods are a natural and important part of the water cycle. They can threaten lives and safety, and damage infrastructure. Most inland floods occur when rivers overtop their banks (fluvial flooding) or when intense rainfall causes water to build up and overflow locally (pluvial flooding).

Climate change is already altering the location, frequency and severity of flooding.

- Close to the coast, sea level rise is causing more frequent and severe coastal flooding; the severity of these floods is exacerbated when combined with heavy rainfall.
- Extreme rainfall events responsible for most peak inland flooding are becoming more intense in many global areas as the climate warms because the atmosphere near the Earth's surface can carry around 7% more water in its gas phase (vapour) for each 1°C of warming. This extra moisture can then be drawn into local weather systems, fuelling heavier rainfall.

In general, therefore, a warming climate will increase the amount and intensity of rainfall during wet events, thereby potentially amplifying the severity of flooding. However, the link between rainfall and flooding is complex, so while the severity of flooding events is expected to worsen in the future, the geographical incidence of floods might change in some regions due to the following factors:

- A warming climate will likely affect wind patterns, how storms form and evolve, and the pathway those storms usually travel. Warming also increases condensation rates, which in turn releases extra heat that can energize storm systems and further intensify rainfall. On the other hand, this energy release can also inhibit the uplift required for cloud development, while increases in particle pollution can delay rainfall but invigorate storms.

Further complexity in relation to future trends in flooding arise due to the dependence of flooding on geomorphological factors such as: the type of river basin, the surface landscape, and how wet the ground is before the rainfall event.

- Some regions may experience a drying in the soil as the climate warms, which could make floods from a rainfall event less probable because the ground can potentially soak up more of the rain. On the other hand, less frequent but more intense downpours can lead to dry, hard ground that is less able to soak up heavy rainfall when it does occur, resulting in more runoff into lakes, rivers and hollows.
- Flooding is also affected by changes in the management of the land and river systems. Land clearing can make rain water flow more rapidly into rivers or low lying areas. On the other hand, increased extraction of water from rivers can reduce water levels and the likelihood of flooding.

All of the above changes mean that the character of extreme flood events (how often, how long-lasting and how heavy they are) will continue to change in complex ways as the climate warms.

Nevertheless, the overall trend is clear: in a warming climate, rainfall depths in extreme events are expected to increase driven by a warmer atmosphere being able to hold more moisture.

4.2 Estimating Climate Change Impacts on Rainfall Intensity

Since the Rum Jungle Rehabilitation project has a long design life (greater than 50 years, (ARR, 2019)), climate change may be significant.

(ARR, 2019) identifies two alternative methods to estimate the impact of climate change on rainfall depths. These are described below.

4.2.1 Simplified Method

The simplified method allows incorporating the effects of climate change in the design rainfall used in flood estimation, by modelling of the 0.5% (1 in 200) Annual Exceedance Probability (AEP) in lieu of the 1% (1 in 100) AEP event.

- For the critical duration 30-hour rainfall event this would represent an **increase in rainfall depth of 15%**.

4.2.2 Detailed Assessment

The second method involves a more detailed assessment of increased rainfall intensity based on predictive modelling of temperature increases sourced from the Climate Change in Australia website (https://www.climatechangeinaustralia.gov.au) and applying a change in design rainfall from global warming in accordance with the following formula – refer Equation 1.6.1, ARR 2019.

$$I_p = I_{ARR} \cdot 1.05^{Tm} \qquad \text{Eq.1.6.1 (ARR,2019)}$$

where:

I_p = Projected rainfall intensity (or depth)

I_{ARR} = Design rainfall intensity (or depth)

Tm = Is the temperature at the midpoint of the selected class interval

Table 3 summarises the climate change predictions for the four standard AR5 RCP climate change scenarios for the year 2070, i.e., ~50 years from design.

Table 3 Summary of Climate Change Data for Year 2070

RCP	No Climate Models	Slightly Warmer >0.5^{0}C	Warmer 0.5 to 1.5^{0}C	Hotter 1.5 to 3.0^{0}C	Much Hotter >3^{0}C
RCP2.6	29	2	25	2	0
RCP4.5	46	1	15	30	7
RCP6.0	22	0	4	18	0
RCP8.5	48	0	0	32	16

In **Table 3**, the outcomes for the upper (RCP 8.5) values for example can be summarised as follows for clarity:

- For RCP 8.5, there are 48 climate model predictions: 67% of these models predict a temperature increase of 1.5°C to 3°C, while 33% predict a temperature increase greater than 3°C.

It is apparent that there is a high level of confidence that temperatures will increase, and for the higher GHG emission RCP pathway models, it appears likely that the temperature increase will be within 1.5°C to 3.0°C.

Based on this information, a conservative temperature increase for the project site of 2.25°C is considered suitable for estimating future rainfall intensity increases.

Using **Eq.1.6.1** ARR (2019) this would equate to **an 11.6% increase in rainfall intensity** (or depth).

4.3 Adopted Climate Change Rainfall

The two methods of estimating increase in rainfall associated with climate change are compared in **Table 4**.

Table 4 Comparison of Climate Change Rainfall Increases

Duration	Rainfall Depth, 30-hour duration	Comment
2019 Rainfall – 1% AEP	318 mm	Baseline
Simplified Method	366 mm (+15.0%)	Adopted for sensitivity analysis
Detailed Method	355 mm (+ 11.6%)	Is of similar magnitude

A conservative approach has been adopted and the 0.5% AEP rainfall has been adopted to examine the effect of climate change on the project design.

5 Climate Change and Effect on Infiltration of Soils

5.1 Physical Impact

The First Nations people have been using controlled fire as an environmental management tool for millennia. Climate change is modifying the fuel, wind and temperature to create situations where fire can be catastrophic, with the potential to destroy the entire contributing catchment relevant to Rum Jungle. The result is exposure of erodible soils via burning of the vegetation on the soil surface. Under intense heat, the following soil changes can occur:

- The predominant sandy clay soil in the upper catchment will crystallize at temperatures of 350°C to 800°C, similar to the firing of clay in a kiln.
- Intensely burning organic material can release a waxy substance which penetrates the soil as a gas and solidifies after cooling, bonding the soil particles together.
- The open pores of a sandy clay soil allow the penetration of heat deep into the soil profile.

These processes result in the top layer of soil becoming hydrophobic which has the following impacts on hydrologic and hydraulic processes.

- The infiltration rate is reduced or stopped;
- The runoff rate increases;
- Velocities increase;
- Flood depths increase; and
- The surface shear stress increases resulting in greater erosion and soils loss.

Hydrophobic soils will eventually break down by flora and fauna, but the process is slow as moisture retention is reduced.

5.2 Impact on Modelling Parameters

The upper catchment at the Rum Jungle site is predominantly sandy clays covered in humus. Refer **Figure 5**.

Figure 5 Classification of soils in the upper catchment

Based on a combination of calibration to actual rainfall and runoff records, information from the ARR Data Hub and in-situ soil testing, the infiltration parameters adopted in the hydrology analysis of Rum Jungle for the upper contributing catchment were as follows:

- Initial loss = 38mm.
- Continuing loss = 0.6mm/h.

As detailed above the consequence to the infiltration of soils of an intense catastrophic fire engulfing the catchment will be to:

- Remove the humus from the surface;
- Make the top 50 mm to 75 mm impervious; and
- Result in cracking of the surface soils (including potential capping materials).

To emulate this behaviour in modelling, the following infiltration parameters have been adopted:

➔ **Initial loss = 10mm**

➔ **Continuing loss = 0mm/h**

6 Climate Change and Effect on Catchment Roughness

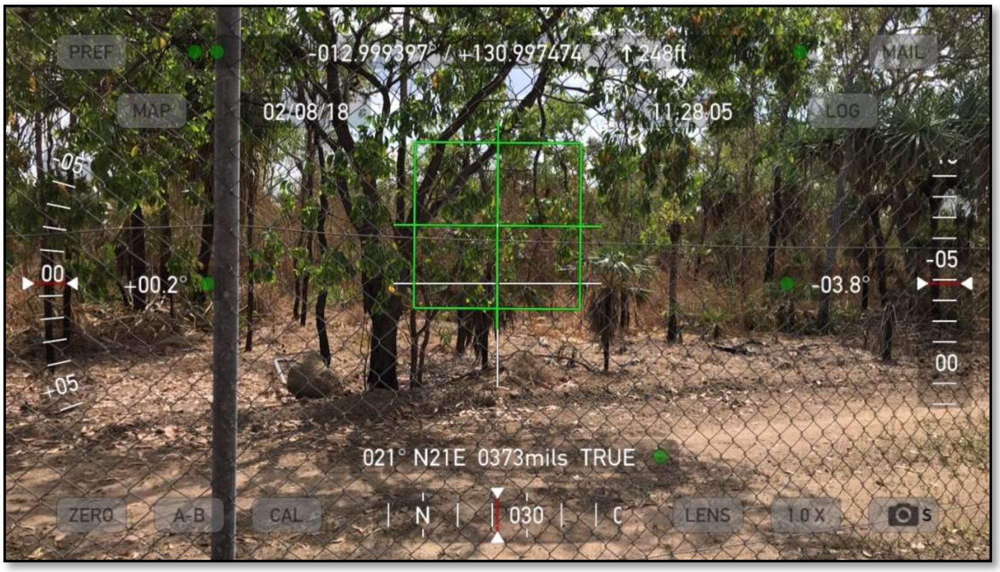
6.1 Physical Impact

Aerial photographs of the contributing catchments show it to be heavily wooded - refer **Figure 6**.

Figure 6 Aerial photograph of the contributing catchments

Ground level photographs show the vegetation to be dense with significant undergrowth and tuff grasses – refer **Figure 7**.

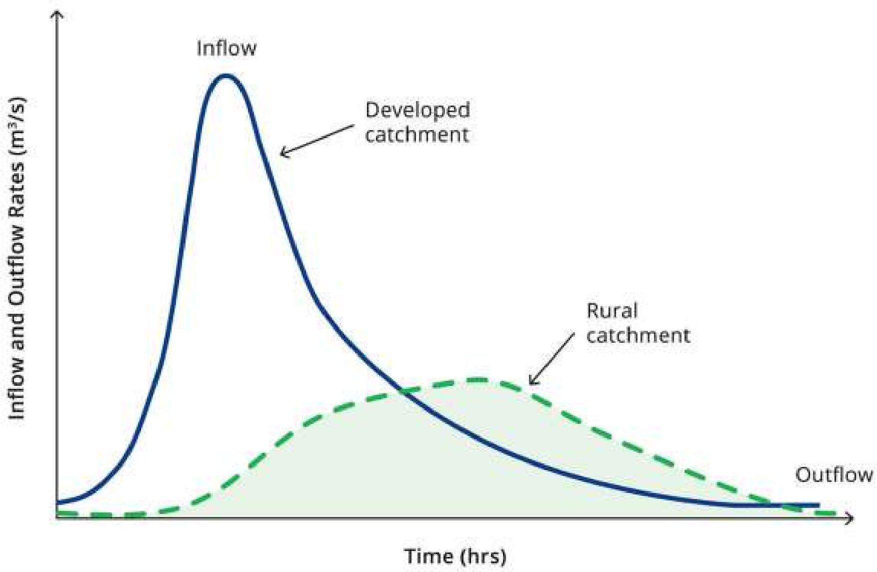
Figure 7 Ground level photograph of the vegetation at Rum Jungle



Not only does vegetation intercept rainfall as it falls through the canopy, but it stores and diverts the flow causing it to meander across the topography. This reduces the surface velocity and delays the travel time of runoff which results in reduced flooding. The effect of a fire denuding the surface is akin to the urbanisation of a catchment - refer **Figure 8** and **Figure 9**.

Figure 8 The result of fire

Figure 9 The effect to surface runoff of burning the vegetation (ref ARR 2019, Figure 9.4.2)



6.2 Effect to Modelling Parameters

The rainfall runoff processes of the Rum Jungle catchment were simulated using the Runoff Analysis and Flow Training Simulation (RAFTS) software. The software divides the sub-catchment into ten equal subareas and each subarea is treated as a cascading non linear storage subject to the following relationship:

$$\text{Storage (S)} = \text{storage delay time coefficient (B)} \times \text{discharge (Q)}^{-0.285}$$

The rainfall is applied to each sub-area, and the rainfall excess is computed and converted into an instantaneous inflow. This instantaneous flow is then routed through the sub-area storages to develop individual sub-catchment outlet hydrographs.

The storage delay time coefficient (B) for a rural catchment is calculated by the following equation:

$$\text{storage delay time coefficient (B)} = 0.285 \times \text{Area}^{0.52} \times \text{Slope}^{-0.5} \times \text{PERN}$$

PERN is inputted as a Manning's 'n' representation of the average sub-catchment roughness according to the relationship in **Figure 10**.

Figure 10 Relationship between Manning's n and PERN and the hydrological consequence of fire

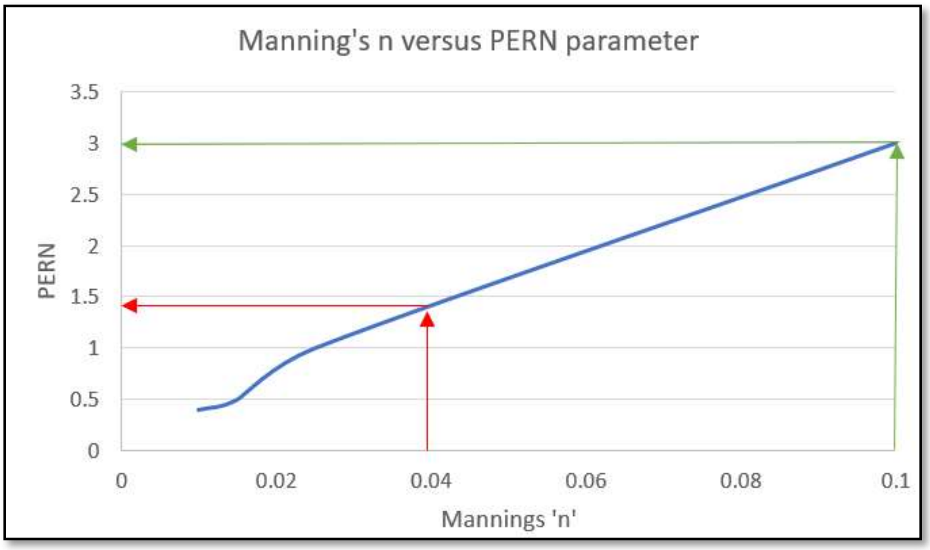


Table 5 is a summary of the lifetime research by Ven Te Chow (1959) which is considered the Mannings 'n' 'bible' in the field of hydrology. It relates the sub-catchment vegetation to a value to be used in hydrologic and hydraulic calculations.

- The upper catchment of Rum Jungle contains vegetation which could be represented with a Manning's 'n' of 0.05 to 0.1.
- In the event of a catastrophic fire these areas would be converted to a Manning's 'n' of 0.04.

In accordance with **Figure 10** the storage delay time coefficient (B) would be:

➔ **for a dense bush sub-catchment (=3) would change to that for fire ravaged sub-catchment (=1.4).**

Table 5 Manning's 'n' according to Ven Te Chow (1959)

Floodplain surface vegetation	Manning's 'n'
No vegetation	0.03
Fire ravaged land, charred tree stumps, no sprouts	0.04
Scattered bush and weeds	0.05
Light bush and trees	0.06
Medium to dense bush	0.07
Dense bushland	0.10
Heavy stand of timber, a few downed trees and flood profile below branches	0.10
Heavy stand of timber, flood profile reaching branches	0.12

The hydrological effects to the runoff calculations include:

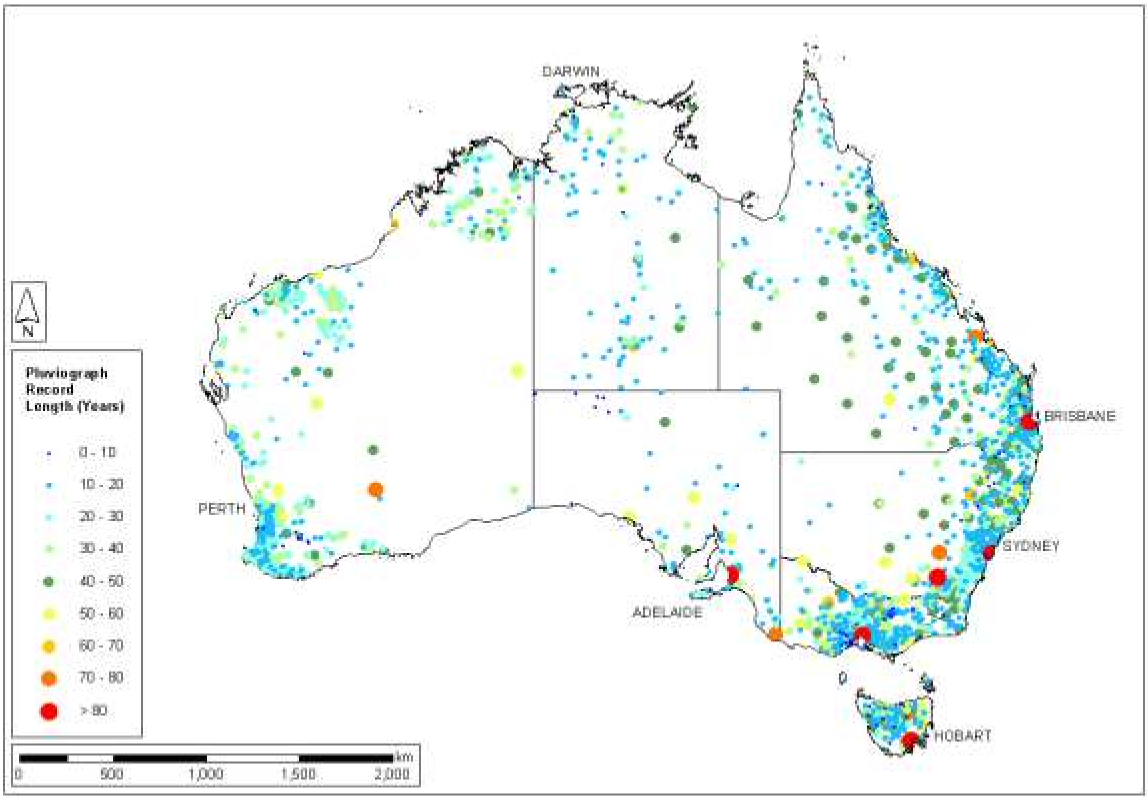
- Increased runoff rate.
- Increased volume of runoff.
- Increased flooding.

7 Hydrological Effects of the Influencers

7.1 Rainfall and Temporal Pattern Records

With the recent release of ARR 2019, the Bureau of Meteorology (BoM) produced a quality controlled pluviography database, containing 2,280 stations with an average station record length of 25 years and a combined record length of 57,000 years. **Figure 11** shows the location of the rainfall stations. The Rum Jungle catchment has only 20 to 30 years of reliable rainfall data.

Figure 11 Pluviometer rainfall stations



7.2 Rainfall Temporal Patterns and the Adoption of Temporal Pattern Ensembles

The use of an ensemble of 10 temporal patterns for each storm duration is now required by ARR, 2019. The temporal patterns have been chosen to represent the variability in observed patterns. Given the available computational power of computers today, the run times of two-dimensional hydraulic models does not make it practical to simulate all 10 patterns for each storm duration for each magnitude (a total of 290 different storms for each magnitude).

The most practical approach is to run a separate hydrological model of the whole catchment to determine the average pattern in terms of peak flow. Testing has demonstrated that on most catchments, a large number of events in the ensemble patterns are clustered around the mean and median. The required approach is to select the storm which represents the mean of the ensemble maximums.

7.3 The Baseline 1% AEP Discharge

The Rum Jungle Rehabilitation hydraulic infrastructure has been designed to safely pass the 1% AEP event. The following table summarises the peak flow for each ensemble duration for the 61.5 km^2 catchment.

Table 6 1% AEP baseline discharge for the range of storm durations simulated

Storm duration (hours)	1% AEP ensemble maximums at site (m^3/s)	Ensemble reference number
4.5	151	10
6	169	2
9	198	9
12	210	4
18	231	1
24	217	3
30	195	6
36	213	5
48	213	1
72	208	1
96	185	6
120	171	3
144	163	6
168	153	4

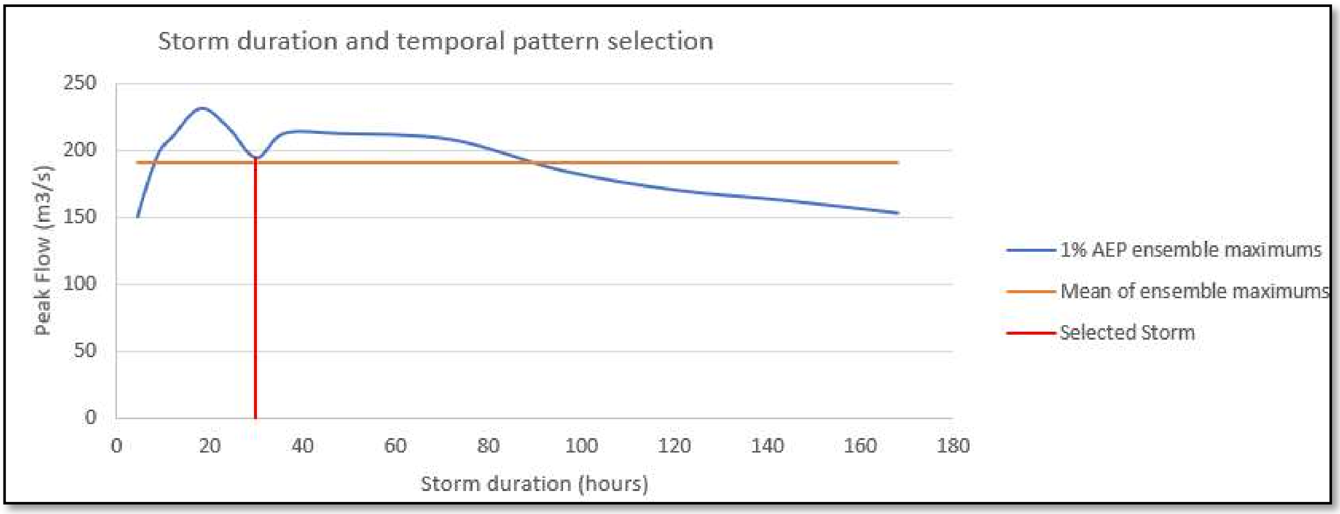
When graphed it can be seen that the catchment produces a peak flow for storm durations of 18 hours, a minimum flow for very short and very long storms and a mean at 30 hours duration. In accordance with ARR 2019 practice, it is this 30-hour duration storm and temporal pattern that is to be used for design of infrastructure.

