24 March 2020

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Re: Snowy 2.0 Main Works - Preferred Infrastructure Report - Response to request

Dear Anthony,

This letter provides a response to your request for information provided via email on 27 February 2020. Responses are provided in the sections below.

1 Water quality

1. Talbingo spoil emplacement: Provide revised predictions around Aluminium levels and other relevant trace metals. This appears to be dismissed with a comment that Aluminium levels will be lower because TSS is lower.

Please see response provided in Appendix A.

2. Tantangara spoil emplacement: As the material between MOL and FSL will now be drill and blast material only, this material will go between wetting and drying as it rises up and down with the operations phases. There does not appear to be any consideration of the impacts of this. Consideration of these impacts are required, including

- ***a. any issues with sediment leaking/leaching;***
- ***b. consideration of TSS levels as you move away from emplacement;***
- ***c. consideration of duration***

Please see response provided in Appendix A.

3. Consideration of the impacts of end of works (in stream works) (TSS levels, mobilisation of metals, cumulative impacts of in stream works etc.).

Changes to reservoir water quality due to intake construction and rock plug removal will be further managed through the development and approval of the water management plan. As outlined in mitigation measure WM11 the specifications and locations of the proposed measures to manage environmental impacts of the rock plug removal will be determined as part of detailed design, including the silt curtains specifications to minimise TSS concentrations/turbidity outside of the silt curtains surrounding the dredging and sediment disposal areas.

As described in the Main Works Preferred Infrastructure Report and Response to Submissions (PIR-RTS), Section 4.4.1ii, sediment testwork indicated that while some metal concentrations in Talbingo Reservoir sediment exceeds default ANZG(2018) sediment quality guideline values, it is predicted that water quality will meet the default ANZG (2018) guidelines for the protection of slight-moderately disturbed ecosystems will be met within a 1:25 (sediment:water) dilution. With appropriately specified silt curtains, it is expected that these dilutions will be achieved within the silt curtains. Sediment testwork indicated that all metal concentrations in Tantangara Reservoir sediment are below ANZG(2018) sediment quality guideline values and therefore there is a low risk of unacceptable water quality impacts occurring during dredging as a result of the mobilisation of metals. Adaptive management measures will be identified and implemented through monitoring for TSS during in-stream works and a corresponding trigger action response plan (TARP).

Notwithstanding this, further consideration of water quality impacts and potential management options for each intake construction is provided in the sections below.

A. Talbingo intake

Dredging for the Talbingo intake will be carried out in a low energy lake environment with shallow soft sediment overlying compact rock. It is expected that a relatively small quantity of sediment will be generated from the construction of this intake. Environmental controls will be implemented during in-stream works. The specifications and locations of the proposed measures to manage environmental impacts of the intake construction will be determined as part of detailed design, including the silt curtains specifications to minimise TSS concentrations/turbidity outside of the silt curtains surrounding the dredging and sediment disposal areas. Turbidity will be monitored during the instream works particularly outside the silt curtains. If elevated turbidity levels are observed actions will be taken to bring turbidity levels below the relevant criteria. Actions that may be taken to minimise turbidity impacts include checking and repairing the silt curtain and slowing the rate of dredging or disposal.

B. Tantangara intake

The lake bed geomorphology at Tantangara differs from Talbingo and unconsolidated sediment may extend much deeper below the top of the bed. Based on a core sample taken in the area, unconsolidated sediment may contain some clay. In low energy lake environments the surficial sediments are typically fine and easily disturbed into plumes. Dredging will also occur over a larger area for the Tantangara intake. Dredging for this intake will use a grab dredge (or potentially a long reach excavator in the shallowest areas). These mechanical methods will minimise water incorporation in the excavated material and will thereby reduce turbidity impacts compared to cutter-suction dredge that forms a slurry, releasing a lot more fine material. Environmental controls will be implemented during in-stream works. The specifications and locations of the proposed measures to manage environmental impacts of the intake construction will be determined as part of detailed design, including the silt curtains specifications to minimise TSS concentrations/turbidity outside of the silt curtains surrounding the dredging and sediment disposal areas. Turbidity will be monitored during the instream works particularly outside the silt curtains. If elevated turbidity levels are observed actions will be taken to bring turbidity levels below the relevant criteria. Actions that may be taken to minimise turbidity impacts include checking and repairing the silt curtain and slowing the rate of dredging or disposal.

4. For the in stream works, it appears that in stream blasting will occur at a fair depth (up to 20m deep). The 2m silt curtain is likely to be inadequate.

As described above, water quality controls to be implemented during the construction of the intakes will be determined as part of detailed design, including the silt curtains specifications to minimise TSS concentrations/turbidity outside of the silt curtains surrounding the dredging and sediment disposal areas. They will be designed such that water quality criteria is agreed with the regulators, with the application of a mixing zone if required.

5. There is discussion about the mixing zone modelling there is a reference to an appendix with the modelling. However, the appendix does not appear to be present.

This appendix was provided as part of the Draft issued to DPIE. It is also part of the final report submitted via the major projects portal. It is Attachment F to Appendix J of the PIR-RTS.

6. ***Geomorphic landscaping style for land placement – we require consideration of leaching from the final land placement (i.e. diffuse source pollution from the material), noting that the original placement will include layers of lime to help neutralise what is put there.***

Please see response provided in Appendix A.

2 Response to BCD/NPWS comments

1. ***Mitigation measures:***

   a) ***Provide more detail on the potential adaptive management options available should an impact be detected;***

Adaptive management options will be selected through the detailed design process. Further details will be provided and approval for adaptive management options will be sought through the development of the biodiversity management plan.

   b) ***Is there possibility to have a tracked changes version showing what mitigation measures have changed since lodgement of EIS;***

Please see mitigation measures with track changes provided in Appendix B.

2. ***General SEARS requirement***

   a) ***Provide visual concepts of key infrastructure elements that would remain in place for duration of the project, including but not limited to the Fish barrier structures proposed at Tantangara, tunnel portals, Lobs Hole substation which would be permanent rather than temporary, Rock Forest (including visual assessment of impacts to neighbouring receivers not associated with the project);***

Please see response provided in Appendix C and D.

   b) ***Provide further details on footprint of emplacement areas (noting volume is provided in Table 3.6), and permanent exclusion areas such as around intakes for safety purposes.***

Please see below table providing the indicative footprint of the emplacement areas.

Table 2.1 Emplacement area footprints

Excavated rock emplacement	Emplacement area (ha) – Total	On-land area (ha)	In-reservoir area (ha)
Ravine Bay	18	15	3
Tantangara peninsula	22	9	13
GF01	7	7	NA
Lobs Hole	24	24	NA
Rock Forest	14	14	NA

Indicative construction and operation navigation exclusion zones around the intakes were provided in Appendix C of the Navigation Impact Assessment that was included in Appendix W of the Main Works EIS.

3 Aquatic ecology

Discussion on impacts to the aquatic ecology within the mid Murrumbidgee and Eucumbene in the event redfin are entrained downstream of the barriers.

Please see response provided in Appendix E.

4 Noise

***Predicted noise impacts of Rock Forest excavated rock emplacement to residence* on 6560 Snowy Mountains Highway, Adaminaby opposite the Rock Forest site. The PIR did not re-evaluate the noise impacts from the revised rock emplacement strategy which now includes spoil disposal at Rock Forest, so presumably the increases will be higher.**

Outline the approach Snowy Hydro are proposing to mitigate impacts and detail any consultation that has occurred or is planned with the landowner.

The EIS predicted construction noise levels for this residence (R6) of 51.2-53.6dBA – an exceedance of 11-14dB - under calm and adverse conditions.

Construction noise modelling was completed for the proposed Rock Forest construction activities including proposed excavated rock emplacement. The construction noise modelling found that noise levels for R6 are predicted to marginally increase by less than <0.5 dB and remain controlled by logistics/laydown activities modelled for EIS.

As outlined in the proposed mitigation measure NV02 (see Appendix B), affected landholders at R6 will be consulted prior to and during construction and will be notified of proposed mitigation measures that will be used to manage construction noise levels to below Interim Construction Noise Guideline (EPA 2009) NMLs where practicable.

5 Disturbance area refinement

We will need updated mapping for the disturbance footprints proposed within Talbingo Reservoir. The text describes a 3ha disturbance footprint for Ravine Bay Spoil emplacement and 1 ha for the intakes, but the maps show a footprint in the order of 40+ ha at Ravine Bay.

As described in Section 3.2.2 of the PIR-RTS the excavated rock management strategy was revised including changes to the design of the excavated rock emplacement areas. The disturbance area at Ravine Bay has been subsequently refined to reflect the revised Ravine Bay emplacement area. The revised disturbance area at Ravine Bay is provided in Figure 5.1 below. This change results in a significant reduction approximately of 43 ha to the disturbance area at Ravine Bay.

The revised disturbance area will result in an in-reservoir disturbance area of approximately 2.7 ha at the Ravine Bay emplacement area and approximately 0.7 ha at the Talbingo intake. This represents a reduction of the cumulative emplacement area footprint within Talbingo Reservoir compared to the Exploratory Works which originally proposed up to approximately 59 ha total subaqueous rock placement area at Ravine Bay, Plain Creek Bay and Cascade Bay.

This also results in a change to the overall Main Works disturbance area reducing it from 640 ha to 597 ha. A revised summary of disturbance area reduction by zone is provided in Table 5.1 below.

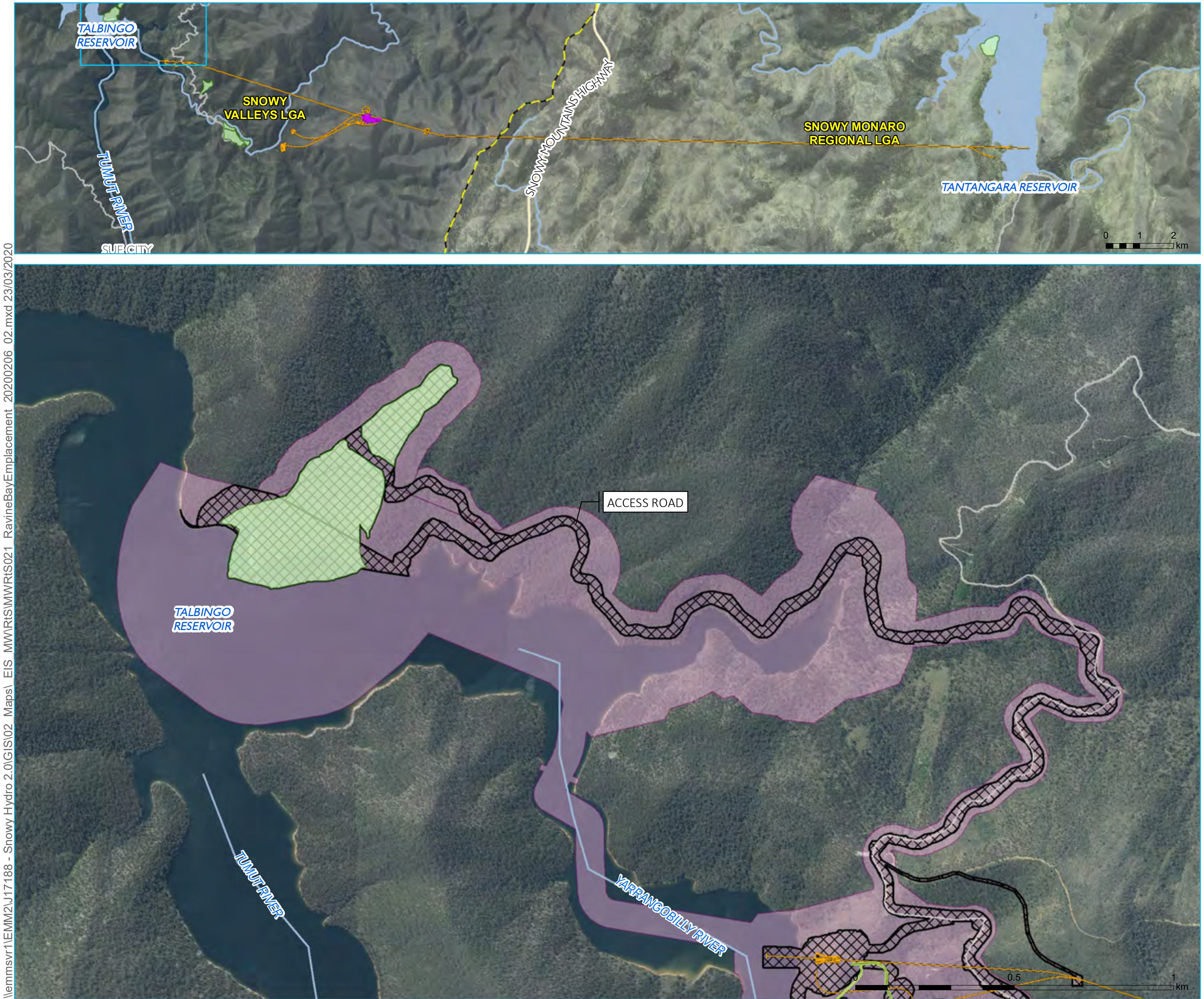
Table 5.1 Summary of disturbance area reduction by zone

Zone	MW EIS disturbance area (ha)	MW PIR-RTS disturbance area (ha)	% change
Total	1,678	597	-64%
Within KNP			
Lobs Hole Ravine Road	125	62	-50%
Lobs Hole	232	139	-40%
Marica	169	67	-60%
Plateau	99	92	-7%
Talbingo Reservoir	169	40	-76%
Tantangara Reservoir	659	161	-76%
Total within KNP	1,453	560	-62%
Outside KNP			
Rock Forest	226	37	-84%

Notes: All areas presented are rounded to the nearest hectare. There is a minor discrepancy whereby the MW PIR-RTS sum of disturbance areas by zone varies from the total disturbance area by 1 ha due to this rounding.

Could you also let me know what the disturbance footprint in Tantangara Reservoir (two numbers would be helpful) one within FSL and the other within MOL.

The in-reservoir (between FSL and MOL) disturbance area of the Tantangara Peninsula emplacement area is approximately 13 ha. This disturbance area does not extend below MOL.



KEY

- Emplacement area

Existing environment

- Main road
- Local road
- Watercourse
- Waterbodies
- Local government area boundary

Snowy 2.0 Main Works operational elements

- Tunnels, portals, intakes, shafts
- Power station
- Disturbance area
- Construction envelope

The disturbance area is an estimation of the area required for construction works based on the current level of project design. Detailed design is still required to be completed, therefore it is expected that the precise location of the disturbance area may move within the broader construction envelope and consequently there will be some further refinements to the disturbance area.

Ravine Bay emplacement area

Snowy 2.0
Preferred infrastructure report
and response to submissions
Main Works
Figure 5.1

Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

GDA 1994 MGA Zone 55

N

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6 Closing

If you have any questions regarding the responses provided, please don't hesitate to contact me.

Yours sincerely

Duncan Peake
Director

dpeake@emmconsulting.com.au

Appendix A

Preferred excavated rock management strategy

Preferred excavated rock management strategy

Concept design information and water quality assessment

Prepared for Snowy Hydro Limited
March 2020

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Preferred excavated rock management strategy

Concept design information and water quality assessment

Report Number

J17188 RP#

Client

Snowy Hydro Limited

Date

24 March 2020

Version

v2 Final

Prepared by

Chris Kuczera
Associate water resources engineer
24 March 2020

Approved by

Duncan Peake
Director
24 March 2020

Executive Summary

ES1 Introduction and background

Snowy Hydro Limited (Snowy Hydro) proposes to develop Snowy 2.0, a large-scale pumped hydro-electric storage and generation project which would increase hydro-electric capacity within the existing Snowy Mountains Hydro-electric Scheme (Snowy Scheme). Snowy 2.0 is the largest committed renewable energy project in Australia and is critical to underpinning system security and reliability as Australia transitions to a decarbonised economy.

The construction of surface and subsurface infrastructure for Snowy 2.0 will require the excavation of significant quantities of rock. Where possible, excavated material will be beneficially used as a construction material. However, it is estimated that 8.9 million m^3 (placed volume) of surplus material will need to be disposed to permanent rock emplacements. The Preferred Infrastructure Report and Response to Submissions (PIR-RTS) presents a preferred strategy for managing the surplus material in five separate emplacement areas.

ES2 Report purpose

This report describes the preferred excavated management rock strategy that is documented in the PIR-RTS. It provides additional information on the proposed concept design, a summary of geochemistry characteristics of the excavated rock and an assessment of potential receiving water (both reservoirs and watercourses) impacts associated with the preferred strategy.

ES3 Preferred excavated rock management strategy

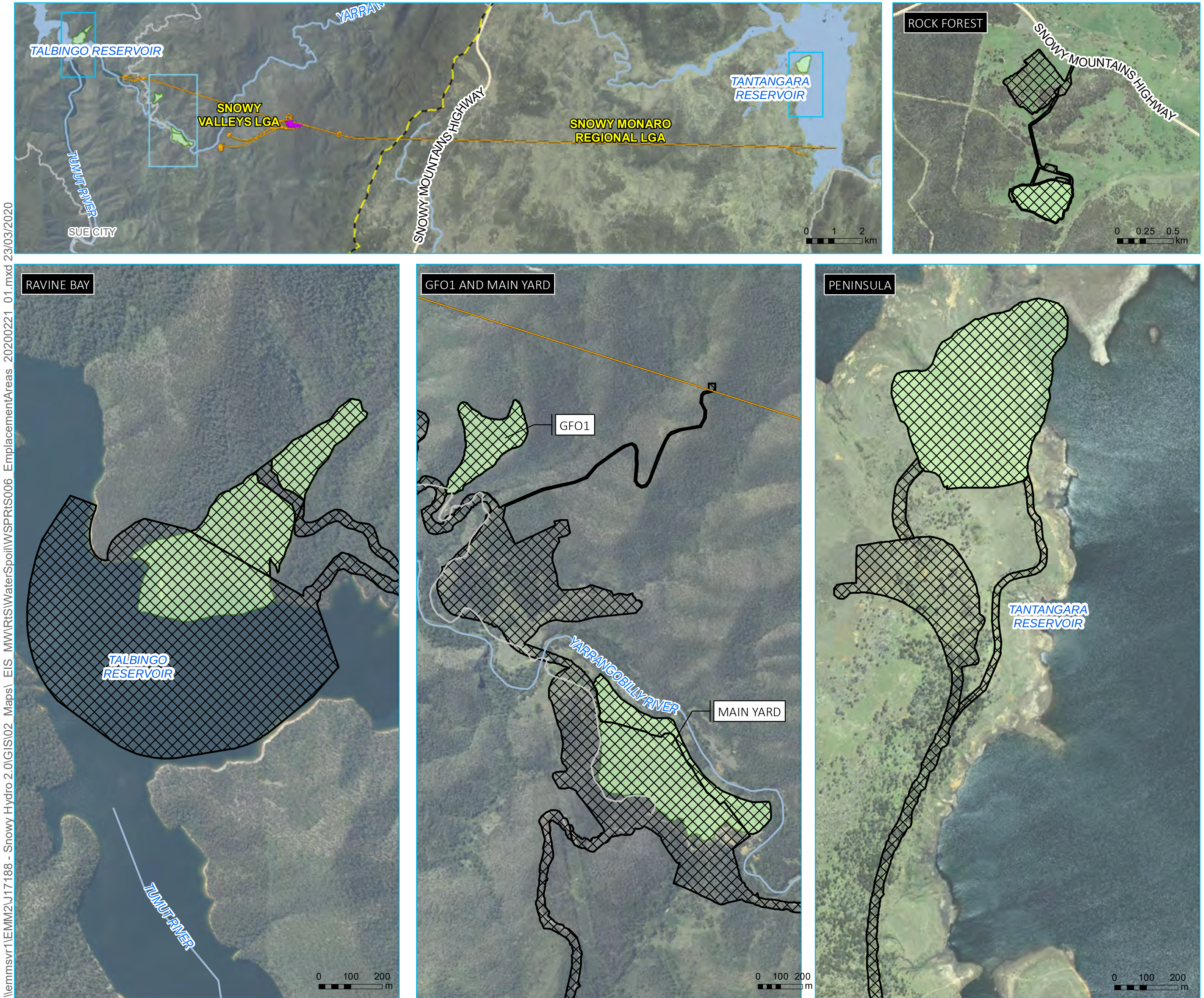
Excavated rock material will be produced at the Talbingo, Marica and Tantangara construction zones. The material is broadly categorised based on excavation method, including subsurface excavation via tunnel boring machine (TBM) and drill and blast (D&B), and surface excavation via D&B. The following emplacements are proposed in each construction zone:

- **Talbingo Zone** – Ravine Bay, GF01 and Main Yard
- **Marica Zone** – Rock Forest
- **Tantangara Zone** – Peninsula

Figure ES1 shows the location and footprint of each emplacement.

The Ravine Bay and Peninsula emplacements will be partially located within Talbingo and Tantangara reservoirs respectively. The concept design for both emplacements incorporates an in-reservoir pad constructed using D&B spoil from the reservoir bed up to Full Supply Level (FSL). Combined D&B and TBM spoil will be placed on top of the D&B pad and on existing land above the reservoir FSL. The GF01, Main Yard and Rock Forest emplacements will be land-based emplacements.

Concept designs the for five rock emplacements have been prepared by Snowy Hydro and Future Generation Joint Venture to inform the PIR-RTS. Opportunities to blend some TBM material into the in-reservoir emplacement will be assessed at detailed design. This alternative approach may be implemented if it can be demonstrated that the proposed granular filter will achieve the water quality outcomes described in Section 5.2.2 of this report. The concept designs are described in Chapter 4 of this report.



KEY

Existing environment

- Main road
- Local road
- Watercourse
- Waterbodies
- Local government area boundary

Snowy 2.0 Main Works operational elements

- Tunnels, portals, intakes, shafts
- Power station
- Disturbance boundary
- PIR-RTS indicative emplacement area

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Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

GDA 1994 MGA Zone 55 N

Proposed excavated rock emplacement areas

Snowy 2.0
Excavated rock management strategy:
Concept design information
and water quality assessment
Main Works
Figure ES1

snowy 2.0

EMM creating opportunities

ES4 Residual impacts

Chapter 5 of this report describes potential water quality impacts to watercourses and reservoirs associated with the proposed emplacements. The description of water quality impacts is informed by geochemistry information presented in Chapter 3, the concept design described in Chapter 4 and numerical modelling undertaken by Royal HaskoningDHV. Table ES1 provides a summary of key impact mechanisms, proposed controls and potential receiving water impacts.

Table ES1 Summary of potential impacts

	Impact mechanism	Proposed controls	Potential impacts
1 - Land-based emplacements			
1.1 - Construction phase (all emplacements)	• Overflows from sedimentation basins during wet weather.	• Sedimentation basins and other erosion and sediment controls. • Captured water will be de-watered from basins within 5 days following the cessation of each rainfall event.	Potential impacts to receiving water quality are described qualitatively based on a review of the effectiveness of the proposed controls and leachate test results. Key impacts include: • Overflows from sedimentation basins will only occur during and shortly after significant wet weather events when elevated streamflow in receiving waters is likely to occur. • The water quality impacts described in the Water Management Report (Appendix J to the PIR-RTS) for construction phase 2 will increase but will be lower in magnitude to the construction phase 1 impacts.
1.2 - Post construction (all emplacements)	• **Seepage (GF01, Main Yard and Rock Forest) -** water that infiltrates into the GF01, Main Yard and Rock Forest emplacements is expected to exit via seeps along the toe of the emplacements. There is also potential for some water to infiltrate into underlying shallow groundwater systems. • **Seepage (Ravine Bay and Peninsula) -** most seepage from the land-based components of the Ravine Bay and Peninsula emplacements is likely to flow into the underlying in-reservoir D&B pad and ultimately enter the reservoirs. • **Surface water runoff** - from the landforms is anticipated during and shortly after intense or prolonged rainfall.	• The land-based emplacements will be constructed and rehabilitated to achieve physically and chemically stable landforms that have similar characteristics to the surrounding landscapes. The emplacements will be revegetated with native endemic vegetation. The concept design includes a range of construction and rehabilitation measures to achieve this objective. Refer to Chapter 4 for details.	Potential impacts to receiving water quality are described qualitatively based on a review of the effectiveness of the proposed controls and leachate test results. Key impacts include: • **Seepage (GF01, Main Yard and Rock Forest) -** impacts to receiving waters have not been quantitatively assessed. However, the following potential changes to water quality are expected: – The water quality in immediate receiving waters (ie 1^{st} to 3^{rd} order watercourses that receive no flows other than seepage may include a moderately alkaline pH, elevated aluminium concentrations and other changes to water quality. Refer to Section 5.1.2 of this report for further information. – Any seepage that enters a larger watercourse such as the Yarrangobilly River would be significantly diluted and is therefore unlikely to materially change the existing water quality. – Potential impacts to the water quality of shallow groundwater systems have not been assessed. However, any impacts are expected to be localised. • **Seepage (Ravine Bay and Peninsula) -** most seepage from the land-based components of the Ravine Bay and Peninsula emplacements is likely to flow into the underlying in-reservoir D&B pad and ultimately enter the reservoirs via the water exchange process that is described below (see item 2.2). • **Surface water runoff (all emplacements)** - from the rehabilitated landforms is anticipated to have water quality similar to the water quality of undisturbed small (1^{st} to 3^{rd} order) watercourses. Hence, no receiving water impacts are expected.