Figure 12 is a graph of the phenomena with the mean of the maximums identified as the selected storm.

- ➔ **The 30-hour duration 1% AEP storm with temporal pattern no.6 is the mean of the maximum ensemble and produces a peak of 195 m^3/s. This storm is the baseline for influencer effects.**

- ➔ **The critical duration is the 18-hour rainfall event which produces a maximum of 231 m^3/s**

Figure 12 Ensemble peak discharge for the range of storm durations modelled



7.4 Effect of Climate Change Induced Rainfall

Based on the accepted procedure in ARR, 2019 and the sixth Assessment Report (AR6) of the IPCC, the climate change rainfall depth is expected to increase by 15% for the 1% AEP magnitude event. **Table 7** summarises the peak flow for each ensemble duration for increased rainfall.

Table 7 Effect of increased rainfall as a consequence of climate change

Storm duration (hours)	1% AEP ensemble maximums at site (m^3/s) (Baseline case)	Influence of increased rainfall as a consequence of climate change (m^3/s)	Ensemble reference number
4.5	151	192	10
6	169	213	2
9	198	245	9
12	210	255	8
18	231	276	1
24	217	257	3
30	195	230	8
36	213	248	5
48	213	246	1
72	208	239	1
96	185	211	6
120	171	193	3
144	163	184	6
168	153	173	4

- **The peak runoff at the site would increase by approximately 18% as a consequence of climate induced rainfall increases.**
- **The critical duration storm is the 18-hour rainfall event which produces a peak flow of 276m³/s.**
- **The mean of the maximum ensemble is the 30-hour rainfall event which produces a peak flow of 230m³/s.**

7.5 Effect of Climate Change Induced Fire

The total incineration of vegetation within the contributing catchment will reduce the hydrological surface roughness. Reducing the Manning's 'n' of all sub-catchments to 0.04 (which were previously higher) will have the following effect if a 1% AEP event were to occur.

Table 8 Effect of a catastrophic fire as a consequence of climate change

Storm duration (hours)	1% AEP ensemble maximums at site (m³/s) (Baseline case)	Influence of fire as a consequence of climate change (m³/s)	Ensemble reference number
4.5	151	259	6
6	169	278	1
9	198	306	9
12	210	302	1
18	231	311	3
24	217	268	7
30	195	258	9
36	213	269	1
48	213	276	8
72	208	265	1
96	185	235	6
120	171	216	4
144	163	207	5
168	153	190	6

- **The peak runoff at the site would increase by approximately 36% as a consequence of a climate change induced catastrophic fire.**
- **The critical duration storm is the 18-hour rainfall event which would produce a peak flow of 311 m³/s.**
- **The mean of the maximum ensembles is the 4.5-hour rainfall event which would produce a peak flow of 259m³/s.**

7.6 Effect of Climate Change Induced Changes to the Soil Structure

The total incineration of vegetation within the contributing catchment may also cause hydrophobic soil. The significant reduction in infiltration losses will have the following effect if a 1% AEP event were to occur within several years after a catastrophic fire.

Table 9 Effect of a climate change induced changes to the structure of the soil

Storm duration (hours)	1% AEP ensemble maximums at site (m^3/s) (Baseline case)	Influence of fire as a consequence of climate change (m^3/s)	Ensemble reference number
4.5	151	202	8
6	169	217	2
9	198	238	5
12	210	244	8
18	231	257	2
24	217	237	3
30	195	218	8
36	213	233	4
48	213	231	1
72	208	222	1
96	185	198	6
120	171	183	3
144	163	175	6
168	153	166	6

- ➔ **The peak runoff at the site would increase by approximately 13% as a consequence of climate change induced structural changes to the soil.**
- ➔ **The critical duration storm is the 18-hour rainfall event which would produce a peak flow of 257 m^3/s.**
- ➔ **The mean of the maximum ensembles is the 6-hour rainfall event which would produce a peak flow of 217 m^3/s.**

7.7 Effect of the Climate Change Influencers

It is plausible for all three of the following climate change influencers investigated to occur simultaneously.

- Climate change induced rainfall.
- A catastrophic fire incinerating the vegetation throughout the catchment.
- The intense heat changing the structure of the soil resulting in hydrophobic conditions.

Table 10 summarises the results of this "worst-case" combined scenario.

Table 10 Effect of all three climate change influencers

Storm duration (hours)	1% AEP ensemble maximums at site (m^3/s) (Baseline case)	Influence of fire as a consequence of climate change (m^3/s)	Ensemble reference number
4.5	151	426	6
6	169	428	1
9	198	427	9
12	210	396	8
18	231	393	6
24	217	340	7
30	195	338	5
36	213	342	4
48	213	339	7
72	208	321	1
96	185	283	6
120	171	259	4
144	163	249	5
168	153	230	6

→ **The peak runoff at the site would increase by approximately 78% as a consequence of the three climate change influencers occurring simultaneously.**

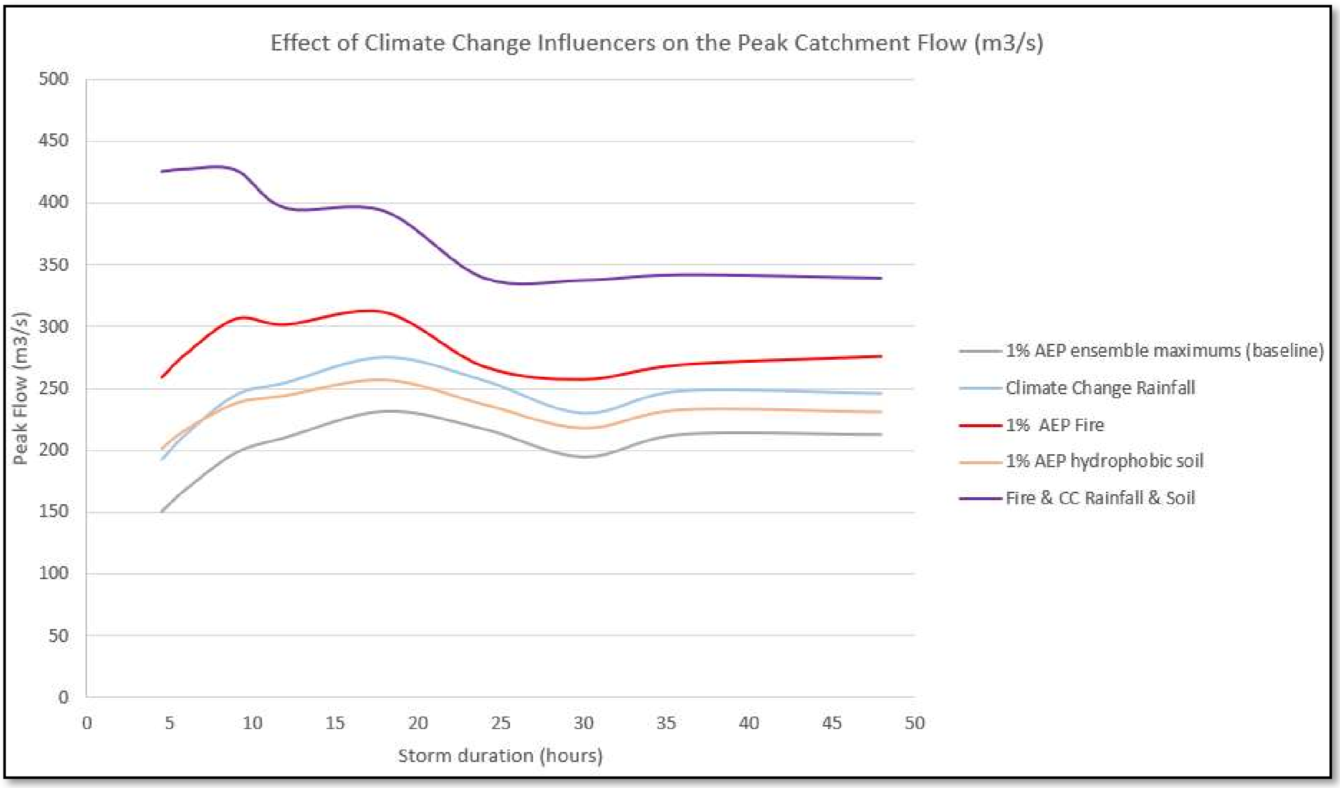
→ **The critical duration storm is the 6-hour rainfall event which produces a peak flow of 428m^3/s.**

→ **The mean of the maximum ensembles is the 24-hour rainfall event which produces a peak flow of 340m^3/s.**

7.8 Summary of Impact of Climate Change Influencers on Peak Catchment Flows

A summary of the above results is shown graphically in **Figure 13.**

Figure 13 Summary of results of climate change influencers



The results indicate that:

- **Catastrophic fire which denudes the catchment of vegetation will have the greatest influence on runoff increases at the site.**
- **The predicted rainfall increases will have a slightly greater influence than the hydrophobic soil conditions.**
- **Overall, the peak runoff could increase by approximately 78% should all influencers occur at once**.

8 Impact of Influencers on the Main Pit and EBFR Designs

8.1 Hydraulic Impact

The Rum Jungle catchment has been hydraulically modelled using two-dimensional (2D) software to accurately represent the complex flow patterns. The 2D model provides an accurate representation of the flow and velocity distribution, water surface elevation, backwater, velocity magnitude and direction, flow depth, and shear stress.

The following scenarios were hydraulically modelled to verify the integrity of the final landform:

- The final rehabilitated topographical surface of the Rum Jungle site during the 1% AEP flood (base case).
- The final rehabilitated topographical surface of the Rum Jungle site with the Climate Change Influencers.
- A subtraction of one from the other to reveal the changes in the flood profile over the rehabilitated site.

Prior to comparing the results, it is necessary to appreciate the proposed landform changes to the Rum Jungle site following rehabilitation.

8.1.1 The Existing Landform

A remnant of the former mining activities is the Main Diversion Channel which bypasses all flows in the East Branch of the Finniss River (EBFR) around both the Main and Intermediate pits.

Figure 14 is a 3D aerial representation of the existing diversion channel with the Main and Intermediate Pits to the right of the channel. The channel is in the vicinity of 6 m deep and highly eroded with near vertical collapsing banks in some areas.

Figure 14 The existing Main diversion channel bypassing flows around the Main and Intermediate Pits

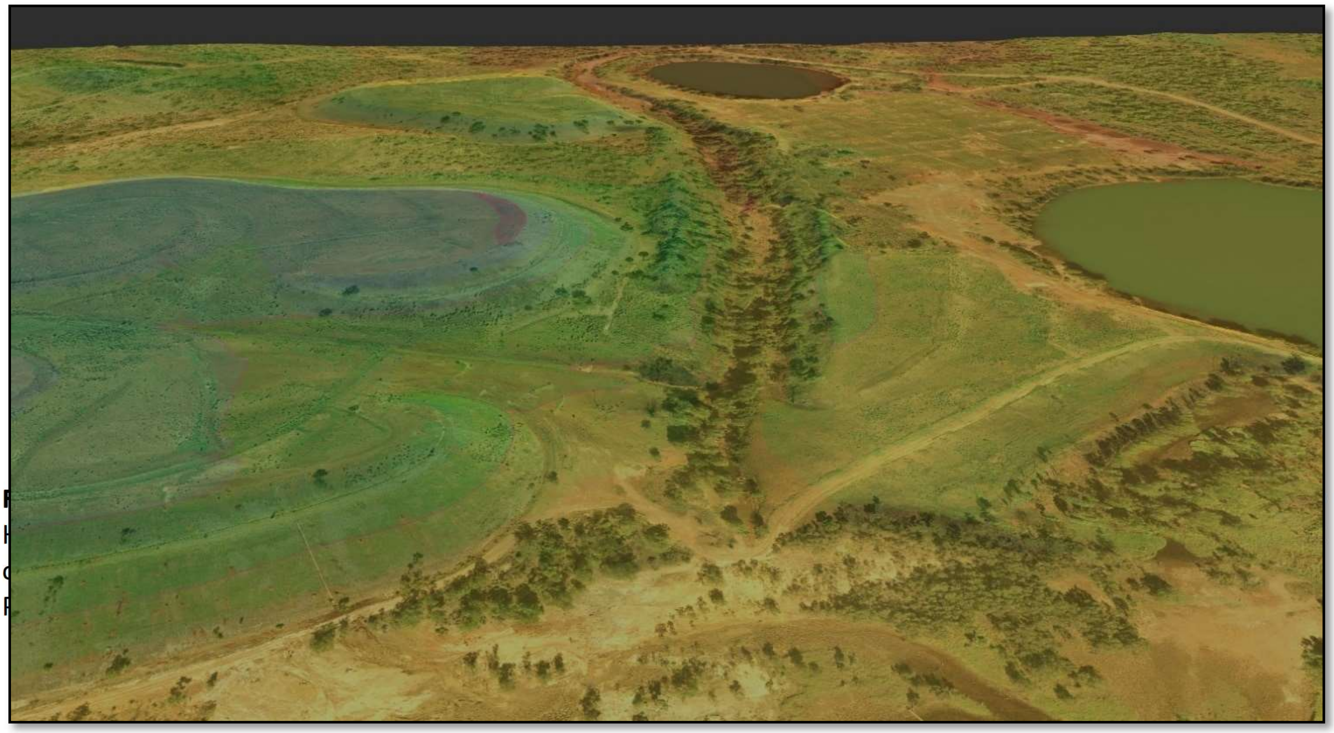


Figure 15 The existing entry into the Main Pit

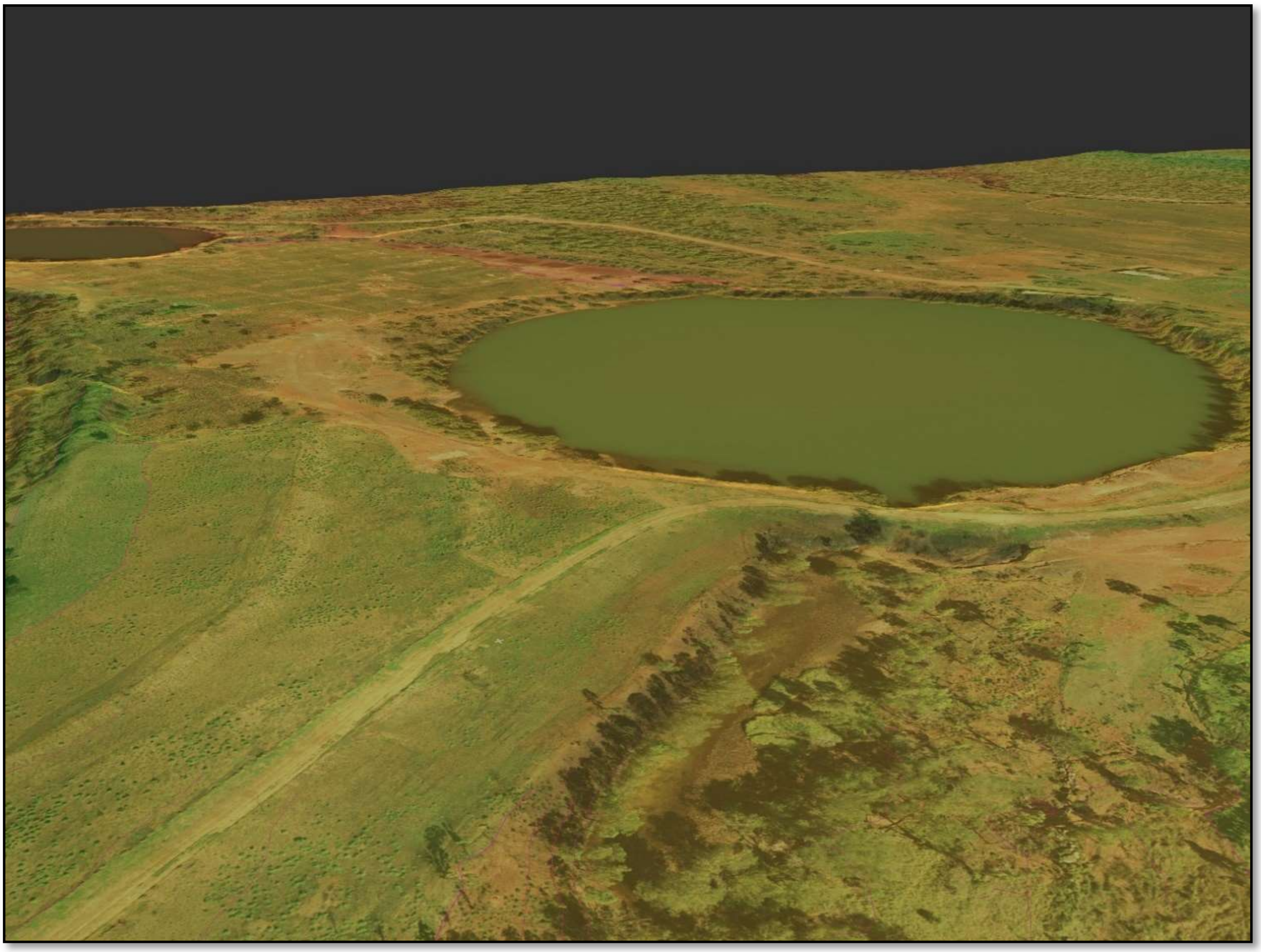
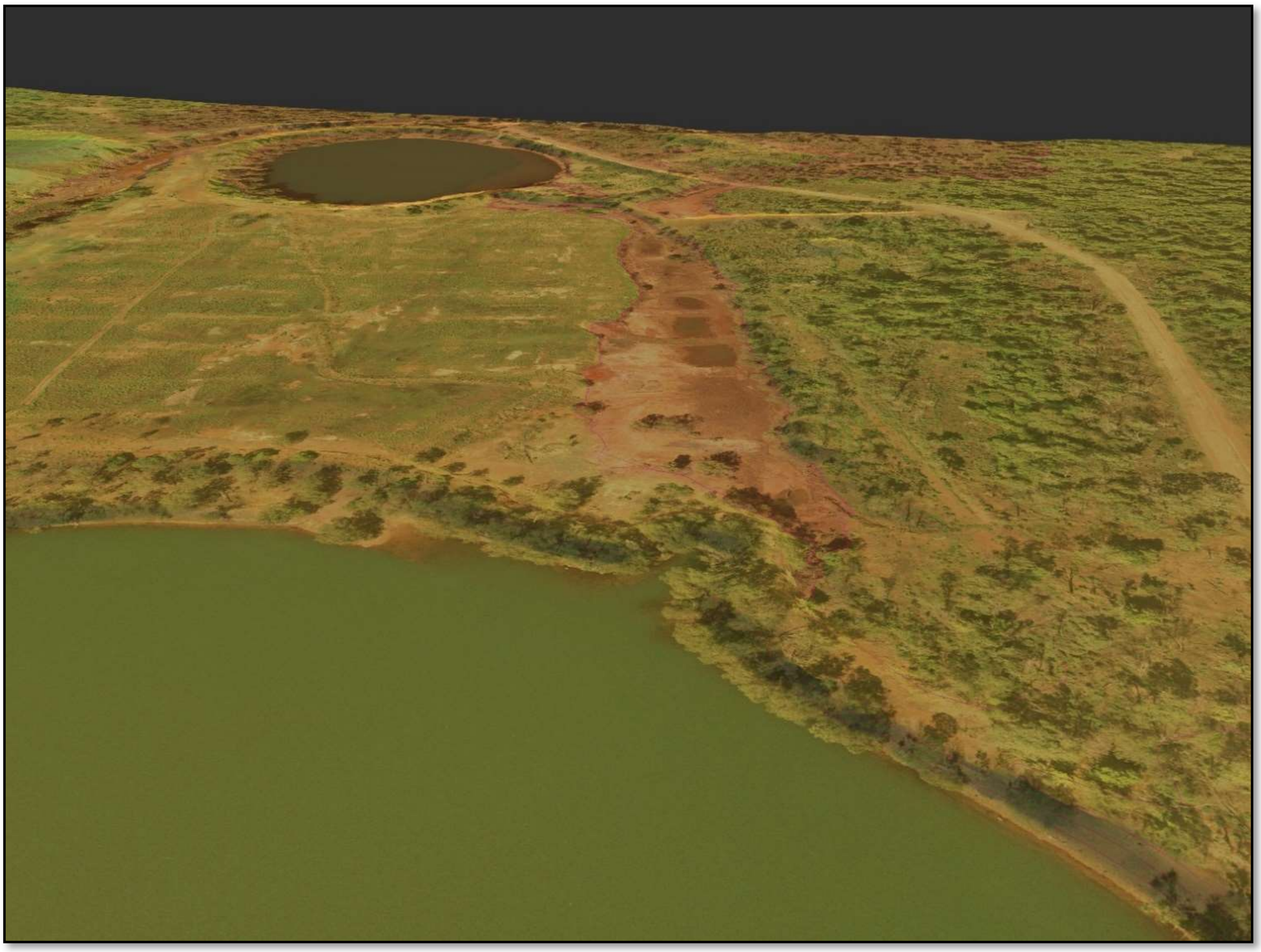


Figure 16 shows the existing flow path between the Main and Intermediate pits. Flows from the Main Pit are limited by the capacity of the outlet RCBC which is approximately 1.2 m x 2.4 m and a 300 mm high weir on the outlet apron. Flows around the northern side of the Intermediate Pit are blocked by a man-made embankment and directed into the Intermediate Pit by a steep box culvert approximately 0.9 m x 2.4 m. This culvert currently manages local runoff which is contaminated for the Heap Leach area. An equivalent dimension culvert discharges overflows from the Intermediate Pit to the EBFR.

Figure 16 The existing flow path between the pits



8.1.2 The Proposed Remediated Landform

8.1.2.1 The key requirements

The First Nations people have been extensively consulted in order to define the final landform. One key requirement was to return the flow of the EBFR to its original flow path through the Main Pit.

Ichthyologists, Ecohydrologists, Agronomists, Geologists, Hydrogeologists, Hydrologists and Acid Mine Drainage (AMD) treatment experts were consulted in the development of the final landform to address the following minimum requirements:

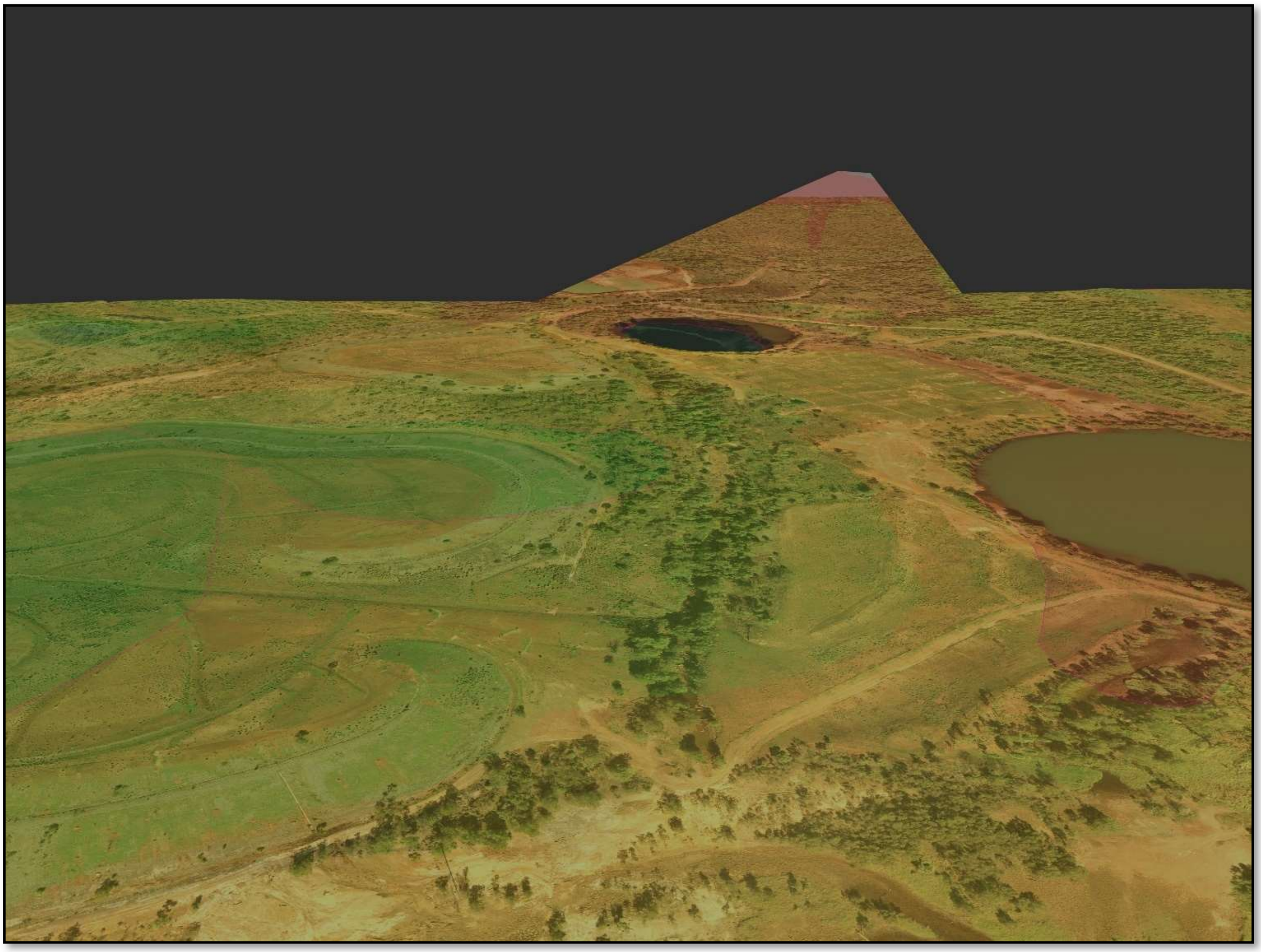
- Provide a passage for native migratory fish to travel up the EBFR for spawning. To accommodate their behaviour, it was necessary to provide sequential ‘pit stops’ in the flow path. These sites consist of pools, protruding boulders, logs, etc, which provide a sanctuary of low velocity on the lee side.
- The sandy clay soils of the flow paths will require erosion protection at the entry and exits to the Main and Intermediate pits. The design would be in accordance with the shear stress requirements of the hydraulic conditions.

- The erosion protection is to be graded natural rock to eliminate the Engineering aesthetics.
- Vegetation is to be encouraged in the interstices of the erosion protection and will be achieved by specifying a seeded sand/soil mix.
- The ingress of groundwater from the Leach Heap area (located between the Main and Intermediate Pits) is to be prevented by long term spearpoint groundwater extraction, local treatment and discharge to the EBFR.
- The contaminated water in the Main Pit is to be treated to below the Project Water Quality Objectives.

8.1.2.2 The Main Diversion Channel

Figure 17 shows the final landform of the Main Diversion Channel. It is to be backfilled and revegetated with a gentle depression to remain to convey surcharge of the EBFR upstream of the Main Pit during extreme floods to relieve the hydraulic load of the Main Pit.

Figure 17 The proposed Main diversion channel & enlarged flow path into the Main Pit



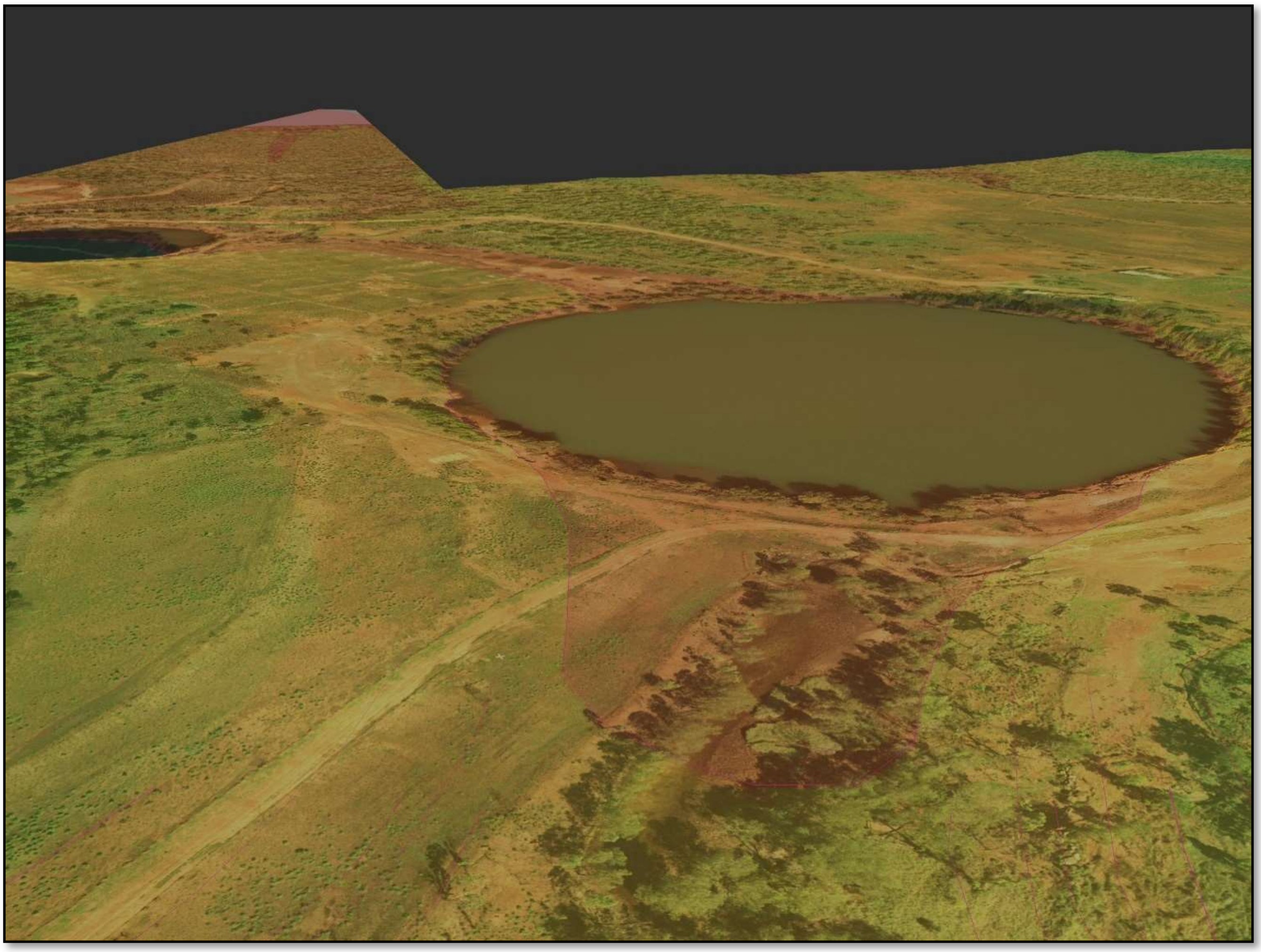
8.1.2.3 The Main Pit inlet

The proposal is to remove the pipe, culvert, embankment and widen the flow path to reduce velocities.

Figure 18 shows the proposed outline in red of the proposed opening which has a gradual (1 in 10) increase in width to reduce eddies before it enters the Main Pit.

The channel surface would be heavily lined with rip rap (angular graded igneous rock carefully placed in the flow path) in this zone to prevent erosion. The interstices of the rip rap would be covered with a seeded soil mix to promote vegetation and eliminate the engineering appearance. Large boulders and logs placed in a meandering arrangement would provide refuges for migratory fish during the wet season. The riverbed would have riffles and depressions to retain water after flows.

Figure 18 The proposed entry into the Main Pit (in red)



8.1.2.4 The Main Pit

Table 11 details the critical levels in the Main Pit post rehabilitation.

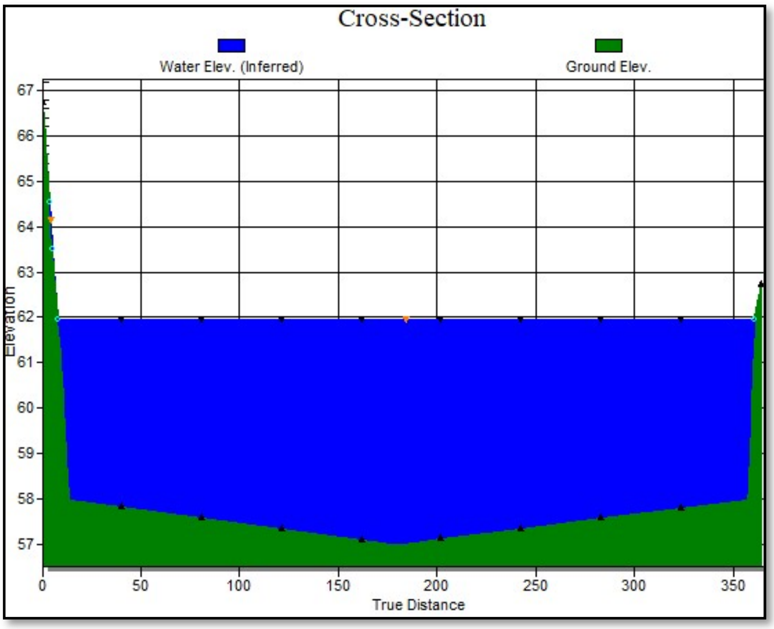
Table 11 Critical levels of the Main Pit post rehabilitation

Main Pit Critical Levels	Level (m AHD)
Top of capping layer	perimeter RL 58m AHD; centre RL 57m AHD (**Figure 19**)
Ground water level in the dry season	RL 59m AHD
Ground water level in the wet season	RL 61m AHD

During the dry season the capping of the Main Pit would be covered by 1 m to 2 m of water. The permanent groundwater table will ensure the capping remains covered in the dry season. During the wet season the level increases by approximately 2 m providing a 3 m to 4 m submergence over the capping.

Figure 19 shows the modelled cross section of the Main Pit which is depressed in the centre. Geotechnical consolidation calculations estimate the centre will subside by up to 6 m in 100 years. It is anticipated that eroded parent rock from the upper catchment will settle and drop out in the Main Pit over time to compensate for some of the consolidation. The highest velocities will be experienced where the base is relatively level, i.e. immediately after rehabilitation or should settlement drop out level out the base over time. This worst case scenario has been modelled here.

Figure 19 Cross section of the Main Pit after backfilling and capping (TWL 1% AEP)

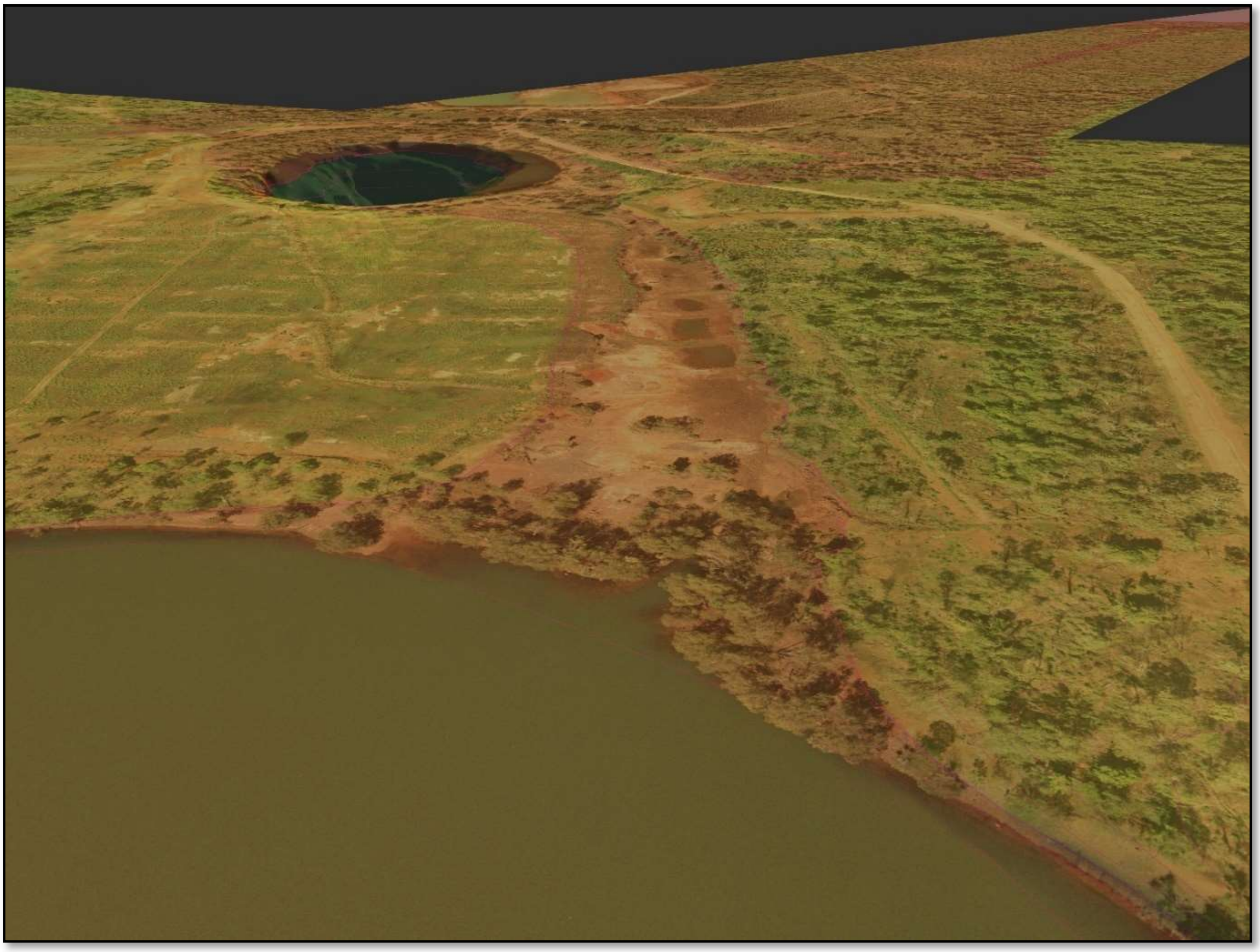


8.1.2.5 The flow path between the Main and Intermediate Pits

The existing culverts at the exit of the Main Pit and the entry of the Intermediate Pit will be removed to provide a continuous flow path between the pits. The drainage path between the pits will be widened, lined with vegetated rip rap in areas of potential erosion. Large boulders and logs placed in a meandering arrangement would provide refuges for migratory fish during the wet season. The bed would have riffles and depressions to retain water after rain events.

Figure 20 shows the flood extent in red of the rehabilitated channel during the 1% AEP event which discharges both into the Intermediate Pit and around to the north of the Pit to flood the former wetland zone.

Figure 20 The proposed flow path between the pits



8.1.2.6 The Intermediate Pit

The Intermediate Pit will remain as a submerged void approximately 68 m deep. The inlet and outlet culverts will be removed and the entry and exist flow paths lined with seeded/vegetated rip rap.

8.1.2.7 The hydraulic capacity of the erosion protection

Appendix B contains a list of drawings identifying the proposed erosion protection required to safely pass the 1% AEP event. It also identifies the flood extent for the 63% AEP (formally 1 in 1 year), 1% AEP (1 in 100 year) and the 1 in 1,000 year AEP events.

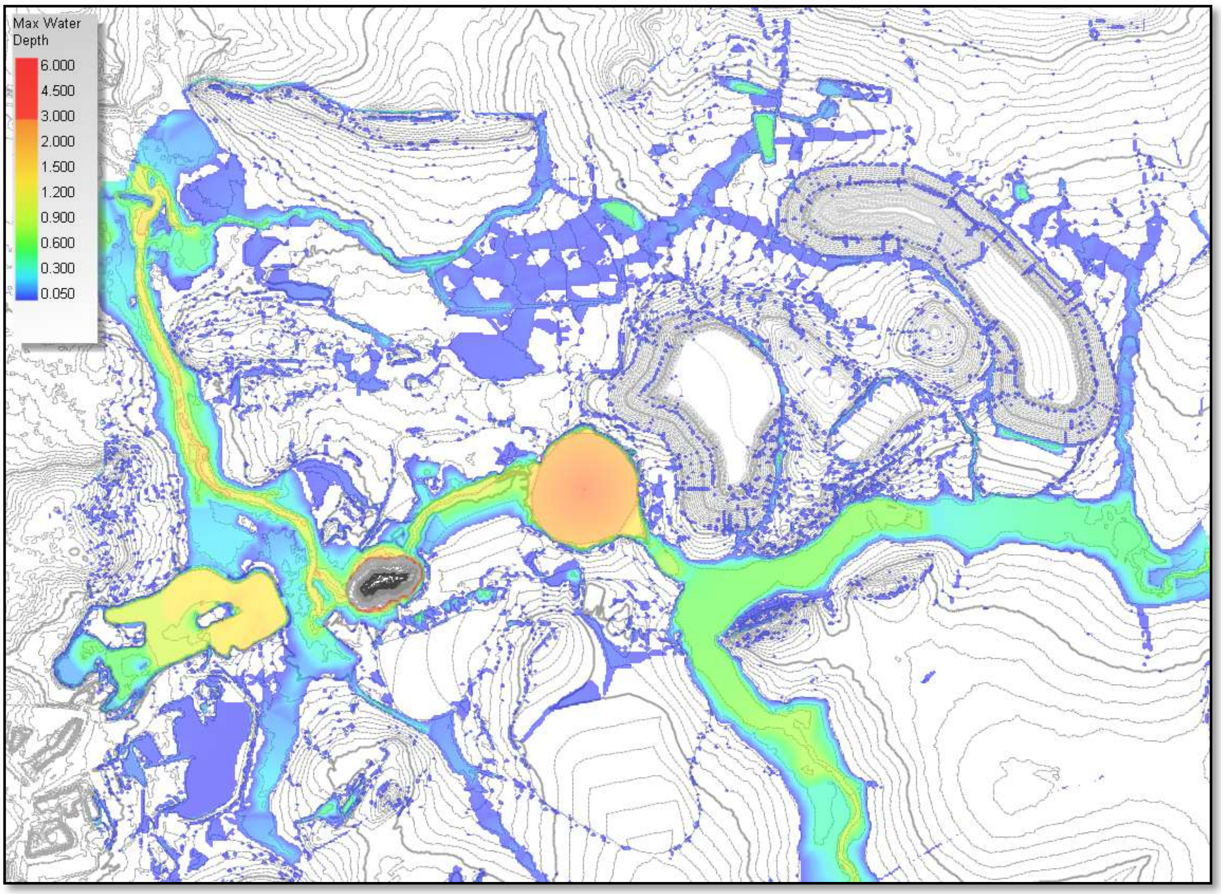
8.1.3 The Influence of Climate Change on Flood Levels

The hydraulic performance of the surface profile has been modelled in two dimensions using SWMM-2D software. The following three climate change influencers were applied to the modelling to determine the potential increase in flood levels:

- Climate change induced rainfall.
- A catastrophic fire decimating the vegetation throughout the catchment.
- The intense heat changing the structure of the soil resulting in hydrophobic conditions.

The flood level results due to the influencers are shown in **Figure 21**.