Table ES1 Summary of potential impacts

	Impact mechanism	Proposed controls	Potential impacts
2 - In-reservoir emplacements			
2.1 - Construction phase (Ravine Bay only)	• The in-reservoir component of the Ravine Bay emplacement will be constructed using the edge push method. This method involves pushing D&B spoil into Talbingo Reservoir using conventional machinery, such as a bulldozer. This can result in suspended sediment and turbidity plumes in nearby portions of the reservoir. • Elutriate test results (described in Section 3.2.4) indicates there is potential for changes to pH and the release of aluminium due to spoil water contact during placement and due to the entrainment of fine material in the water column.	• Silt curtains will be used to reduce the horizontal movement of water from the emplacement area into the greater reservoir.	An assessment of potential impacts to the water quality of Talbingo Reservoir was informed by numerical modelling undertaken by Royal HaskoningDHV and elutriate test results that are described in Section 3.2.4. The assessment concluded that: • Total suspended solids (TSS) concentrations will generally be below 10 mg/L 1 km north of Ravine Bay and will be less than 5 mg/L at the dam wall. • pH and aluminium concentrations are unlikely to exceed the Water Quality Obective[1] (WQO) values when the TSS concentration is <100 mg/L. The TSS concentration is expected to exceed 100 mg/L outside of the silt curtain less than 5% of the time.
2.2 - Post construction (Ravine Bay and Peninsula)	• The Ravine Bay and Peninsula in-reservoir D&B pads will be constructed from the reservoir bed up to FSL. During the operation of Snowy 2.0, water exchange between in-reservoir D&B spoil pads and the adjoining reservoir will occur primarily due to changes in reservoir water level. Water draining out of the pads has potential to contain elevated TSS and turbidity (due to the entrainment of fines) Other water quality impacts such as changes to pH, and elevated nutrients and metals may also occur due to spoil water contact.	**Ravine Bay and Peninsula** • A geotextile filter will be installed at the interface of the in-reservoir D&B pad and the overlying land-based emplacement to reduce the propagation of fines from the overlying TBM spoil into the in-reservoir D&B pad. **Peninsula (only)** • A granular filter will be installed between the D&B pad and rock armour layer to minimise the propagation of fines from the D&B pad to the reservoir.	Potential impacts to reservoir water quality are described qualitatively based on a review of the effectiveness of the proposed controls and leachate test results. Key impacts include: • **Fines (Ravine Bay)** - It is expected that most of the available fines in the Ravine Bay emplacement will have been 'washed' or flushed from the emplacement during the construction phase, which will take approximately three years. Hence, any post construction impacts are likely to be minor. • **Fines (Peninsula) -** No material impacts are expected due to the effectiveness of the proposed granular filter. As a result, numerical modelling to determine the impact on water quality is not considered necessary. • **Other water quality parameters (Ravine Bay and Peninsula)** - Leachate results indicate that water draining from the emplacements will have an alkaline pH, salinity that is greater than ambient levels and dissolved aluminium concentrations that exceed the WQOs for reservoirs by a factor of 7 to 8. It is expected that there will be a near-field mixing zone (likely to be in the order of 10s of metres) around the emplacements. It is expected that the magnitude of any impacts will gradually decline over time as leachable salts and metals are released from the spoil.

1. Water Quality Objective values for reservoirs and watercourses that were established in the water assessment (Appendix J to the EIS).

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Appendices

Tables

Figures

1 Introduction

1.1 Snowy 2.0

Snowy Hydro Limited (Snowy Hydro) proposes to develop Snowy 2.0, a large-scale pumped hydro-electric storage and generation project which would increase hydro-electric capacity within the existing Snowy Mountains Hydro-electric Scheme (Snowy Scheme). Snowy 2.0 is the largest committed renewable energy project in Australia and is critical to underpinning system security and reliability as Australia transitions to a decarbonised economy.

Snowy 2.0 will link the existing Tantangara and Talbingo reservoirs within the Snowy Scheme through a series of underground tunnels and a new hydro-electric power station will be built underground. The major construction elements of Snowy 2.0 include permanent infrastructure, temporary construction infrastructure, management and storage of extracted rock material and establishing supporting infrastructure. Snowy 2.0 Main Works also includes the operation of Snowy 2.0.

1.2 Background

The construction of surface and subsurface infrastructure for Snowy 2.0 will require the excavation of significant quantities of rock. Where possible, excavated material will be beneficially used as a construction material. However, it is estimated that 8.9 million m^3 (placed volume) of surplus material will need to be disposed to permanent rock emplacements. The Preferred Infrastructure Report and Response to Submissions (PIR-RTS) presents a preferred strategy for managing the surplus material in five separate emplacement areas.

The preferred excavated rock management strategy was prepared by Snowy Hydro and its appointed contractor, Future Generation Joint Venture (FGJV). The strategy development process considered several options. Refer to Section 3.2 of the PIR-RTS for a description of the strategy development process and a comparison to the strategy that was presented in the Main Works Environmental Impact Statement (EIS).

1.3 Concept design development program

A concept design for the preferred excavated rock management strategy has been prepared by Snowy Hydro and FGJV to inform the PIR-RTS. The design provides information on proposed construction methods, the location, shape and footprint of emplacements and measures to manage water quality risks. Further design development is required to define implementation for some aspects of the design, including landform rehabilitation and watercourse reinstatement. Some of these aspects will require field trials to identify the most effective approaches to execute the concept design.

This report describes the concept design prepared for the PIR-RTS and expected water quality risks associated with the proposed emplacements. Where further design development is required, commitments to design principles are described. These design principles will be further developed and verified prior to detailed design.

This report refers to the following design stages:

- **Concept design PIR-RTS or concept design** – refers to the concept design that is documented in this report. As described above, this includes a combination of design information provided by FGJV and Snowy Hydro and commitments to design principles for aspects that have not been fully developed.

- **Concept design completion** – refers to a concept design that includes design information for all key aspects of the preferred excavated rock management strategy.

- **Detailed design** – refers to the detailed design of the proposed emplacements.

1.4 Report purpose

This report describes the preferred excavated management rock strategy documented in the PIR-RTS. It provides additional information on the proposed concept design (including commitments to design principles for aspects that have not been fully developed), a summary of geochemistry characteristics of the excavated rock and an assessment of potential receiving water (both reservoirs and watercourses) impacts associated with the preferred strategy.

1.5 Report structure

This report is supplementary to the PIR-RTS and is structured as follows:

- **Chapter 2** describes the preferred excavated management rock strategy and includes information on the expected excavated rock volumes and the proposed emplacements.
- **Chapter 3** provides a summary of expected geochemical characteristics of the excavated material and the interpreted water quality of leachate from excavated rock emplacements.
- **Chapter 4** describes the concept design for each emplacement and key design principles.
- **Chapter 5** describes potential residual water quality impacts to downstream waterways.

2 Preferred excavated rock management strategy

This chapter provides information on the excavated rock volumes and a brief description of each rock emplacement. Refer to the PIR-RTS for a description of the strategy development process and a comparison to the strategy presented in the EIS.

2.1 Excavated rock volumes

Excavated material will be produced at the Talbingo, Marica and Tantangara construction zones. The material is broadly categorised based on the excavation method as follows:

- **Subsurface excavation via a tunnel boring machine (subsurface TBM)** – tunnel boring machines (TBMs) will be used to excavate most tunnel sections. TBMs excavate by grinding the rock to produce a slurry material that is transported to the surface. At the surface, water is decanted from the slurry and the spoil is allowed to dry. TBM spoil is expected to be a sandy/gravely material with some fines.

- **Subsurface excavation via drill and blast (subsurface D&B)** – D&B methods will be used to excavate the power station cavern and some tunnel sections. The material will be loaded onto trucks and transported to the surface. D&B generated material is expected to be a gravely/cobbly material with a small amount of fines.

- **Surface excavation via drill and blast (surface D&B)** – D&B methods will be used to excavate intake structures, tunnel portals, access roads etc. The material will be loaded onto trucks and transported to either temporary or final stockpiles. D&B generated material is expected to be a gravely/cobbly material with a small amount of fines.

Table 2.1 provides a summary of the estimated volumes of excavated rock from each construction zone that will be disposed to permanent rock emplacements. The volumes allow for:

- the beneficial use of some material as a construction material, reducing the overall volume; and

- bulking of material, which increases the volume of material.

Unless otherwise stated, all material volumes in this report refer to the placed volume of material in the proposed rock emplacements. This placed volume accounts for compaction and consolidation of material during placement. The term bank volume is used in some of the technical appendices to this report. Bank volume refers to the in situ volume of rock prior to excavation and is less than the placed volume.

Table 2.1 Estimated rock volumes to be disposed to permanent rock emplacements

	Talbingo Zone	Marica Zone	Tantangara Zone
Units	million m^3	million m^3	million m^3
Subsurface (TBM)	2.1	0.0	1.4
Subsurface (D&B)	0.8	0.3	1.2
Surface (D&B)	2.8	0.1	0.2
Total	**5.6**	**0.4**	**2.9**

Notes: All volumes are rounded to 0.1 million m^3 (and may not add up) and refer to the placed volume of rock.

Source: All volumes have been provided by FGJV

2.2 Construction zones and proposed rock emplacements

The following construction zones require five permanent rock emplacements:

- **Talbingo Zone** – Excavated rock will be produced by the construction of the underground power station, tailrace tunnel, Talbingo intake structure and various access roads and surface works. The following three emplacements are proposed:

  - **Ravine Bay** – The concept design incorporates an in-reservoir pad constructed using D&B spoil from the Talbingo Reservoir bed up to Full Supply Level (FSL). Combined D&B and TBM spoil will be placed on top of the D&B pad and on existing land to the north of the reservoir.

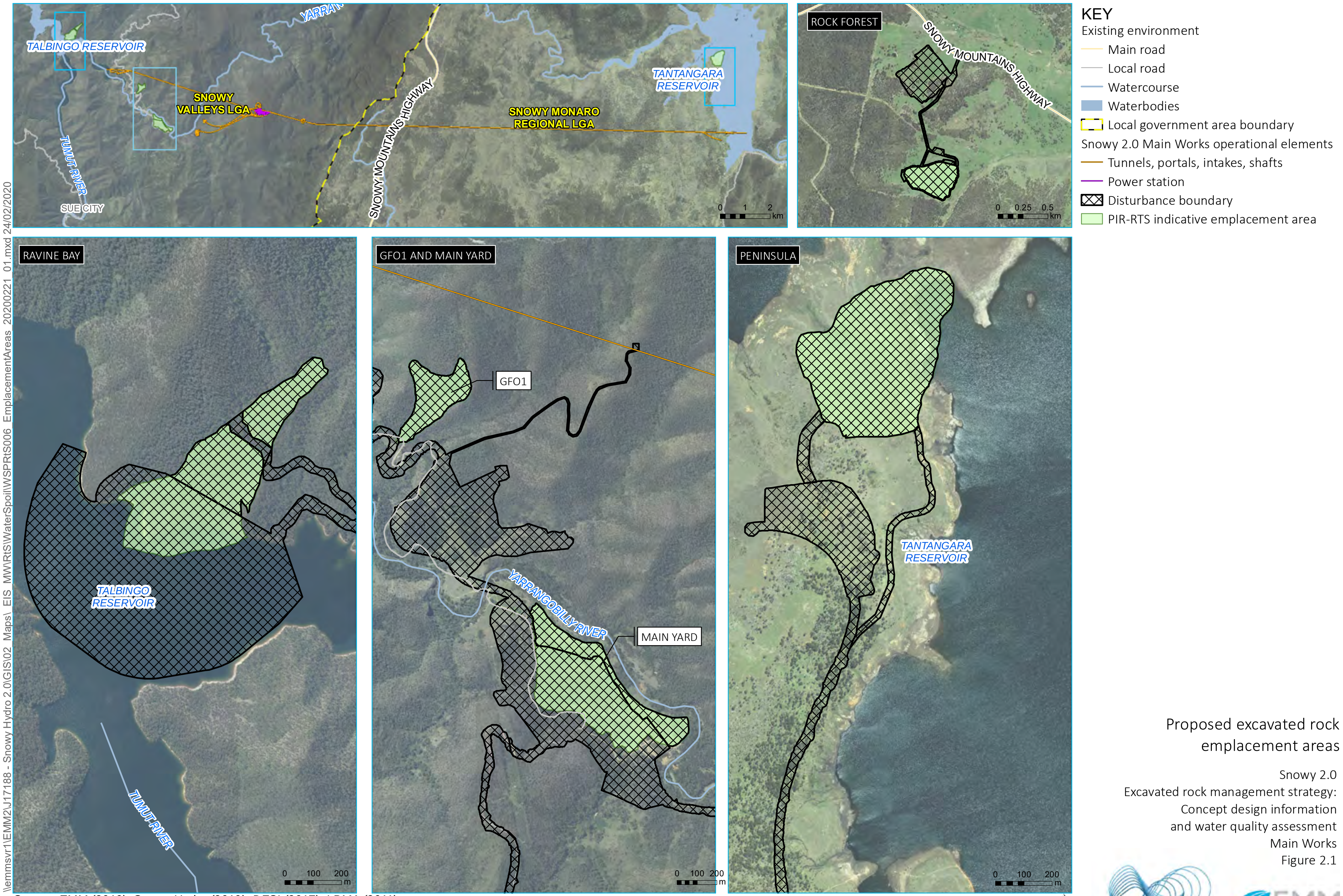
  - **GF01** – is a land-based emplacement in a gully between Ravine Bay and Lobs Hole.

  - **Main Yard** – As described in the Main Works EIS, during the construction phase of the project, construction pads will be established in Lobs Hole to facilitate laydown areas, workshops, sheds, machinery, offices and other project related infrastructure. It is proposed to construct these pads out of surface generated D&B material. Following the completion of most construction activities, the construction pads will be decommissioned, and the landform will be reshaped and rehabilitated. It is proposed to incorporate additional TBM spoil into the final landform.

- **Marica Zone** – All surplus excavated rock will be transported to Rock Forest (outside of Kosciuszko National Park (KNP)) and disposed in a land-based emplacement referred to as the **Rock Forest** emplacement.

- **Tantangara Zone** – All surplus excavated rock will be disposed in an emplacement area referred to as the **Peninsula** emplacement. The concept design incorporates an in-reservoir pad constructed using D&B spoil from the Tantangara Reservoir bed up to FSL. It is noted that this pad will be constructed above the typical reservoir operating levels and will only be inundated during construction if a major flood event were to occur. The pad is expected to be inundated once Snowy 2.0 operation commences. Combined D&B and TBM spoil will be placed on top of the D&B pad and on adjoining land above the FSL.

Figure 2.1 shows the location and footprint of each emplacement.



Proposed excavated rock emplacement areas

Snowy 2.0
Excavated rock management strategy:
Concept design information
and water quality assessment
Main Works
Figure 2.1

Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

GDA 1994 MGA Zone 55

3 Geochemistry

This chapter provides a summary of relevant geochemistry information used to inform the concept design (described in Chapter 4) and assessment of water quality impacts (described in Chapter 5). This chapter is structured as follows:

- Section 3.1 provides a summary of geochemistry studies prepared by CSIRO for the Main Works EIS; and
- Section 3.2 provides a summary of geochemistry data applied to assess water quality risks.

3.1 CSIRO studies

As part of the Main Works EIS, CSIRO prepared several studies (the CSIRO studies) to identify and assess the environmental risks associated with the placement of excavated rock from the development of Snowy 2.0. These studies were focused on describing water quality risks associated with the subaqueous disposal of excavated rock, which was the previous management strategy presented in the EIS. Notwithstanding, much of the data collected and analysed can be applied to assess water quality risks associated with the current proposed strategy, which incorporates a combination of in-reservoir and land-based emplacements.

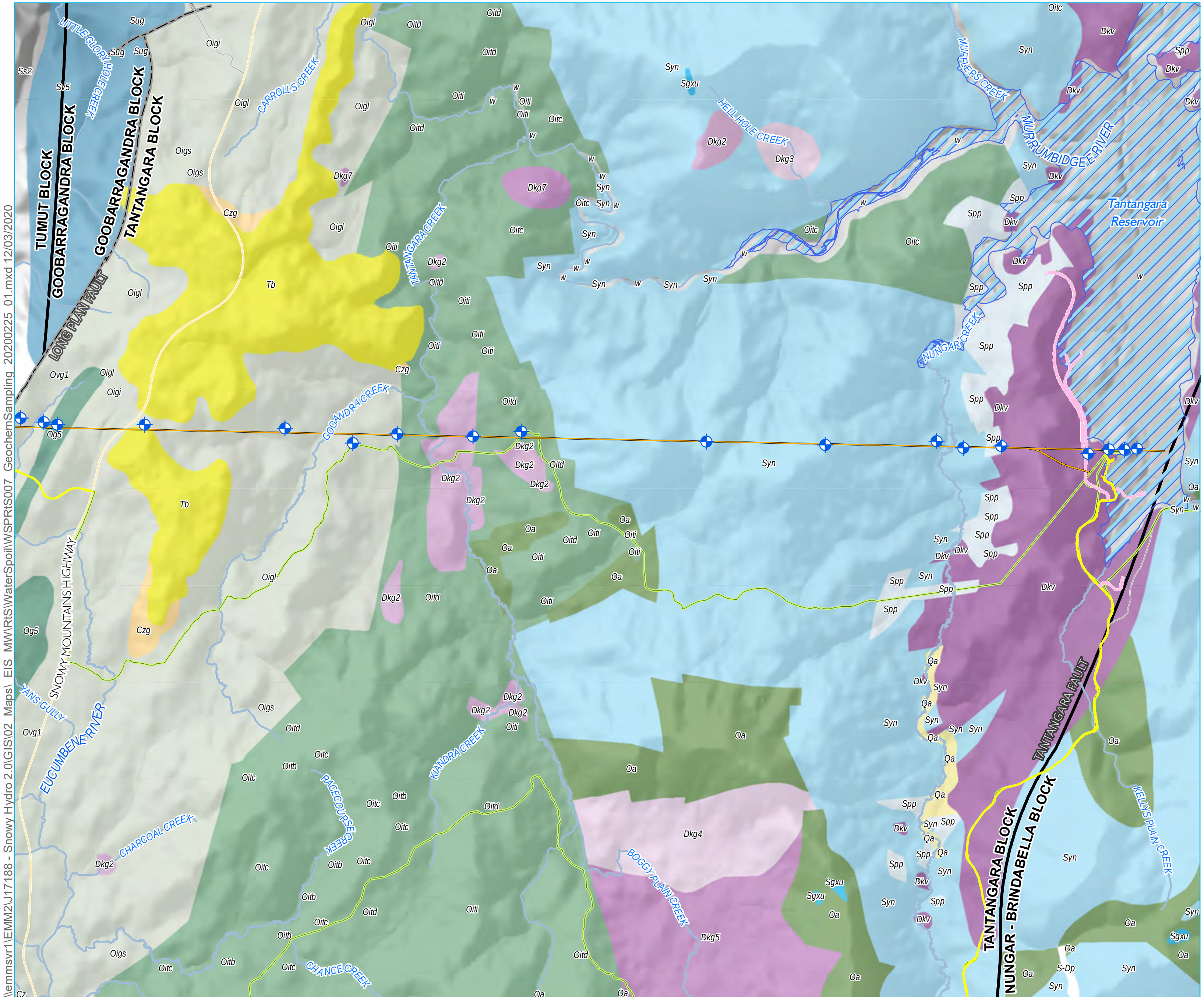
The CSIRO studies are documented in the following reports:

- CSIRO 2018, *Snowy 2.0 P1: Comprehensive Geochemistry Examination Final Report* (EIS Appendix L, Annexure A).
- CSIRO 2019a, *Snowy 2.0 P2: Environmental Risk Categorisation of Rock Materials* (EIS Appendix L, Annexure B).
- CSIRO 2019b, *Snowy 2.0 P4: Environmental Characterisations of Excavated Rock Interactions with and Potential Impacts on Reservoir Waters and Sediments* (EIS Appendix L, Annexure C).
- CSIRO 2019c, *Snowy 2.0 P5: Ecotoxicology Assessment of Excavated Rock Leachates in Water and Excavated Rock-Sediment Mixtures* (EIS Appendix L, Annexure D).
- CSIRO 2019d, *Dissolved Aluminium Assessment for Talbingo Reservoir* (EIS Appendix L, Annexure E).

Relevant information from these studies has been applied to assess water quality risks associated with the placement of excavated rock (discussed in Chapter 5) and is summarised in this chapter.

3.1.1 Sampling program for geochemistry analysis

CSIRO undertook detailed geochemical and mineralogical characterisation of drill core samples collected from the Snowy 2.0 Feasibility Study and Exploratory Works drilling programs, which comprised drilling geotechnical investigation holes along the proposed headrace and tailrace tunnel alignments. Geochemical and mineralogical characterisation was undertaken on 290 drill core samples collected from 37 boreholes (CSIRO 2019a). Figure 3.1 shows the borehole locations and regional geology. Is it noted that the drill core samples (and subsequent testing) only constitutes a small fraction of the rock to be excavated and that rock characteristics between drill holes may vary. In addition, no specific geochemistry sampling or analysis has been undertaken to characterise rock that will be excavated via surface excavations. However, surface excavations will primarily be in similar geology to sub-surface excavations.



Source: EMM (2019); Snowy Hydro (2019); FGJV (2019); DFSI (2017); LPMA (2011)

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GDA 1994 MGA Zone 55
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KEY

- Geochemistry sampling location

Snowy 2.0 operational elements
- Tunnels, portals, intakes, shafts
- Utilities
- Permanent road

Snowy 2.0 construction elements
- Temporary access road

Existing environment
- Main road
- Local road
- Watercourse
- Scheme storage
- Geological domain boundary
- Long Plain Fault (interpreted)

Quaternary
- *Qa* - Alluvium (undifferentiated)

Tertiary
- *Tb* - Basalt (undifferentiated)

Cainozoic
- *Czg* - Unknown (undifferentiated)

Devonian
- *Dkg3, Dkg4* - unknown (Hell Hole Creek Adamellite)
- *Dkg2*- Boggy Plain Suite (undifferentiated)
- *Dkg5, Dkg7* - Boggy Plain Suite (Boggy Plain Adamellite)
- *Dkv* - Unknown (Kellys Plain Volcanics)

Silurian
- *Spp* - Coolemon Plains Group (Peppercorn Formation)
- *Syn* - Yalmy Group (Tantangara Formation)
- *Sgxu* - Unknown (undifferentiated)
- *Sug, Sv5* - Young Suite (Goobarragandra Volcanics)

Ordovican
- *Oigi, Oigl, Oigs, Ovg1* - unknown - (Gooandra Volcanics)
- *Oitb, Oitc, Oitd, Oiti* - Kiandra Group (Temperance Formation)
- *Oa* - Adaminaby Group (undifferentiated)
- *Og5* - Unknown (Shaw Hill Gabbro)

Geochemistry sampling locations - Tantangara zone

Snowy 2.0
Excavated rock management strategy:
Concept design information
and water quality assessment
Main Works
Figure 3.1a

KEY

- Geochemistry sampling location

Snowy 2.0 operational elements
- Tunnels, portals, intakes, shafts
- Power station
- Utilities
- Permanent road

Snowy 2.0 contruction elements
- Temporary access road
- Main road
- Local road or track
- Watercourse
- Scheme storage
- Geological domain boundary
- Long Plain Fault (interpreted)

Quaternary
- *Qa* - Alluvium

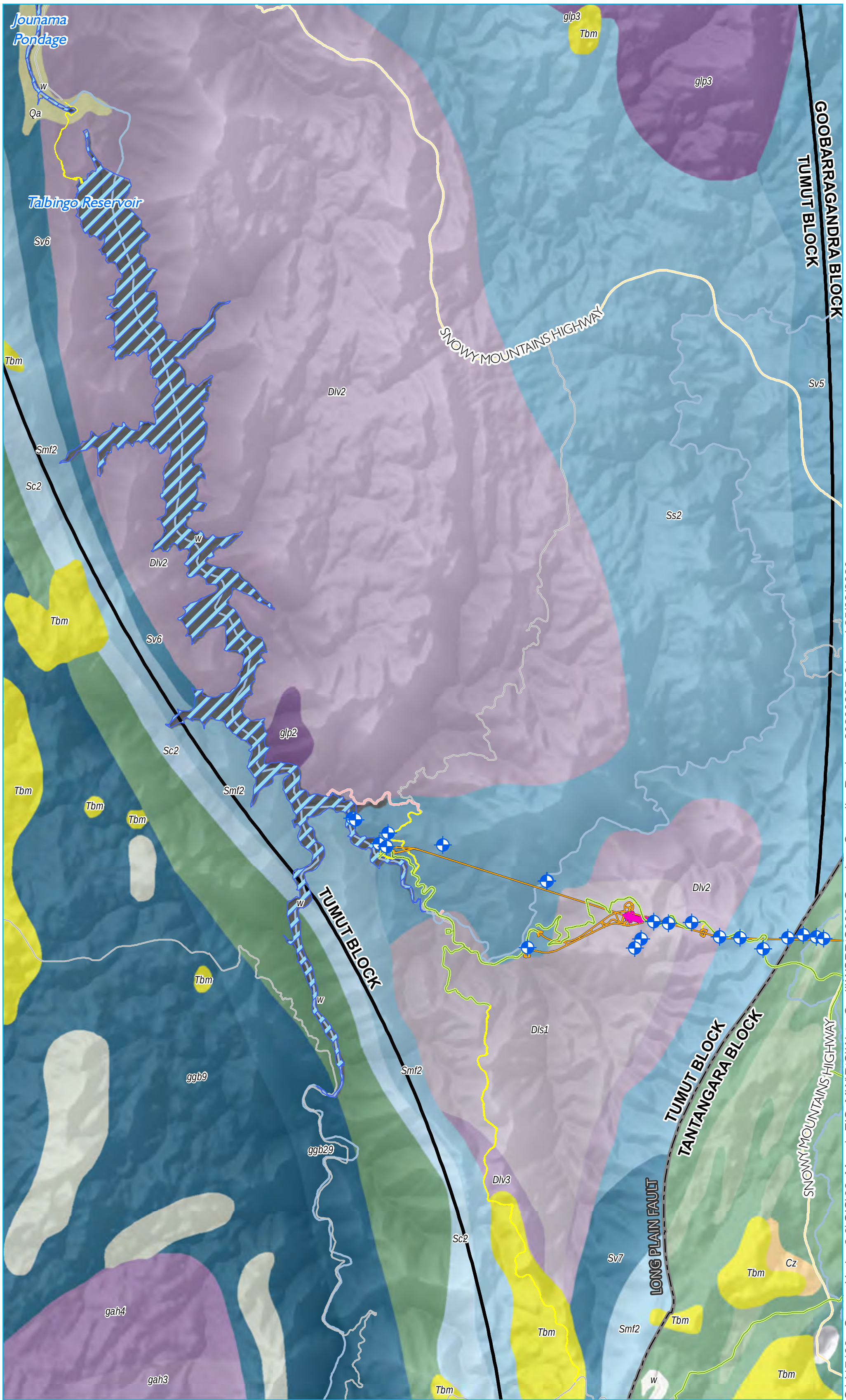
Tertiary
- *Tbm* - Basalt

Cainozoic
- *Cz* - Unknown (undifferentiated)

Devonian
- *Dls1* - Byron Range Group (undifferentiated)
- *Dlv2* - Boraig Group (unnamed)
- *Dlv3* - Black Range Group (Mountain Creek Volcanics)
- *gah3* - Free Damper Suite (Free Dampier Adamellite)
- *gah4* - Free Damper Suite (Pennyweight Adamellite)
- *glp2* - Tumut Granites (Lobs Hole Adamellite)
- *glp3* - Bogong Suite (Bogong Granite)

Silurian
- *Sc2* - Unknown (Tumut Ponds Sepentinite)
- *Smf2* - Unknown (Jackalass Slate)
- *Ss2* - Bredbo Group (Ravine Beds/Yarrangobilly Limestone)
- *Sv5* - Young Suite (Goobarragandra Volcanics)
- *Sv6* - Unknown (Blowering Formation)
- *Sv7* - Unknown (Kings Cross Formation)
- *ggb29* - Tom Groggin Suite (Rough Creek Tonalite)
- *ggb9* - Tom Groggin Suite (Green Hills Granodiorite)

Ordovician
- *Of* - Adaminaby Group (Adaminaby Group)
- *Og5* - Unknown (Shaw Hill Gabbro)
- *Ovg1* - Unknown (Gooandra Volcanics)
- *Ovk1* - Kiandra Group (unnamed)



Source: EMM (2019); FGJV (2019); Snowy Hydro (2019); DFSI (2017); GA (2015); LPMA (2011)

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Geochemistry sampling locations - Talbingo/Marica zone

Snowy 2.0
Excavated rock management strategy:
Concept design information
and water quality assessment
Main Works
Figure 3.1b

snowy 2.0
EMM creating opportunities

3.2 Summary of relevant information

Table 3.1 describes the information that is presented in this section and its applicability to the concept design (described in Chapter 4) and/or assessment of water quality risks (described in Chapter 5).