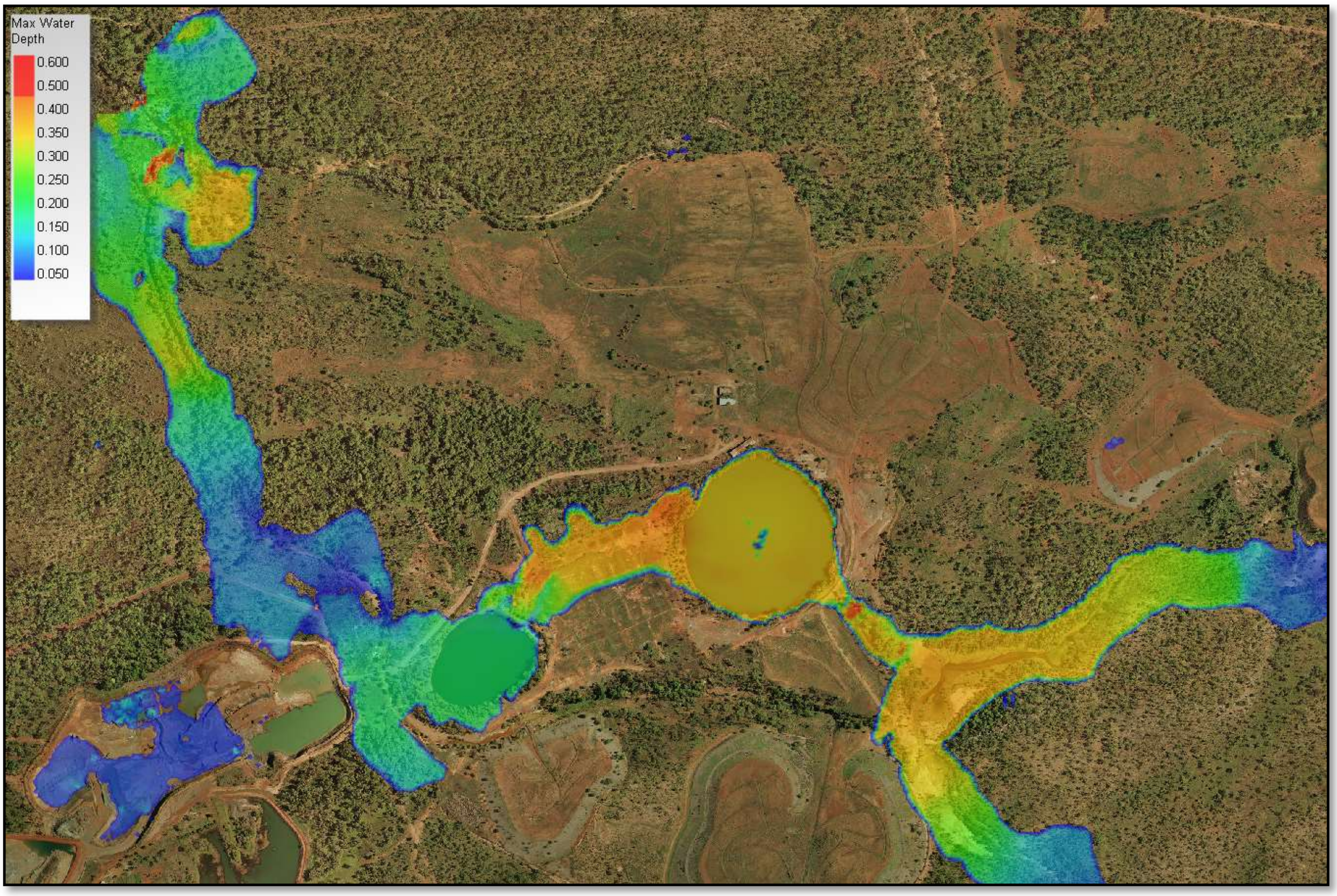
Figure 21 1% AEP flood depth as a consequence of the climate change influencers



The flood level during the 1% AEP (today) was subtracted from the results with the application of the climate change influencers to produce a plan which shows the flood level difference - refer **Figure 22.**

The results indicate that the flood level increase over the site would vary between 50 mm and 600 mm. The greatest level increase would occur at the channel necking upstream of the entry to the Main Pit. The flow path between the Main and Intermediate Pits would increase by approximately 400 mm with the remainder of the catchment 300 mm and less.

Figure 22 Increase in flood depth as a consequence of the climate change influencers (1% AEP)



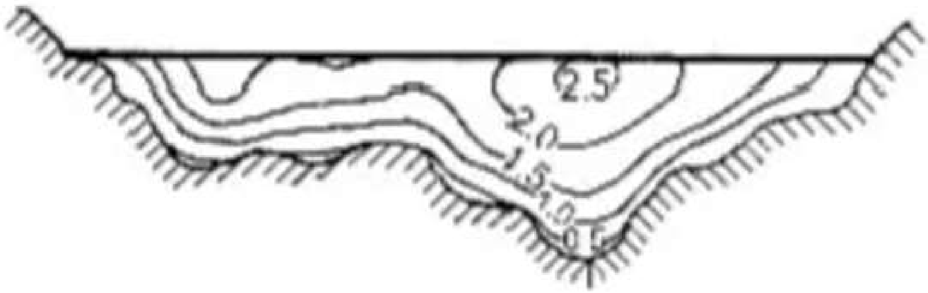
- **Hydraulic modelling has confirmed that the climate influencers would increase flood levels within the EBFR and Fitch Creek flow paths between 50 mm and 600 mm with the average increase approximately 350 mm.**
- **The flood level increase would not exceed the defined channel and hence would not inundate the proposed waste storage facility (WSF) areas.**
- **The modified Main Diversion Channel will not be activated.**

8.1.4 The Influence of Climate Change on Velocities

Two-dimensional hydraulic modelling assumes an average velocity over the full depth of flow for each 1 m x 1 m plan grid. It cannot stratify the velocity across the full depth. An approximation of the velocity on the channel bed can be made using the research conducted by Venn Te Chow in 1959.

Figure 23 shows contours of equal velocity of a natural channel with the average channel velocity marked by unity. The actual velocity on the floor of the main pit would be approximately 50% of the average velocity.

Figure 23 A typical velocity profile of a natural channel (Venn Te Chow, 1959)

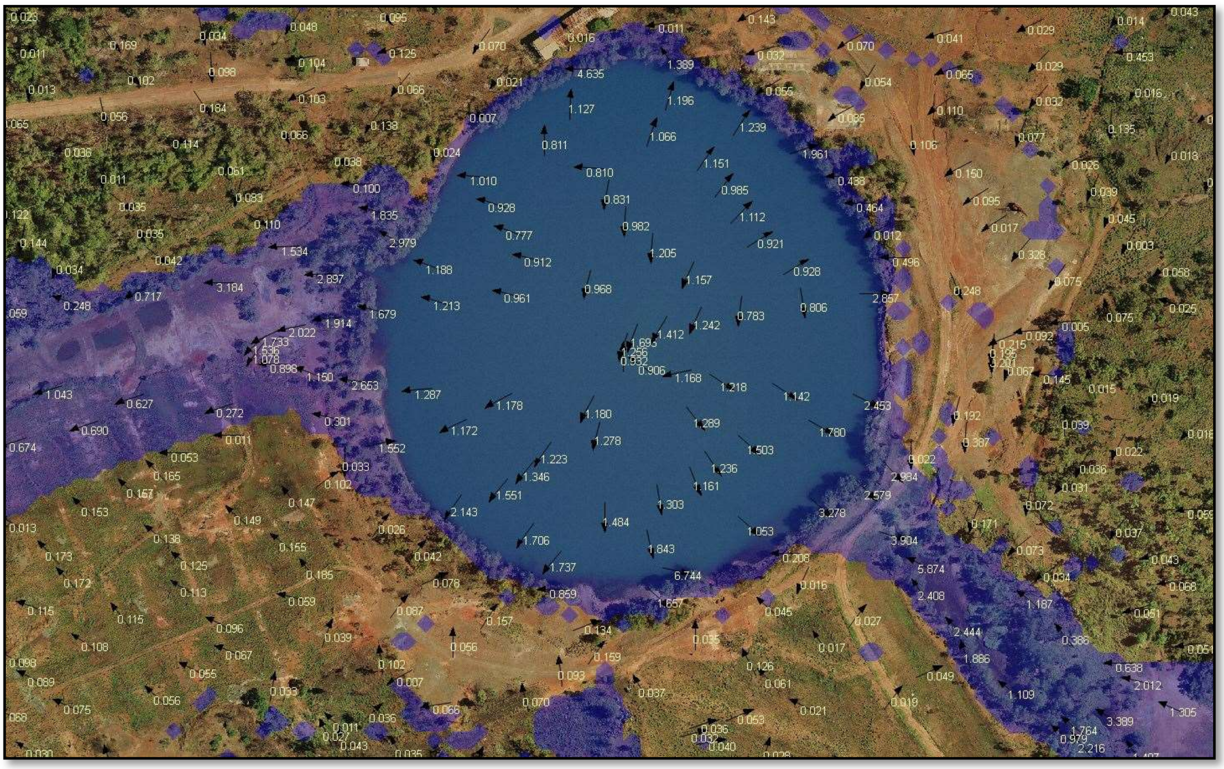


8.1.4.1 Velocities in and around the Main Pit (1% AEP)

The hydraulic behaviour of the Main pit is of paramount concern as detailed in section **8.1.2.1**. **Figure 24** shows the maximum velocity and direction averaged over the depth. The bed velocity will be 50% of this value.

- ➔ **The existing bed velocities within the Main Pit would be between 0.35 m/s and 0.6 m/s over the sandy bed which would not mobilize the sand.**
- ➔ **The bed velocity over the rip rap at the entrance to the Main Pit would vary between 0.5 m/s and 2.9 m/s.**
- ➔ **The velocity on the outer fringes of the flow path between the pits would be between 0.015 m/s and 0.1 m/s.**
- ➔ **The remediation has been designed with a 2-fold safety factor.**

Figure 24 The maximum calculated velocity and direction during the 1% AEP

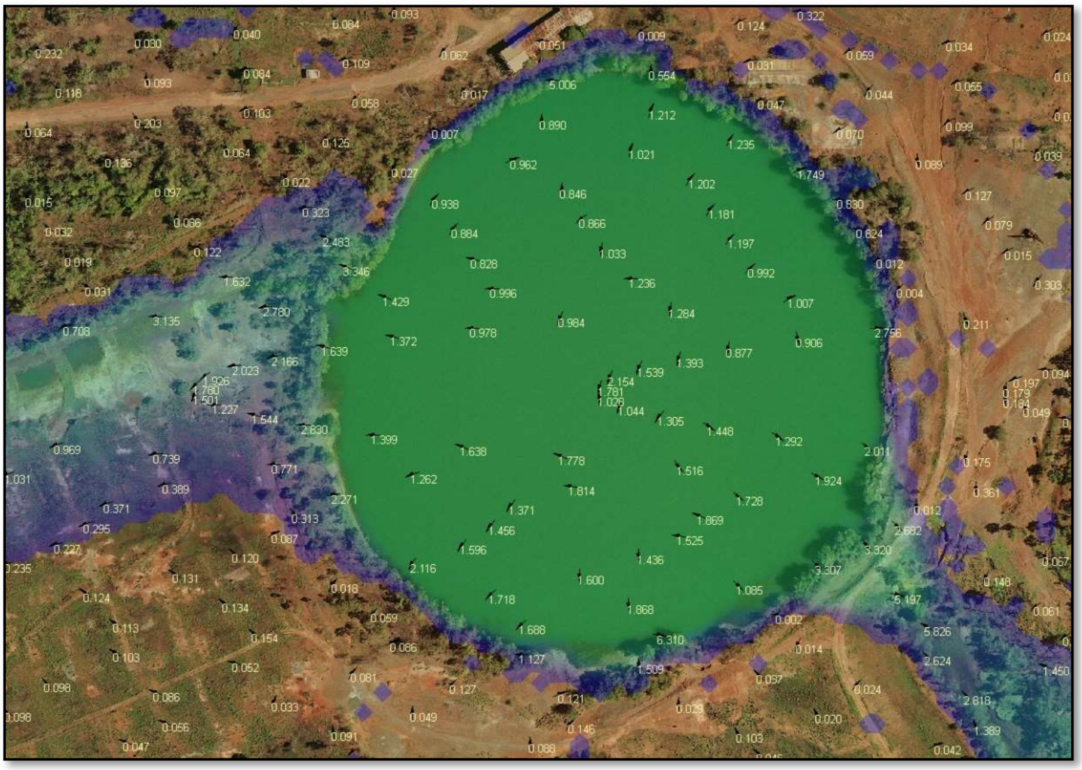


8.1.4.2 Velocities in and around the Main Pit with the climate influencers

Figure 25 shows the maximum velocity and direction averaged over the depth with the application of the climate influencers.

- ➔ **Velocities are higher at the entrance and exit of the Main Pit.**
- ➔ **Velocities are consistent over the sandy bottom.**
- ➔ **The increased depth of 350 mm in the Main Pit void, which has near vertical sides, has mitigated the bed velocities.**

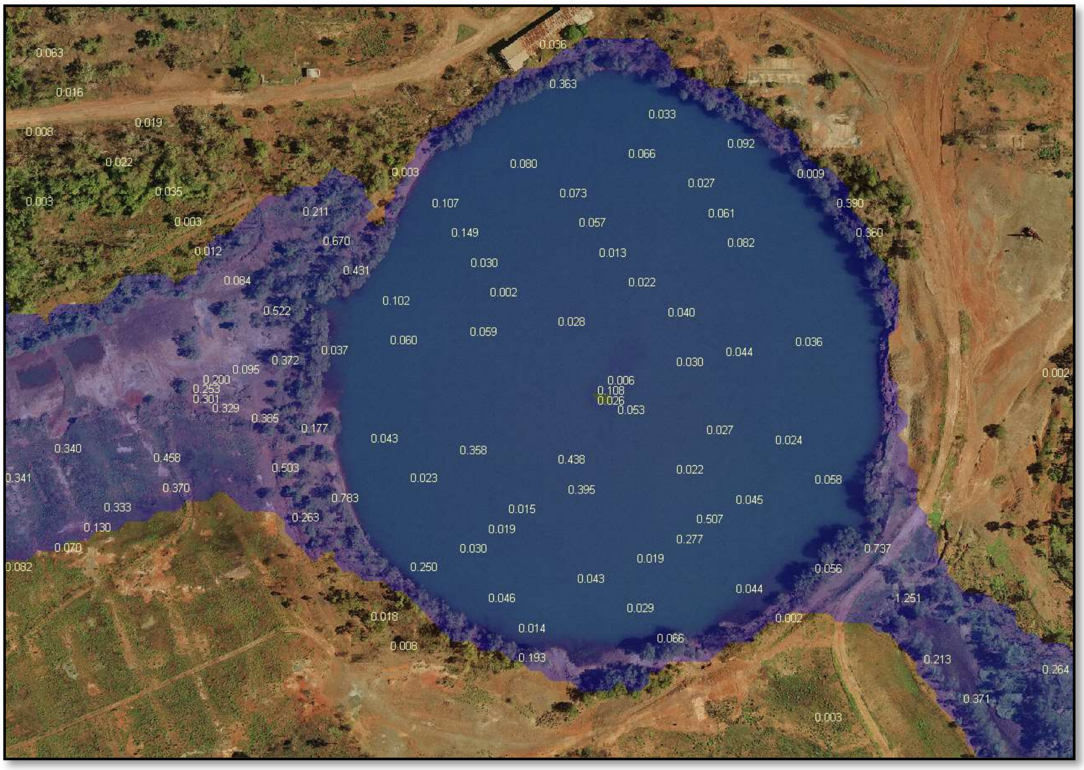
Figure 25 The maximum calculated velocity and direction with the climate change influencers



8.1.4.3 Difference in velocities with and without the climate influencers

The 2D hydraulic software has the capability to subtract the pre from the post climate change influenced results to reveal the increase (or decrease) in velocity over the catchment. **Figure 26** shows the increase in velocity within and around the Main Pit.

Figure 26 Increase in velocity as a result of the climate change influencers



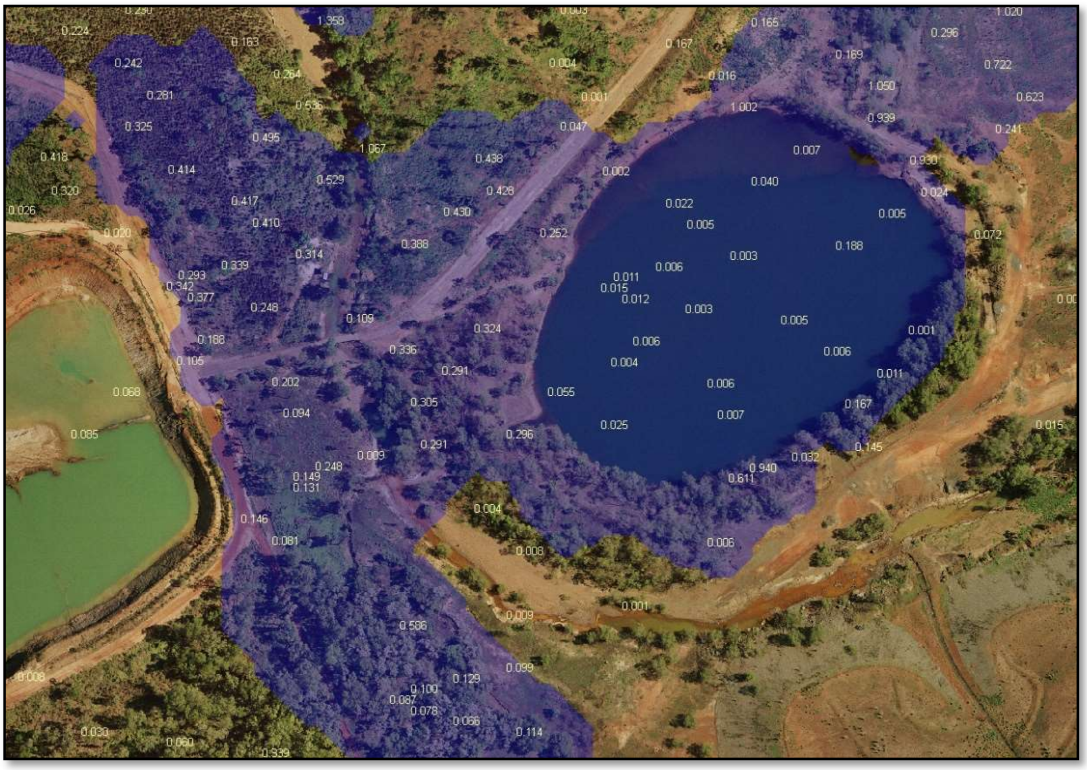
- **The climate change influencers could increase bed velocities by up to 0.6m/s at the entrance and exit to the Main Pit.**
- **The climate change influencers could increase bed velocities by up to 0.2m/s in the direct flow path in the Main Pit between the inlet and outlet.**
- **The climate change influencers will not change the bed velocities over the remainder of the Main Pit floor.**

8.1.4.4 Velocities in and around the Intermediate Pit with the climate change influencers

Figure 27 displays the potential increase in velocity upstream and downstream of the Intermediate Pit following the influence of climate change. With reference to drawing 680.10421.RFR.D02 (Appendix A) the following conclusions have been reached.

- **The erosion protection in the drainage path up stream of the Intermediate Pit has sufficient spare capacity to accommodate the increased in velocity.**
- **The velocity in the Intermediate pit is unchanged.**
- **The erosion protection downstream of the Intermediate Pit to the assigned boundary has sufficient spare capacity to accommodate the effects of climate change.**

Figure 27 Velocity increase following climate change influencers



8.1.5 Addressing the Hydraulic Conclusions

It is apparent there will be potential changes, albeit modest, in hydraulic behavior over some areas of the Rum Jungle site following the influence of the climate change variables assessed in this study.

These changes suggest a need for minor enhancements to the erosion protection in strategic locations.

The following is a summary of the aspects of the remediation design which require enhancement:

- ➔ **To maintain the design safety factor, it will be necessary to enhance the erosion protection immediately upstream and downstream of the Main Pit**
- ➔ **The larger flows are resulting in values within the “line of site” between the inlet and outlet of the Main Pit which exceed the mobilization velocity. This can be alleviated by minor modifications (i.e., widening) to the inlet design to ensure flow moves in an anti-clockwise direction around the pit rim, i.e., increasing the flow path and reducing the velocity.**
- ➔ **No other modifications are necessary to the remediation design to mitigate the effects of climate change.**

8.2 Impact of Evaporation Increase and Pit Lake Maintenance

The level of the Main Pit Lake will be dictated by the permanent groundwater table, however it is acknowledged evaporation can exceed groundwater inflow during dry seasons and lower the standing water level in the Pit.

Should the capping layer be exposed however there will be no ongoing environmental impact as the capping is inert material. Additionally, ongoing geomorphic processes will result in deposition of natural sediments from upstream over the capping. However, given the long-term settlement of up to 6 m over the first 100 years, it is unlikely the capping layer will be exposed.

It is recommended this topic be addressed with RGC.

8.3 Main Pit capping layer erosion

It is asserted with high confidence that there will be differential settlement across the pit resulting in an undulating surface. Furthermore, this cannot be easily 'engineered' out. The natural geomorphic processes, including deposition of upstream sediments and meandering of the EBFR will, with time, 'even out' these surface variations, i.e., the Main Pit will be a "sink" - it is more likely that deposition will occur within the Main Pit than erosion.

9 Waste Storage Facilities

9.1 Erosion

9.1.1 Stage 2A Erosion Modelling

SIBERIA Erosion Modelling was undertaken by SLR as part of the Stage 2A detailed design (SLR, 2020). The modelling made the following assumptions relevant to this climate change modelling:

- A 3.65 m deep cap, of which the upper 2 m is growth medium. The growth medium will be a combination of laterite and saprolite, i.e., gravelly, sandy CLAY and/or silty/sandy CLAY.
- Modelling was done with and without vegetation. A long-term vegetation establishment plan, paying special attention to wet and dry seasons, was included, with cover ranging from 40% to 95% over a period of 500 years.
- A 1:2-year storm as the most gynomorphically active rainfall event. This is the storm that on average does the most geomorphic work according to (Willgoose, 2005).

The results indicated:

- With no vegetation:
    - The average erosion rate is around 1.40 m^3/ha/yr.
    - The gully depths are represented by:
        - A maximum gully depth of 1.45 m.
        - ~ 1% of surface area has gully depths > 1 m.
        - ~48% of surface has gully depths > 0.25 m.
- With long term vegetation plan:
    - The average erosion rate is around 0.37 m^3/ha/yr.
    - The gully depths are represented by:
        - A maximum gully depth of 1.18 m.
        - ~ 1% of surface area has gully depths > 1 m.
        - ~ 3% of surface area has gully depths > 0.25 m.

9.1.2 Literature Research

Soil denudation has two components, the chemical alteration of minerals and the physical erosion or in other terms the mechanical detachment of soil particles. SIBERIA erosion modelling only addresses the physical processes, the soil production, biology and climatic variation is beyond the scope.

Two studies relating to the Ranger Uranium Mine in the NT were reviewed and it was found:

- A study by (R, M, & J, 2021) calculated a weighted average of 0.075 ±0.013 mm/year. This study included the chemical component of denudation.
- In (Lowry, Coulthard, Saynor, & Hancock, 2020) the authors utilise CAESAR erosion modelling to predict rates of denudation, including a rainfall with an annual return interval of greater than 100 years with an annual exceedance probability of less than 1%. The resulting average denudation rate were ~0.07 mm/yr.

There is currently no wide agreement on what can be considered as ‘acceptable’ rate of erosion on a mine site. However, the Queensland Department of Minerals and Energy (QDME) ‘target erosion rate’ for rehabilitated spoil is 12 to 40 t/ha/yr (Society for Mining, Metallurgy, and Exploration, Inc., 2000).

A typical material bulk density of 1.25 t/m^3 can be adopted, give erosion rates as:

- Unvegetated – 1.40 m^3/ha/yr = 1.75 t/ha/yr.
- Vegetated - 0.37 m^3/ha/yr = 0.46t/ha/yr.

Both values are significantly lower than the specified by QDME.

9.1.3 Climate Change Influence WSF Erosion

Modelling has shown that even after 500 years without vegetation that:

- Gully depths are not likely to exceed the growth medium depth (i.e., 2 m).
- Erosion rates are likely to be of the ordre of 1.75 t/ha/yr, significantly below industry acceptable guidelines.

9.2 Flooding Sensitivity

Flooding sensitivity to climate change influences is addressed in **Section 8.1.3** and shown in **Figure 21**.

In summary:

- Hydraulic modelling has confirmed that the climate influencers would increase flood levels within the EBFR and Fitch Creek flow paths between 50 mm and 600 mm with the average increase approximately 350 mm.
- The flood level increase would not exceed the defined channel and inundate the proposed waste rock dump areas.

9.3 Impact of Evaporation

Increased evaporation, or in the case of WSFs, increasing evapotranspiration can have two impacts on the rehabilitation design:

- Decreased infiltration of surface water into the WSFs, which minimise the risk of the generation of AMD.
- Less availability of moisture to support vegetation. In this case, this is will be a region wide issue and given that the capping materials are sourced from local soil, die-back of vegetation on the WSFs will be commensurate with the surrounding regional vegetation status. The impact of vegetation die back is addressed in **Section 9.1**.

9.4 WSF Climate Change Management

It is important to note that the WSF landforms are draft, and the final landform, materials and vegetation will be determined as construction progresses. The results indicate that the erosional performance is acceptable, however it is important to understand that modelling relies on assumptions and/or simplification in order to obtain results.

An adaptive management approach to erosion monitoring is outlined in (SLR, 2020) and it is considered that these measures will account for climate change variations in the future. Key approaches include:

- Rock armouring of areas of high susceptibility to erosion, as identified after construction is complete.
- Long term erosion monitoring (up to 20 years).
- Detail of actions to identify causes of erosion based on monitoring after 20 years to allow for remediation and future erosion protection.

10 Summary

Evidence (IPCC, 2021) indicates that continued emissions of greenhouse gases are expected to cause further warming and changes in all components of the climate system:

- Mean, minimum and maximum temperatures are predicted to keep increasing with very high confidence, along with the frequency of hot spells and droughts.
- While overall average rainfall is predicted to result in both wetter and drier periods depending upon regional geographical influences, climate modelling predicts with high confidence that heavy rainfall events will become more intense.
- Rising temperatures and prolonged hot spells are predicted to lead to an increase in the frequency and intensity of bush fires.
- Finally, and relevant to Rum Jungle Mine's location, climate change may alter evapotranspiration, soil moisture and runoff.

This report has addressed the likely impact of climate change influencers including:

- Climate change induced rainfall.
- A catastrophic fire decimating the vegetation throughout the catchment.
- The intense heat changing the structure of the soil resulting in hydrophobic conditions.

The specific design elements for which the requests relate to are:

- Backfilling and capping of the Main mine pit with potentially acid forming (PAF) waste rock to a level below the currently predicted lowest pit water level.
- Realignment of the East Branch Finnis River (EBFR) to follow its original course back through the Main pit.
- Cover design and landform profile of the Waste Storage Facilities (WSFs).

Table 12 provides a summary of responses to the queries form the Department.

Table 12 Summary of responses

No.	Department Query	Response
1.	Please provide a climate change assessment demonstrating that all design components can withstand varied climatic conditions over the next, for example, 1000 years.	The design components that could be impacted by climate change include: • Backfilling and capping of the Main Pit. • Realignment of the EBFR through the Main Pit. • Capping and landform of the WSFs.
a) b) c) v.	The climate change assessment should include modelling for a wide range of possible seasonal rainfall scenarios (e.g., between 45 per cent drier and 44 per cent wetter in the dry season and between 23 per cent drier to 19 per cent wetter in the wet season). and The impacts of changing rainfall patterns (i.e., intensity, frequency and duration) including changes in individual event characteristics (e.g., increased intensity). and Flowrates in the proposed diversion/realignment through the pit pathway, including the effects of modelled change in the intensity, frequency and duration of rainfall events.	Climate change influencers relevant to the Rum Jungle region have been developed based on recommendations given in ARR, 2019 and ICCP, 2021. The following climate change influencers have been identified and the impact on rainfall scenarios, storm frequencies, temporal patterns, runoff factors and soil conditions, have been assessed: • Climate change induced rainfall patterns. • A catastrophic fire decimating the vegetation throughout the catchment. • The intense heat changing the structure of the soil resulting in hydrophobic conditions. Modelling results indicate: • Catastrophic fire which denudes the catchment of vegetation will have the greatest influence on runoff increases at the site. • The predicted rainfall increases will have a slightly greater influence than the hydrophobic soil conditions. • Overall, the peak runoff could increase by approximately 78% should all influencers occur at once. The impact on the rehabilitation design for the Main Pit is as follows: • The climate change influencers could increase bed velocities by up to 0.6m/s at the entrance and exit to the Main Pit. • The climate change influencers could increase bed velocities by up to 0.2m/s in the direct flow path in the Main Pit between the inlet and outlet.

No.	Department Query	Response
		• The climate change influencers will not change the bed velocities over the remainder of the Main Pit floor. The impact to design changes for the Main Pit and the EBFR realignment are as follows: • To maintain the design safety factor, it will be necessary to enhance the erosion protection immediately upstream and downstream of the Main Pit. • The larger flows are resulting in values within the "line of site" between the inlet and outlet of the Main Pit which exceed the mobilization velocity. This can be alleviated by minor modifications (i.e., widening) to the inlet design to ensure flow moves in an anti-clockwise direction around the pit rim, i.e., increasing the flow path and reducing the velocity. It is recommended that as the backfilling of the Main Pit is nearing end of construction, i.e., when the final profile of the Pit and capping is better understood, that the modelling be redone with the correct profile and the inlet redesigned as appropriate. • No other modifications are necessary to the remediation design to mitigate the effects of climate change.
c) i. c) ii.	*Potential impacts of increased evaporation on aspects of the design including ground water levels and ground water quality.* *and* *Maintenance of the proposed Main Pit Lake, including the proposed 2 metre deep water cover*	The level of the Main Pit Lake will be dictated by the permanent groundwater table, however it is acknowledged evaporation can exceed groundwater inflow during dry seasons and lower the standing water level in the Pit. Should the capping layer be exposed however there will be no ongoing environmental impact as the capping is inert material. Additionally, ongoing geomorphic processes will result in deposition of natural sediments from upstream over the capping. However, given the long-term settlement of up to 6m over the first 100 years, it is unlikely the capping layer will be exposed. It is recommended this topic be discussed with RGC.

No.	Department Query	Response
c) iii.	*Potential for erosion of the waste storage facility capping layer*	It is important to note that the WSF landforms are draft, and the final landform, materials and vegetation will be determined as construction progresses. The results indicate that the erosional performance is acceptable, however it is important to understand that modelling relies on assumptions and/or simplification in order to obtain results. Modelling has shown that even with 500 years of no vegetation on the WSF, erosion is as follows: • Gully depths are not likely to exceed 1.0 m over 99% of the WSFs, with a maximum expected of 1.45 m, which is less than the growth medium depth of 2 m. • Erosion rates are likely to be of the order of 1.75 t/ha/yr, significantly below industry acceptable guidelines Regardless of these results, an adaptive management approach to erosion monitoring is proposed and it is considered that these measures will account for climate changes. Key approaches include: • Rock armouring of areas of high susceptibility to erosion, as identified after construction is complete. • Long term erosion monitoring (up to 20 years). • Detail of actions to identify causes of erosion based on monitoring after 20 years to allow for remediation and future erosion protection.
c) iv.	*Potential for erosion of the Main Pit capping layer. The Department notes this potential could be exacerbated as settlement occurs within the pit, resulting in an undulating surface and varied rates of capping layer erosion, and that any erosion that occurs will impact downstream water quality*	It is certain that there will be differential settlement across the pit resulting in an undulating surface and this cannot be ‘engineered’ out. The natural geomorphic processes, including deposition of upstream sediments and meandering of the EBFR will, with time, ‘even out’ these surfaces, i.e., the Main Pit will be a “sink” - it is more likely that deposition will occur within the Main Pit that erosion.

<table>
<tr><th>No.</th><th>Department Query</th><th>Response</th></tr>
<tr><td>c) vi.</td><td>The Department notes that flooding is likely to cause erosion of the waste storage facility and Main Pit capping layer material. Please provide a flooding sensitivity analysis that investigate the impacts of more extreme flooding than a 1 per cent AEP event (the currently modelled scenario)."</td><td>Modelling of climate change influencers indicates that the flood level increase over the site would vary between 50mm and 600mm. The greatest level increase would occur at the channel necking upstream of the entry to the Main Pit. The flow path between the Main and Intermediate Pits would increase by approximately 400mm with the remainder of the catchment 300mm and less.
Hydraulic modelling has confirmed that the climate influencers would increase flood levels within the EBFR and Fitch Creek flow paths between 50 and 600mm with the average increase approximately 350mm.
The flood level increase would not exceed the defined channel and inundate the proposed waste storage facility (WSF) areas.
The modified Main Diversion Channel will not be activated.</td></tr>
</table>

11 Bibliography

ARR. (2019). *Australian Rainfall and Runoff - A Guide to Flood Estimation.*

IPCC. (2021). *United Nations Intergovernmental Panel on Climate Change (IPCC) for its sixth Assessment Report (AR6).*

Lowry, J., Coulthard, T., Saynor, M., & Hancock, G. (2020). *A Comparison of Landform Evolution Model Predictions with Multi-year Observations from a Rehabilitated Landform.* Department of Agriculture, Water and the Environment, Australian Government.

R, W., M, S., & J, L. (2021). The Natural Denudation Rate of the Lowlands Near the Ranger Mine, Australia: A Target for Mine Site Rehabilitation. *Geomorphology*.

Sherwood, S. H. (2010). An adaptability limit to climate change due to heat stress.

SLR. (2020). *Rum Jungle Rehabilitation Project Stage 2A - Erosion Assessment for the New Waste Storage Facility.*

Society for Mining, Metallurgy, and Exploration, Inc. (2000). *Slope Stability in Surface Mining.*

Willgoose, G. (2005). *User Manual for SIBERIA.*

APPENDIX A

CMIP5 Climate Change Projections

Monsoonal North Cluster

Projections are for the 2030 and 2090 Outcomes

Results are given for the RCP2.6, RCP4.5 and RCP8.5 future climate scenarios

LEGEND

	Very high model agreement on substantial increase
	High model agreement on substantial increase
	Medium model agreement on substantial increase
	High model agreement on increase
	Medium model agreement on increase
	High model agreement on little change
	Medium model agreement on little change
	Low model agreement on the direction of change
	High model agreement on substantial decrease
	Medium model agreement on substantial decrease
	High model agreement on decrease
	Medium model agreement on decrease

Monsoonal North (West) Sub-Cluster

Projections are for the 2030 and 2090 Outcomes

Results are given for the RCP2.6, RCP4.5 and RCP8.5 future climate scenarios

Monsoonal North Cluster

VARIABLE	SEASON	2030, RCP26	2030, RCP45	2030, RCP85	2090, RCP26	2090, RCP45	2090, RCP85
Temperature mean (°C)	Annual	0.8 (0.5 to 1.2)	0.9 (0.6 to 1.3)	1 (0.7 to 1.3)	0.9 (0.5 to 1.6)	1.8 (1.3 to 2.7)	3.8 (2.8 to 5.1)
	DJF	0.7 (0.5 to 1.3)	0.8 (0.5 to 1.3)	0.8 (0.6 to 1.3)	0.9 (0.6 to 1.9)	1.7 (1.1 to 3)	3.5 (2.3 to 5.1)
	MAM	0.8 (0.5 to 1.2)	0.9 (0.5 to 1.4)	1 (0.6 to 1.4)	1 (0.5 to 1.7)	1.9 (1.2 to 2.9)	3.9 (2.6 to 5.2)
	JJA	0.9 (0.4 to 1.3)	1 (0.5 to 1.4)	1.1 (0.7 to 1.4)	1 (0.5 to 1.6)	2 (1.5 to 2.7)	4.2 (3.2 to 5.3)
	SON	0.8 (0.5 to 1.3)	0.9 (0.6 to 1.3)	1 (0.7 to 1.4)	0.9 (0.4 to 1.7)	1.8 (1.2 to 2.7)	3.7 (2.7 to 4.9)
Temperature maximum (°C)	Annual	0.9 (0.5 to 1.3)	1 (0.6 to 1.3)	1 (0.7 to 1.3)	1 (0.5 to 1.8)	1.9 (1.3 to 2.9)	3.7 (2.7 to 5)
	DJF	0.8 (0.5 to 1.3)	0.9 (0.5 to 1.4)	0.9 (0.6 to 1.4)	1 (0.4 to 2.3)	1.8 (1.1 to 3.5)	3.6 (2.2 to 5.1)
	MAM	0.8 (0.4 to 1.3)	1 (0.5 to 1.5)	1 (0.6 to 1.5)	1.1 (0.5 to 1.8)	1.8 (1.1 to 3)	3.8 (2.6 to 5.1)
	JJA	0.9 (0.3 to 1.3)	1 (0.5 to 1.4)	1.1 (0.7 to 1.4)	1.1 (0.4 to 1.6)	2 (1.3 to 2.7)	3.9 (2.9 to 4.9)
	SON	0.8 (0.4 to 1.5)	1 (0.6 to 1.4)	1.1 (0.7 to 1.4)	1 (0.4 to 1.8)	1.8 (1.2 to 2.8)	3.7 (2.8 to 4.8)
Temperature minimum (°C)	Annual	0.7 (0.5 to 1.2)	0.9 (0.6 to 1.3)	1 (0.8 to 1.3)	0.9 (0.5 to 1.5)	1.9 (1.3 to 2.7)	3.9 (2.9 to 5.2)
	DJF	0.7 (0.5 to 1.1)	0.9 (0.5 to 1.2)	0.9 (0.6 to 1.4)	0.9 (0.5 to 1.5)	1.8 (1.1 to 2.6)	3.7 (2.4 to 4.8)
	MAM	0.8 (0.4 to 1.2)	0.9 (0.6 to 1.2)	1.1 (0.7 to 1.4)	1 (0.5 to 1.6)	2 (1.3 to 2.8)	3.8 (2.8 to 5.3)
	JJA	0.8 (0.2 to 1.2)	1 (0.6 to 1.4)	1.1 (0.7 to 1.4)	1.1 (0.4 to 1.6)	2.1 (1.4 to 2.8)	4.2 (3.4 to 5.5)
	SON	0.7 (0.4 to 1.3)	1 (0.6 to 1.4)	1 (0.7 to 1.4)	0.9 (0.4 to 1.6)	1.8 (1.3 to 2.8)	3.9 (2.9 to 5.1)
Rainfall (%)	Annual	-3 (-11 to +8)	0 (-10 to +5)	-2 (-7 to +6)	-4 (-14 to +4)	-1 (-15 to +7)	+0 (-24 to +24)
	DJF	0 (-9 to +7)	-1 (-7 to +9)	0 (-7 to +9)	-3 (-14 to +4)	0 (-17 to +9)	+3 (-24 to +20)
	MAM	-2 (-15 to +15)	+0 (-19 to +9)	-3 (-18 to +10)	-5 (-20 to +13)	-1 (-19 to +15)	+0 (-31 to +32)
	JJA	-8 (-36 to +20)	-7 (-31 to +19)	-11 (-33 to +19)	-8 (-45 to +19)	-18 (-39 to +19)	-15 (-53 to +44)
	SON	-5 (-25 to +17)	-4 (-26 to +18)	-6 (-23 to +14)	-8 (-31 to +14)	-8 (-30 to +29)	-14 (-46 to +30)
Solar radiation (%)	Annual	+0.3 (-0.4 to +1.3)	-0.1 (-0.8 to +1.1)	+0 (-0.9 to +0.9)	+0.5 (-0.3 to +2.4)	+0.1 (-1.5 to +2)	-0.4 (-3.1 to +1.8)
	DJF	+0.3 (-1.2 to +2.5)	+0.2 (-1.8 to +1.7)	-0.3 (-1.9 to +1.6)	+1.2 (-1.1 to +4.6)	-0.1 (-2.3 to +3.7)	-1.1 (-5 to +4.3)
	MAM	+0 (-1.8 to +2.3)	-0.4 (-2 to +2.4)	+0 (-1.7 to +2.4)	+0.7 (-1.5 to +3.5)	+0 (-2.7 to +2.9)	-0.8 (-5.1 to +2.7)
	JJA	+0.2 (-0.5 to +1.9)	+0.2 (-1.1 to +1.5)	+0.3 (-1 to +2)	+0.4 (-0.9 to +2.3)	-0.3 (-1.6 to +2.1)	-0.9 (-3.4 to +1.7)
	SON	+0.5 (-0.4 to +1.8)	+0.3 (-0.9 to +1.1)	+0 (-0.8 to +1.4)	+0.5 (-1.1 to +2.2)	-0.2 (-1.4 to +1.4)	-0.5 (-2.6 to +2)
Relative humidity (%, absolute)	Annual	-0.4 (-1.7 to +0.6)	-0.2 (-1.6 to +0.6)	-0.5 (-1.5 to +0.5)	-0.8 (-3.5 to +0.3)	-0.7 (-3.4 to +0.5)	-1.1 (-5.5 to +1.4)
	DJF	-0.7 (-2.7 to +0.9)	-0.2 (-2.3 to +1)	-0.6 (-2.4 to +0.6)	-1.6 (-4.8 to +1)	-1 (-6.2 to +1.5)	-1.6 (-5 to +1.9)
	MAM	-0.4 (-2.3 to +1.8)	-0.4 (-2.7 to +1.5)	-0.7 (-3.1 to +1.3)	-1.3 (-4.2 to +0.6)	-0.4 (-5.7 to +1.1)	-0.9 (-8.3 to +2.8)
	JJA	-0.3 (-2.7 to +0.3)	-0.3 (-1.5 to +0.6)	-0.8 (-2.2 to +0.5)	-0.6 (-3 to +0.5)	-0.8 (-3.9 to +1)	-1.3 (-5.2 to +2.1)
	SON	-0.4 (-1.6 to +1)	+0 (-1.9 to +1.4)	-0.3 (-1.6 to +0.7)	-0.7 (-2.9 to +1)	-0.2 (-1.9 to +1.2)	-0.5 (-2.9 to +1.7)
Evapo-transpiration (%)	Annual	2.5 (1.4 to 3.7)	2.9 (1.6 to 4.3)	3.1 (2.3 to 5.1)	3.4 (2.1 to 6)	6.5 (3.9 to 8.6)	12.4 (8.3 to 16.7)
	DJF	2.6 (1.2 to 4.4)	3.2 (0.6 to 4.4)	3 (1 to 5.4)	4.3 (2.7 to 6.8)	5.8 (2 to 9.4)	11.5 (3.1 to 15.7)
	MAM	2.3 (1 to 4)	2.4 (1.5 to 4.3)	3.3 (2 to 5.7)	3.1 (0.7 to 5.7)	5.9 (4 to 10.3)	12.6 (9.2 to 19.7)
	JJA	2.6 (1.2 to 3.8)	3.3 (1 to 5.4)	3.7 (1.2 to 5.6)	3.3 (0.8 to 6.9)	7.3 (4.7 to 9.4)	15.3 (8.4 to 19.5)
	SON	2.7 (1 to 4.7)	3.1 (1.7 to 5)	3.3 (2 to 4.8)	3.4 (1.5 to 4.7)	6.2 (4.2 to 7.9)	11.7 (8.5 to 16.2)
Soil moisture (Budyko) (%)	Annual	NA	-0.7 (-3.7 to +3.3)	-0.8 (-3.6 to +1.8)	NA	-0.9 (-7.6 to +1.4)	-2.6 (-13.1 to +4)
	DJF	NA	-0.6 (-5.7 to +5.4)	-0.2 (-5.5 to +3.6)	NA	-0.6 (-13.9 to +4.2)	-1.9 (-22.4 to +7.1)
	MAM	NA	-1.1 (-8.1 to +5.5)	-1.6 (-7.1 to +4.9)	NA	-1.9 (-10.3 to +1.5)	-5.4 (-20.8 to +3.9)
	JJA	NA	-0.2 (-3.3 to +2)	-0.3 (-2.1 to +1.3)	NA	-0.7 (-4.8 to +0.3)	-1.5 (-6.3 to +0.8)
	SON	NA	-0.2 (-1.3 to +0.6)	-0.1 (-1.1 to +0.7)	NA	-0.1 (-1.4 to +1.7)	-0.1 (-3.8 to +4.9)
Wind speed (%)	Annual	0.5 (-1.2 to 2)	-0.1 (-2.4 to 0.7)	0.2 (-0.9 to 1.4)	1.1 (-1.7 to 4.9)	-0.4 (-3.4 to 2.6)	0.8 (-3.7 to 5.1)
	DJF	0.2 (-2.4 to 4.7)	0 (-3.7 to 2.6)	1 (-1.1 to 2.8)	1.6 (-1.7 to 6)	0 (-3.3 to 4.6)	1.9 (-3.9 to 8.3)
	MAM	-0.2 (-2.6 to 1.7)	-0.6 (-3.4 to 1.7)	-0.6 (-2.9 to 1)	1.1 (-3.4 to 4.2)	-1.6 (-4.6 to 0.7)	-3.3 (-7.6 to 2.5)
	JJA	0 (-2.7 to 2.9)	-0.3 (-4.2 to 2.7)	-0.2 (-1.5 to 3.1)	0.3 (-1.4 to 5.6)	-0.6 (-5 to 3.8)	0.4 (-2.6 to 6)
	SON	0.9 (-1.2 to 3.3)	0.6 (-2 to 2.6)	0.6 (-1.1 to 2.4)	1.3 (0.1 to 6.6)	1 (-2.7 to 4.9)	2.1 (-0.5 to 8.4)