Table 3.1 Summary of relevant information

Presented information	Purpose
Geology (Section 3.2.1)	The geology of rock to be excavated in each construction zone is categorised into the geological groups used by CSIRO for analysis purposes. Leachate test results are presented on both a geological group and construction zone basis.
Acid-base characteristics (Section 3.2.2)	The known acid-base characteristics of excavated rock are described to support the proposed management approach documented in Chapter 4.
Leachate test results (Section 3.2.3)	Leachate test results are applied to assess the water quality of leachate from both land-based and in-reservoir emplacements.
Elutriate test results (Section 3.2.4)	Elutriate test results have been applied to assess potential for the release of aluminium and other toxicants during the placement of D&B material into Talbingo Reservoir.
Naturally occurring asbestos (NOA) – (Section 3.2.5)	Available information on NOA is summarised to support the proposed management approach that is described in Chapter 4.

3.2.1 Geology

The composition of each rock emplacement will be a function of the geology of the excavated rock. In each construction zone, excavations will occur from several different geologies. Hence, most emplacements will comprise rock excavated from more than one geology.

For analysis purposes, the CSIRO studies categorised rock samples into geological groups based on geochemical composition, hand specimen analysis and examination of regional geology. Samples obtained for each of the geological groups were further categorised as ‘baseline’ or ‘enriched’. Baseline samples constitute what was assessed by CSIRO to be a representative baseline composition for each geological group. The selected baseline samples were culled from a larger number of rock samples. In contrast, the enriched samples constitute a set of samples that are enriched in a range of elements. The most common attribute of the enriched samples are elevated sulphur and trace element concentrations (including metals and metalloids) relative to the baseline samples. Generally, an equal number of baseline and enriched samples were analysed for each geological group. This may result in enriched samples being overrepresented in any statistics calculated from the combined samples if enriched samples are representative of less than half of the excavated rock.

The CSIRO studies report results according to geological group, where results for baseline and enriched samples are presented separately. Table 3.2 describes the geological groups presented in the CSIRO studies and notes which groups will be excavated in each construction zone. Leachate test results are presented in this report on both a geological group and a construction zone basis (ie considering the range of geology of excavated rock in each zone).

Table 3.2 Geological groups of excavated rock

Construction zone	Geological group
Talbingo and Marica	**Subsurface excavations:** Ravine Group and Byron/Boraig Group **Surface excavations:** As per subsurface excavations (weathered and unweathered)
Tantangara[1]	**Subsurface excavations:** Shaw Hill Gabbro, Gooandra Volcanics, Peppercorn/Tantangara/ Temperance Formations, Kellys Plain Volcanics **Surface excavations:** Kellys Plain Volcanics (weathered and unweathered)

Notes: 1. The Boggy Plain Suite geological formation is referred to in Section 3.2.5. Rock from this formation expected to contribute to the volume of excavated rock at the Tantangara construction zone. Geological characterisation of Boggy Plain Suite rock was undertaken, however material from the formation was not identified as contributing to geological groups established by CSIRO.

3.2.2 Acid-base accounting

CSIRO undertook a risk characterisation of rock material (EIS Appendix L, Annexure B). As part of the risk characterisation, 115 samples were investigated for acid-base accounting. Key results are summarised below:

- Total sulphur and associated maximum potential acidity (MPA) varied by a factor of 15 between baseline and enriched groups, respectively.
- 23% of samples were classified as having net acid generation (NAG) capacity.
- Mean acid neutralisation capacity (ANC) was similar in both baseline and enriched groups.
- The ANC was in excess of MPA for all samples with 93% nominally classified as very low risk.

Figure 3.2 (reproduced from EIS Appendix L, Annexure B) compares the ANC and MPA from all 115 samples and demonstrates the above key results. All samples except one were analysed to have greater capacity to neutralise than to generate acid and are therefore shown to occur above the ANC:MPA 1:1 ratio line in Figure 3.2. Samples that did not contain twice the amount of ANC compared to MPA are classified as Potentially Acid Forming (PAF). A few samples are shown to occur below the ANC:MPA 2:1 ratio line in Figure 3.2.

A relative risk ranking based on mean ANC to MPA ratios identified excavated rock from the Gooandra Volcanics, Byron/Boraig Groups and Peppercorn/Tantangara/Temperance Formation geological groups as having the greatest, but importantly low risk, potential for acid generation.

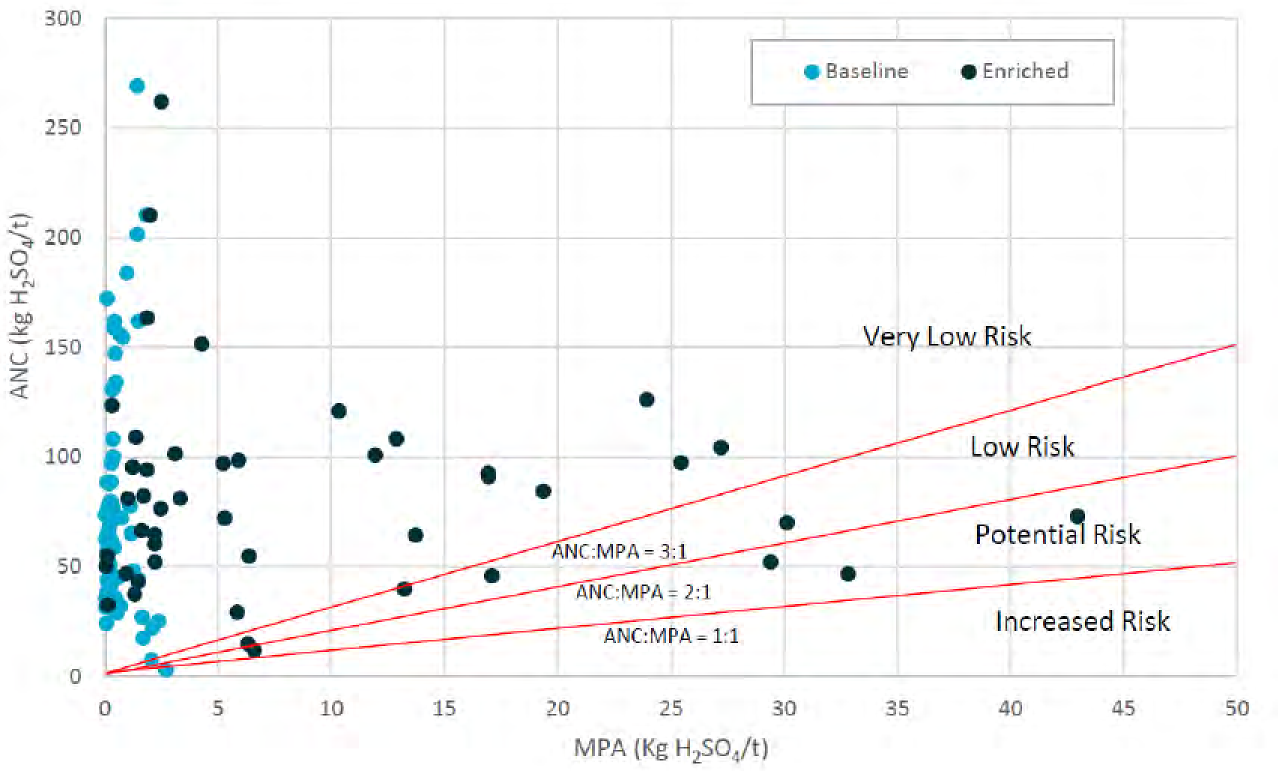


Figure 3.2 Categorisation of ANC versus MPA risk (source: EIS Appendix L, Annexure B)

In summary, available geochemistry data indicates that some excavated material is likely to be PAF. However, overall excavated material is likely to have acid neutralising capacity that is in excess of the maximum potential acidity. Therefore, there is considerable opportunity to utilise the available acid neutralising capacity to mitigate acid risks.

3.2.3 Leachate testing

i Overview of analysis

CSIRO undertook a risk characterisation of rock material (EIS Appendix L, Annexure B). As part of the risk characterisation, 115 samples were investigated for leachate analysis using the Australian Standard Leaching Procedure (ASLP). Table 3.3 describes the number of samples analysed from each geological group in each construction zone. Of the seven geological groups described in Table 3.3, six are expected to be intersected by subsurface excavations.

Table 3.3 Geological groups and number of leachate samples analysed

Emplacement zone	Geological groups[1]	Number of leachate samples
Talbingo/Marica	Ravine Group	31
	Byron/Boraig Group	23
Tantangara	Shaw Hill Gabbro	8
	Gooandra Volcanics	23
	Peppercorn/Tantangara/Temperance Formations	16
	Kellys Plain Volcanics	3
N/A[2]	Felsics/granitoids/gniess/ignimbrites	11

Notes: 1. For testing purposes, CSIRO (2019a) categorised geological groups into groups based on the analysis of geology and geochemistry.
2. Leachate results from the felsics/granitoids/gneiss/ignimbrites geological group have not been assessed as it is uncertain whether this material type will contribute to the emplacement areas.

The ASLP was applied to assess the leachability of pollutants (major ions, carbon, metals and nutrients etc) under anoxic, oxic and weak acid conditions. Table 3.4 provides the test suite.

Table 3.4 Leachate test suite (CSIRO 2019a)

Category	Analytes tested	Analysis method
Physico-chemical properties	pH, electrical conductivity (EC)	-
Nutrients	Total carbon (TC), total nitrogen (TN)	-
Major ions	Fluoride (F), chloride (Cl), sulphate	Ion chromatography
Metals/toxicants (0.45 µm filtered)	Aluminium (Al), arsenic (As), barium (Ba), calcium (Ca), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), potassium (K), magnesium (Mg), manganese (Mn), molybdenum (Mo), sodium (Na), nickel (Ni), phosphorus (P), sulphur (S), lead (Pb), antimony (Sb), selenium (Se), tin (Sn), thorium (Th), uranium (U), vanadium (V), zinc (Zn)	Inductively coupled plasma optical emission spectrometry (ICP-OES) and/or inductively coupled plasma-mass spectrometry (ICP-MS)

As noted above, for each sample, the ASLP procedure was applied under oxic, anoxic and weak acid conditions. The oxic and anoxic conditions were designed to simulate the sub-aqueous storage of excavated rock in reservoirs where it may be exposed to varying redox conditions dependent on placement in the reservoirs (EIS Appendix L, Annexure B). These conditions are also expected to occur in land-based emplacements, with oxic conditions generated where water or air infiltrates through the excavated rock emplacements. The weak acid conditions relate to the rock material being exposed to ambient air that will oxidise minerals such as sulphur. Weak acid conditions may occur in some portions of land-based emplacements or in spoil that is stockpiled prior to final emplacement. Overall, the three conditions tested cover the likely range of conditions expected in both land-based and in-reservoir emplacements.

ii Results summary

The ASLP results have been applied to establish the potential water quality of seepage from the proposed land-based emplacements and water exchange from the in-reservoir emplacements to the reservoirs. ASLP results are presented in the following tables:

- Table A.1 and Table A.2 in Appendix A provide a summary of ASLP results from each geological group in the Talbingo/Marica zones and Tantangara Zone respectively. The results are presented as minimum, maximum and median values for each group. A minimum, maximum and median value is also established for each construction zone using data from all applicable geological groups (see Table 3.2). For context, the results are compared to the Water Quality Objective (WQO) values for reservoirs and watercourses that were established in the water assessment (Appendix J to the EIS). It is noted that only results for analytes that exceeded WQOs in at least one sample across the geological groups and test conditions (anoxic, oxic or dilute acid) are presented.

- Table 3.5 provides a summary of the calculated minimum, maximum and median values for each construction zone. For context, the results are compared to the WQO values for reservoirs and watercourses.

In all results tables, the minimum, maximum and median values have been calculated from an approximately equal number of baseline and enriched samples (EIS Appendix L, Annexure B). As most of the emplacement material may be categorised as baseline material the enriched sample results may be overrepresented in the combined statistics. Accordingly, the results should be interpreted as follows:

- The maximum values represent the upper bound of enriched sample results. These results are not expected to be representative of the water quality of seepage from a large emplacement that would be formed with predominantly baseline material.

- The calculated median values are a conservative estimate of the water quality of seepage from a large emplacement that comprises rock from several geological groups with some baseline and enriched material. The values are conservative as the enriched sample results are overrepresented in the calculation of median values.

Table 3.5 Leachate testing results summary

		Water quality objectives[1]		Water quality profile (Talbingo and Marica Zones)		Water quality profile (Tantangara Zone)	
Analytes	Units	Reservoirs	Watercourses	Likely range[2]	Median value[3]	Likely range[2]	Median value[3]
Anoxic conditions							
pH	-	**8**	**8**	6.6–7.7	7.2	6.2–7.6	7.2
EC	µS/cm	**30**	**350**	100–289	**226**	93–324	**221**
TN	µg/L	**350**	**250**	80–855	**272**	62–409	181
Al	µg/L	**55**	**27**	<WQO	<WQO	WQO occasionally exceeded	<WQO
As	µg/L	**13**	**0.8**	<WQO–22	**0.9**	WQO occasionally exceeded	<WQO
Cu	µg/L	**14**	**1**	WQO occasionally exceeded	<WQO	WQO occasionally exceeded	<WQO
Fe	µg/L	**300**	**300**	WQO occasionally exceeded	<WQO	WQO occasionally exceeded	<WQO
Mn	µg/L	**1900**	**1200**	WQO occasionally exceeded	<WQO	WQO occasionally exceeded	<WQO
Sb	µg/L	**9**	**9**	WQO occasionally exceeded	<WQO	WQO occasionally exceeded	<WQO
U	µg/L	**0.5**	**0.5**	WQO occasionally exceeded	<WQO	WQO occasionally exceeded	<WQO
Zn	µg/L	**8**	**2.4**	WQO occasionally exceeded	<WQO	WQO occasionally exceeded	<WQO
Oxic conditions							
pH	-	**8**	**8**	8.1–10	**9.5**	8.2–9.9	**9.4**
EC	µS/cm	**30**	**350**	42–239	**85**	43–116	**76**
TN	µg/L	**350**	**250**	116–689	**350**	87–5951	199
Al	µg/L	**55**	**27**	<WQO–5009	**362**	<WQO–2227	**438**
As	µg/L	**13**	**0.8**	<WQO–65	**2.2**	<WQO–84	**1.3**
Cr	µg/L	**370**	**90**	WQO occasionally exceeded	< WQO	WQO occasionally exceeded	<WQO
Cu	µg/L	**14**	**1**	WQO occasionally exceeded	< WQO	WQO occasionally exceeded	<WQO
Fe	µg/L	**300**	**300**	WQO occasionally exceeded	< WQO	WQO occasionally exceeded	<WQO

Table 3.5 Leachate testing results summary

		Water quality objectives[1]		Water quality profile (Talbingo and Marica Zones)		Water quality profile (Tantangara Zone)	
Analytes	**Units**	**Reservoirs**	**Watercourses**	**Likely range[2]**	**Median value[3]**	**Likely range[2]**	**Median value[3]**
Pb	µg/L	**3.4**	**1**	WQO occasionally exceeded	<WQO	WQO occasionally exceeded	<WQO
Sb	µg/L	**9**	**9**	WQO occasionally exceeded	<WQO	<WQO	<WQO
U	µg/L	**0.5**	**0.5**	WQO occasionally exceeded	<WQO	WQO occasionally exceeded	<WQO
V	µg/L	**6**	**6**	WQO occasionally exceeded	<WQO	WQO occasionally exceeded	<WQO
Zn	µg/L	**8**	**2.4**	WQO occasionally exceeded	<WQO	WQO occasionally exceeded	<WQO
Dilute acid conditions							
pH	-	**8**	**8**	7.6–9.6	**9.2**	8–9.8	**9.3**
EC	µS/cm	**30**	**350**	40–274	**101**	37–124	**75**
TN	µg/L	**350**	**250**	114–4891	**290**	28–4488	151
Al	µg/L	**55**	**27**	<WQO–1523	**187**	<WQO–4368	**288**
As	µg/L	**13**	**0.8**	<WQO–87	**2.4**	<WQO–48	**1.0**
Cr	µg/L	**370**	**90**	WQO occasionally exceeded	<WQO	WQO occasionally exceeded	<WQO
Cu	µg/L	**14**	**1**	<WQO	<WQO	WQO occasionally exceeded	<WQO
Mo	µg/L	**34**	**34**	<WQO	<WQO	WQO occasionally exceeded	<WQO
Sb	µg/L	**9**	**9**	WQO occasionally exceeded	<WQO	<WQO	<WQO
V	µg/L	**6**	**6**	WQO occasionally exceeded	<WQO	WQO occasionally exceeded	<WQO

Notes: 1. The WQO values for pH, EC and TN refer to the WQO values for physical and chemical stressors in south-east Australia (upland river) that are reported in Tables 3.3.2 and 3.3.3 of ANZECC/ARMCANZ (2000). Toxicant trigger values for the protection of 95% and 99% of aquatic species presented in (ANZG 2018) have been used for reservoir and watercourse receiving waters respectively. However, the 95% values apply to watercourses at Rock Forest, which is outside of KNP. Further information on the establishment of WQOs is provided in the water assessment (Appendix J to the EIS).

2. Likely range calculated as the minimum and maximum leachate results (baseline and enriched) from all geological groups expected to contribute to a specific emplacement zone. Where the maximum value is greater than the WQO and the median value is less than the WQO, the analyte is considered to be 'occasionally exceeded'.

3. Median value calculated from leachate results (baseline and enriched) for all geological groups expected to contribute to a specific emplacement zone.

General note: For results, text style '**0.9**' indicates WQO values for watercourses are exceeded, '**0.9**' indicates WQO values for reservoirs are exceeded and '**0.9**' indicate WQO values for both watercourses and reservoirs are exceeded.

iii Summary

Table 3.6 presents a summary of the potential water quality of leachate (as indicated by ASLP results) under anoxic, oxic and weak acid conditions. It is important to note that the information in this table does not apply these water quality profiles to the receiving waters when they are placed within the emplacement areas. This table only presents information and data gathered from geochemical testing of materials.

Chapter 5 provides a description of the potential water impacts applying these water quality profiles to receiving waters.

Table 3.6 Potential leachate quality

	Leachate characteristics	
Conditions	**Talbingo/Marica Zones**	**Tantangara Zone**
Anoxic conditions (potential to occur in both in reservoir and land-based emplacements)	• Neutral pH ranging from 6.6 to 7.7. • Low leachable salts (EC ranges from 100 to 289 µS/cm). • Total nitrogen is likely to be similar to or below WQO values for reservoirs and watercourses. • Arsenic is likely to be similar to the WQO value for watercourses but below the value for reservoirs. • Concentrations of other metals are likely to be below WQO values for reservoirs and watercourses.	• Neutral pH ranging from 6.2 to 7.6. • Low leachable salts (EC ranges from 93 to 324 µS/cm). • Total nitrogen is likely to be similar to or below WQO values for reservoirs and watercourses. • Concentrations of metals are likely to be below WQO values for reservoirs and watercourses.
Oxic conditions (likely to occur in both in-reservoir and land-based emplacements)	• Moderately alkaline (pH ranges from 8.1 to 10). • Low leachable salts (EC ranges from 42 to 239 µS/cm). • Total nitrogen is likely to be similar to or below WQO values for reservoirs and watercourses. • Aluminium is likely to exceed the WQO for watercourses by a factor of 13 and reservoirs by a factor of 7. • Arsenic is likely to exceed the WQO for watercourses by a factor of 3 but be below the value for reservoirs. • Concentrations of other metals are likely to be below WQO values for reservoirs and watercourses.	• Moderately alkaline (pH ranges from 8.2 to 9.9). • Low leachable salts (EC ranges from 43 to 116 µS/cm). • Total nitrogen is likely to be similar to or below WQO values for reservoirs and watercourses. • Aluminium is likely to exceed the WQO for watercourses by a factor of 16 and reservoirs by a factor of 8. • Arsenic is likely to exceed the WQO for watercourses by a factor of >2 but be below the value for reservoirs. • Concentrations of other metals are likely to be below WQO values for reservoirs and watercourses.

Table 3.6 Potential leachate quality

Conditions	Leachate characteristics Talbingo/Marica Zones	Tantangara Zone
Weak acid conditions (potential to occur in land-based emplacements)	• Moderately alkaline (pH ranges from 7.6 to 9.6). • Low leachable salts (EC ranges from 40 to 274 µS/cm). • Total nitrogen is likely to be similar to or below WQO values for reservoirs and watercourses. • Aluminium is likely to exceed the WQO for watercourses by a factor of 7 and reservoirs by a factor of 3. • Arsenic is likely to exceed the WQO for watercourses by a factor of 3 but be below the value for reservoirs. • Concentrations of other metals are likely to be below WQO values for reservoirs and watercourses.	• Moderately alkaline (pH ranges from 8.0 to 9.8). • Low leachable salts (EC ranges from 37 to 124 µS/cm). • Total nitrogen is likely to be similar to or below WQO values for reservoirs and watercourses. • Aluminium is likely to exceed the WQO for watercourses by a factor of 11 and reservoirs by a factor of 5. • Arsenic is likely to be similar to the WQO value for watercourses but below the value for reservoirs. • Concentrations of other metals are likely to be below WQO values for reservoirs and watercourses.

3.2.4 Elutriate tests

i Test overview

CSIRO (2019b) undertook an environmental categorisation of excavated rock to provide information to assist in assessing the potential impacts of the placement of excavated rock materials on water and sediment quality within Talbingo Reservoir.

The release of substances from the rock material was assessed using a series of elutriate tests that involved mixing and leaching rock with reservoir water. The tests covered a wide range of mixing-leaching scenarios and conditions, and included testing for the range of analytes provided in Table 3.4. Of the analytes tested, pH, EC and aluminium frequently exceeded WQOs, with dissolved aluminium being the only substance consistently identified as a contaminant of potential concern (CSIRO 2019b). Consequently, a *Dissolved Aluminium Assessment for Talbingo Reservoir* (CSIRO 2019d) was undertaken to investigate the relationships between the concentrations Total Suspended Solids (TSS) and concentrations of dissolved aluminium.

ii Results summary

The relationship between TSS concentrations and pH was assessed by CSIRO (2019b) using a series of elutriate tests where crushed rock samples were mixed with reservoir water and the resulting water quality was measured (EIS Appendix L, Annexure C). This test work generally considered TSS concentrations between 10,000 and 100 mg/L The results of these tests are provided in Figure 3.3.

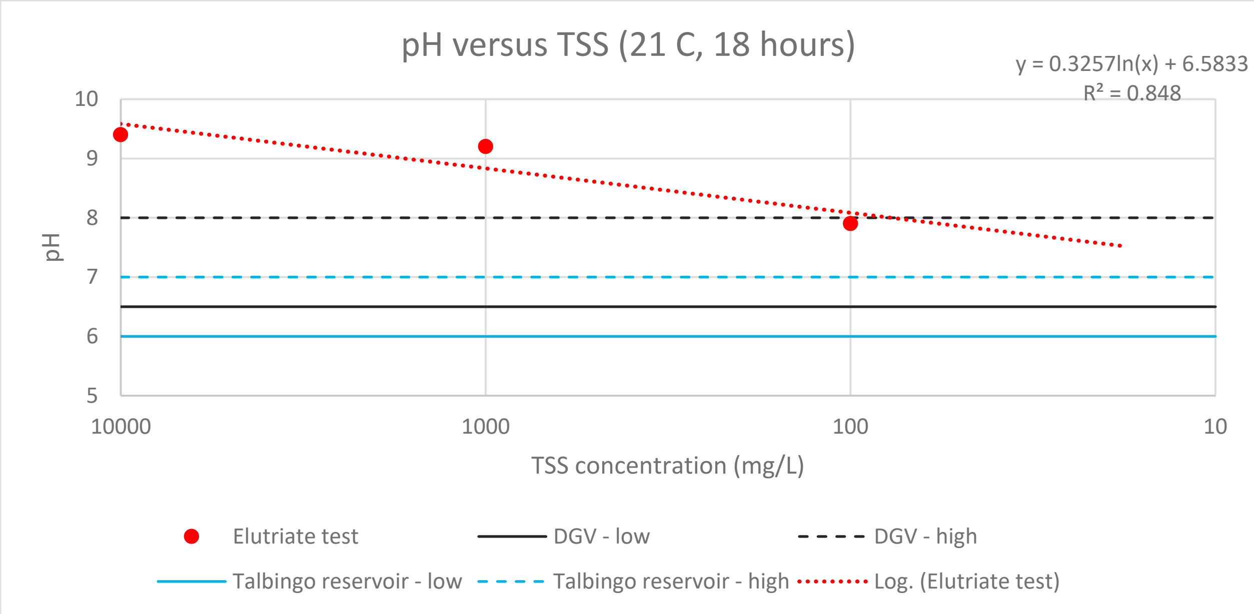


Figure 3.3 Elutriate test results: pH vs TSS

Importantly, at TSS concentrations below 100 mg/L, the pH is predicted to be less than pH 8, and within the WQO range for reservoirs.

a Relationship between TSS concentrations and the aluminium concentrations

The relationship between TSS concentrations and aluminium concentrations is discussed in Appendix B of *Dissolved Aluminium Assessment for Talbingo Reservoir* (CSIRO 2019d) (EIS Appendix L, Annexure E). The concentrations of aluminium released for the TSS scenarios considered by CSIRO are summarised in Table 3.7.

Table 3.7 Dissolved aluminium release

	Dissolved aluminium concentration (µg/L)[1]	
TSS concentration (mg/L)	**Mid to long-term release in main excavated rock disposal area**	**18 hr short-term, reoccurring release, and representing release further from excavated rock disposal area**
1,000	79 ± 10	39 ± 7.4
333	22 ± 3.6	15 ± 1.8
100	16	9 ± 1.5
1	4.2 ± 0.2	4.2 ± 0.2

Source: Appendix B of the CSIRO (2019d) (EIS Appendix L, Annexure E).

1. mean ± standard error.

The aluminium concentration released decreases as the TSS concentration decreases. At 100 mg/L, the aluminium release (9–16 µg/L) is predicted to be similar to the background aluminium concentration in the reservoir and well below the WQO value of 55 µg/L. The TSS concentration of 100 mg/L has been conservatively applied to spatially describe a mixing zone for aluminium during the construction of the in-reservoir component of the Ravine Bay emplacement. This is discussed further in Section 5.2.1.

3.2.5 Naturally occurring asbestos

Naturally occurring asbestos (NOA) has been identified within select geologies proposed to be intersected by tunnelling activities. The likelihood of intersecting NOA along the proposed tunnel alignment was investigated by SMEC (2019), and is described as follows:

- Possible: possible presence of asbestiform minerals – Boraig Group and Boggy Plain Suite.
- Likely: rock formations known to contain asbestiform minerals – Boraig Group/Ravine Beds contact area and Temperance Formation.
- Confirmed: asbestiform confirmed in the formations test – Gooandra Volcanics, Shaw Hill Gabbro and Boggy Plain Suite.

Confirmed NOA in the Gooandra Volcanics, Boggy Plain Suite and Shaw Hill Gabbro units predominantly consists of tremolite-actinolite and actinolite fibres, although the distribution of mineral fibres is complex and non-uniform. The confirmed presence of NOA in the Gooandra Volcanics is consistent with the NSW Resources & Geoscience (2018) NOA mapping. In summary, NOA material is likely to be encountered in the Tantangara construction zone but may also be encountered in the Talbingo and Marica zones.

4 Concept design

This chapter describes the concept designs for the five excavated rock emplacements. The concept designs have been prepared by Snowy Hydro and FGJV to inform the PIR-RTS and will be further developed as per the design development program (see Section 1.3). This chapter is structured as follows:

- Section 4.1 provides information on the capacities of each emplacement.
- Section 4.2 describes design principles and proposed design development.
- Sections 4.3 to 4.7 describes the concept design for each emplacement.

4.1 Emplacement capacities

The concept designs for each emplacement are based on a design capacity. In most cases, the design capacity will be in excess of the estimated volume of material that is to be disposed, providing contingency for changes to design and/or the volume of rock that needs to be disposed. Table 4.1 provides the design capacity, the estimated required volume and composition of each emplacement and the resulting contingent volume.

Table 4.1 Composition of proposed emplacements

		Estimate of required volumes/composition				
	Design capacity	Subsurface (TBM)	Subsurface (D&B)	Surface (D&B)	**Total**	**Contingent volume**
Units			million m^3			
Talbingo Zone						
– Ravine Bay	**4.5**	1.2	0.8	0.9	**2.8**	**1.7**
– GF01	**1.0**	0.3	0.0	0.7	**1.0**	**0.0**
– Main Yard	**2.0**	0.6	0.0	1.2	**1.8**	**0.2**
Talbingo Zone Total	**7.5**	2.1	0.8	2.8	**5.6**	**1.9**
Marica Zone						
– Rock Forest	**0.7**	0.0	0.3	0.1	**0.4**	**0.3**
Tantangara Zone						
– Tantangara	**2.9**	1.4	1.2	0.2	**2.9**	**0.0**
Total (all zones)	**11.1**	3.5	2.3	3.1	**8.9**	**2.2**

Notes: All volumes are rounded to 0.1 million m^3 (and may not add up) and refer to the placed volume of rock.

Source: All volumes have been provided by FGJV

4.2 Concept design principles

The concept designs for each emplacement apply many common design principles. These common principles are described in Table 4.2. The concept design for each emplacement is described individually in Sections 4.3 to 4.7.

Table 4.2 Concept design principles

	Applicable emplacements	Management design principles	Proposed design development
1 – Emplacement methods			
1.1 – In-reservoir emplacement	Ravine Bay	Methods for in-reservoir emplacements are described in Section 4.3 (Ravine Bay) and Section 4.7 (Peninsula).	**Concept design completion** • No further design development is proposed. **Detailed design** • Emplacement methods will be further developed at detailed design as required.
1.2 – Land-based emplacement	All emplacements	Land-based emplacement will be constructed from the 'bottom up' using conventional earthmoving techniques. The following broad stages are proposed: 1. Prior to the placement of any material, topsoil and vegetation will be removed and stockpiled for potential use in landform rehabilitation. 2. Spoil will be placed in horizontal layers that are approximately 300 mm thick and compacted to reduce volume and permeability. The expected compaction factor is 1.16 (relative to the bank volume). 3. Materials may be selectively handled/blended/placed to provide improved erosion protection and rehabilitation outcomes. 4. When the landform is close to design levels, the surface will be trimmed to achieve design levels established by the landform design process.	**Concept design completion** • No further design development is proposed. **Detailed design** • Emplacement methods will be further developed at detailed design as required.
1.3 – Management of PAF material	All emplacements	As described in Chapter 3, available geochemistry data indicates that some excavated material may be PAF. However, overall the material is likely to have acid neutralising capacity that is in excess of the maximum potential acidity. Therefore, the proposed management approach is to utilise the available acid neutralising capacity to mitigate acid risks.	**Concept design completion** • No further design development is proposed. **Detailed design** • An excavated rock management plan will be prepared that describes methods for characterising excavated material and managing identified PAF material.

Table 4.2 Concept design principles

	Applicable emplacements	Management design principles	Proposed design development
1.4 – Management of NOA material	Peninsula and potentially other emplacements	As described in Chapter 3, available geochemistry data indicates that NOA is likely to be encountered in the Gooandra Volcanics, which will be excavated within the Tantangara Zone and may also be encountered in other construction zones. It is proposed to contain NOA material in the rock emplacements using the methods described in the PIR-RTS. Proposed containment methods will be further developed at concept design completion.	**Concept design completion** • A concept design for the containment of NOA will be further developed. **Detailed design** • An excavated rock management plan will be prepared that describes methods for characterising excavated material and managing identified material that contains NOA.
2 – Water management during construction			
2.1 – In-reservoir emplacements	Ravine Bay	Silt curtains will be used to reduce the horizontal movement of water from the emplacement areas to the greater reservoir. The optimal depth and alignment of each curtain will be established at detailed design. During construction, the depth and alignment can be further adjusted (using real-time monitoring) to optimise performance.	**Concept design completion** • No further design development is proposed. **Detailed design** • The optimal configuration of each silt curtain will be established at detailed design.
2.2 – Land-based emplacement	All emplacements	The following methods are proposed to manage runoff and seepage during the construction of land-based emplacements: • Where practical, clean water runoff from upslope areas will be diverted around construction areas using either gravity or pump assisted diversions. • Where practical, runoff and seepage from emplacement areas will drain to sedimentation basins designed to capture the 85th percentile 5-day rainfall event. Larger basins (ie sized to capture the 90th or 95th percentile 5-day rainfall event) may be constructed in areas where the topography is favourable and space is available. Captured water will be dewatered from the basins within 5 days following the cessation of a rainfall event and will be either: – applied to access roads or stockpiles for dust suppression; – irrigated to vegetated areas; and/or – treated with appropriate water treatment chemicals and discharged. The construction phase management measures will be maintained until rehabilitation in the contributing catchment area is established.	**Concept design completion** • No further design development is proposed. **Detailed design** • An erosion and sediment control plan will be developed for each emplacement as part of the detailed design.

Table 4.2 Concept design principles

	Applicable emplacements	Management design principles	Proposed design development
3 – Landform design and rehabilitation			
3.1 – Landform surface design	All emplacements	The surface of land-based emplacements will be designed using a 'geomorphic landform' design method such as GeoFluv™ (or equivalent). This method will seek to develop stable free draining landforms that have similar characteristics to the surrounding landscape with slope designs and lengths appropriate for the constraints posed by the excavated rock. The use of traditional methods such as benching will be avoided to minimise erosion, improve visual amenity of the landforms and minimise the need for long term maintenance. The landforms will be designed to interface with drainage and ridge lines of the surrounding landscapes to minimise the redistribution of catchment boundaries and visual impacts.	**Concept design completion** • As described in the PIR-RTS, the geomorphic landform design prepared as part of the concept design PIR-RTS will be further developed to incorporate: – Characterisation of spoil for erosion and revegetation constraints. – Erosion modelling to determine slope gradient and slope length rules for input into the design model. – Outcomes of rehabilitation trials. **Detailed design** • The geomorphic landform design will be updated as required during detailed design.
3.2 – Slope stability	All emplacements	All emplacements will be designed and constructed to be structurally stable under all foreseeable conditions.	**Concept design completion** • As described in the PIR-RTS, slope stability assessments and geotechnical concept designs will be undertaken for each emplacement. **Detailed design** • Slope stability assessments will be updated, and detailed geotechnical designs will be undertaken as part of the detailed design of each emplacement.

Table 4.2 Concept design principles

	Applicable emplacements	Management design principles	Proposed design development
3.3 – Flood risks	Main Yard	The northern portion of the Main Yard emplacement is on the Yarrangobilly River floodplain. The landform will be designed and constructed to be stable during a rare[1] Yarrangobilly River flood.	**Concept design completion** • A flood risk assessment will be undertaken as part of the concept design completion, some amendments to the Main Yard landform may be required. **Detailed design** • The flood risk assessment will be updated if required.
3.4 – Watercourse and drainage line reinstatement	All emplacements	All watercourses and drainage lines that will be reinstated into rehabilitated landforms will be designed and constructed to be geomorphologically stable using natural channel design techniques.	**Concept design completion** • A concept design will be prepared for all 2nd order and greater watercourses that will be reinstated through rehabilitated landforms. The concept design will consider all factors that contribute to the stability of a watercourse reinstated over unconsolidated material. **Detailed design** • At detailed design, the concept design approach will be applied to the design of all watercourses and drainage lines that are to be reinstated into the rehabilitated landform.
3.5 – Rehabilitation	All emplacements	All land-based emplacements will be revegetated with endemic native vegetation. The proposed rehabilitation approach for each emplacement is currently being developed but will include consideration of: • methods for establishing suitable growing media (topsoil reuse, spoil amelioration, hydraulically/pneumatically applied growth mediums etc); • weed management; and • methods for native vegetation establishment (species selection, planting methods etc).	**Concept design completion** • A rehabilitation strategy will be prepared for each emplacement. • Field trials of potential methods will be undertaken to identify/verify appropriate methods. **Detailed design** • A rehabilitation plan for each emplacement will be prepared.

Notes

1. A rare flood event is defined in Australian Rainfall and Runoff as an event that has an annual probability of exceedance of between 1 to 0.05% (Geoscience Australia 2019).

4.3 Ravine Bay rock emplacement

The Ravine Bay emplacement concept design incorporates an in-reservoir pad constructed using D&B spoil from the reservoir bed up to FSL. Combined D&B and TBM spoil will be placed on top of the in-reservoir D&B pad and on existing land to the north of the reservoir (the land-based emplacement). The land-based component of the emplacement will fill an existing gully that contains an unnamed 3rd order watercourse that is likely to have an intermittent flow regime. It is proposed to reinstate this watercourse along the western edge of the emplacement.

As noted in Table 4.1, the overall design capacity of the emplacement is 4.5 million m^3. However, it is currently estimated that 2.8 million m^3 of the design capacity will be utilised. Figure 4.2 (overleaf) shows a conceptual visualisation of the land-based emplacement and Figure 4.3 (also overleaf) shows the landform concept design. The landforms presented in both figures are based on the design capacity.

The concept design for the proposed in-reservoir D&B pad is discussed further below.

i In-reservoir D&B pad design concept

The in-reservoir D&B pad will be constructed from the reservoir shore using conventional earthmoving techniques. The following broad stages are proposed:

- All underwater debris will be removed.
- D&B spoil will be placed in the reservoir using conventional earthmoving techniques (referred to as edge push). The placed material is expected to slope at the natural angle of repose (approximately 1.3H to 1V).
- A rock armour layer comprising >200 mm D&B spoil will be placed along the edge of the pad to provide additional stability and erosion protection. Some of this material can be placed using a barge or long reach excavator to achieve a batter slope that is flatter than the natural angle of repose.
- A geotextile filter will be installed at the interface of the in-reservoir D&B pad and land-based emplacement to reduce the propagation of fines from the overlying TBM spoil into the in-reservoir D&B pad. The filter will comprise a A44 or similar geofabric, with pore sizes of 75 µm.

Figure 4.1 shows the design concept.

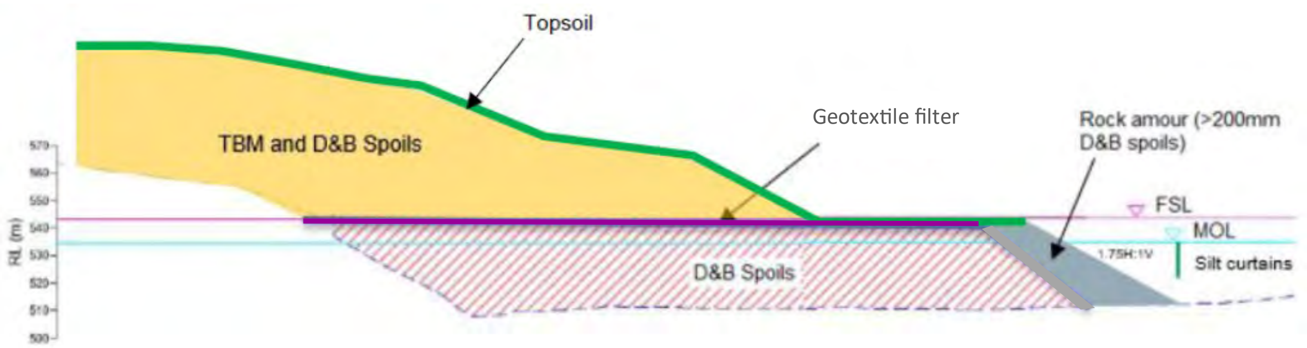


Figure 4.1 Ravine Bay rock emplacement – conceptual cross section (Background image source: FGJV)

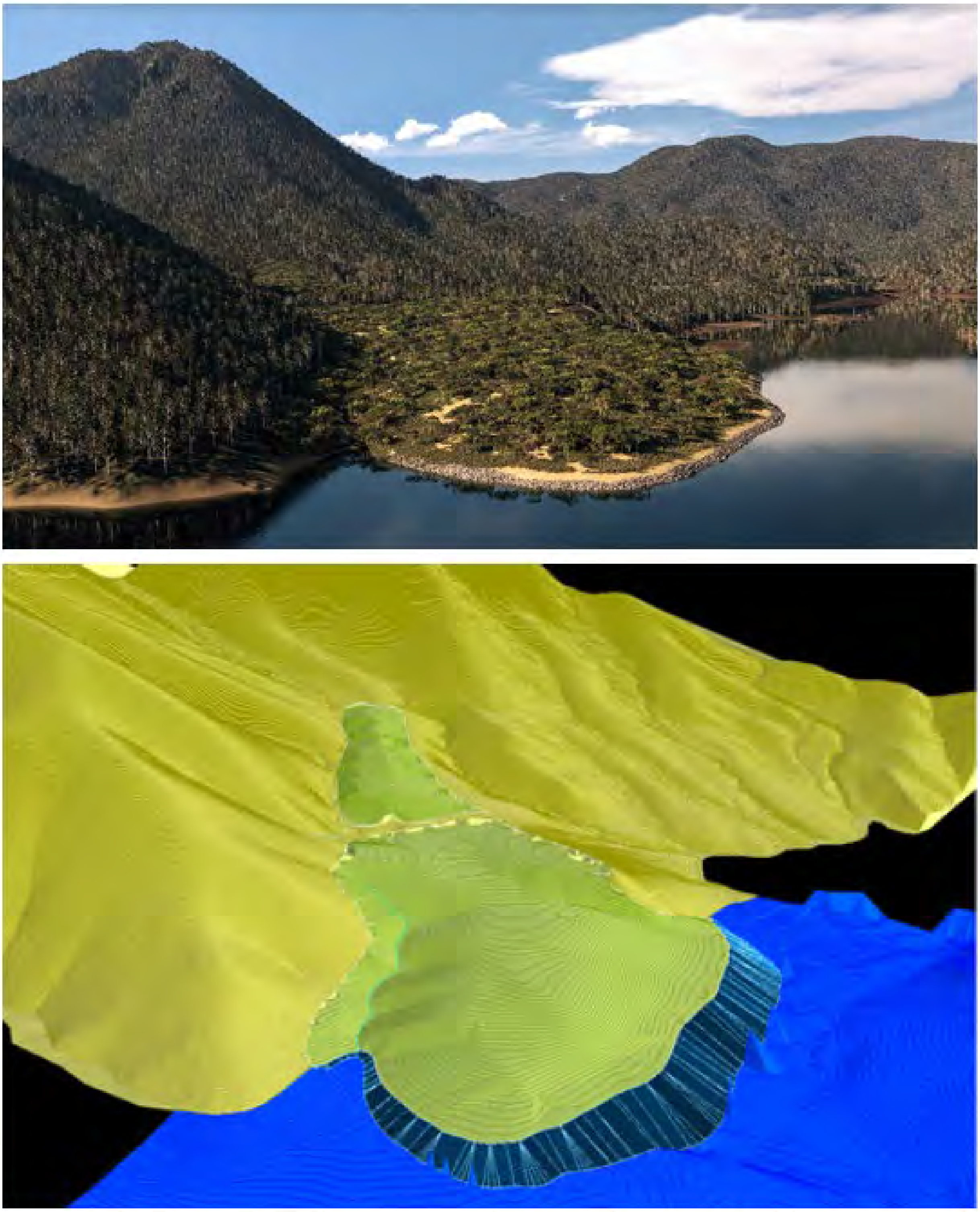
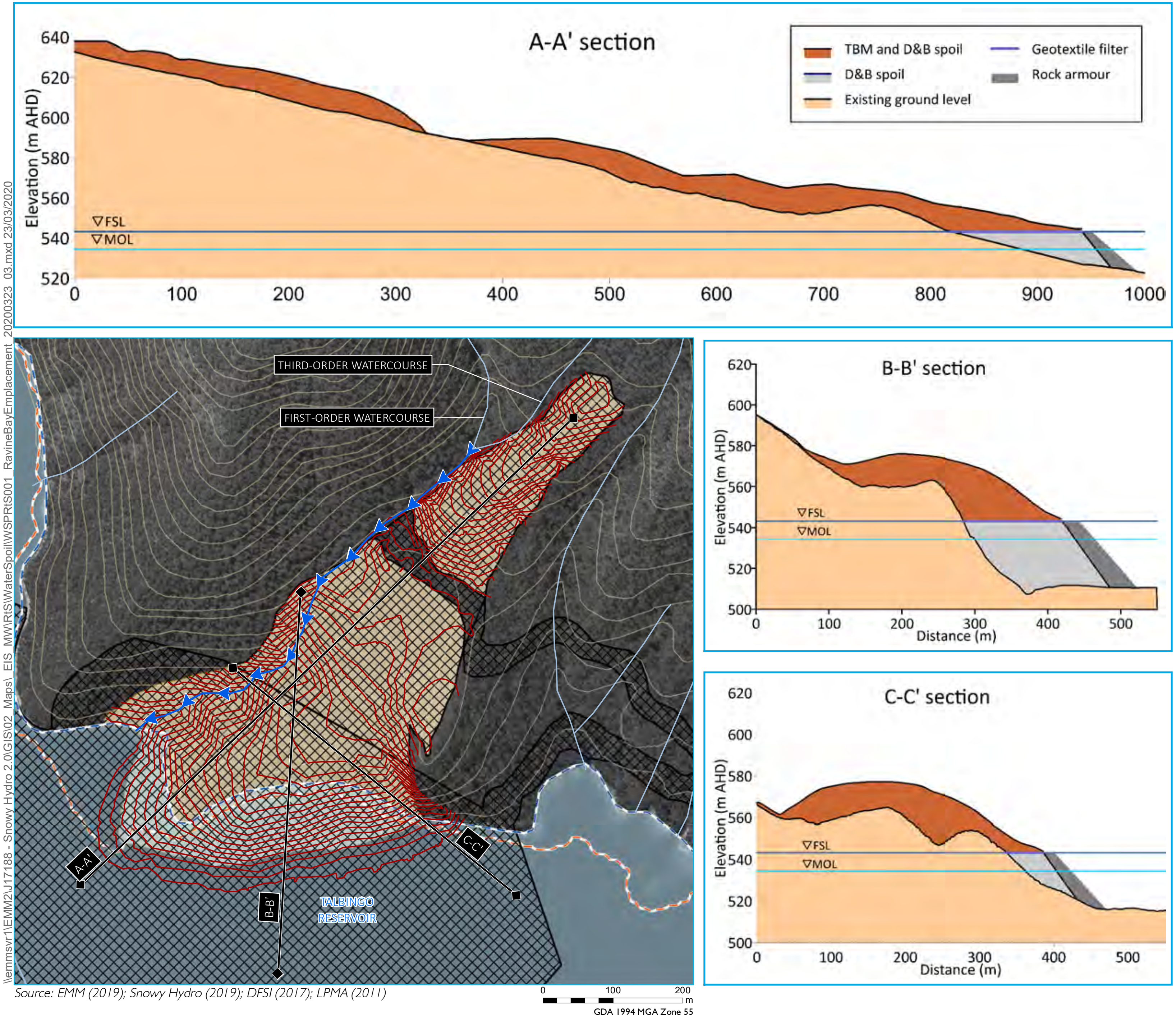


Figure 4.2 Ravine Bay rock emplacement – landform visualisation (Source PIR-RTS)



Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

KEY

Existing environment
- Talbingo Reservoir - Minimum operating level (MOL)
- Talbingo Reservoir - Full supply level (FSL)
- Existing contours (10 m)
- Existing watercourse

Project information
- Disturbance boundary
- Land-based emplacement extent
- Proposed surface level contour (2 m)
- Watercourse to be reinstated
- Cross-section

Notes:
1) The landform concept design has been prepared by Snowy Hydro and FGJV to inform the PIR-RTS. The concept will be further developed as per the design development program (see report for details).
2) For clarity, only existing watercourses that will be reinstated are shown. Additional drainage lines will need to be constructed as part of the landform rehabilitation.
3)The landform presented is based on the design capacity.

Ravine Bay rock emplacement: landform concept

Snowy 2.0
Excavated rock management strategy:
Concept design information and water quality assessment
Main Works
Figure 4.3

4.4 GF01 rock emplacement

The proposed GF01 rock emplacement is a land-based emplacement between the Lobs Hole and Ravine Bay. As noted in Table 4.1, the emplacement has a design capacity of 1.0 million m^3, which is proposed to be fully utilised by a combination of surface generated D&B and TBM spoil.

The emplacement will be in a gully of an unnamed 2^{nd} order watercourse that is likely to have an intermittent flow regime. It is proposed to reinstate this watercourse and contributing tributaries into the rehabilitated landform.

Figure 4.4 shows a conceptual visualisation of the land-based emplacement and Figure 4.5 (overleaf) shows the landform concept design.