Monsoonal North (West) Sub-Cluster

Changes in MEAN, MIN & MAX Temperature (relative to 1986-2005)

	2030 (2020–2039)			2050 (2040–2059)			2090 (2080–2099)		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
MONSOONAL NORTH (WEST)									
Annual									
Mean	0.8 (0.5 to 1.2)	0.9 (0.6 to 1.3)	1.0 (0.7 to 1.4)	1.0 (0.7 to 1.6)	1.3 (1.0 to 1.8)	1.8 (1.4 to 2.4)	1.0 (0.6 to 1.8)	1.8 (1.3 to 2.8)	3.7 (2.8 to 5.1)
Min	0.7 (0.5 to 1.2)	0.9 (0.6 to 1.3)	1.1 (0.7 to 1.4)	0.9 (0.7 to 1.5)	1.3 (1.0 to 1.8)	1.9 (1.4 to 2.4)	1.0 (0.6 to 1.7)	1.9 (1.3 to 2.7)	3.8 (3.1 to 5.2)
Max	0.8 (0.5 to 1.3)	0.9 (0.5 to 1.3)	1.0 (0.7 to 1.4)	1.1 (0.7 to 1.7)	1.3 (0.9 to 1.9)	1.9 (1.3 to 2.5)	1.0 (0.6 to 2.1)	1.8 (1.3 to 2.9)	3.6 (2.7 to 5.2)
Wet (November–April)									
Mean	0.7 (0.5 to 1.2)	0.8 (0.5 to 1.2)	0.9 (0.7 to 1.4)	1.0 (0.7 to 1.6)	1.3 (0.5 to 2.1)	1.8 (1.0 to 2.8)	0.9 (0.5 to 1.8)	1.7 (1.1 to 2.6)	3.3 (2.4 to 5.1)
Min	0.7 (0.5 to 1.1)	0.9 (0.6 to 1.2)	0.9 (0.7 to 1.3)	0.9 (0.7 to 1.5)	1.3 (0.7 to 1.9)	1.9 (1.0 to 2.6)	0.9 (0.6 to 1.6)	1.8 (1.2 to 2.7)	3.6 (2.7 to 5.0)
Max	0.8 (0.5 to 1.4)	0.9 (0.4 to 1.3)	0.9 (0.7 to 1.3)	1.1 (0.6 to 1.8)	1.4 (0.3 to 2.3)	1.8 (0.6 to 3.0)	1.1 (0.5 to 2.1)	1.8 (1.1 to 2.9)	3.4 (2.3 to 5.3)
Dry (May–October)									
Mean	0.9 (0.5 to 1.3)	1.0 (0.7 to 1.4)	1.0 (0.7 to 1.4)	0.9 (0.8 to 1.6)	1.5 (0.7 to 2.3)	1.9 (1.1 to 2.7)	1.0 (0.6 to 1.8)	2.0 (1.4 to 2.8)	4.0 (3.2 to 5.2)
Min	0.7 (0.4 to 1.2)	1.0 (0.6 to 1.2)	1.1 (0.8 to 1.5)	0.9 (0.6 to 1.6)	1.4 (0.7 to 2.3)	1.9 (1.2 to 2.8)	1.0 (0.5 to 1.8)	2.0 (1.4 to 2.7)	4.2 (3.5 to 5.4)
Max	0.9 (0.4 to 1.4)	1.0 (0.6 to 1.3)	1.1 (0.7 to 1.4)	1.1 (0.6 to 1.6)	1.4 (0.6 to 2.2)	1.8 (0.9 to 2.9)	1.0 (0.5 to 1.9)	1.9 (1.3 to 2.9)	3.8 (3.0 to 5.1)

Changes in Number of Days Exceeding 35°C and 40°C (relative to 1981-2010)

Threshold	Historical (1981–2010)	2030 (2016–2045)		2050 (2036–2065)		2090 (2075–2104)	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
MILIKAPITI							
35°C or above	6	23 (13 to 39)	28 (14 to 50)	41 (24 to 67)	65 (34 to 102)	70 (42 to 102)	205 (155 to 250)
40°C or above	0	0	0	0	0	0	0
DARWIN							
35°C or above	47	107 (80 to 133)	118 (82 to 156)	139 (108 to 172)	176 (136 to 209)	184 (152 to 214)	288 (256 to 317)
40°C or above	0	0	0	0	0	0	5 (1 to 11)
JABIRU							
35°C or above	135	191 (169 to 214)	198 (172 to 224)	212 (187 to 233)	238 (203 to 267)	243 (219 to 266)	310 (284 to 332)
40°C or above	2	7 (3 to 11)	8 (3 to 13)	12 (5 to 21)	21 (8 to 31)	19 (9 to 28)	70 (29 to 111)
NHULUNBUY							
35°C or above	7	17 (12 to 22)	19 (14 to 27)	26 (18 to 35)	38 (23 to 53)	38 (26 to 51)	121 (80 to 173)
40°C or above	0	0	0	0	0	0	0
BATCHELOR							
35°C or above	86	142 (119 to 160)	153 (124 to 180)	168 (144 to 193)	199 (168 to 226)	205 (177 to 229)	291 (261 to 318)
40°C or above	0	1 (1 to 2)	2 (1 to 3)	2 (1 to 4)	5 (2 to 8)	5 (2 to 7)	32 (10 to 53)
PINE CREEK							
35°C or above	110	159 (137 to 176)	169 (146 to 188)	179 (160 to 197)	208 (181 to 231)	211 (187 to 230)	282 (253 to 309)
40°C or above	1	4 (1 to 6)	4 (2 to 9)	7 (3 to 12)	14 (5 to 22)	12 (5 to 20)	57 (17 to 90)
KATHERINE							
35°C or above	157	200 (178 to 214)	208 (189 to 220)	216 (198 to 231)	240 (218 to 255)	242 (225 to 255)	298 (274 to 320)
40°C or above	7	19 (11 to 27)	22 (14 to 35)	28 (18 to 39)	43 (24 to 57)	38 (21 to 51)	101 (54 to 138)
BORROLOOLA							
35°C or above	125	154 (134 to 167)	164 (144 to 179)	171 (149 to 189)	194 (170 to 213)	196 (178 to 213)	255 (221 to 286)
40°C or above	5	11 (7 to 14)	12 (8 to 18)	15 (9 to 23)	24 (13 to 37)	21 (12 to 35)	69 (29 to 98)

Changes in AVERAGE RAINFALL (relative to 1986-2005)

MONSOONAL NORTH (WEST)									
	2030 (2020–2039)			2050 (2040–2059)			2090 (2080–2099)		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
Annual	-2 (-10 to +5)	0 (-11 to +6)	0 (-6 to +6)	-3 (-10 to +5)	0 (-10 to +7)	-1 (-14 to +9)	-5 (-11 to +4)	-1 (-13 to +8)	+4 (-24 to +19)
Wet	0 (-8 to +6)	0 (-8 to +6)	-1 (-5 to +7)	-3 (-10 to +6)	+1 (-7 to +7)	0 (-7 to +8)	-3 (-11 to +5)	0 (-11 to +8)	+4 (-23 to +19)
Dry	-7 (-32 to +17)	-5 (-35 to +19)	-5 (-22 to +29)	-11 (-27 to +12)	-11 (-35 to 5)	-6 (-40 to +26)	-7 (-29 to +7)	-6 (-30 to +22)	-4 (-45 to +44)

Changes in RELATIVE HUMIDITY (relative to 1986-2005)

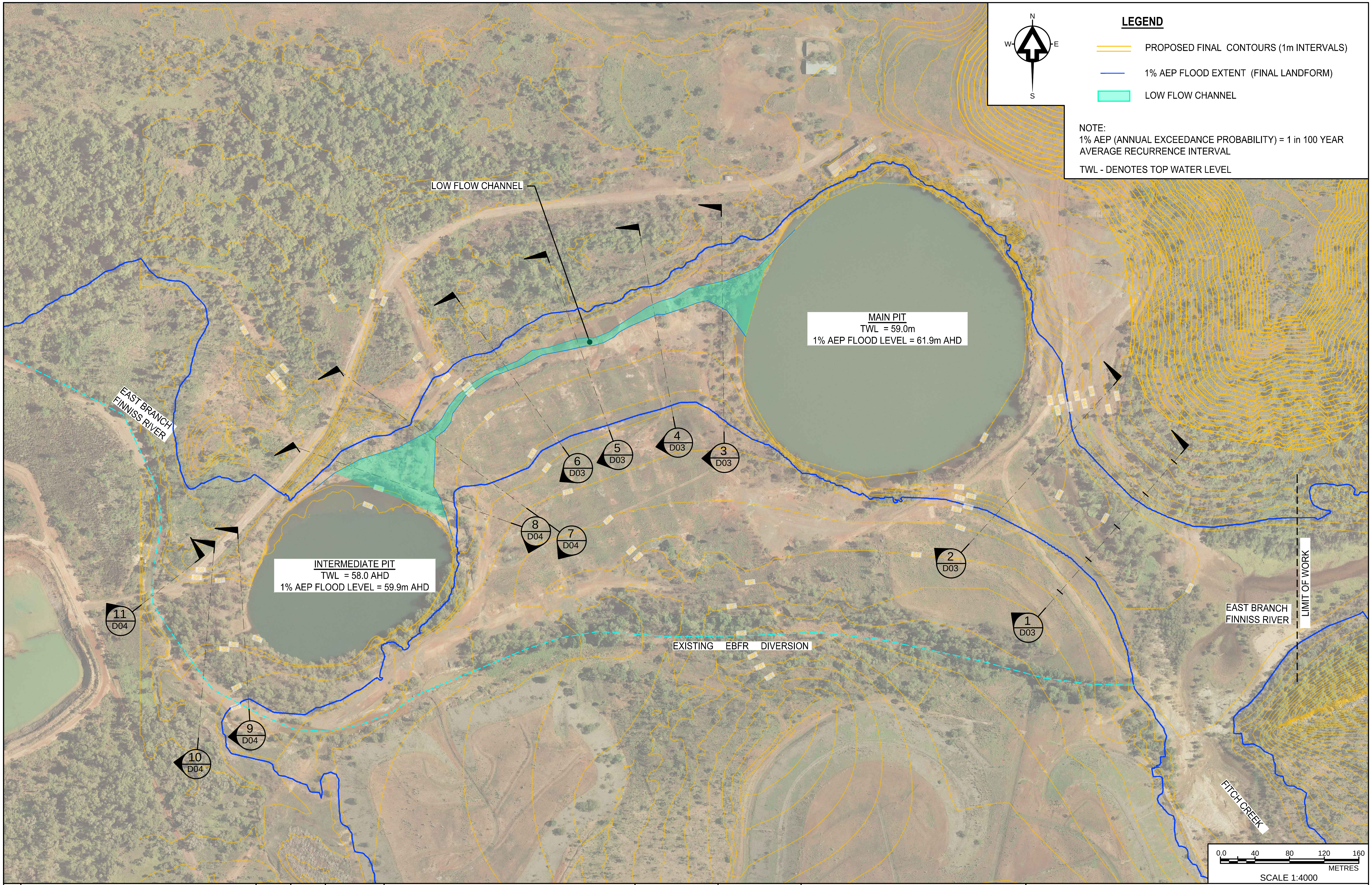
MONSOONAL NORTH (WEST)									
	2030 (2020–2039)			2050 (2040–2059)			2090 (2080–2099)		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
Annual	-0.5 (-2.2 to 0.5)	0.1 (-1.6 to 0.7)	-0.3 (-1.3 to 0.4)	-0.9 (-2.2 to 0.9)	-0.4 (-2.2 to 0.8)	-0.5 (-2.3 to 0.9)	-1.0 (-3.1 to 0.4)	-0.7 (-3.5 to 0.6)	-0.9 (-6.3 to 1.4)
Wet	-1.0 (-2.7 to 1.1)	-0.5 (-2.3 to 1.5)	-0.9 (-2.8 to 0.8)	-1.0 (-4.8 to 0.5)	-0.8 (-4.6 to 3.4)	-0.9 (-5.6 to 3.2)	-2.1 (-4.7 to 0.1)	-1.3 (-5.0 to 1.0)	-1.7 (-7.2 to 3.0)
Dry	-0.9 (-3.3 to 0.8)	-0.5 (-3.4 to 1.8)	-0.7 (-2.7 to 1.3)	-1.7 (-3.6 to 1.8)	-1.0 (-6.7 to 3.7)	-1.3 (-6.1 to 3.5)	-1.0 (-5.2 to 0.6)	-1.0 (-6.6 to 1.3)	-2.0 (-12.5 to 3.2)

Changes in POTENTIAL EVAPOTRANSPIRATION (relative to 1986-2005)

MONSOONAL NORTH (WEST)									
	2030 (2020–2039)			2050 (2040–2059)			2090 (2080–2099)		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
Annual	2.8 (1.4 to 3.6)	3.2 (1.4 to 4.0)	3.2 (2.1 to 4.8)	3.4 (1.5 to 5.1)	4.3 (1.9 to 6.8)	6.2 (4.1 to 8.3)	3.6 (2.2 to 5.8)	6.8 (4.0 to 8.5)	12.2 (7.8 to 16.7)
Wet	Not available	2.8 (1.0 to 4.1)	3.1 (1.5 to 4.2)	Not available	3.8 (0.4 to 7.6)	5.1 (1.5 to 9.5)	Not available	5.9 (2.9 to 8.2)	9.9 (4.9 to 14.9)
Dry	Not available	3.4 (1.4 to 5.3)	3.8 (2.5 to 5.0)	Not available	4.8 (1.8 to 7.8)	7.2 (3.2 to 10.4)	Not available	6.7 (4.8 to 8.9)	14.4 (10.6 to 18.2)

APPENDIX B

Reinstatement Plan of the East Branch Finniss River



No.	DESCRIPTION	DATE	INIT.	DEPT/COMPANY.
1	ISSUED FOR IMPLEMENTATION	10/06/20	MS	SLR

AMENDMENTS — Plot Date: 11/06/2020

SLR
UNIT 5 / 21 PARAP ROAD
DARWIN
NT 0820
AUSTRALIA
T: 61 8 8998 0100
F: 61 8 8998 0101
www.slrconsulting.com

DRAWN	M Skoljarev	DATE: 20.05.2020	
CHECKED	P Delaney	DATE: 20.05.2020	
DESIGNED	P Cupitt	DATE: 20.05.2020	
CHECKED	P Delaney	DATE: 20.05.2020	
DESIGN PROJECT LEADER	D O'Toole	DATE: 20.05.2020	
NTG PROJECT MANAGER	J Hartnett	DATE: 20.05.2020	

Northern Territory Government

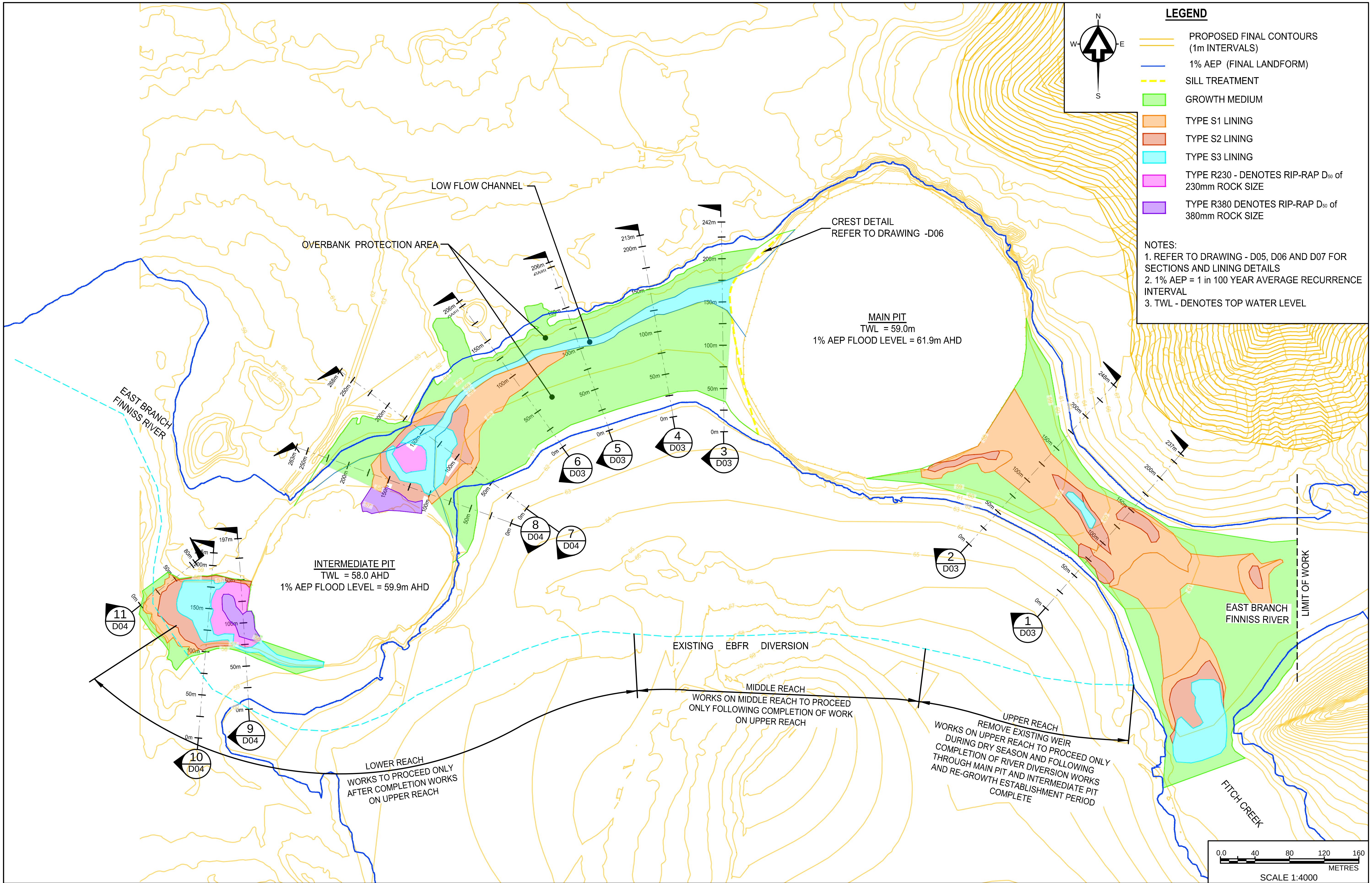
RUM JUNGLE REHABILITATION
STAGE 2A DETAILED ENGINEERING DESIGN

REINSTATEMENT OF EAST BRANCH FINNISS RIVER
GENERAL ARRANGEMENT

NTG PROJECT No.	NTG ASSET No.	SHEET No.	NTG DRAWING No.	AMENDMENT	SHEET SIZE
N/A	N/A	1 OF 7	680.10421.RFR.D01	1	A3

Ver. Jan' 2020

PLOTTED ON: 11/Jun/2020 7:16 AM
USER: MARIN SKOLJAREV
FILE LOCATION: C:\temp\680.10421 RUM JUNGLE\Flood-MPS\FINAL DRAWINGS\680.10421.RFR.D01 to D06 (REV A).dwg



PLOTTED ON: 11/Jun/2020 7:17 AM
USER: MARIN SKOLJAREV
FILE LOCATION: C:\temp\680.10421 RUM JUNGLE\Flood-MPS\FINAL DRAWINGS\680.10421.RFR.D01 to D06 (REV A).dwg

No.	DESCRIPTION	DATE	INIT.	DEPT/COMPANY.
1	ISSUED FOR IMPLEMENTATION	10/06/20	MS	SLR

AMENDMENTS — Plot Date: 11/06/2020

SLR
UNIT 5 / 21 PARAP ROAD
DARWIN
NT 0820
AUSTRALIA
T: 61 8 8998 0100
F: 61 8 8998 0101
www.slrconsulting.com

DRAWN: M Skoljarev, DATE: 20.05.2020	CHECKED: P Delaney, DATE: 20.05.20
DESIGNED: P Cupitt, DATE: 20.05.2020	CHECKED: P Delaney, DATE: 20.05.2020
DESIGN PROJECT LEADER: D O'Toole, DATE: 20.05.2020	NTG PROJECT MANAGER: J Hartnett, DATE: 20.05.2020