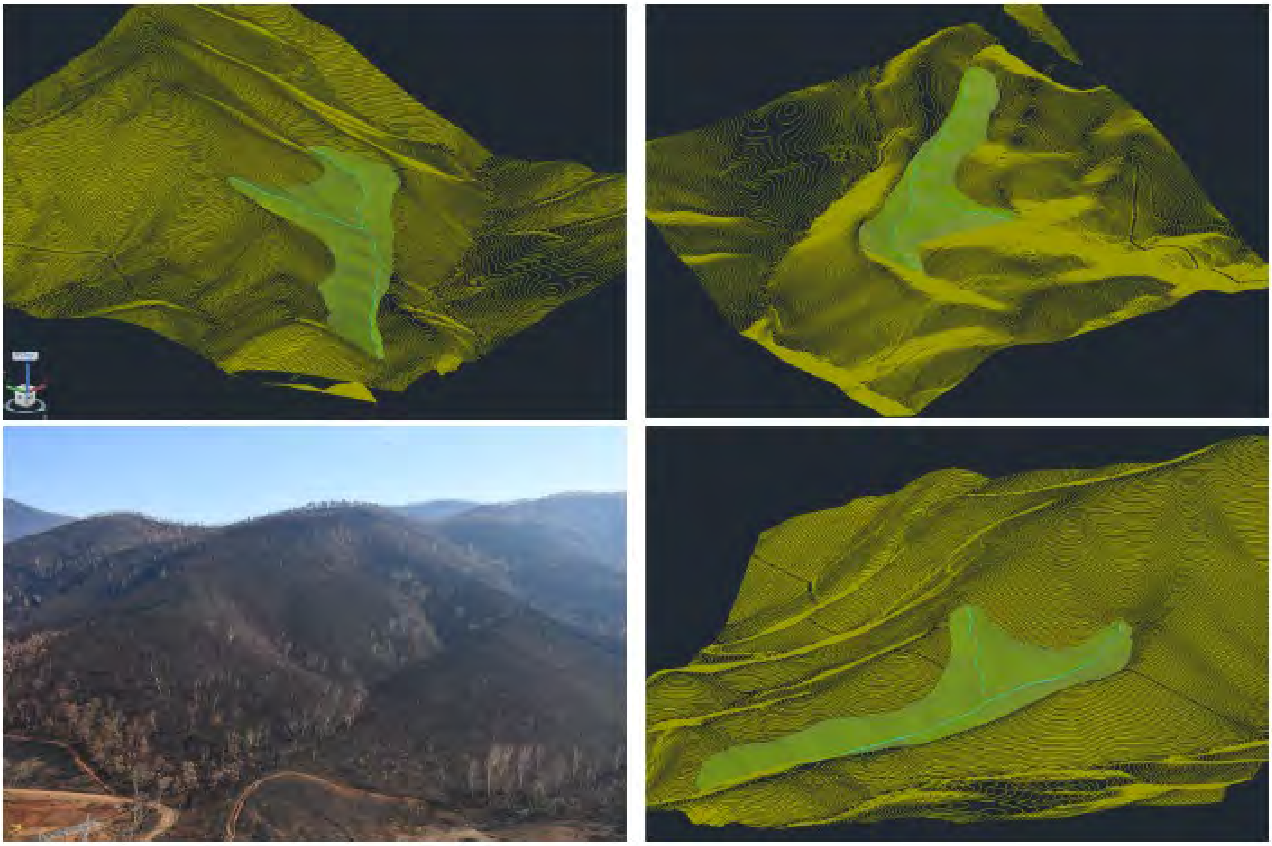
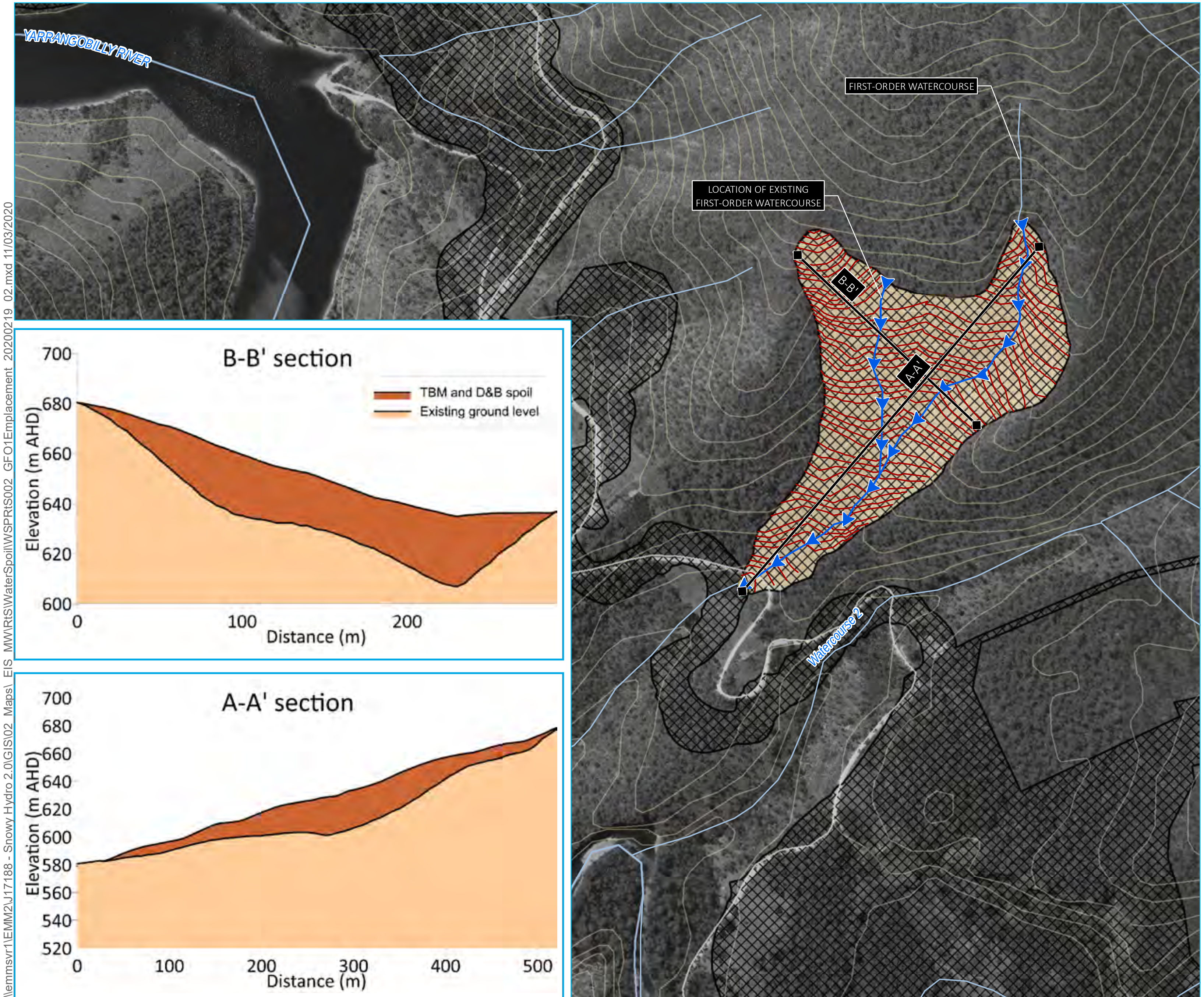


Figure 4.4 GF01 rock emplacement – landform visualisation (Source PIR-RTS)



0 100 200 m
GDA 1994 MGA Zone 55
N

KEY

Existing environment
- Existing contours (10 m)
- Existing watercourse

Project information
- Disturbance boundary
- Land-based emplacement extent (D&B and TBM spoil)
- Proposed surface level contour (2 m)
- Watercourse to be reinstated
- Cross-section

Notes:
1) The landform concept design has been prepared by Snowy Hydro and FGJV to inform the PIR-RTS. The concept will be further developed as per the design development program (see report for details).
2) For clarity, only existing watercourses that will be reinstated are shown. Additional drainage lines will need to be constructed as part of the landform rehabilitation.
3)The landform presented is based on the design capacity.

Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

GF01 rock emplacement: landform concept

Snowy 2.0
Excavated rock management strategy:
Concept design information and water quality assessment
Main Works
Figure 4.5

snowy2.0 EMM creating opportunities

\\emmsvr1\EMM2\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_MW\RtS\WaterSpoil\WSPRtS002_GFO1Emplacement_20200219_02.mxd 11/03/2020

4.5 Main Yard

As described in the Main Works EIS, during the construction phase of the project, construction pads will be established in Lobs Hole to facilitate laydown areas, workshops, sheds, machinery, offices and other project related infrastructure. It is proposed to construct these pads using between 1.2 to 1.4 million m^3 surface generated D&B material. Following the completion of most construction activities, the construction pads will be decommissioned and the landform will be reshaped and rehabilitated applying the design principles described in Table 4.2. It is proposed to incorporate an additional 0.6 million m^3 of TBM spoil into the final landform, bringing to total design capacity of the emplacement to 2.0 million m^3. As noted in Table 4.1, it is currently estimated that 1.8 million m^3 of the design capacity will be utilised.

Two watercourses (Lick Hole Gully and a 2nd order watercourse referred to as watercourse 4 in the EIS) and a number of ephemeral drainage lines will be reinstated through the landform applying the design principles described in Table 4.2.

Some portions of the landform prepared as part of the concept design are located on the Yarrangobilly River floodplain. As noted in Table 4.2, the landform will be designed and constructed to be stable during a rare Yarrangobilly River flood event. A flood risk assessment will be undertaken as part of the concept design completion to establish a landform extent that can achieve this objective. Some amendments to the landform extent may be required.

Figure 4.6 shows a conceptual visualisation of the land-based emplacement and Figure 4.7 (overleaf) shows the landform concept design and notes portions of the landform that will be subject to a flood risk assessment. The landforms presented in both figures are based on the design capacity.

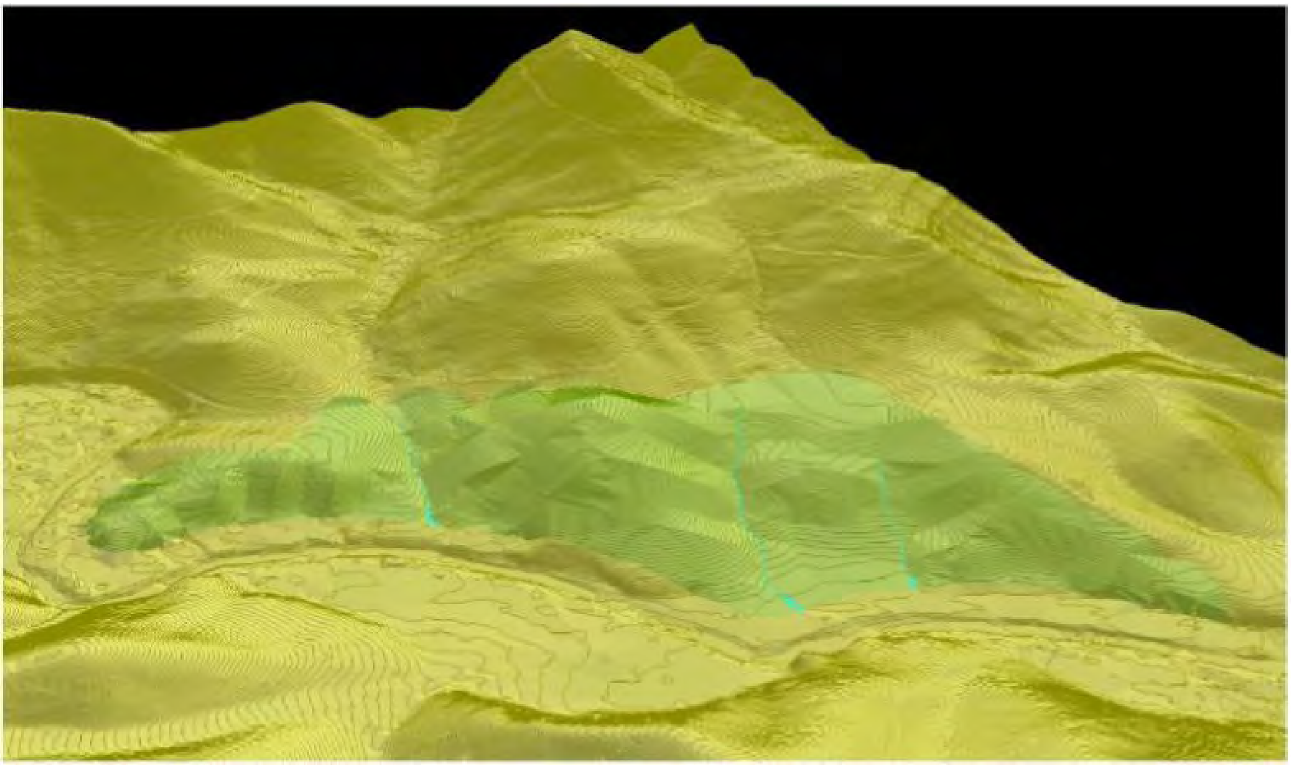
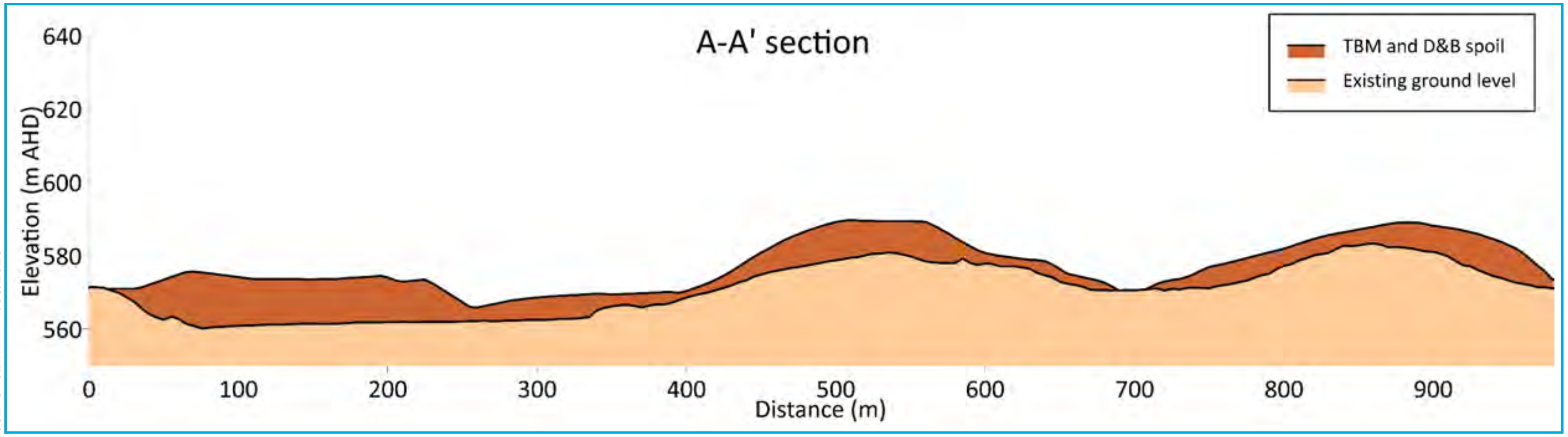


Figure 4.6 Main Yard rock emplacement – landform visualisation (Source FGJV)



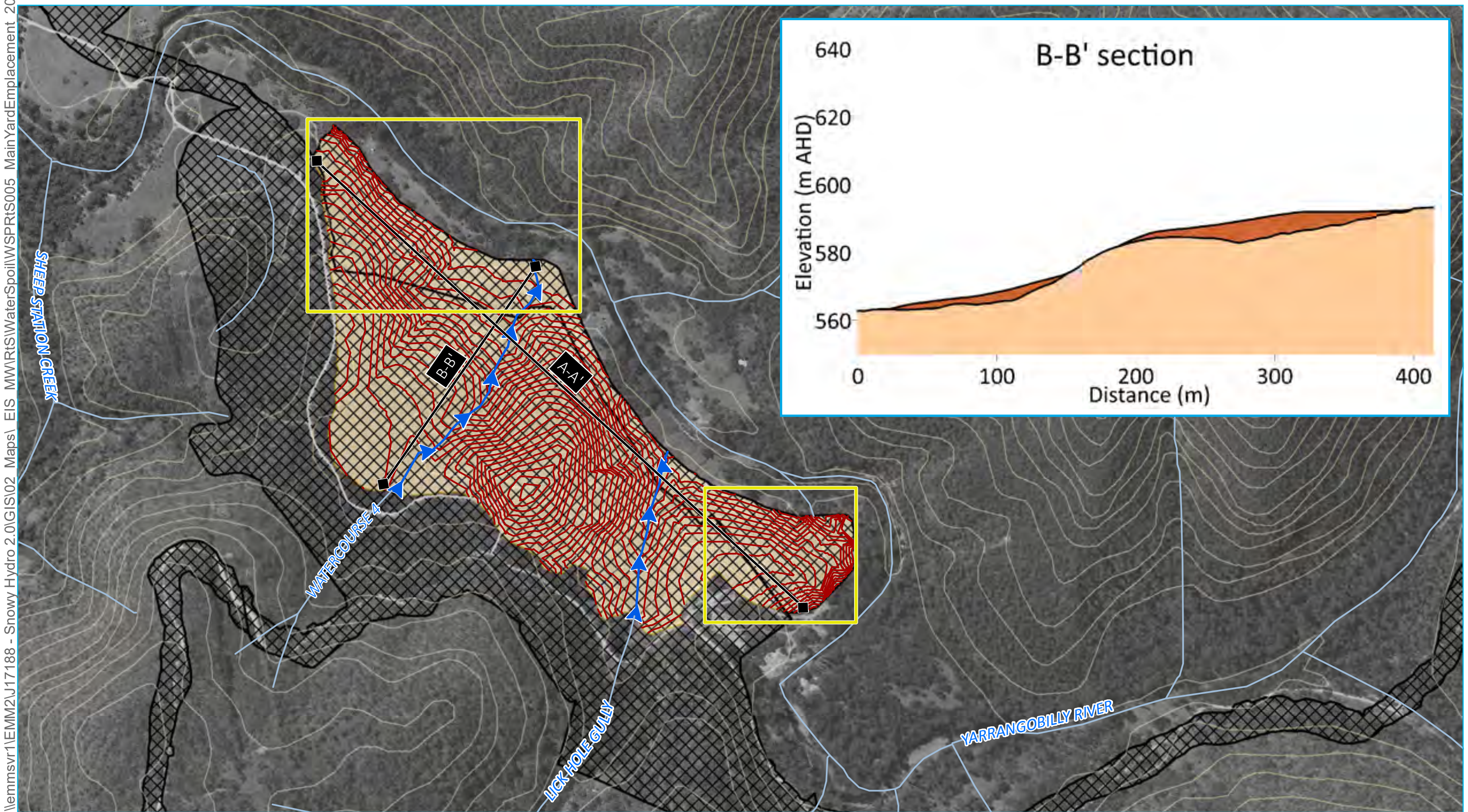
KEY

Existing environment

- Existing contours (10 m)
- Existing watercourse

Project information

- Disturbance boundary
- Land-based emplacement extent
- Flood investigation area
- Proposed surface level contour (2 m)
- Watercourse to be reinstated
- Cross-section



Notes:
1) The landform concept design has been prepared by Snowy Hydro and FGJV to inform the PIR-RTS. The concept will be further developed as per the design development program (see report for details).
2) For clarity, only existing watercourses that will be reinstated are shown. Additional drainage lines will need to be constructed as part of the landform rehabilitation.
3)The landform presented is based on the design capacity.

Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

\\emmsvr1\EMM2\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_MW\RtS\WaterSpoil\WSPRtS005_MainYardEmplacement_20200219 -02.mxd 11/03/2020

Main Yard rock emplacement: landform concept

Snowy 2.0
Excavated rock management strategy:
Concept design information and water quality assessment
Main Works
Figure 4.7

snowy 2.0

EMM creating opportunities

4.6 Rock Forest

The preferred management strategy for excavated rock produced from the Marica Zone is to transport the material to a land-based emplacement at Rock Forest (outside of KNP). As noted in Table 4.1, the Rock Forest emplacement has a design capacity of 0.7 million m^3. However, it is currently estimated that 0.4 million m^3 of the design capacity will be utilised for a combination of surface and subsurface generated D&B material.

The emplacement will be on favourable topography, west of Camerons Creek. The emplacement will be at least 60 m from the creek, above flood prone land. A 2nd order ephemeral watercourse that is a tributary to Camerons Creek will be diverted around the southern edge of the emplacement.

Figure 4.8 shows a conceptual visualisation of the land-based emplacement and Figure 4.9 (overleaf) shows the landform concept design. The landforms presented in both figures are based on the design capacity.

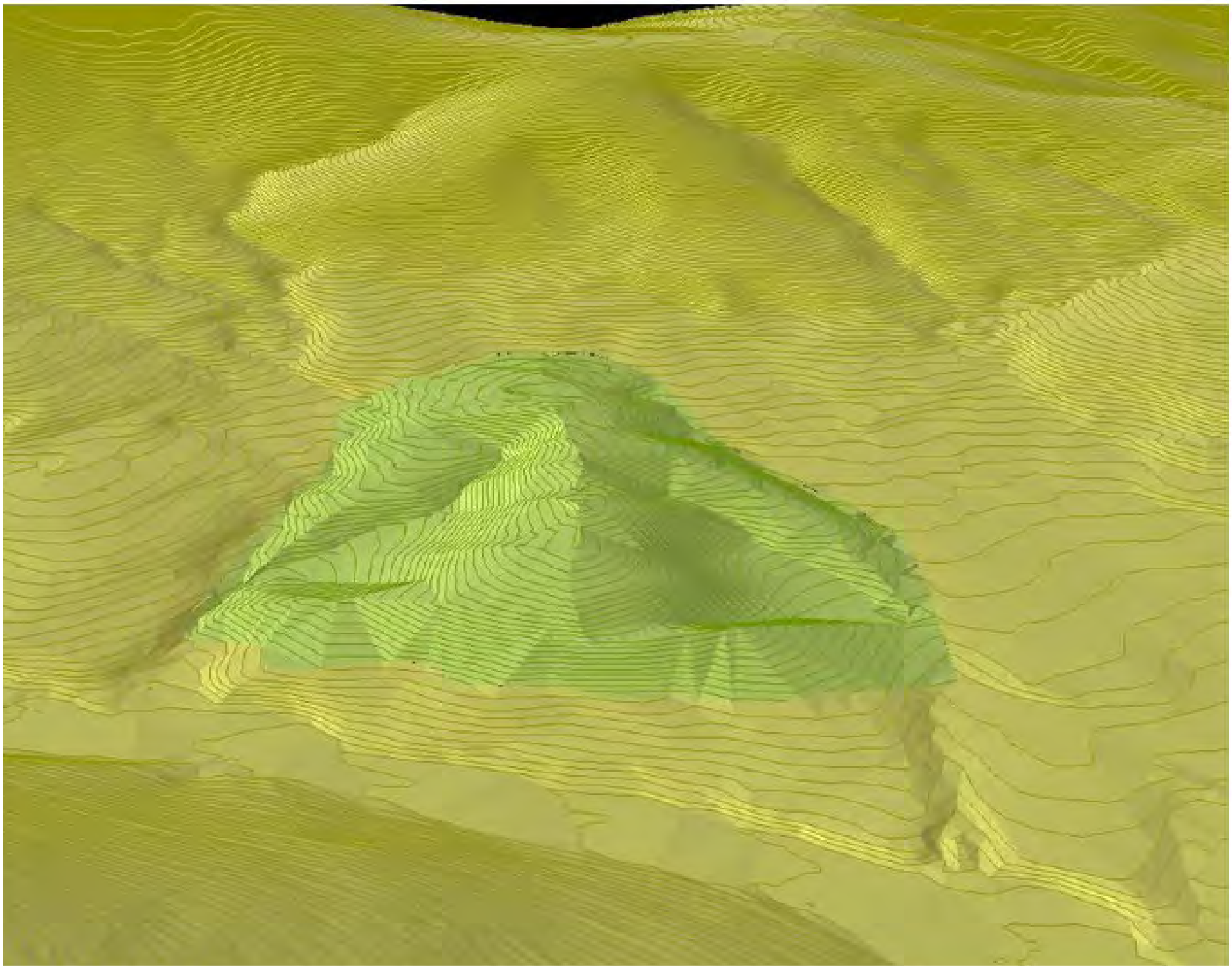
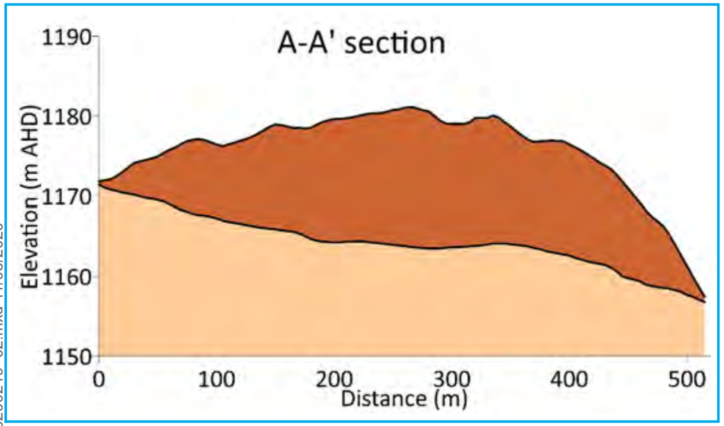
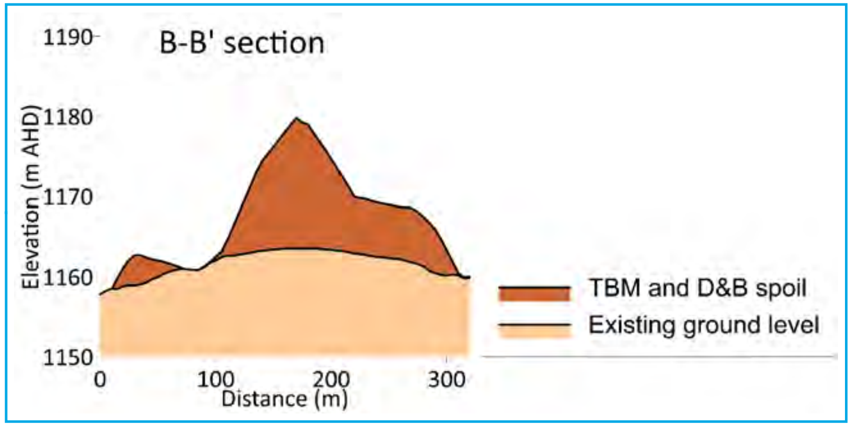
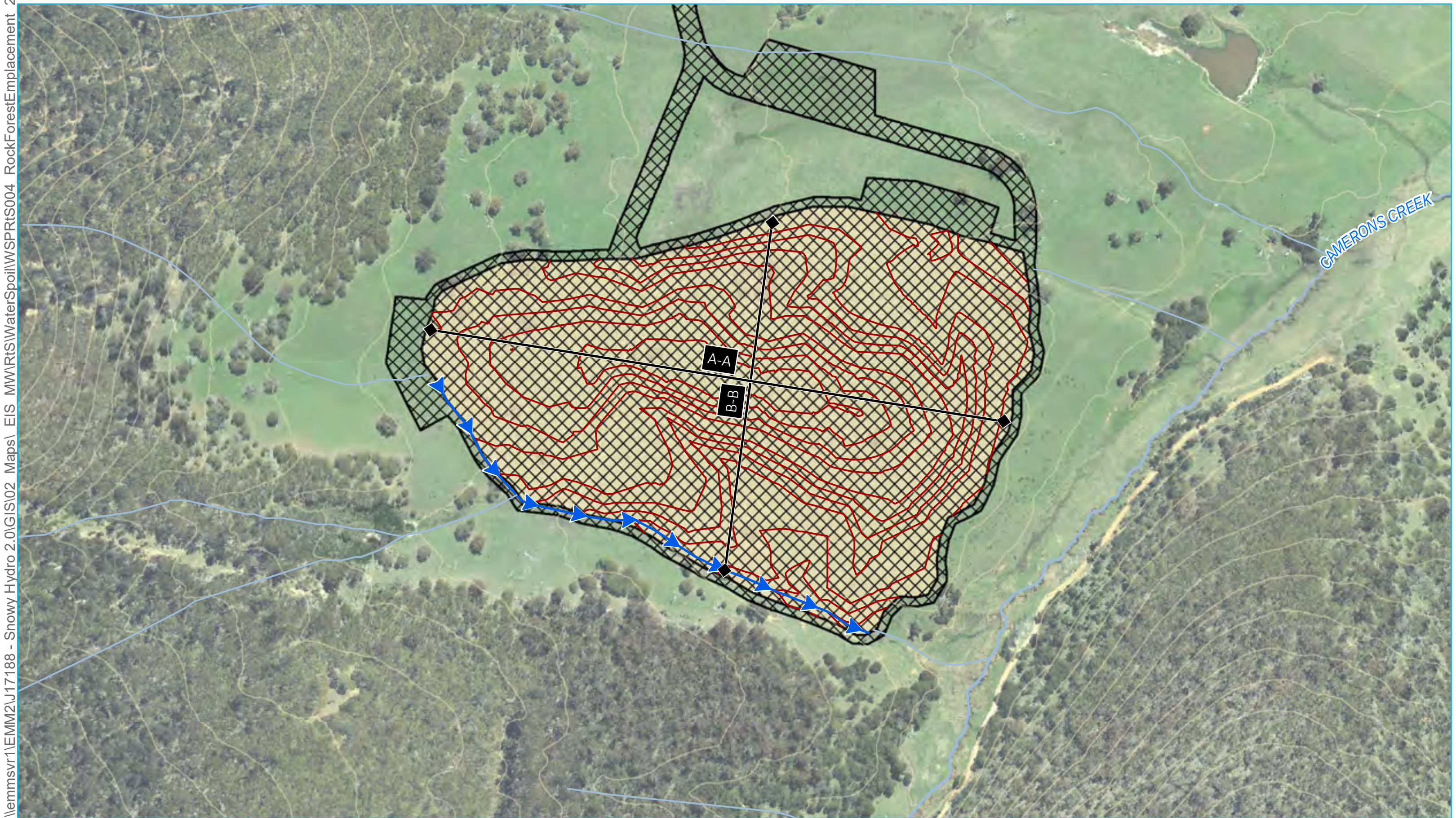


Figure 4.8 Rock Forest rock emplacement – landform visualisation (Source FGJV)







KEY

Existing environment

Existing contours (5 m)

Existing watercourse

Project information

Disturbance boundary

Land-based emplacement extent

Proposed surface level contours (2 m)

Watercourse to be reinstated

Cross-section

Notes:

1) The landform concept design has been prepared by Snowy Hydro and FGJV to inform the PIR-RTS. The concept will be further developed as per the design development program (see report for details).

2) For clarity, only existing watercourses that will be reinstated are shown. Additional drainage lines will need to be constructed as part of the landform rehabilitation.

3)The landform presented is based on the design capacity.

Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

Rock Forest rock emplacement: landform concept

Snowy 2.0
Excavated rock management strategy: Concept design information and water quality assessment
Main Works
Figure 4.9

4.7 Peninsula

The Peninsula emplacement will receive surplus TBM and D&B material excavated from the Tantangara Zone. The emplacement will be constructed north of the Tantangara construction compound, with the proposed landform extending along a ridge line that separates the Nungar Creek inlet and the main reservoir.

The concept design is similar to the Ravine Bay design in that it incorporates an in-reservoir D&B spoil pad below the FSL of Tantangara Reservoir. It is noted that the pad is well above the typical existing operating levels of the reservoir and is not expected to be inundated during construction unless a significant flood event were to occur. Hence, it can be constructed using land-based methods.

A combination of D&B and TBM spoil will be placed on top of the in-reservoir pad and on adjoining land that is above the FSL.

When Snowy 2.0 commences operations, the in-reservoir pad will be inundated when Tantangara Reservoir is filled to near FSL. A rock armour layer comprising >200 mm D&B spoil will be placed along the edge of the below FSL pad to provide additional stability and erosion protection when it is inundated. The following filters will also be constructed:

- A geotextile filter will be installed at the interface of the in-reservoir pad and land-based emplacement to reduce the propagation of fines from the overlying TBM spoil into the in-reservoir pad. The filter will comprise a A44 or similar geofabric, with pore sizes of 75 µm.

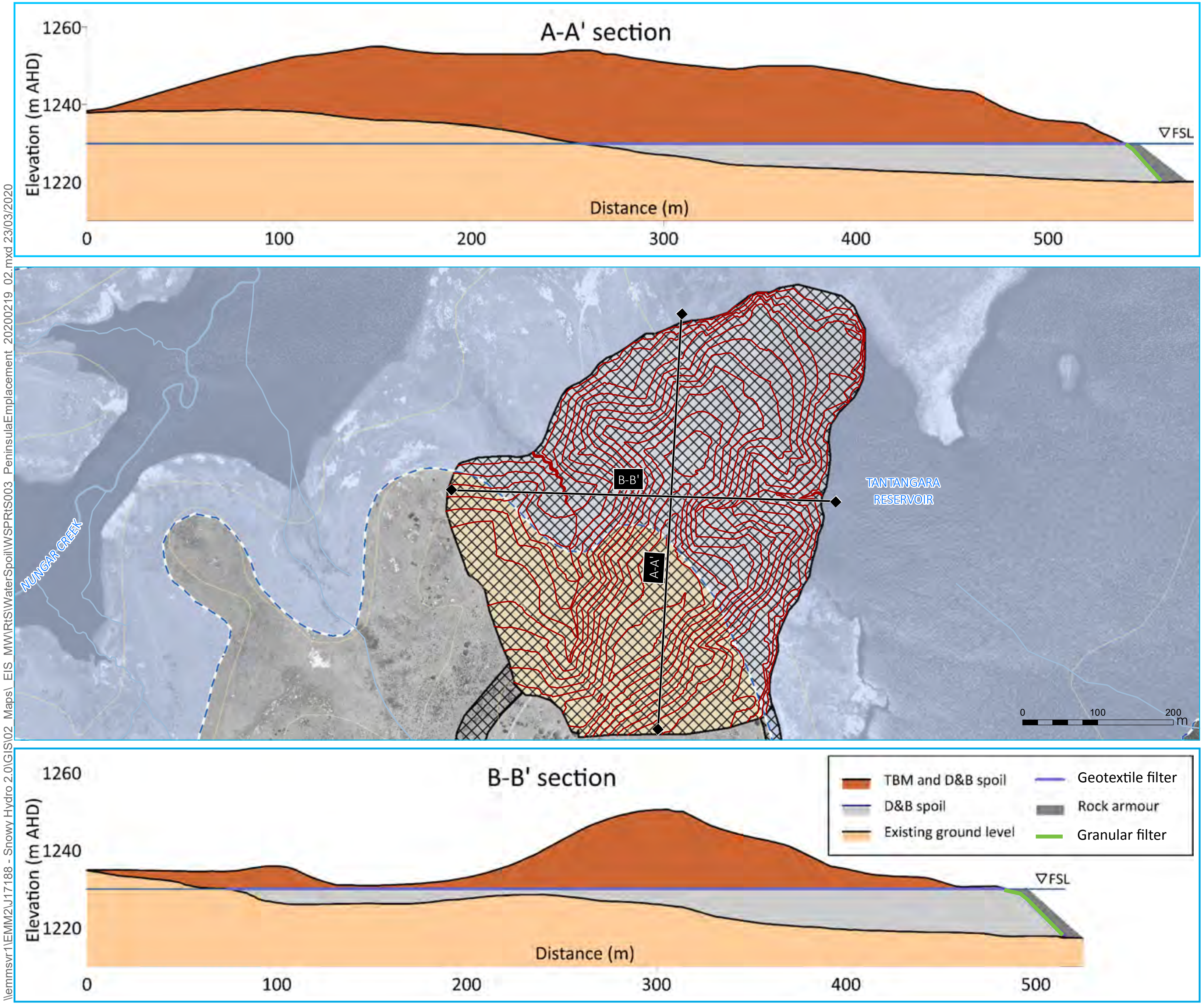
- A granular filter will be installed between the D&B pad and rock armour layer to minimise the propagation of fines from the D&B pad to the reservoir. Design options for the granular filter are described in Appendix C.

The concept design describes the in-reservoir emplacement to be constructed using D&B material only. Opportunities to blend some TBM material into the in-reservoir emplacement will be assessed at detailed design. This alternative approach may be implemented if it can be demonstrated that the proposed granular filter will achieve the water quality outcomes described in Section 5.2.2 of this report.

As described in Chapter 3, available geochemistry data indicates that NOA is likely to be encountered in the Gooandra Volcanics, which will be excavated within the Tantangara Zone. It is proposed to contain NOA material in the rock emplacements using the methods described in the PIR-RTS. Proposed containment methods will be further developed at concept design completion.

As noted in Table 4.1, the emplacement has a design capacity of 2.9 million m^3, which is proposed to be fully utilised. Figure 4.10 (overleaf) shows a conceptual visualisation of the emplacement and Figure 4.11 (also overleaf) shows the landform concept design. The landforms presented in both figures are based on the design capacity.

Figure 4.10 Peninsula rock emplacement – landform visualisation (Source FGJV)



KEY

Existing environment
- Tantangara Reservoir - Full supply level (FSL)
- Existing contours (10 m)
- Existing watercourse

Project information
- Disturbance boundary
- Land-based emplacement extent
- Proposed surface level contour (2 m)
- Cross-section

Notes:
1) The landform concept design has been prepared by Snowy Hydro and FGJV to inform the PIR-RTS. The concept will be further developed as per the design development program (see report for details).
2) For clarity, only existing watercourses that will be reinstated are shown. Additional drainage lines will need to be constructed as part of the landform rehabilitation.
3)The landform presented is based on the design capacity.

Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

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Peninsula rock emplacement:
landform concept

Snowy 2.0
Excavated rock management strategy:
Concept design information and
water quality assessment
Main Works
Figure 4.11

5 Residual impacts

This chapter describes potential water quality impacts to watercourses and reservoirs associated with the proposed emplacements. Impacts are described separately for land-based and in-reservoir emplacements and for the construction and post construction phases. The description of water quality impacts is informed by geochemistry information presented in Chapter 3, the concept design described in Chapter 4 and the following technical assessments:

- Royal HaskoningDHV 2020, *Snowy 2.0 – Summary of Updated ERP Sediment Plume Modelling Scenario* (provided as Appendix B to this report).
- Royal HaskoningDHV 2020, *Snowy 2.0 – In-reservoir rock emplacements: filter layer concept design* (provided as Appendix C to this report).

This chapter is structured as follows:

- Section 5.1 describes impacts associated with land-based emplacements.
- Section 5.2 describes impacts associated with the in-reservoir portion of the Ravine Bay and Peninsula emplacements.
- Section 5.3 provides a summary of key impact mechanisms, proposed controls and potential receiving water impacts.

5.1 Land-based emplacements

This section describes potential receiving water impacts of land-based emplacements during the construction and post construction phases.

5.1.1 Impacts during construction

The land-based emplacements will be constructed and rehabilitated applying the principles described in Table 4.2. It is expected that construction of each emplacement will take several years. During this time completed portions of the emplacements will be progressively rehabilitated, reducing the active construction area requiring management.

The following sections describe the expected water cycle processes, proposed mitigation measures during emplacement, discharge regimes and receiving water impacts.

i Water cycle processes

During construction the permeability of the landform is likely to be highly variable. It is expected that most direct rainfall onto construction areas will be either absorbed within the spoil and lost to evaporation or infiltrate into and through the emplacement. Water that infiltrates through the emplacement is likely to accumulate in low points in the underlying topography or in any purpose-built drainage systems, where it will flow downgradient and exit via seeps along the toe of the emplacement. There is also potential for some water to infiltrate into underlying shallow groundwater systems.

Surface water runoff from construction areas is expected to occur only during and shortly after intense or prolonged rainfall. Surface water runoff will drain from the landforms via purpose-built drainage systems.

ii Summary of proposed management measures

Design Principle 2.2 (see Table 4.2) describes the following methods to manage runoff and seepage during the construction of the land-based emplacements:

- Where practical, clean water runoff from upslope areas will be diverted around construction areas using either gravity or pump assisted diversions.

- Where practical, runoff and seepage from emplacement areas will drain to sedimentation basins designed to capture the 85th percentile 5-day rainfall event. Larger basins (ie sized to capture the 90th or 95th percentile 5-day rainfall event) may be constructed in areas where the topography is favourable and space is available. Captured water will be dewatered from the basins within 5 days following the cessation of a rainfall event and will be either:

  - applied to access roads or stockpiles for dust suppression;

  - irrigated to vegetated areas; and/or

  - treated with appropriate water treatment chemicals and discharged.

The construction phase management measures will be maintained until rehabilitation in the contributing catchment area is established.

iii Discharge regimes and locations

As per Design Principle 2.2 (see Table 4.2), where practical, runoff and seepage from emplacement areas will be captured in sedimentation basins and captured water will be dewatered from the basins within 5 days following the cessation of a rainfall event. Discharges are expected to occur when sedimentation basins fill and overflow. This is only expected to occur following intense and/or prolonged rainfall events when surface runoff from construction areas occurs. A basin sized to capture runoff from the 85th percentile 5-day rainfall event is expected to overflow approximately 4-6 times per year (WMR Appendix J to the PIR-RTS). Larger basins would reduce this frequency.

Any seepage from the emplacements that enters the sedimentation basins is likely to occur at slow rates and can be actively managed via dewatering to avoid any overflows.

iv Water quality profile and receiving water impacts

The proposed sedimentation basins are expected to effectively manage coarse sediment. However, overflows from the basins may have elevated turbidity if fines are mobilised in surface water runoff from the construction area. ASLP results for oxic conditions, which are the most likely conditions for surface water spoil contact, indicate that surface water runoff may be moderately alkaline in pH and have elevated aluminium concentrations. Refer to Table 3.6 for further information on ASLP results for each construction zone.

Residual impacts to receiving waters have not been quantitatively assessed. However, it is expected that:

- Overflows from sedimentation basins will only occur during and shortly after significant wet weather events when elevated streamflow in receiving waters is likely to occur.

- The water quality impacts described in the WMR (Appendix J to the PIR-RTS) for construction phase 2 will increase but will be lower in magnitude to the construction phase 1 impacts.

5.1.2 Post construction impacts

The land-based emplacements will be constructed and rehabilitated applying the principles described in Table 4.2, which collectively are intended to achieve physically and chemically stable landforms that have similar characteristics to the surrounding landscapes and are revegetated with native endemic vegetation. The following sections describe the expected water cycle processes, proposed mitigation measures, discharge regimes and receiving water impacts.

i Water cycle processes

It is expected that most direct rainfall onto the landforms will be absorbed in the upper spoil/soil matrix and lost to evapotranspiration processes. Infiltration into the underlying spoil is anticipated due to the following processes:

- **Infiltration of direct rainfall** – infiltration from the upper spoil/soil matrix into the underlying emplacement is likely to occur following prolonged periods of wet weather and during snow melt events. Most infiltration is expected to occur during winter and spring when evapotranspiration rates are low, and rainfall is generally persistent. Infiltration during summer and autumn is only anticipated following significant rainfall.

- **Seepage losses from watercourses that traverse the landform –** As described in Chapter 4, it is proposed to reinstate watercourses over the Ravine Bay, GF01 and Main Yard emplacements. These watercourses have intermittent flow regimes with persistent streamflow occurring in winter and spring and ephemeral streamflow in summer and autumn (EIS Appendix J, Annexure A). Some seepage losses from these watercourses are expected, with any seepage likely to infiltrate into the underlying spoil.

Water that infiltrates through the emplacement is expected to accumulate in low points in the underlying topography or in any purpose-built drainage systems, where it will flow downgradient and exit via seeps along the toe of the emplacement. There is also potential for some water to infiltrate into underlying shallow groundwater systems. Most seepage from the land-based components of the Ravine Bay and Peninsula emplacements is likely to seep into the underlying in-reservoir D&B pad and ultimately enter the reservoirs.

Surface water runoff from emplacements is also anticipated during and shortly after intense or prolonged rainfall.

ii Summary of proposed management measures

The land-based emplacements will be constructed and rehabilitated applying the principles described in Table 4.2. The relevant principles are:

- Emplacement methods – Design Principles 1.2, 1.3 and 1.4; and

- Landform design and rehabilitation – Design Principles 3.1 to 3.5.

iii Discharge regimes and locations

As described above, water that infiltrates into and through the emplacements is expected to accumulate in low points in the underlying topography or in any purpose-built drainage systems, where it will flow downgradient and exit via seeps along the toe of the emplacement. There is also potential for some water to infiltrate into underlying shallow groundwater systems. Most seepage from the land-based components of the Ravine Bay and Peninsula emplacements is likely to seep into the underlying in-reservoir D&B pad and ultimately enter the reservoirs. Table 5.1 describes the expected seepage flow paths and receiving water for each emplacement.

Table 5.1 Receiving waters – seepage from land-based emplacements

Emplacement	Receiving water
Ravine Bay	Most water that infiltrates into and through the land-based component of the emplacement is expected to seep into the underlying in-reservoir D&B pad and ultimately enter Talbingo Reservoir.
GF01	Seepage is likely to exit the landform at the toe of the south-western emplacement batter and flow into the existing 2nd order watercourse. This watercourse flows into the Yarrangobilly River arm of Talbingo Reservoir. Some infiltration into the underlying shallow groundwater system may also occur.
Main Yard	Seepage is likely to exit the landform at multiple locations along the north-eastern boundary of the emplacement that adjoins the Yarrangobilly River floodplain and flow into the Yarrangobilly River. There is also potential for seepage to infiltrate into underlying colluvium and alluvium that is connected to the Yarrangobilly River.
Rock Forest	Seepage is likely to exit the landform at multiple locations along the northern and eastern emplacement boundaries. All seepage is expected to flow into Camerons Creek. Some infiltration into the underlying shallow groundwater system may also occur.
Peninsula	Most water that infiltrates into and through the land-based component of the emplacement is expected to seep into the underlying in-reservoir D&B pad and ultimately enter Tantangara Reservoir.

As with infiltration regimes, persistent seeps are expected during winter and spring. Seeps during summer and autumn are only expected following significant rainfall.

Surface water runoff will drain from the landforms via purpose-built drainage systems and reinstated watercourses. Runoff is only anticipated during and shortly after intense or prolonged rainfall.

iv Water quality profile and receiving water impacts

a Seepage

The ASLP results presented in Section 3.2.3 describe the potential water quality of seepage from emplacements in each construction zone. Seepage is a term used to describe water that flows through and out of a land-based rock emplacement. As described in Design Principle 1.3 (Table 4.2), it is proposed to blend any identified PAF material with appropriate volumes of acid consuming material to mitigate acid related risks. Hence, ASLP results for oxic and anoxic conditions are likely to be the most representative of the water quality of seepage. Refer to Table 3.6 for further information on ASLP results for each construction zone.

Residual impacts to receiving waters have not been quantitatively assessed. However, the following potential changes to water quality are expected:

- **GF01, Main Yard and Rock Forest emplacements**:
  - The water quality in immediate receiving waters (ie 1st to 3rd order watercourses that receive no flows other than seepage from the emplacement) is likely to be similar to the water quality described in Table 3.6. This may result in a long-term change to the existing water quality in these watercourse reaches. Figure 5.1 shows the potentially impacted watercourse reaches.
  - Any seepage that enters a larger watercourse such as the Yarrangobilly River would be significantly diluted and is therefore unlikely to materially change the existing water quality. It is noted that seepage is most likely to occur during winter and spring when streamflow in larger watercourses is at seasonal highs and is unlikely to occur during dry periods in summer and autumn when streamflow in larger watercourses is at seasonal lows (EIS Appendix J, Annexure A).

- Potential impacts to the water quality of shallow groundwater systems have not been assessed. However, any impacts are expected to be localised.

- **Ravine bay and Peninsula emplacements:** most seepage from the land-based components of the Ravine Bay and Peninsula emplacements is likely to flow into the underlying in-reservoir D&B pad and ultimately enter the reservoirs via the water exchange process that is described in Section 5.2.2.

b Surface water runoff

Surface water runoff from the rehabilitated landforms is anticipated to have water quality similar to the water quality of undisturbed small (1st to 3rd order) watercourses. Hence, no receiving water impacts are expected.

5.2 In-reservoir emplacements

As described in Chapter 4, the Ravine Bay and Peninsula emplacements include an in-reservoir pad constructed using D&B spoil from the reservoir bed up to FSL. The Ravine Bay emplacement will be constructed within Talbingo Reservoir using the edge push method (described in Section 4.3). The Peninsula emplacement will be well above the operating levels of Tantangara Reservoir and can therefore be constructed as a land-based emplacement.

This section describes receiving water impacts during construction (for Ravine Bay only) and post construction (both Ravine Bay and Peninsula), which includes consideration of the operation of Snowy 2.0.

KEY

Existing environment
- Existing contours (5 m)
- Existing watercourse

Project information
- Disturbance boundary
- Land-based emplacement extent
- Proposed surface level contours (2 m)
- Watercourse reach that may be impacted by seepage

Notes:
1) The landform concept design has been prepared by Snowy Hydro and FGJV to inform the PIR-RTS. The concept will be further developed as per the design development program (see report for details).
2) For clarity, only existing watercourses that will be reinstated are shown. Additional drainage lines will need to be constructed as part of the landform rehabilitation.
3)The landform presented is based on the design capacity.

Potentially impacted watercourse reaches

Snowy 2.0
Excavated rock management strategy:
Concept design information and water quality assessment
Main Works
Figure 5.1

Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

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5.2.1 Impacts during construction

As noted above, the in-reservoir component of the Ravine Bay emplacement will be constructed using the edge push method. This method involves pushing D&B spoil into Talbingo Reservoir using conventional machinery, such as a bulldozer. As noted in Section, 2.1, D&B spoil is expected to be a gravely/cobbly material with a small amount of fines. For the purpose of assessing impacts, it is assumed that D&B spoil (pre-placement) contains 2% (by mass) fines (< 63 micron). As the spoil is placed into the reservoir, a significant portion of material will be suspended in the water column. Cobbles, gravels and coarse sediment are expected to settle rapidly near the emplacement location. However, fines (silts and clays) are expected to settle very slowly or remain suspended. This can potentially result in suspended sediment and turbidity plumes in nearby portions of the reservoir. There is also potential for other water quality impacts such as changes to pH, and the release of nutrients and metals due to spoil water contact during placement and the entrainment of fine material in the water column.

The following sections describe proposed mitigation measures implemented during emplacement and predicted impacts to reservoir water quality.

i Summary of proposed management measures

As per Design Principle 2.1 (see Table 4.2), silt curtains will be used to reduce the horizontal movement of water from the emplacement area into the greater reservoir. The optimal depth and alignment of each curtain will be established at detailed design. During construction, the depth and alignment can be further adjusted (using real-time monitoring) to optimise performance.

ii Impacts to reservoir water quality

An assessment of impacts to the water quality of Talbingo Reservoir is informed by numerical modelling undertaken by Royal HaskoningDHV (RHDHV) and elutriate test results that are described in Section 3.2.4. The assessment approach and results are described below. Reference is made to the RHDHV technical report (2020) that is provided as Appendix B.

a Approach – numerical modelling

RHDHV applied a three-dimensional hydraulic model of Talbingo Reservoir coupled with a sediment transport model to simulate suspended sediment (as TSS) plumes at near-surface, mid-depth and the reservoir bottom over a 36-month period. Key assumptions applied to the model include:

- The model simulates the placement of 1.5 million m^3 (bank volume) over a 33-month period. The peak placement rate is approximately 100,000 m^3 (bank volume) per month.
- D&B spoil contains 2% (by mass) fines (< 63 micron), which includes 0.3% of fines in the clay fraction.
- 45% of total silt and 60% of total clay will be suspended in the water column during placement.

The model results are presented in Appendix B:

- as TSS concentration time-series (at near-surface, mid-depth and the reservoir bed) at eleven locations within Talbingo Reservoir; and
- spatially as the 50^{th}, 95^{th} percentile and maximum TSS concentrations (at near-surface) that were calculated from results over the 36-month simulation period.

Select results are presented and discussed below. Refer to Appendix B for detailed results.

b Approach – application of elutriate test results

Section 3.2.4 describes elutriate testing that was undertaken by CSIRO to assist in assessing the potential impacts of the placement of excavated rock materials on water and sediment quality in Talbingo Reservoir.

Elutriate tests assess potential changes to water quality due to spoil water contact that will occur during placement and as a result of the entrainment of fine material in the water column. The tests covered a wide range of mixing/leaching scenarios and conditions, and included testing for the range of analytes provided in Table 3.4. The tests identified that pH, EC and aluminium frequently exceeded WQOs, with dissolved aluminium being the only substance consistently identified as a contaminant of potential concern (CSIRO 2019b). Relationships between TSS concentration and pH and between TSS concentration and dissolved aluminium concentrations were established from the test results (see Figure 3.3 and Table 3.7, respectively). This analysis concluded that at TSS concentrations below 100 mg/L:

- the pH is likely to be less than pH 8, and within the WQO range for the reservoir; and
- aluminium release (9-16 µg/L) is predicated to be similar to the background aluminium concentration in the reservoir and well below the WQO value of 55 µg/L.

Hence, the TSS 100 mg/L contour (calculated from the numerical model results) has been applied to spatially describe a conservative mixing zone for pH and aluminium.

c Summary of impacts

Select numerical model results are provided in the following figures:

- Figure 5.2 and Figure 5.3 (overleaf) show the TSS concentrations at near-surface, mid-depth and the reservoir bed at model output location 9 (approximately 1 km north of Ravine Bay) and model output location 1 (near the dam wall). The results indicate that TSS concentrations will generally be below 10 mg/L 1 km north of Ravine Bay and will be less than 5 mg/L at the dam wall.
- Figure 5.4 (also overleaf) compares the 95th percentile and maximum TSS concentrations (at near-surface) that were provided by RHDHV. The TSS 100 mg/L contour is shown for context. This figure shows the upper bound extent of TSS impacts in Talbingo Reservoir and the conservatively estimated spatial extent of mixing zones for pH and aluminium. It is noted that there is a significant difference between the 95th percentile concentrations (which are only exceeded 5% of the time).

Refer to Appendix B for further results and description of predicted TSS impacts to Talbingo Reservoir.