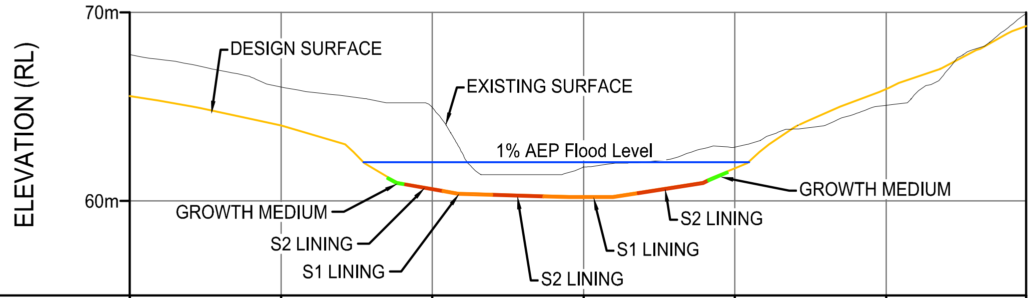
Northern Territory Government

RUM JUNGLE REHABILITATION
STAGE 2A DETAILED ENGINEERING DESIGN

REINSTATEMENT OF EAST BRANCH FINNISS RIVER
EXISTING AND FINAL CONTOURS PLAN

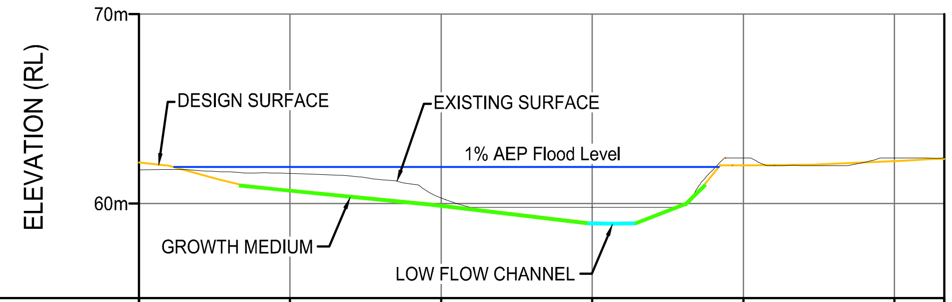
NTG PROJECT No.	NTG ASSET No.	SHEET No.	NTG DRAWING No.	AMENDMENT	SHEET SIZE
N/A	N/A	2 OF 7	680.10421.RFR.D02	1	A3

Ver. Jan' 2020



ORIGINAL GROUND (RLm)	67.76	66.04	64.96	61.80	62.86	65.07	69.92
DESIGN SURFACE (RLm)	65.56	64.00	60.67	60.26	61.73	65.93	69.26
EXCAVATION INVERT (RLm)	-2.20	-2.04	-4.29	-1.55	-1.13	0.86	-0.66
CHAINAGE (m)	0.00	40.00	80.00	120.00	160.00	200.00	237.04

SECTION 1 D02
SCALE H - 1: 2000
V - 1: 400



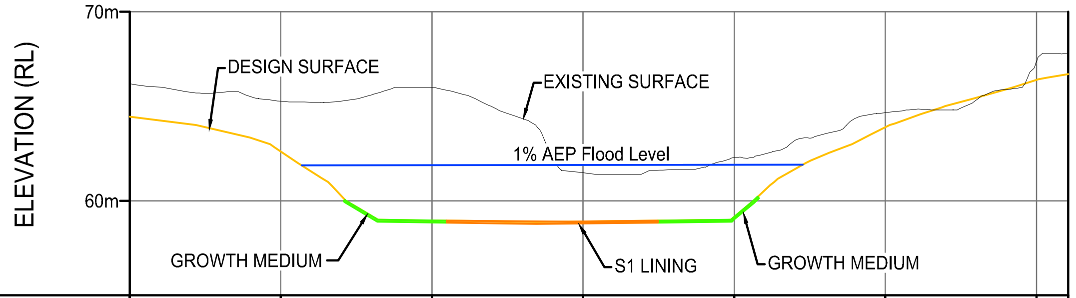
ORIGINAL GROUND (RLm)	61.78	61.58	60.29	59.80	62.40	62.40	62.39
DESIGN SURFACE (RLm)	62.16	60.72	59.92	59.00	62.01	62.24	62.36
EXCAVATION INVERT (RLm)	0.38	-0.86	-0.36	-0.80	-0.39	-0.16	-0.04
CHAINAGE (m)	0.00	40.00	80.00	120.00	160.00	200.00	213.17

SECTION 4 D02
SCALE 1: 2000
V - 1: 400

LEGEND

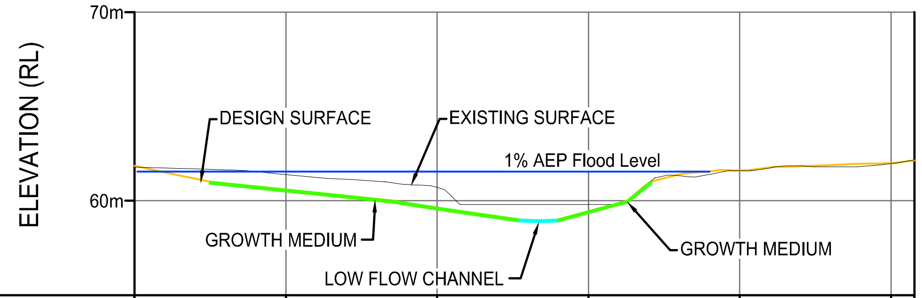
- EXISTING SURFACE
- DESIGN SURFACE
- GROWTH MEDIUM
- S1 LINING
- S2 LINING
- S3 LINING
- 1% AEP Flood Level

NOTE:
FOR TYPICAL LOW FLOW SECTION
REFER TO DRAWING RFR.D06 .
FOR SURFACE TREATMENT MATERIAL
REFER TO DRAWING RFR.D06.



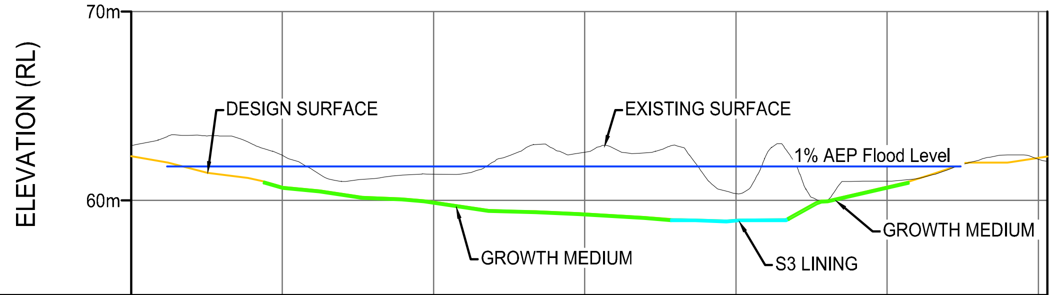
ORIGINAL GROUND (RLm)	66.18	65.26	66.00	61.49	62.29	64.66	67.35	67.80
DESIGN SURFACE (RLm)	64.45	62.61	58.96	58.90	59.15	63.89	66.40	66.71
EXCAVATION INVERT (RLm)	-1.74	-2.66	-7.04	-2.58	-3.14	-0.77	-0.95	-1.09
CHAINAGE (m)	0.00	40.00	80.00	120.00	160.00	200.00	240.00	248.44

SECTION 2 D02
SCALE 1: 2000
V - 1: 400



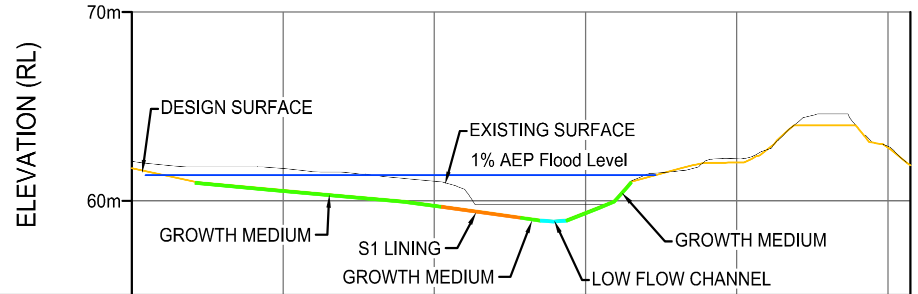
ORIGINAL GROUND (RLm)	61.78	61.38	60.70	59.80	61.60	61.97	62.16
DESIGN SURFACE (RLm)	61.86	60.60	59.63	59.44	61.61	61.99	62.14
EXCAVATION INVERT (RLm)	0.08	-0.79	-1.07	-0.36	0.00	0.02	-0.01
CHAINAGE (m)	0.00	40.00	80.00	120.00	160.00	200.00	206.21

SECTION 5 D02
SCALE 1: 2000
V - 1: 400



ORIGINAL GROUND (RLm)	62.91	62.39	61.39	62.55	60.37	61.02	62.18	62.08
DESIGN SURFACE (RLm)	62.34	60.73	59.93	59.31	58.98	60.73	62.25	62.32
EXCAVATION INVERT (RLm)	-0.57	-1.66	-1.47	-3.24	-1.38	-0.29	0.07	0.24
CHAINAGE (m)	0.00	40.00	80.00	120.00	160.00	200.00	240.00	242.38

SECTION 3 D02
SCALE 1: 2000
V - 1: 400



ORIGINAL GROUND (RLm)	62.09	61.71	61.04	59.80	62.23	62.88	61.87
DESIGN SURFACE (RLm)	61.72	60.57	59.78	59.39	62.02	62.82	61.92
EXCAVATION INVERT (RLm)	-0.37	-1.14	-1.26	-0.41	-0.21	-0.06	0.06
CHAINAGE (m)	0.00	40.00	80.00	120.00	160.00	200.00	205.98

SECTION 6 D02
SCALE 1: 2000
V - 1: 400

0.0 20 40 60 80
METRES
SCALE 1:2000

No.	DESCRIPTION	DATE	INIT.	DEPT/COMPANY.
1	ISSUED FOR IMPLEMENTATION	10/06/20	MS	SLR

AMENDMENTS
Plot Date: 11/06/2020

SLR
UNIT 5 / 21 PARAP ROAD
DARWIN
NT 0820
AUSTRALIA
T: 61 8 8998 0100
F: 61 8 8998 0101
www.slrconsulting.com

DRAWN M Skoljarev DATE: 20.05.2020	CHECKED P Delaney DATE: 20.05.2020
DESIGNED P Cupitt DATE: 20.05.2020	CHECKED P Delaney DATE: 20.05.2020
DESIGN PROJECT LEADER D O'Toole DATE: 20.05.2020	NTG PROJECT MANAGER J Hartnett DATE: 20.05.2020

Northern Territory Government

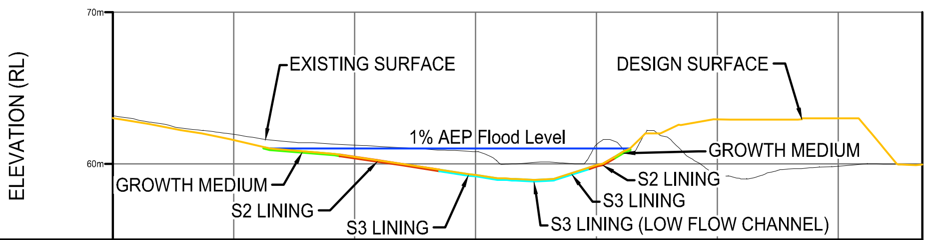
RUM JUNGLE REHABILITATION
STAGE 2A DETAILED ENGINEERING DESIGN

SURFACE TREATMENT
SECTIONS SHEET 1 OF 2

NTG PROJECT No.	NTG ASSET No.	SHEET No.	NTG DRAWING No.	AMENDMENT	SHEET SIZE
N/A	N/A	3 OF 7	680.10421.RFR.D03	1	A3

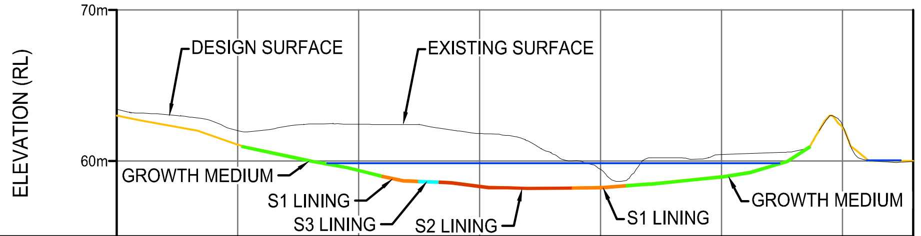
Ver. Jan' 2020

PLOTTED ON: 11/Jun/2020 7:17 AM
USER: MARIN SKOLJAREV
FILE LOCATION: C:\temp\680.10421 RUM JUNGLE\Flood-MPS\FINAL DRAWINGS\680.10421.RFR.D01 to D06 (REV A).dwg



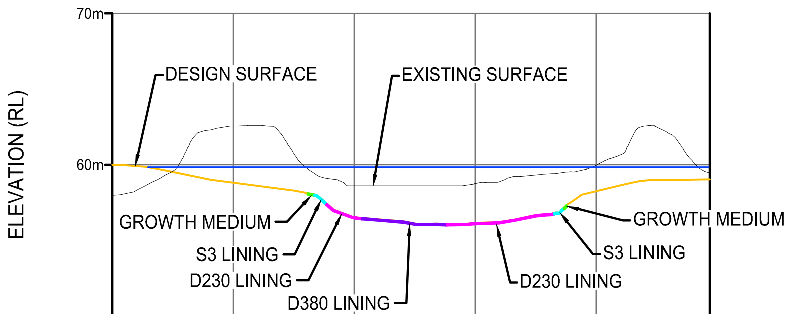
ORIGINAL GROUND (RLm)	63.16	61.94	61.23	60.80	61.25	59.20	59.84	59.97
DESIGN SURFACE (RLm)	63.01	61.56	60.46	59.27	59.91	62.93	63.00	59.95
EXCAVATION INVERT (RLm)	-0.15	-0.38	-0.78	-1.54	-1.34	3.74	3.16	-0.02
CHAINAGE (m)	0.00	40.00	80.00	120.00	160.00	200.00	240.00	267.88

SECTION 7 / D02
SCALE H - 1: 2000
V - 1: 400



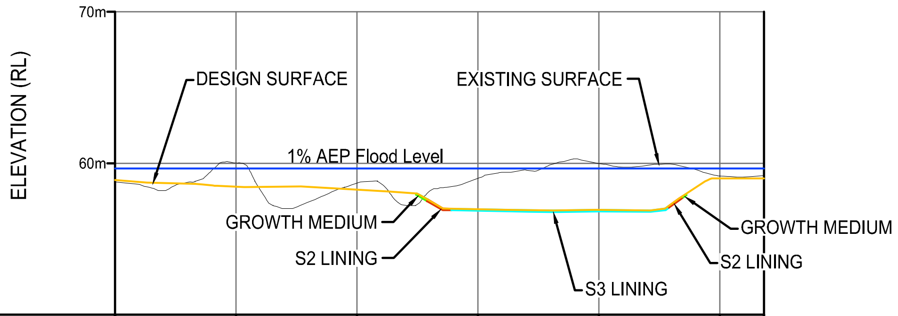
ORIGINAL GROUND (RLm)	63.45	62.00	62.42	61.81	59.44	60.42	62.37	59.96
DESIGN SURFACE (RLm)	63.00	61.08	59.42	58.36	58.27	58.99	62.24	60.00
EXCAVATION INVERT (RLm)	-0.44	-0.92	-3.00	-3.45	-1.17	-1.43	-0.13	0.04
CHAINAGE (m)	0.00	40.00	80.00	120.00	160.00	200.00	240.00	263.46

SECTION 8 / D02
SCALE H - 1: 2000
V - 1: 400



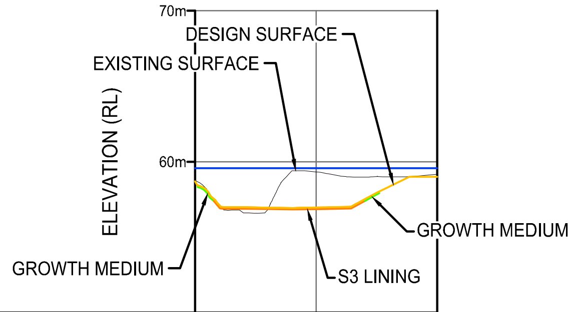
DESIGN SURFACE (RLm)	59.99	58.80	56.54	56.14	58.24	59.01
ORIGINAL GROUND (RLm)	57.96	62.56	58.60	58.75	59.96	59.44
EXCAVATION INVERT (RLm)	2.03	-3.76	-2.06	-2.61	-1.72	-0.43
CHAINAGE (m)	0.00	40.00	80.00	120.00	160.00	197.48

SECTION 9 / D02
SCALE H - 1: 2000
V - 1: 400



ORIGINAL GROUND (RLm)	58.75	60.01	58.68	58.99	59.99	59.16	59.18
DESIGN SURFACE (RLm)	58.89	58.45	58.26	56.96	56.92	59.00	59.00
EXCAVATION INVERT (RLm)	0.14	-1.56	-0.42	-2.04	-3.07	-0.16	-0.18
CHAINAGE (m)	0.00	40.00	80.00	120.00	160.00	200.00	214.67

SECTION 10 / D02
SCALE H - 1: 2000
V - 1: 400



ORIGINAL GROUND (RLm)	58.77	59.31	59.17
DESIGN SURFACE (RLm)	58.70	56.96	59.00
EXCAVATION INVERT (RLm)	-0.07	-2.36	-0.16
CHAINAGE (m)	0.00	40.00	79.99

SECTION 11 / D02
SCALE H - 1: 2000
V - 1: 400

LEGEND

- EXISTING SURFACE
- DESIGN SURFACE
- GROWTH MEDIUM
- S1 LINING
- S2 LINING
- S3 LINING
- D230 LINING
- D380 LINING
- 1% AEP Flood Level

NOTE:
FOR TYPICAL LOW FLOW SECTION
REFER TO DRAWING RFR.D06.
FOR SURFACE TREATMENT MATERIAL
REFER TO DRAWING RFR.D06.

0.0 20 40 60 80
METRES
SCALE 1:2000

No.	DESCRIPTION	DATE	INIT.	DEPT/COMPANY.
1	ISSUED FOR IMPLEMENTATION	10/06/20	MS	SLR

AMENDMENTS
Plot Date: 11/06/2020

SLR
UNIT 5 / 21 PARAP ROAD
DARWIN
NT 0820
AUSTRALIA
T: 61 8 8998 0100
F: 61 8 8998 0101
www.slrconsulting.com

DRAWN M Skoljarev DATE: 20.05.2020	CHECKED P Delaney DATE: 20.05.2020
DESIGNED P Cupitt DATE: 20.05.2020	CHECKED P Delaney DATE: 20.05.2020
DESIGN PROJECT LEADER D O'Toole DATE: 20.05.2020	NTG PROJECT MANAGER J Hartnett DATE: 20.05.2020

Northern Territory Government

RUM JUNGLE REHABILITATION
STAGE 2A DETAILED ENGINEERING DESIGN

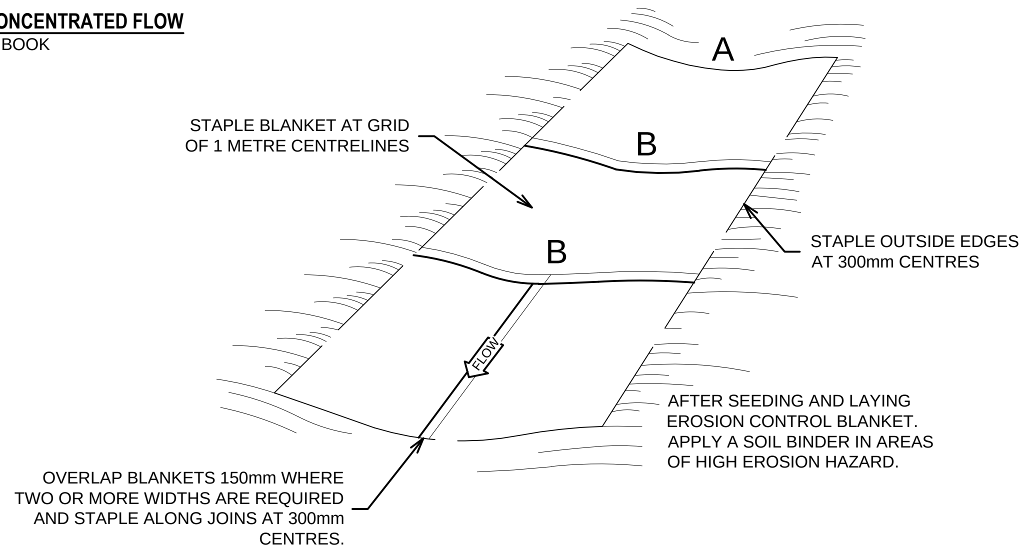
SURFACE TREATMENT
SECTIONS SHEET 2 OF 2

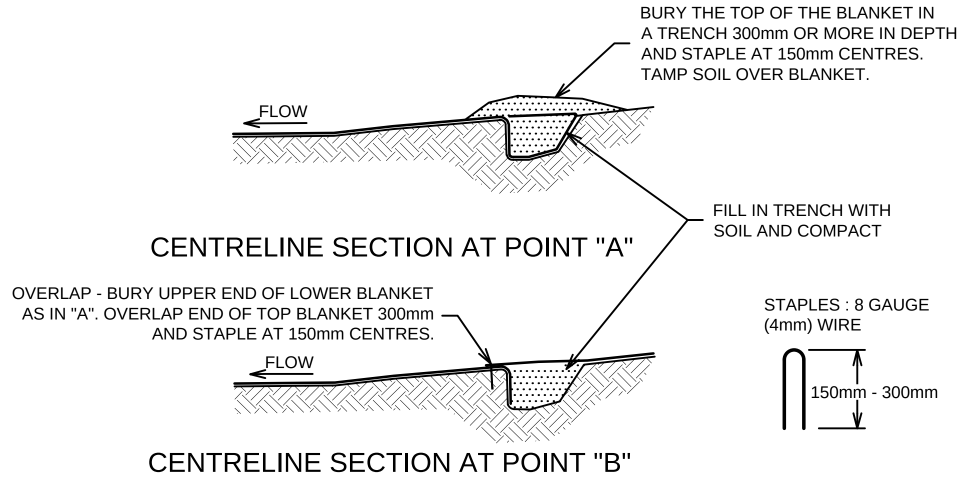
NTG PROJECT No.	NTG ASSET No.	SHEET No.	NTG DRAWING No.	AMENDMENT	SHEET SIZE
N/A	N/A	4 OF 7	680.10421.RFR.D04	1	A3

Ver. Jan' 2020

PLOTTED ON: 11/Jun/2020 7:18 AM
USER: MARIN SKOLJAREV
FILE LOCATION: C:\temp\680.10421 RUM JUNGLE\Flood-MPS\FINAL DRAWINGS\680.10421.RFR.D01 to D06 (REV A).dwg