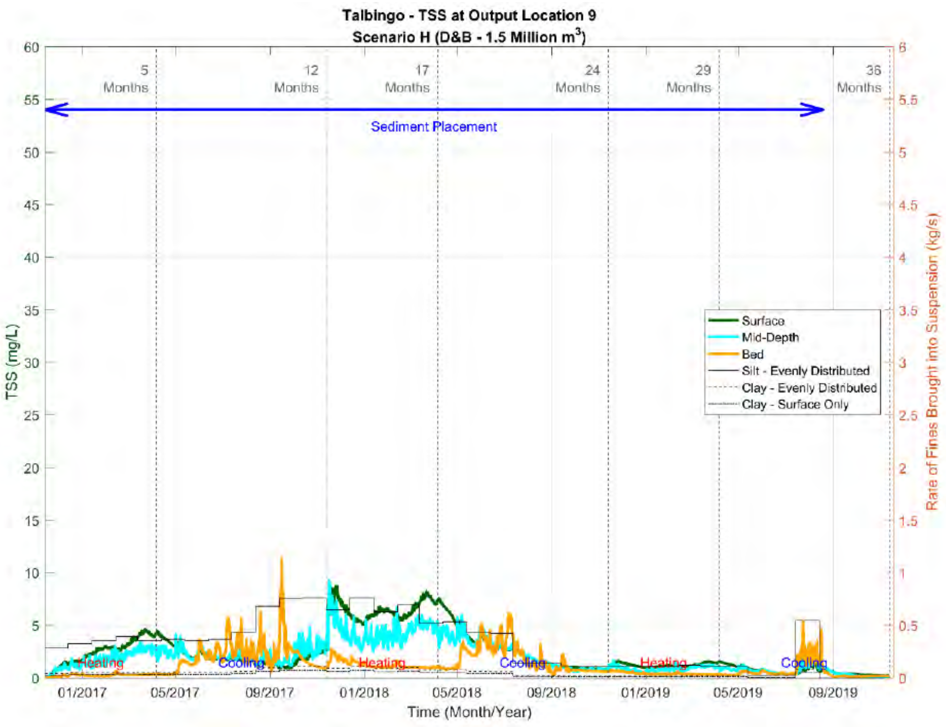


Figure 5.2 TSS results at location 9 (~1 km to the north of Ravine Bay)

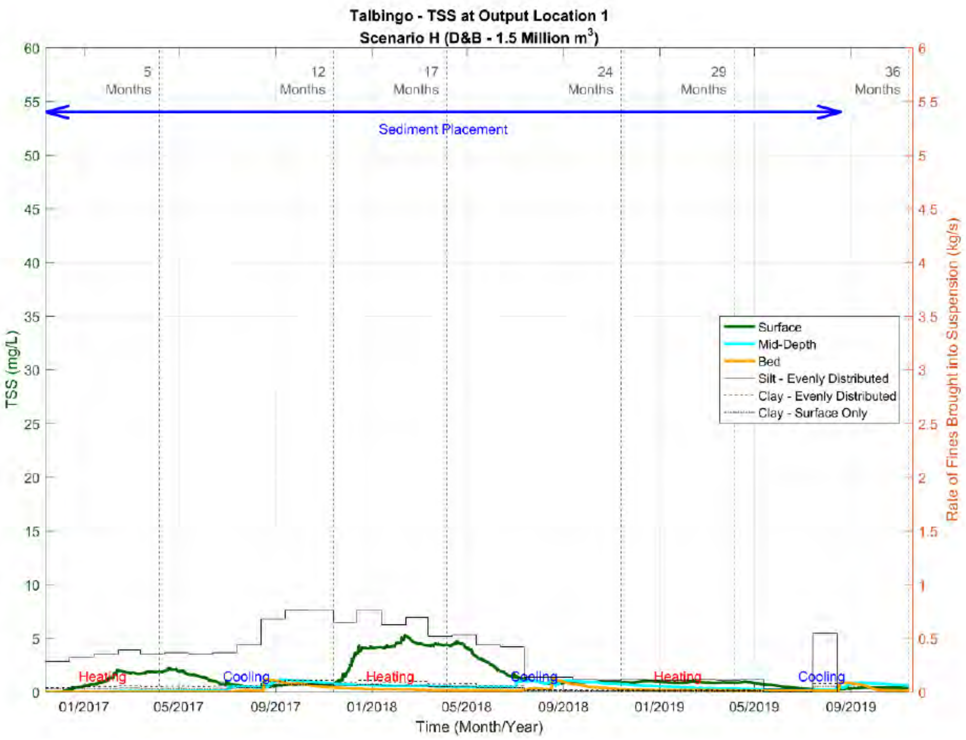
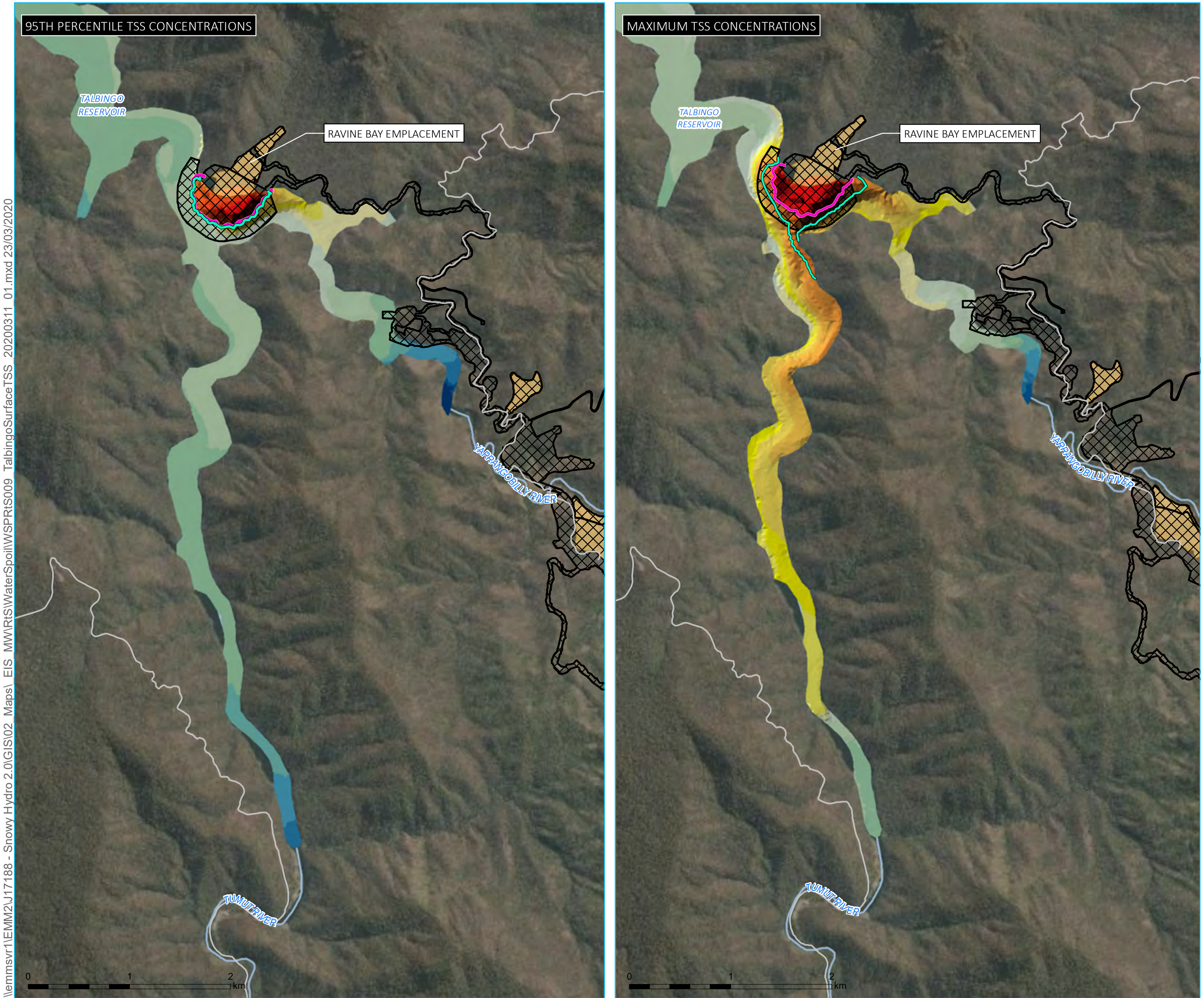


Figure 5.3 TSS results at location 1 (near Talbingo Dam wall)



Source: EMM (2020); Snowy Hydro (2020); DFSI (2017); LPMA (2011)

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KEY

Existing environment

- Main road
- Local road
- Watercourse

Project information

- Disturbance boundary
- PIR-RTS indicative emplacement area
- TSS 100 mg/L contour
- Location of simulated silt curtain (RHDHV)

Surface suspended solids (mg/L)

- 500 +
- 400 - 500
- 300 - 400
- 200 - 300
- 150 - 200
- 100 - 150
- 70 - 100
- 50 - 70
- 40 - 50
- 30 - 40
- 25 - 30
- 20 - 25
- 15 - 20
- 10 - 15
- 7 - 10
- 5 - 7
- 4 - 5
- 3 - 4
- 2 - 3
- 1 - 2
- 0 - 1

Model results provided by Royal HaskoningDHV.
Refer to report for details.

Numerical model results overview - Ravine Bay construction phase

Snowy 2.0
Excavated rock management strategy:
Concept design information
and water quality assessment
Main Works
Figure 5.4

snowy 2.0

EMM creating opportunities

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iii Difference to PIR-RTS construction assessment approach at Ravine Bay

Figures 3.10 and 3.11 of the PIR-RTS presented time series charts for the modelled TSS levels resulting from the in-reservoir Ravine Bay spoil emplacement. These time series charts were based on realistic concept design predictions of the volume of material to be disposed of in Ravine Bay, which was approximately 700,000 m^3 (bank volume). The PIR-RTS did however also detail that the design capacity of the Ravine Bay in-reservoir emplacement would be approximately 1.8 million m^3 (placed volume), equivalent to 1.5 million m^3 (bank volume).

As final disposal volumes will change throughout design development and to ensure that the impact assessment presents a conservative scenario, the numerical results presented in Section 5.2.1 of this report have been based on the design capacity of the in-reservoir emplacement (1.5 million m^3 bank volume) rather than the predicted volume (700,000 m^3 bank volume).

The difference between the modelled TSS results presented in the PIR-RTS and this assessment are detailed in Table 5.2.

Table 5.2 Peak surface TSS concentration differences (PIR-RTS/design capacity)

	Peak surface TSS concentration (mg/L) - PIR-RTS	Peak surface TSS concentration (mg/L) - Design capacity
Location 1 (near the dam wall)	2.5	5
Location 9 (1 km north of Ravine Bay)	5	9

While the predicted TSS impacts based on the volume of material for the design capacity of the Ravine Bay in-reservoir emplacement are greater than that presented in the PIR-RTS, the results still demonstrate greatly improved water quality outcomes compared to those presented in the EIS.

5.2.2 Post construction impacts

Both the Ravine Bay and Peninsula in-reservoir D&B pads will be constructed from the reservoir bed up to FSL. During the operation of Snowy 2.0, water exchange between in-reservoir D&B spoil pads and the adjoining reservoir will occur primarily due to changes in reservoir water level. Water draining out of the pads has potential to contain elevated TSS and turbidity (due to the entrainment of fines). Other water quality impacts such as changes to pH, and elevated nutrients and metals can also occur due to spoil water contact.

The following sections provide an overview of the construction methods, describe the expected water cycle processes, discharge regimes and potential receiving water impacts. This section references Appendix C, which describes concept design options and the effectiveness of the proposed filters.

i Overview of construction methods

Table 5.3 provides an overview of the emplacement construction methods (that are described in Chapter 4) and information on the associated porosity, permeability and fines content of the placed material. This information is relevant to the assessment of potential receiving water impacts.

Table 5.3 In-reservoir emplacement – overview of construction methods and key characteristics

	Ravine Bay	Peninsula
Overview of construction methods/concept design		
Spoil placement method	D&B spoil will be placed into the reservoir using the edge push method (described in Section 4.3). The material will be placed at the angle of repose and will be unconsolidated.	D&B spoil will be placed in horizontal layers that are approximately 300 mm thick and compacted to reduce volume and permeability.
Rock armouring	A rock armour layer comprising >200 mm D&B spoil will be placed along the edge of the pad to provide additional stability and erosion protection. Some of this material can be placed using a barge or long reach excavator to achieve a batter slope that is flatter than the natural angle of repose.	A rock armour layer comprising >200 mm D&B spoil will be placed along the edge of the pad to provide additional stability and erosion protection. The rock armouring will be constructed using conventional machinery.
Filters	A geotextile filter will be installed at the interface of the in-reservoir D&B pad and the overlying land-based emplacement to reduce the propagation of fines from the overlying TBM spoil into the in-reservoir D&B pad. The filter will comprise a A44 or similar geofabric, with pore sizes of 75 µm.	The following filters are proposed: • A geotextile filter will be installed at the interface of the in-reservoir D&B pad and land-based emplacement to reduce the propagation of fines from the overlying TBM spoil into the in-reservoir D&B pad. The filter will comprise a A44 or similar geofabric, with pore sizes of 75 µm. • A granular filter will be installed between the D&B pad and rock armour layer to minimise the propagation of fines from the D&B pad to the reservoir. Design options for the granular filter are described in Appendix C.
D&B pad characteristics		
Porosity and permeability	The porosity and permeability of placed material is expected to be greater than material placed in the Peninsula emplacement as the material will be unconsolidated and will be 'washed' during placement, reducing the fines content.	The porosity and permeability of placed material is expected to be lower than material placed in the Ravine Bay emplacement as the material will be compacted during placement.
Fines content	Potentially <1%[1] of the total mass as the material will be 'washed' during and shortly after placement (due to water exchange processes).	Approximately 3%[2] of the total mass as compaction can increase the fines content.
Depth to width ratio	With reference to Section B-B in Figure 4.3, the in-reservoir D&B pad will be approximately 35 m deep and 200 m wide. Hence the depth to width ratio is approximately 1 to 6.	With reference to Section A-A in Figure 4.11, the in-reservoir D&B pad will be approximately 10 m deep and 250 m wide. Hence the depth to width ratio is approximately 1 to 25.

Notes: 1. The estimated fines content is based on D&B spoil having a 2% fines content pre-placement.
2. Estimated by RHDHV (see Appendix C).

ii Water cycle processes

Water exchange between in-reservoir D&B spoil pads and the adjoining reservoir will occur primarily due to changes in reservoir water level, with water entering the pads when the water level is rising and draining out of the pads when the water level is receding. Some mixing is also likely to occur due to convection and dispersion processes as well as wave action.

The rate of water exchange between the reservoir and D&B spoil pads has not been quantitatively assessed, but will primarily be a function of the:

- Porosity and permeability of the placed D&B material. As described Table 5.3 the permeability and porosity of placed D&B material in the Peninsula emplacement is expected to be lower than the placed D&B material in the Ravine Bay emplacement (due to different construction methods).
- Geometry of the inundated portion of the in-reservoir D&B pad. Water exchange rates will be a function of the depth to width ratio, with larger ratios having higher exchange rates. As described in Table 5.3, the depth to width ratio for the Ravine Bay emplacement (1 to 6) is approximately four times smaller than the depth to width ratio for Peninsula (1 to 25).
- Water level regime in the reservoirs, which is expected to be variable in both reservoirs once Snowy 2.0 is operational.

In summary, the rate of water exchange between the Peninsula emplacement and Tantangara Reservoir is likely to be lower (potentially by a significant margin) than the rate of water exchange between the Ravine Bay emplacement and Talbingo Reservoir. This is due to the Peninsula emplacement having lower porosity and permeability and a larger depth to width ratio. A lower rate of water exchange implies a reduced potential for impacts to reservoir water quality as water will drain more slowly from the emplacements reducing the potential for, or magnitude of, any concentration impacts in adjoining reservoir areas.

iii Water exchange regimes and locations

Water exchange is expected along the interface between the in-reservoir D&B spoil pads and the reservoir (see Figure 4.3 for Ravine Bay and Figure 4.11 for Peninsula emplacements). Most exchange is expected to occur when reservoir levels recede, allowing water to drain out of the in-reservoir D&B spoil pads into the reservoir. Small amounts of exchange are expected during other times due to convection and dispersion processes and wave action.

iv Potential receiving water impacts

a Qualitative assessment of reservoir impacts

Impacts to water quality have not been assessed quantitatively. However, they are expected to be a function of:

- Water exchange rates (as described above).
- The potential for changes to pH and elevated nutrients and metals due to spoil water contact.
- The fines content of the in-reservoir D&B spoil pads, the potential for fines mobilisation and the effectiveness of the proposed filters in mitigating the propagation of fines into the reservoirs.

Table 5.4 (overleaf) presents a qualitative assessment of reservoir impacts, applying information established earlier in this section and:

- the ASLP results that are presented in Section 3.2.3; and
- advice from RHDHV on the effectiveness of the proposed filters (see Appendix C).

Table 5.4 Qualitative assessment of potential impacts to reservoir water quality

Key considerations	Discussion	Receiving water impacts: Tantangara Reservoir	Receiving water impacts: Talbingo Reservoir
1 – Propagation of fines from in-reservoir D&B pads			
1.1 – Water exchange rates between in-reservoir D&B pads and the reservoir	A lower rate of water exchange implies a reduced potential for impacts to reservoir water quality as water will drain more slowly from the emplacements, reducing the potential for, or magnitude of, any concentration impacts in adjoining reservoir areas.	As discussed earlier in Section 5.2.1iii, water exchange from the Peninsula emplacement is expected to occur at lower rates (potentially by a significant margin) than from Ravine Bay. This is due to the Peninsula emplacement having lower porosity and permeability and a larger depth to width ratio.	
1.2 – Fines availability	The D&B material will be widely graded. It is possible that fines within this material (particularly particles in the clay fraction) will flow towards the reservoir (during water exchange events) through the interstitial space between larger grains/cobbles. A higher portion of available fines (especially in the clay fraction) may result in higher TSS concentrations and turbidity levels in water exchange from the pad and a longer duration of any impact.	As described in Table 5.3, the Peninsula emplacement is estimated by RHDHV to have a fines content of approximately 3% compared to potentially <1% at Ravine Bay. The difference in fines content is due to the following factors: • material emplaced in Ravine Bay will be 'washed' during and shortly after placement (due to water exchange processes); and • the compaction of material in peninsula may increase the fines content.	
1.3 – Effectiveness of the geotextile filter between the interface of the in-reservoir D&B pad and the overlying land-based emplacement	The proposed geotextile filter concept is expected to be effective in reducing the propagation of fines from the overlying TBM spoil into the in-reservoir D&B pad as it is likely to be blinded (or clogged) over time. Refer to Appendix C for further information.	The proposed concept is expected to effectively mitigate the risk of fines leaching from the overlying TBM spoil into the in-reservoir D&B pad, where available fines could flow into the reservoir via water exchange processes. Refer to Appendix C for further information.	
1.4 – Effectiveness of the granular filter between the interface of the in-reservoir D&B pad and the reservoir (Peninsular only)	The proposed granular filter concept is expected to effectively mitigate the leaching of fines into Tantangara Reservoir. Refer to Appendix C for further information.	No material impacts are expected due to the effectiveness of the proposed granular filter.	Not applicable.
1 – Overall risk		No material impacts are expected due to the effectiveness of the proposed granular filter. As a result, numerical modelling to determine the impact on water quality is not considered necessary.	It is expected that most of the available fines in the Ravine Bay emplacement will have been 'washed' or flushed from the emplacement during the construction phase, which will take approximately three years. Hence, any post construction impacts are likely to be minor (ie significantly less than construction impacts described in Section 5.2).

Table 5.4 Qualitative assessment of potential impacts to reservoir water quality

Key considerations	Discussion	Receiving water impacts: Tantangara Reservoir	Receiving water impacts: Talbingo Reservoir
2 – Potential changes to pH and elevated nutrients and metals due to spoil water contact			
2.1 – Water exchange rates between in-reservoir D&B pads and the reservoir	As per item 1.1.	As per item 1.1.	As per item 1.1.
2.2 – Change to water quality	The ASLP results presented in Section 3.2.3 describe the potential quality of reservoir water that is exposed to spoil. The results for oxic conditions are expected to be the most representative of potential changes to water quality during water exchange events.	Potential water quality (from Table 3.6): • Moderately alkaline (pH ranges from 8.2 to 9.9). • Low leachable salts (EC ranges from 43 to 116 µS/cm) – ambient levels in Tantangara Reservoir range from 14 - 22 µS/cm (WMR). • Total nitrogen is likely to be similar to WQO values for reservoirs. • Aluminium is likely to exceed the WQO for reservoirs by a factor of 8. • Concentrations of other metals are likely to be below WQO values for reservoirs.	Potential water quality (from Table 3.6): • Moderately alkaline (pH ranges from 8.1 to 10). • Low leachable salts (EC ranges from 42 to 239 µS/cm) – ambient levels in Talbingo Reservoir range from 22 -27 µS/cm (WMR). • Total nitrogen is likely to be similar to or below WQO values for reservoirs. • Aluminium is likely to exceed the WQO for reservoirs by a factor of 7. • Concentrations of other metals are likely to be below WQO values for reservoirs.
2 – Overall risk		ASLP results indicate that water draining from the in-reservoir emplacements will have an alkaline pH, salinity that is greater than ambient levels and dissolved aluminium concentrations that exceed the WQOs for reservoirs by a factor of 7 to 8. It is expected that there will be a near-field mixing zone (likely to be in the order of 10s of metres) around the emplacements. It is expected that the magnitude of any impacts will gradually decline over time as leachable salts and metals are released from the spoil.	

5.3 Summary of impacts

Table 5.5 provides a summary of key impact mechanisms, proposed controls and potential receiving water impacts.

Table 5.5 Summary of potential impacts

	Impact mechanism	Proposed controls	Potential impacts
1 - Land-based emplacements			
1.1 - Construction phase (all emplacements)	• Overflows from sedimentation basins during wet weather.	• Sedimentation basins and other erosion and sediment controls. • Captured water will be de-watered from basins within 5 days following the cessation of each rainfall event.	Potential impacts to receiving water quality are described qualitatively based on a review of the effectiveness of the proposed controls and leachate test results. Key impacts include: • Overflows from sedimentation basins will only occur during and shortly after significant wet weather events when elevated streamflow in receiving waters is likely to occur. • The water quality impacts described in the Water Management Report (Appendix J to the PIR-RTS) for construction phase 2 will increase but will be lower in magnitude to the construction phase 1 impacts.
1.2 - Post construction (all emplacements)	• **Seepage (GF01, Main Yard and Rock Forest) -** water that infiltrates into the GF01, Main Yard and Rock Forest emplacements is expected to exit via seeps along the toe of the emplacements. There is also potential for some water to infiltrate into underlying shallow groundwater systems. • **Seepage (Ravine Bay and Peninsula) -** most seepage from the land-based components of the Ravine Bay and Peninsula emplacements is likely to flow into the underlying in-reservoir D&B pad and ultimately enter the reservoirs. • **Surface water runoff** - from the landforms is anticipated during and shortly after intense or prolonged rainfall.	• The land-based emplacements will be constructed and rehabilitated to achieve physically and chemically stable landforms that have similar characteristics to the surrounding landscapes. The emplacements will be revegetated with native endemic vegetation. The concept design includes a range of construction and rehabilitation measures to achieve this objective. Refer to Chapter 4 for details.	Potential impacts to receiving water quality are described qualitatively based on a review of the effectiveness of the proposed controls and leachate test results. Key impacts include: • **Seepage (GF01, Main Yard and Rock Forest) -** impacts to receiving waters have not been quantitatively assessed. However, the following potential changes to water quality are expected: – The water quality in immediate receiving waters (ie 1st to 3rd order watercourses that receive no flows other than seepage may include a moderately alkaline pH, elevated aluminium concentrations and other changes to water quality. Refer to Section 5.1.2 for further information. – Any seepage that enters a larger watercourse such as the Yarrangobilly River would be significantly diluted and is therefore unlikely to materially change the existing water quality. – Potential impacts to the water quality of shallow groundwater systems have not been assessed. However, any impacts are expected to be localised. • **Seepage (Ravine Bay and Peninsula) -** most seepage from the land-based components of the Ravine Bay and Peninsula emplacements is likely to flow into the underlying in-reservoir D&B pad and ultimately enter the reservoirs via the water exchange process that is described below (see item 2.2). • **Surface water runoff (all emplacements)** - from the rehabilitated landforms is anticipated to have water quality similar to the water quality of undisturbed small (1st to 3rd order) watercourses. Hence, no receiving water impacts are expected.

Table 5.5 Summary of potential impacts

	Impact mechanism	Proposed controls	Potential impacts
2 - In-reservoir emplacements			
2.1 - Construction phase (Ravine Bay only)	• The in-reservoir component of the Ravine Bay emplacement will be constructed using the edge push method. This method involves pushing D&B spoil into Talbingo Reservoir using conventional machinery, such as a bulldozer. This can result in suspended sediment and turbidity plumes in nearby portions of the reservoir. • Elutriate test results (described in Section 3.2.4) indicates there is potential for changes to pH and the release of aluminium due to spoil water contact during placement and due to the entrainment of fine material in the water column.	• Silt curtains will be used to reduce the horizontal movement of water from the emplacement area into the greater reservoir.	An assessment of potential impacts to the water quality of Talbingo Reservoir was informed by numerical modelling undertaken by Royal HaskoningDHV and elutriate test results that are described in Section 3.2.4. The assessment concluded that: • Total suspended solids (TSS) concentrations will generally be below 10 mg/L 1 km north of Ravine Bay and will be less than 5 mg/L at the dam wall. • pH and aluminium concentrations are unlikely to exceed the Water Quality Objective values when the TSS concentration is <100 mg/L. The TSS concentration is expected to exceed 100 mg/L outside of the silt curtain less than 5% of the time.
2.2 - Post construction (Ravine Bay and Peninsula)	• The Ravine Bay and Peninsula in-reservoir D&B pads will be constructed from the reservoir bed up to FSL. During the operation of Snowy 2.0, water exchange between in-reservoir D&B spoil pads and the adjoining reservoir will occur primarily due to changes in reservoir water level. Water draining out of the pads has potential to contain elevated TSS and turbidity (due to the entrainment of fines) Other water quality impacts such as changes to pH, and elevated nutrients and metals may also occur due to spoil water contact.	**Ravine Bay and Peninsula** • A geotextile filter will be installed at the interface of the in-reservoir D&B pad and the overlying land-based emplacement to reduce the propagation of fines from the overlying TBM spoil into the in-reservoir D&B pad. **Peninsula (only)** • A granular filter will be installed between the D&B pad and rock armour layer to minimise the propagation of fines from the D&B pad to the reservoir.	Potential impacts to reservoir water quality are described qualitatively based on a review of the effectiveness of the proposed controls and leachate test results. Key impacts include: • **Fines (Ravine Bay)** - It is expected that most of the available fines in the Ravine Bay emplacement will have been 'washed' or flushed from the emplacement during the construction phase, which will take approximately three years. Hence, any post construction impacts are likely to be minor. • **Fines (Peninsula) -** No material impacts are expected due to the effectiveness of the proposed granular filter. As a result, numerical modelling to determine the impact on water quality is not considered necessary. • **Other water quality parameters (Ravine Bay and Peninsula)** - Leachate results indicate that water draining from the emplacements will have an alkaline pH, salinity that is greater than ambient levels and dissolved aluminium concentrations that exceed the WQOs for reservoirs by a factor of 7 to 8. It is expected that there will be a near-field mixing zone (likely to be in the order of 10s of metres) around the emplacements. It is expected that the magnitude of any impacts will gradually decline over time as leachable salts and metals are released from the spoil.