INSERT 1
SD 5-7 RECP: CONCENTRATED FLOW
SOURCE - BLUE BOOK



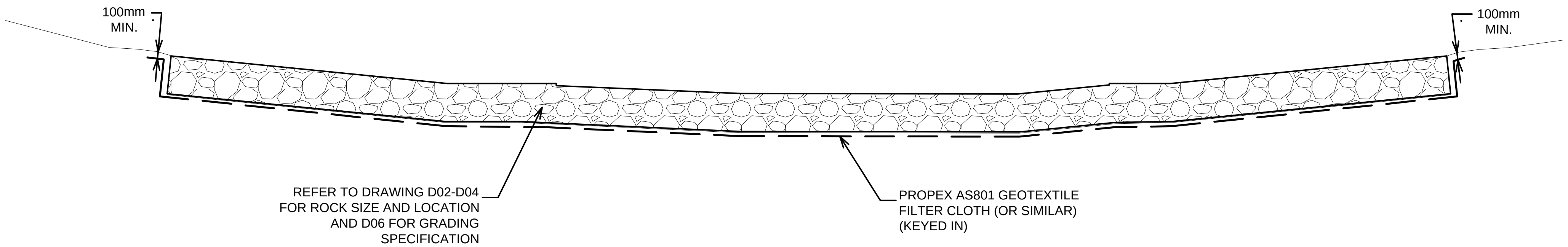


TYPICAL GEOTEXTILE LAYING PROCEDURE
NTS

CONSTRUCTION NOTES:

1. RIP-RAP SHOULD OVERLAY A 1M DEEP BASE OF STABILISED AND WELL COMPACTED MATERIAL WHICH IS NON-DISPERSIVE AND WITH PERMEABILITY NON GREATER THAN $1x10^5$ m/s.
2. USE GRADED DURABLE RIP-RAP (ROCK). RIP-RAP SHOULD NOT BE SINGLE SIZED, BUT SHOULD BE A WELL-GRADED MIXTURE DESIGNED TO ENSURE THAT ALL GAPS BETWEEN LARGE ROCKS ARE FILLED WITH ROCK OF PROGRESSIVELY SMALLER SIZE SO THAT NO SIGNIFICANT VOIDS OCCUR IN THE RIP-RAP BLANKET. GRADING RECOMMENDATIONS ARE PROVIDED IN **TABLE 1** BELOW.
3. ROCK FOR RIP RAP SHOULD BE HARD, TOUGH AND DURABLE WITH A CRUSHING STRENGTH OF AT LEAST 25MPa. THE ROCK SHOULD BE FREE OF DEFINED CLEAVAGE PLANES AND SHOULD NOT BE ADVERSELY AFFECTED BY REPEATED WETTING AND DRYING. ROCK SHOULD PREFERABLY BE PREDOMINANTLY ANGULAR IN SHAPE WITH NOT MORE THAN 25% OF ROCKS, DISTRIBUTED THROUGH THE GRADATION, HAVING A LENGTH MORE THAN TWICE THE BREADTH AND THICKNESS.
4. USE PROPEX AS801 NON-WOVEN GEOTEXTILE FILTER CLOTH (GEOFABRIC) (OR SIMILAR) BETWEEN THE RIP RAP AND THE PARENT MATERIAL. MAXIMUM RESISTANCE BETWEEN THE RIP RAP AND THE CLOTH IS REQUIRED. THIS CAN BE ACHIEVED BY:
   - ENSURING PREPARATION OF THE BANK TO A ROUGH AND UNEVEN BATTER BEFORE PLACING THE CLOTH.
   - NOT STRETCHING CLOTH TIGHTLY OVER THE UNDERLYING BANK
   - AVOID CLOTHS WITH LOW FRICTION SURFACES
   - LAY GEOFABRIC IN "SHINGLE-FASHION", WITH THE END OF EACH UPSTREAM ROLL OVERLAPPING THOSE DOWNSTREAM. ENSURE EACH ROLL IS ANCHORED PROPERLY AT ITS UPSLOPE END.
5. REFER TO DRAWING RFR.D06 FOR RIP-RAP DETAILS

NOTE:
ALL DISTURBED AREAS (OUTSIDE ROCK RIP RAP) SHOULD BE REVEGETATED AS PER PROJECT REVEGETATION PLAN.



TYPICAL RIP-RAP SECTION
NTS

PLOTTED ON: 11/Jun/2020 7:18 AM
USER: MARIN SKOLJAREV
FILE LOCATION: C:\temp\680.10421 RUM JUNGLE\Flood-MPS\FINAL DRAWINGS\680.10421.RFR.D01 to D06 (REV A).dwg

No.	DESCRIPTION	DATE	INIT.	DEPT/COMPANY.
1	ISSUED FOR IMPLEMENTATION	10/06/20	MS	SLR

AMENDMENTS — Plot Date: 11/06/2020

UNIT 5 / 21 PARAP ROAD
DARWIN
NT 0820
AUSTRALIA
T: 61 8 8998 0100
F: 61 8 8998 0101
www.slrconsulting.com

DRAWN M Skoljarev DATE: 20.05.2020	CHECKED P Delaney DATE: 20.05.2020
DESIGNED P Cupitt DATE: 20.05.2020	CHECKED P Delaney DATE: 20.05.2020
DESIGN PROJECT LEADER D O'Toole DATE: 20.05.2020	NTG PROJECT MANAGER J Hartnett DATE: 20.05.2020

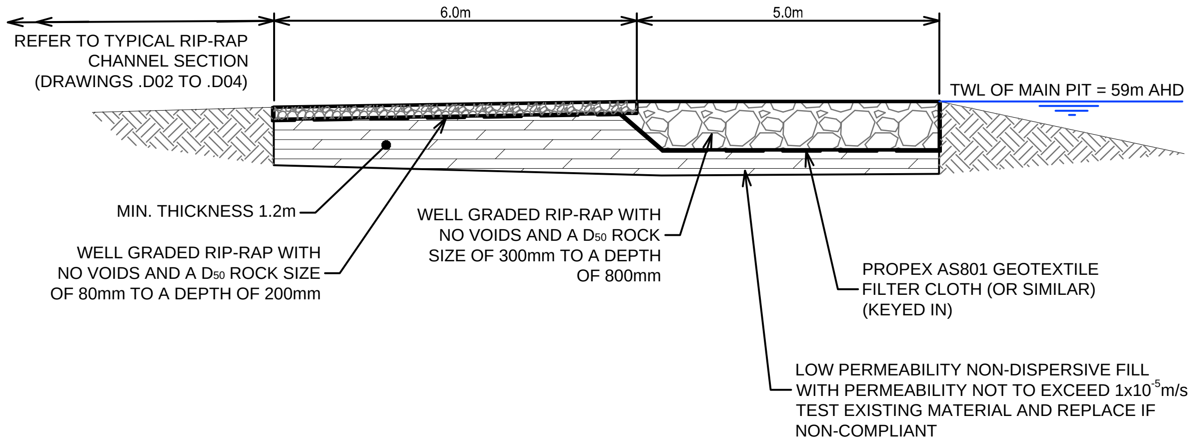
Northern Territory Government

RUM JUNGLE REHABILITATION
STAGE 2A DETAILED ENGINEERING DESIGN

REINSTATEMENT OF EAST BRANCH FINNISS RIVER
DETAILS SHEET 1

NTG PROJECT No.	NTG ASSET No.	SHEET No.	NTG DRAWING No.	AMENDMENT	SHEET SIZE
N/A	N/A	5 OF 7	680.10421.RFR.D05	1	A3

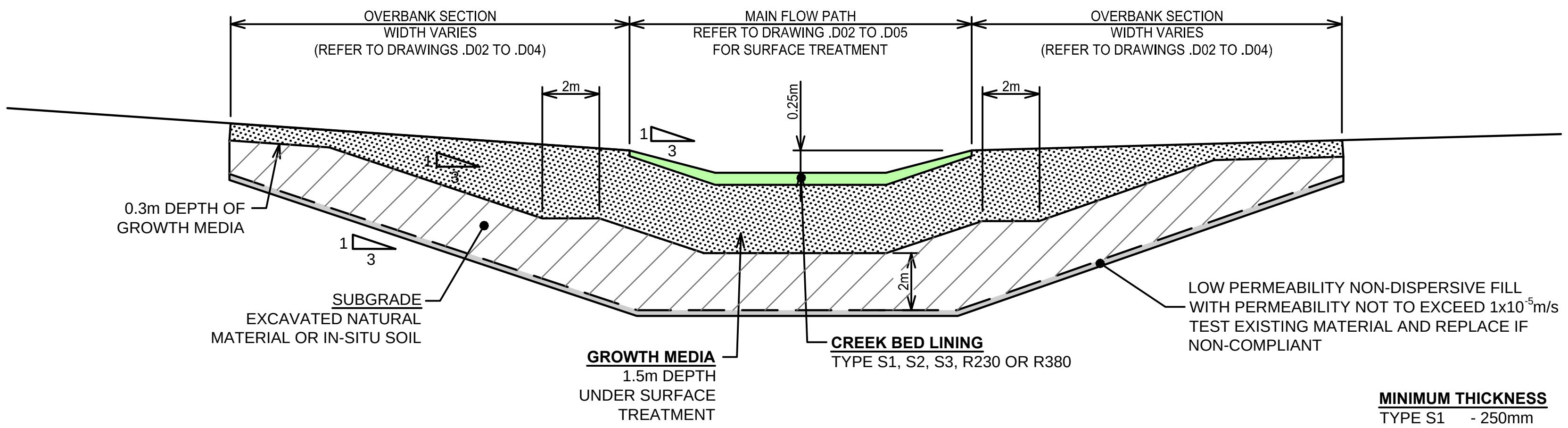
Ver. Jan' 2020



MAIN PIT SPILLWAY CREST DETAIL

NTS

NOTE:
CREST IS NOT LEVEL BUT FOLLOWS SURFACE CONTOUR OF FLOW PATH.
REFER SECTION 3 ON DRAWING .D03.



MINIMUM THICKNESS
TYPE S1 - 250mm
TYPE S2 - 300mm
TYPE S3 - 500mm
TYPE R230 - D50 OF 230mm ROCK AT A DEPTH OF 350mm
TYPE R380 - D50 OF 380mm ROCK AT A DEPTH OF 600mm

TYPICAL SECTION FOR CHANNEL REINSTATEMENT DESIGN

NTS

MATERIAL SPECIFICATIONS FOR CONSTRUCTION WITH FLOOD ENVELOPE

TYPE S1: RIP-RAP SOIL SAND MIX (FINE)

PERCENTAGE BY WEIGHT		SPECIFICATION
MINIMUM	MAXIMUM	
10%	15%	GROWTH MEDIUM
0%	5%	MEDIUM TO COARSE SAND (0.25 to 1.0mm)
15%	20%	COARSE SAND (1.0 to 2.0mm)
15%	20%	FINE GRAVEL (2.0 to 3.4mm)
20%	25%	COARSE GRAVEL (3.4 to 10mm)
30%	35%	GRADED RIP-RAP, 10 to 100mm, WITH D_{50} of 70mm TO A DEPTH OF 150mm

TYPE S2: RIP-RAP SOIL SAND MIX (MEDIUM)

PERCENTAGE BY WEIGHT		SPECIFICATION
MINIMUM	MAXIMUM	
10%	15%	GROWTH MEDIUM
0%	5%	MEDIUM TO COARSE SAND (0.25 to 1.0mm)
10%	15%	COARSE SAND (1.0 to 2.0mm)
10%	15%	FINE GRAVEL (2.0 to 3.4mm)
25%	30%	COARSE GRAVEL (3.4 to 10mm)
35%	40%	GRADED RIP-RAP, 10 to 160mm, WITH D_{50} of 100mm TO A DEPTH OF 100mm

TYPE S3: RIP-RAP SOIL SAND MIX (COARSE)

PERCENTAGE BY WEIGHT		SPECIFICATION
MINIMUM	MAXIMUM	
10%	15%	GROWTH MEDIUM
0%	5%	MEDIUM TO COARSE SAND (0.25 to 1.0mm)
5%	10%	COARSE SAND (1.0 to 2.0mm)
5%	10%	FINE GRAVEL (2.0 to 3.4mm)
20%	25%	COARSE GRAVEL (3.4 to 10mm)
50%	55%	GRADED RIP-RAP, 10 to 200mm, WITH D_{50} of 150mm TO A DEPTH OF 250mm

RIP-RAP

RIP-RAP IS DESIGNATED BY THE D_{50} (EG: R250 HAS A D_{50} 250mm
REFER TO DRAWING -D02 FOR APPLICATION AREAS AND REFER TO SPECIFICATION ON -D06 FOR GRADING REQUIREMENTS FOR RIP-RAP
RIP-RAP MUST BE WELL GRADED WITH FEW VOIDS

GROWTH MEDIUM

REFER TO GENERAL SPECIFICATIONS

EXCAVATED NATURAL MATERIAL

REFER TO GENERAL SPECIFICATIONS

NOTE 1
THE CONTRACTOR IS REQUIRED TO IMPLEMENT THE LANDFORM AS SPECIFIED. REVEGETATION IS NOT PART OF THIS CONTRACT.

PLOTTED ON: 11/Jun/2020 7:09 AM
USER: MARIN SKOLJAREV
FILE LOCATION: C:\temp\680.10421 RUM JUNGLE\Flood-MPS\FINAL DRAWINGS\680.10421.RFR.D01 to D06 (REV A).dwg

No.	DESCRIPTION	DATE	INIT.	DEPT/COMPANY.
1	ISSUED FOR IMPLEMENTATION	10/06/20	MS	SLR

AMENDMENTS — Plot Date: 11/06/2020

SLR
UNIT 5 / 21 PARAP ROAD
DARWIN
NT 0820
AUSTRALIA
T: 61 8 8998 0100
F: 61 8 8998 0101
www.slrconsulting.com

DRAWN: M Skoljarev, DATE: 20.05.2020	CHECKED: P Delaney, DATE: 20.02.2020
DESIGNED: P Cupitt, DATE: 20.05.2020	CHECKED: P Delaney, DATE: 20.05.2020
DESIGN PROJECT LEADER: D O'Toole, DATE: 20.05.2020	NTG PROJECT MANAGER: J Hartnett, DATE: 20.05.2020

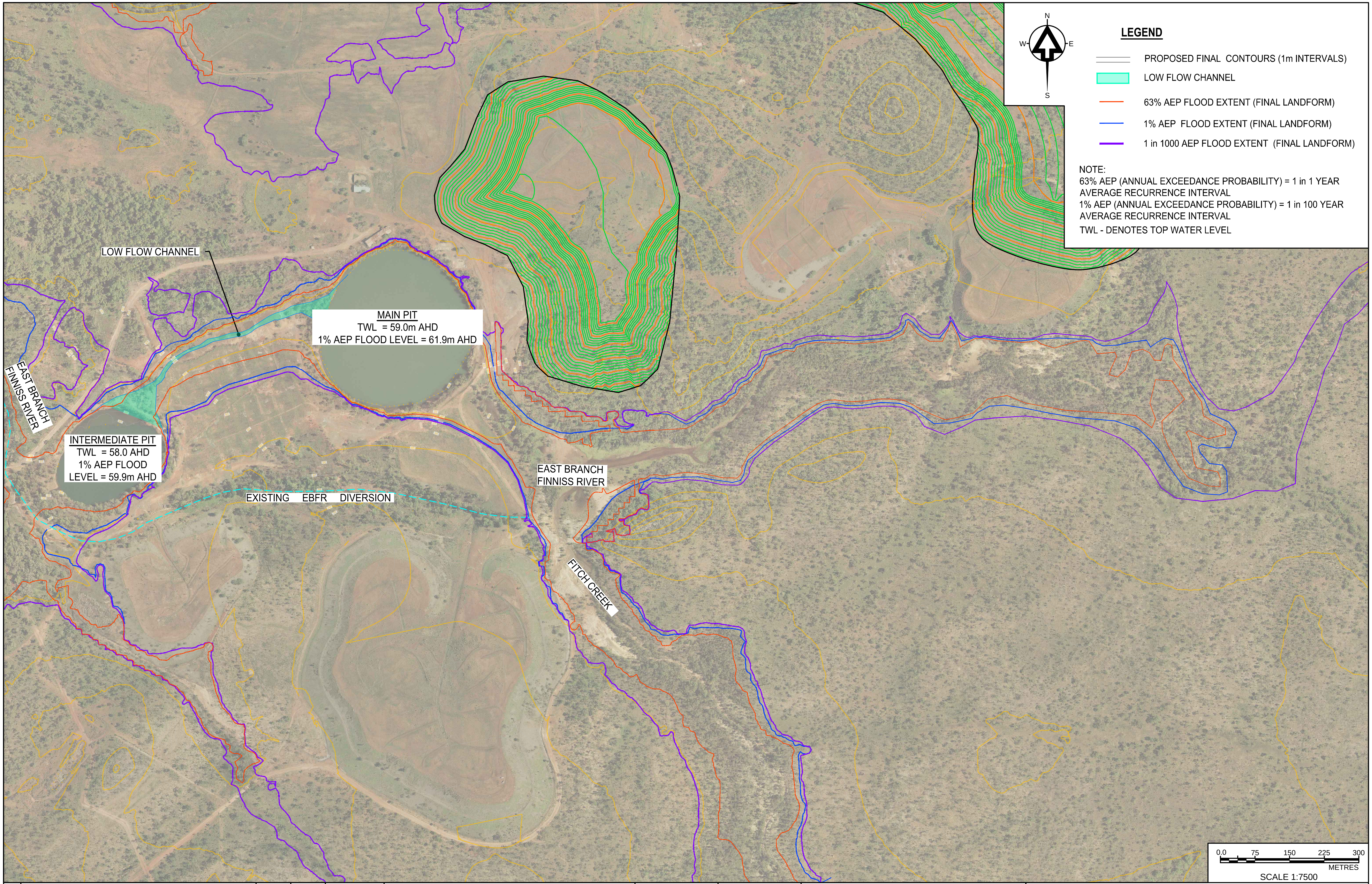
Northern Territory Government

RUM JUNGLE REHABILITATION
STAGE 2A DETAILED ENGINEERING DESIGN

REINSTATEMENT OF EAST BRANCH FINNISS RIVER
DETAILS SHEET 2

NTG PROJECT No.	NTG ASSET No.	SHEET No.	NTG DRAWING No.	AMENDMENT	SHEET SIZE
N/A	N/A	6 OF 7	680.10421.RFR.D06	1	A3

Ver. Jan' 2020



PLOTTED ON: 11/Jun/2020 7:28 AM
USER: MARIN SKOLJAREV
FILE LOCATION: C:\temp\680.10421 RUM JUNGLE\Flood-MPS\FINAL DRAWINGS\680.10421.RFR.D07 (REV 1).dwg

No.	DESCRIPTION	DATE	INIT.	DEPT/COMPANY.
1	ISSUED FOR IMPLEMENTATION	10/06/20	MS	SLR

AMENDMENTS
Plot Date: 11/06/2020

SLR
UNIT 5 / 21 PARAP ROAD
DARWIN
NT 0820
AUSTRALIA
T: 61 8 8998 0100
F: 61 8 8998 0101
www.slrconsulting.com

DRAWN: M Skoljarev, DATE: 22.05.2020	CHECKED: P Delaney, DATE: 22.05.2020
DESIGNED: P Cupitt, DATE: 22.05.2020	CHECKED: P Delaney, DATE: 22.05.2020
DESIGN PROJECT LEADER: D O'Toole, DATE: 22.05.2020	NTG PROJECT MANAGER: J Hartnett, DATE: 22.05.2020

Northern Territory Government

RUM JUNGLE REHABILITATION
STAGE 2A DETAILED ENGINEERING DESIGN

REINSTATEMENT OF EAST BRANCH FINNISS RIVER
FLOOD INUNDATION AND WSF POSITION

NTG PROJECT No.	NTG ASSET No.	SHEET No.	NTG DRAWING No.	AMENDMENT	SHEET SIZE
N/A	N/A	7 OF 7	680.10421.RFR.D07	1	A3

Ver. Jan' 2020

ASIA PACIFIC OFFICES

ADELAIDE
60 Halifax Street
Adelaide SA 5000
Australia
T: +61 431 516 449

BRISBANE
Level 16, 175 Eagle Street
Brisbane QLD 4000
Australia
T: +61 7 3858 4800
F: +61 7 3858 4801

CANBERRA
GPO 410
Canberra ACT 2600
Australia
T: +61 2 6287 0800
F: +61 2 9427 8200

DARWIN
Unit 5, 21 Parap Road
Parap NT 0820
Australia
T: +61 8 8998 0100
F: +61 8 9370 0101

GOLD COAST
Level 2, 194 Varsity Parade
Varsity Lakes QLD 4227
Australia
M: +61 438 763 516

MACKAY
21 River Street
Mackay QLD 4740
Australia
T: +61 7 3181 3300

MELBOURNE
Level 11, 176 Wellington Parade
East Melbourne VIC 3002
Australia
T: +61 3 9249 9400
F: +61 3 9249 9499

NEWCASTLE CBD
Suite 2B, 125 Bull Street
Newcastle West NSW 2302
Australia
T: +61 2 4940 0442

NEWCASTLE
10 Kings Road
New Lambton NSW 2305
Australia
T: +61 2 4037 3200
F: +61 2 4037 3201

PERTH
Grd Floor, 503 Murray Street
Perth WA 6000
Australia
T: +61 8 9422 5900
F: +61 8 9422 5901

SYDNEY
Tenancy 202 Submarine School
Sub Base Platypus
120 High Street
North Sydney NSW 2060
Australia
T: +61 2 9427 8100
F: +61 2 9427 8200

TOWNSVILLE
12 Cannan Street
South Townsville QLD 4810
Australia
T: +61 7 4722 8000
F: +61 7 4722 8001

WOLLONGONG
Level 1, The Central Building
UoW Innovation Campus
North Wollongong NSW 2500
Australia
T: +61 2 4249 1000

AUCKLAND
Level 4, 12 O'Connell Street
Auckland 1010
New Zealand
T: 0800 757 695

NELSON
6/A Cambridge Street
Richmond, Nelson 7020
New Zealand
T: +64 274 898 628

WELLINGTON
12A Waterloo Quay
Wellington 6011
New Zealand
T: +64 2181 7186

SINGAPORE
39b Craig Road
Singapore 089677
T: +65 6822 2203