6 References

ANZECC & ARMCANZ 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand Environment Conservation Council and Agriculture and Resource Management Council of Australian and New Zealand.

ANZG 2018, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia, Available at www.waterquality.gov.au/anz-guidelines

Cardno 2019, *Snowy 2.0 Excavated Rock Placement*: *Excavated Rock Placement Assessment Summary* (EIS Appendix L), report prepared for EMM Consulting Pty Limited by Cardno (NSW/ACT) Pty Ltd.

CSIRO 2018, *Snowy 2.0 P1: Comprehensive Geochemistry Examination Final Report* (EIS Appendix L, Annexure A), report prepared by Commonwealth Scientific and Industrial Research Organisation for Haskoning Australia on behalf of Snowy Hydro Limited.

- CSIRO 2019a, *Snowy 2.0 P2: Environmental Risk Categorisation of Rock Materials* (EIS Appendix L, Annexure B).
- CSIRO 2019b, *Snowy 2.0 P4: Environmental Characterisations of Excavated Rock Interactions with and Potential Impacts on Reservoir Waters and Sediments* (EIS Appendix L, Annexure C).
- CSIRO 2019c, *Snowy 2.0 P5: Ecotoxicology Assessment of Excavated Rock Leachates in Water and Excavated Rock-Sediment Mixtures* (EIS Appendix L, Annexure D).
- CSIRO 2019d, *Dissolved Aluminium Assessment for Talbingo Reservoir* (EIS Appendix L, Annexure E).

EMM 2019, *Environmental Impact Statement: Main Works for Snowy 2.0: Appendix J Water Assessment*, prepared for Snowy Hydro Limited by EMM Consulting Pty Limited.

- EMM 2020, *Preferred Infrastructure Report and Response to Submissions: Main Works for Snowy 2.0: Appendix J Revised Water Management Report*.

Geological Survey of NSW, *Naturally Occurring Asbestos Risk Mapping*, https://www.resourcesandgeoscience.nsw.gov.au/miners-and-explorers/safety-and-health/topics/NOA

Geoscience Australia 2019, *Australian Rainfall and Runoff: A Guide to Flood Estimation*, eds Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M & Testoni I, Commonwealth of Australia.

SMEC 2019, *Naturally Occurring Asbestos and Other Hazardous Mineral Fibres*, Issue F 22 March 2018 SC-1704-TCN-016009-F, report prepared for Snowy Hydro Limited by SMEC Australia Pty Ltd.

Abbreviations

Abbreviation	Description
AEP	Annual Exceedance Probability
ANC	Acid neutralisation capacity
ASLP	Australian Standard Leaching Procedure
cm	Centimetre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
D&B	Drill and blast
EC	Electrical conductivity
EIS	Environmental Impact Statement
FGJV	Future Generation Joint Venture
FSL	Full supply level
ICP-MS	Inductively coupled plasma-mass spectrometry
ICP-OES	Inductively coupled plasma optical emission spectrometry
KNP	Kosciuszko National Park
L	Litre
m	Metre
m^3	Cubic metre
mm	Millimetre
mg	Milligram
µg	Microgram
µm	Micrometre
µS	Microsiemens
MPA	Maximum potential acidity
NAG	Net acid generation
NOA	Naturally occurring asbestos
NSW	New South Wales
PAF	Potentially acid forming
PIR-RTS	Preferred infrastructure report - Response to submissions
TBM	Tunnel boring machine
TC	Total carbon
TN	Total nitrogen
TSS	Total suspended solids
WMR	Water management report (Appendix J to the PIR-RTS)
WQO	Water quality objective

Glossary

Term	Definition
Acidic	With low pH, typically lower than pH 6
Anoxic	Depleted of oxygen
Asbestos	Silicate minerals, grouped into six classes, that are composed of long and thin fibrous crystals
Bank volume	The in situ volume of material (ie before excavation)
Baseline sample	Geochemistry sample that constitutes what is believed to be a representative baseline composition for a particular geological group/group culled from a larger number of rock samples
Bulked volume	The volume of material following excavation but prior to emplacement and compaction
Catchment	The land area draining to a point of interest, such as a water storage or monitoring site on a watercourse
Clean water	Surface water runoff from catchments that are undisturbed or rehabilitated following disturbance
Detailed design	The phase of the project where the design is refined into drawings, plans, specifications and estimates, suitable for construction
Discharge	A general term that refers to all discharge mechanisms
Discharge via runoff	Water management system discharges that occur due to stormwater runoff from a water management area
Drill and blast	The controlled use of explosives to break rock for excavation
Electrical conductivity (EC)	Electrical conductivity (EC) measures dissolved salt in water. The standard EC unit is microsiemens per centimetre (µS/cm) at 25 °C
Enriched sample	Geochemistry sample that is enriched in a range of elements (typically sulphur and metals)
Ephemeral	Something which only lasts for a short time. Typically used to describe rivers, lakes and wetlands that are intermittently dry
Evapotranspiration	The combined loss of water from a given area during a specified period of time by evaporation from the soil or water surface and by transpiration from plants
Excavated rock	Hard, compacted, or cemented materials that have been removed using blasting or other excavation methods
Full supply level	The normal maximum operating water level of a surface water storage when not affected by floods. This water level corresponds to 100% capacity
Geological group	Refers to the geological groups described in the CSIRO studies.
Groundwater	Water contained within rocks and sediments below the ground surface in the saturated zone, including perched systems above the regional watertable
Headrace tunnel	The upstream tunnel between Tantangara Reservoir and the underground power station
Infiltration	The process by which water on the ground surface enters the soil profile
In-reservoir emplacement	The placement and storage of excavated rock within the footprint and below the level of a reservoir's full supply level (FSL)
Land-based emplacement	The placement and storage of excavated rock outside of a waterbody footprint, or within but above a reservoir's full supply level (FSL)
Leachate	The product resulting from the process of leaching, whereby solid constituents including soluble minerals are displaced from soil by a liquid (typically water) percolating through the subsurface profile
Marica rock emplacement area	Emplacement area associated with spoil generated at the Marica construction zone

Term	Definition
Oxic	In the presence of oxygen
pH	Value that represents the acidity or alkalinity of an aqueous solution. It is defined as the negative logarithm of the hydrogen ion concentration of the solution
Placed volume	The volume of material following emplacement and compaction
Precipitation	All forms in which water falls on the land surface and open water bodies as rain, sleet, snow, hail, or drizzle
Rare flood event	A rare flood event is defined in Australian Rainfall and Runoff as an event that has an annual probability of exceedance of between 1 to 0.05% (Geoscience Australia 2019)
Receiving water	Any watercourse or waterbody that receives discharge from the water management system
Residual impact	Those effects that remain following the application of mitigation measures to reduce adverse impacts from the project
Rock emplacement area	Land area identified for the placement and storage of excavated rock material
Seepage	A term used to describe water that flows through and out of a land-based rock emplacement
Snowy 2.0	A pumped hydro-electric expansion of the Snowy Scheme that will link the two existing reservoirs of Tantangara and Talbingo through underground tunnels, and include a new underground power station with pumping capabilities
Streamflow	The flow of water in streams, rivers and other channels
Subaqueous	Existing, formed, or taking place under water
Subsurface excavation	The excavation of rock material from below the ground. Generally associated with the tunnelling process
Surface excavation	The excavation of rock material at ground level. Generally associated with intake structures, tunnel portals and access roads.
Surface runoff	Water from precipitation or other sources that flows over the land surface
Surface water	Water that flows over or is stored on the surface of the earth that includes: (a) water in a watercourse, lake or wetland and (b) any water flowing over or lying on land: (i) after having precipitated naturally or (ii) after having risen to the surface naturally from underground
Tailrace tunnel	The downstream tunnel between the underground power station and Talbingo Reservoir
Talbingo rock emplacement area	Emplacement area associated with spoil generated at the Talbingo construction zone
Tantangara rock emplacement area	Emplacement area associated with spoil generated at the Tantangara construction zone
Water exchange	Refers to the exchange of water between an in-reservoir D&B emplacement and the reservoir.
Water quality	The physical, chemical and biological characteristics of water. Water-quality compliance is usually assessed by comparing these characteristics with a set of reference standards. Common standards used are those for drinking water, safety of human contact and the health of ecosystems

Appendix A

ASLP results

Table A.1 Leachate results summary – Talbingo and Marica Zones

			WQO value[1]		Ravine Group (Talbingo/Marica Zone)[2]			Byron/Boraig Group (Talbingo Zone only)[2]			Talbingo and Marica Zone summary[2,3]		
Analyte	**Units**	**LOR**	**Reservoir**	**Watercourse**	**Min**	**Median**	**Max**	**Min**	**Median**	**Max**	**Min**	**Median**	**Max**
						Anoxic							
pH	-	-	**8**	**8**	6.7	7.2	7.5	6.6	7.2	7.7	6.6	7.2	7.7
EC	µS/cm	-	**30**	**350**	**100**	**221**	**288**	**137**	**258**	**289**	**100**	**226**	**289**
TN	µg/L	-	**350**	**250**	80	**307**	**855**	104	**266**	**584**	80	**272**	**855**
S	µg/L	200	-	-	111	318	24,713	147	295	5,665	111	308	24,713
Al	µg/L	50	**55**	**27**	<50	<50	<50	<50	<50	<50	<50	<50	<50
As	µg/L	0.5	**13**	**0.8**	<0.5	**1.1**	**14.6**	<0.5	<0.5	**21.6**	<0.5	**0.9**	**21.6**
Cr	µg/L	1	**1**	**0.01**	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cu	µg/L	0.5	**14**	**1**	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Fe	µg/L	10	**300**	**300**	2.0	2.0	**357.0**	2.0	6.0	57.0	<2	<2	**357.0**
Mn	µg/L	1	**1900**	**1200**	17.7	132.4	**1,699.0**	13.0	74.6	603.0	13.0	122.5	**1,699.0**
Mo	µg/L	0.1	**34**	**34**	<0.1	1	5	<0.1	<0.1	3	<0.1	0.4	5.4
Pb	µg/L	0.1	**3.4**	**1**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sb	µg/L	0.5	**9**	**9**	<0.5	2.1	**24.9**	<0.5	1.3	8.7	<0.5	2.0	**24.9**
U	µg/L	0.05	**0.5**	**0.5**	<0.05	<0.05	0.4	<0.05	<0.05	**0.5**	<0.05	<0.05	**0.5**
V	µg/L	0.1	**6**	**6**	<0.1	0.4	2.7	<0.1	<0.1	1.8	<0.1	0.3	2.7
Zn	µg/L	0.5	**8**	**2.4**	<0.5	<0.5	**2.6**	<0.5	<0.5	0.9	<0.5	<0.5	**2.6**
						Oxic							
pH	-	-	**8**	**8**	**8.1**	**9.4**	**9.9**	**8.2**	**9.6**	**10.0**	**8.1**	**9.5**	**10.0**
EC	µS/cm	-	**30**	**350**	**60**	**88**	**239**	**42**	**84**	**126**	**42**	**85**	**239**
TN	µg/L	-	**350**	**250**	158	**366**	**689**	116	**324**	**592**	116	**350**	**689**
S	µg/L	200	-	-	181	503	24,560	172	413	5,582	172	472	24,560

Table A.1 Leachate results summary – Talbingo and Marica Zones

			WQO value[1]		Ravine Group (Talbingo/Marica Zone)[2]			Byron/Boraig Group (Talbingo Zone only)[2]			Talbingo and Marica Zone summary[2,3]		
Analyte	Units	LOR	Reservoir	Watercourse	Min	Median	Max	Min	Median	Max	Min	Median	Max
Al	µg/L	50	55	27	<50	351	5,009	107	527	3,648	<50	362	5,009
As	µg/L	0.5	13	0.8	<0.5	3.0	64.8	<0.5	1.8	63.1	<0.5	2.2	64.8
Cr	µg/L	1	1	0.01	<1	<1	3.0	<1	<1	8.0	<1	<1	8.0
Cu	µg/L	0.5	14	1	<0.5	<0.5	<0.5	<0.5	<0.5	1.1	<0.5	<0.5	1.1
Fe	µg/L	10	300	300	2.0	49.0	332.0	4.0	34.0	308.0	<2	42.0	332.0
Mn	µg/L	1	1900	1200	2.0	5.0	46.0	<1	3.0	74.0	<1	4.0	74.0
Mo	µg/L	0.1	34	34	<0.1	1	3	<0.1	0	4	<0.1	0.4	4.1
Pb	µg/L	0.1	3.4	1	<0.1	<0.1	2	<0.1	<0.1	2	<0.1	<0.1	2.4
Sb	µg/L	0.5	9	9	<0.5	2.5	24.1	<0.5	2.2	20.9	<0.5	2.5	24.1
U	µg/L	0.05	0.5	0.5	<0.05	<0.05	0.8	<0.05	0.2	1.1	<0.05	0.1	1.1
V	µg/L	0.1	6	6	0.4	2.7	20.6	0.5	4.7	10.1	0.4	3.3	20.6
Zn	µg/L	0.5	8	2.4	<0.5	<0.5	5.6	<0.5	<0.5	3.6	<0.5	<0.5	5.6
Dilute acid													
pH	-	-	8	8	7.6	9.1	9.6	8.3	9.2	9.4	7.6	9.2	9.6
EC	µS/cm	-	30	350	42	101	274	40	102	134	40	101	274
TN	µg/L	-	350	250	144	315	4,891	114	288	463	114	290	4,891
S	µg/L	200	-	-	<200	289	23,356	<200	282	5,677	<200	286	23,356
Al	µg/L	50	55	27	<50	206	1,523	72	180	1,153	<50	187	1,523
As	µg/L	0.5	13	0.8	<0.5	2.7	87.0	<0.5	1.4	27.8	<0.5	2.4	87.0
Cr	µg/L	1	1	0.01	<1	<1	9.0	<1	<1	5.0	<1	<1	9.0
Cu	µg/L	0.5	14	1	<0.5	<0.5	0.7	<0.5	<0.5	0.8	<0.5	<0.5	0.8

Table A.1 Leachate results summary – Talbingo and Marica Zones

			WQO value[1]		Ravine Group (Talbingo/Marica Zone)[2]			Byron/Boraig Group (Talbingo Zone only)[2]			Talbingo and Marica Zone summary[2,3]		
Analyte	**Units**	**LOR**	**Reservoir**	**Watercourse**	**Min**	**Median**	**Max**	**Min**	**Median**	**Max**	**Min**	**Median**	**Max**
Fe	µg/L	10	**300**	**300**	2.0	11.0	218.0	2.0	8.0	216.0	<2	9.5	218.0
Mn	µg/L	1	**1900**	**1200**	2.0	7.0	148.0	<1	6.0	22.9	<1	6.0	148.0
Mo	µg/L	0.1	**34**	**34**	<0.1	1	4	<0.1	0	6	<0.1	0.3	5.8
Pb	µg/L	0.1	**3.4**	**1**	<0.1	<0.1	0	<0.1	<0.1	<0.1	<0.1	<0.1	0.4
Sb	µg/L	0.5	**9**	**9**	<0.5	2.9	**33.1**	<0.5	3.1	**14.4**	<0.5	3.0	**33.1**
U	µg/L	0.05	**0.5**	**0.5**	<0.05	<0.05	0.3	<0.05	<0.05	0.2	<0.05	<0.05	0.3
V	µg/L	0.1	**6**	**6**	0.2	2.0	**16.1**	0.4	2.3	**8.4**	0.2	2.1	**16.1**
Zn	µg/L	0.5	**8**	**2.4**	<0.5	<0.5	1.0	<0.5	<0.5	0.8	<0.5	<0.5	1.0

Notes: 1. The WQO values for pH, EC and TN refer to the WQO values for physical and chemical stressors in south-east Australia (upland river) that are reported in Tables 3.3.2 and 3.3.3 of ANZECC/ARMCANZ (2000). Toxicant trigger values for the protection of 95% and 99% of aquatic species presented in (ANZG 2018) have been used for reservoir and watercourse receiving waters respectively. However, the 95% values apply to watercourses at Rock Forest, which is outside of KNP. Further information on the establishment of WQOs is provided in the water assessment (Appendix J to the EIS).

2. Minimum, maximum and median values for each geological group have been calculated using leachate results from an approximately equal number of 'baseline' and 'enriched' rock samples. The most common attribute of the enriched group being elevated sulphur (S) and trace element concentrations (including metals and metalloids) compared to the baseline group CSIRO (2019b). As most of the emplacement material is expected to be formed from baseline material, the enriched samples are overrepresented in the combined leachate results statistics, which is expected to result in an overestimation of maximum values and conservative median values.

3. Talbingo and Marica Zone summary statistics have been calculated using baseline and enriched sample leachate results for Ravine and Byron/Boraig Group geological groups.

General note: For results, text style '**0.9**' indicates WQO values for both watercourses and reservoirs are exceeded and '**0.9**' indicates WQO values for reservoirs only are exceeded.

Table A.2 Leachate results summary – Tantangara Zone

			WQO value[1]		Shaw Hill Gabbro[2]			Gooandra Volcanics[2]			Peppercorn/Tantangara/ Temperance Formations[2]			Kellys Plain Volcanics[2]			Tantangara Zone summary[3]		
Analyte	Units	LOR	Reservoir	Watercourse	Min	Median	Max	Min	Median	Max	Min	Median	Max	Min	Median	Max	Min	Median	Max
									Anoxic										
pH	-	-	8	8	6.7	7.3	7.6	7.0	7.2	7.3	6.2	7.1	7.4	6.4	6.5	6.8	6.2	7.2	7.6
EC	µS/cm	-	30	350	170	213	244	198	234	322	115	196	324	93	103	161	93	221	324
TN	µg/L	-	350	250	62	110	160	89	181	297	65	180	389	266	311	409	62	181	409
S	µg/L	200	-	-	<200	<200	<200	129	246	2,664	<200	510	7,858	257	300	955	129	246	7,858
Al	µg/L	50	55	27	<50	<50	<50	<50	<50	<50	<50	<50	187	<50	<50	<50	<50	<50	187.0
As	µg/L	0.5	13	0.8	<0.5	<0.5	<0.5	<0.5	<0.5	2.2	<0.5	<0.5	1.6	<0.5	<0.5	<0.5	<0.5	<0.5	2.2
Cr	µg/L	1	1	0.01	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cu	µg/L	0.5	14	1	<0.5	<0.5	<0.5	<0.5	<0.5	1.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.2
Fe	µg/L	10	300	300	2.0	2.0	2.0	2.0	2.0	25.0	2.0	2.0	348.0	2.0	11.0	90.0	<2	<2	348.0
Mn	µg/L	1	1900	1200	13.0	25.0	238.0	16.0	61.0	701.0	20.0	74.0	906.0	82.0	103.0	274.0	13.0	66.0	906.0
Mo	µg/L	0.1	34	34	<0.1	<0.1	0	<0.1	0	9	<0.1	1	25	<0.1	<0.1	1	<0.1	0.3	25.4
Pb	µg/L	0.1	3.4	1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0	<0.1	<0.1	0.2
Sb	µg/L	0.5	9	9	<0.5	<0.5	<0.5	<0.5	<0.5	2.5	<0.5	<0.5	2.3	<0.5	<0.5	<0.5	<0.5	<0.5	2.5
U	µg/L	0.05	0.5	0.5	<0.05	<0.05	<0.05	<0.05	<0.05	0.7	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.7
V	µg/L	0.1	6	6	<0.1	0.2	0.6	<0.1	0.2	0.9	<0.1	<0.1	0.6	<0.1	<0.1	<0.1	<0.1	0.2	0.9
Zn	µg/L	0.5	8	2.4	<0.5	<0.5	<0.5	<0.5	<0.5	3.0	<0.5	<0.5	2.4	0.7	0.8	3.5	<0.5	<0.5	3.5
									Oxic										
pH	-	-	8	8	9.4	9.5	9.7	9.1	9.5	9.9	8.7	9.4	9.6	8.2	8.4	9.2	8.2	9.4	9.9

Table A.2 Leachate results summary – Tantangara Zone

			WQO value[1]		Shaw Hill Gabbro[2]			Gooandra Volcanics[2]			Peppercorn/Tantangara/ Temperance Formations[2]			Kellys Plain Volcanics[2]			Tantangara Zone summary[3]		
Analyte	Units	LOR	Reservoir	Watercourse	Min	Median	Max	Min	Median	Max	Min	Median	Max	Min	Median	Max	Min	Median	Max
EC	µS/cm	-	**30**	**350**	**67**	**77**	**91**	**60**	**75**	**107**	**56**	**83**	**116**	**43**	**51**	**74**	**43.0**	**76**	**116**
TN	µg/L	-	**350**	**250**	87	119	**491**	133	208	**5,951**	105	181	**434**	**250**	**385**	**710**	87.2	198.7	**5,951**
S	µg/L	200	-	-	<200	<200	<200	137	321	3,440	<200	737	9,316	312	419	1,126	137.0	309	9,316
Al	µg/L	50	**55**	**27**	<50	<50	**2,188**	<50	**538**	**1,284**	<50	**187**	**2,227**	**340**	**347**	**528**	<50	**438**	**2,227**
As	µg/L	0.5	**13**	**0.8**	<0.5	<0.5	**0.9**	<0.5	**1.6**	**83.6**	<0.5	**1.0**	**11.7**	0.8	**1.1**	**2.6**	<0.5	**1.3**	**83.6**
Cr	µg/L	1	**1**	**0.01**	<1	<1	**3.0**	<1	<1	**7.0**	<1	<1	**2.0**	<1	<1	<1	<1	<1	**7.0**
Cu	µg/L	0.5	**14**	**1**	<0.5	<0.5	**1.3**	<0.5	<0.5	**1.9**	<0.5	<0.5	**1.2**	<0.5	<0.5	<0.5	<0.5	<0.5	**1.9**
Fe	µg/L	10	**300**	**300**	4.0	8.5	47.0	3.0	33.0	92.0	2.0	60.5	**356.0**	85.0	108.0	136.0	<2	34.0	**356.0**
Mn	µg/L	1	**1900**	**1200**	<1	1.5	19.0	<1	2.0	14.0	<1	4.5	11.0	<1	3.0	4.0	<1	2.0	19.0
Mo	µg/L	0.1	**34**	**34**	<0.1	<0.1	<0.1	<0.1	<0.1	3	<0.1	0	25	<0.1	<0.1	3	<0.1	<0.1	25.2
Pb	µg/L	0.1	**3.4**	**1**	<0.1	<0.1	0	<0.1	<0.1	**11**	<0.1	<0.1	1	<0.1	0	0	<0.1	<0.1	**10.6**
Sb	µg/L	0.5	**9**	**9**	<0.5	<0.5	<0.5	<0.5	<0.5	2.7	<0.5	<0.5	2.4	<0.5	<0.5	0.6	<0.5	<0.5	2.7
U	µg/L	0.05	**0.5**	**0.5**	<0.05	<0.05	<0.05	<0.05	0.1	**1.2**	<0.05	0.1	0.2	0.1	0.1	0.2	<0.05	0.1	**1.2**
V	µg/L	0.1	**6**	**6**	0.5	1.1	3.1	0.7	2.0	**7.7**	0.9	2.3	**7.4**	2.2	4.1	5.4	0.5	2.0	**7.7**
Zn	µg/L	0.5	**8**	**2.4**	<0.5	<0.5	<0.5	<0.5	<0.5	**2.7**	<0.5	<0.5	**5.7**	<0.5	<0.5	0.6	<0.5	<0.5	**5.7**
Dilute acid																			
pH	-	-	**8**	**8**	**9.4**	**9.5**	**9.8**	**8.1**	**9.1**	**9.7**	**8.6**	**9.4**	**9.8**	8.0	**8.2**	**9.0**	8.0	**9.3**	**9.8**
EC	µS/cm	-	**30**	**350**	**59**	**67**	**73**	**66**	**82**	**114**	**37**	**70**	**102**	**89**	**102**	**124**	**37.0**	**75.0**	**124**
TN	µg/L	-	**350**	**250**	45	54	151	49	173	**1,300**	28	56	**2,763**	**3,774**	**4,176**	**4,488**	27.8	150.6	**4,488**

Table A.2 Leachate results summary – Tantangara Zone

			WQO value[1]		Shaw Hill Gabbro[2]			Gooandra Volcanics[2]			Peppercorn/Tantangara/ Temperance Formations[2]			Kellys Plain Volcanics[2]			Tantangara Zone summary[3]		
Analyte	Units	LOR	Reservoir	Watercourse	Min	Median	Max	Min	Median	Max	Min	Median	Max	Min	Median	Max	Min	Median	Max
S	µg/L	200	-	-	<200	<200	<200	<200	<200	3,100	<200	634	12,038	<200	224	947	<200	<200	12,038
Al	µg/L	50	55	27	175	338	1,586	<50	282	1,497	65	373	4,368	67	79	159	<50	287.5	4,368
As	µg/L	0.5	13	0.8	<0.5	<0.5	1.5	<0.5	1.5	47.6	<0.5	1.1	10.0	<0.5	0.6	1.8	<0.5	1.0	47.6
Cr	µg/L	1	1	0.01	<1	<1	3.0	<1	<1	12.0	<1	<1	<1	<1	<1	<1	<1	<1	12.0
Cu	µg/L	0.5	14	1	<0.5	<0.5	<0.5	<0.5	<0.5	1.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.1
Fe	µg/L	10	300	300	4.0	6.0	14.0	2.0	6.0	11.0	2.0	15.0	86.0	2.0	14.0	15.0	<2	7.0	86.0
Mn	µg/L	1	1900	1200	<1	<1	6.0	<1	3.0	12.0	<1	3.0	22.0	<1	2.0	5.0	<1	2.0	22.0
Mo	µg/L	0.1	34	34	<0.1	<0.1	<0.1	<0.1	<0.1	4	<0.1	<0.1	34	<0.1	<0.1	3	<0.1	<0.1	34
Pb	µg/L	0.1	3.4	1	<0.1	<0.1	<0.1	<0.1	<0.1	0	<0.1	<0.1	0	<0.1	<0.1	<0.1	<0.1	<0.1	0.4
Sb	µg/L	0.5	9	9	<0.5	<0.5	<0.5	<0.5	<0.5	2.9	<0.5	<0.5	2.0	<0.5	<0.5	0.6	<0.5	<0.5	2.9
U	µg/L	0.05	0.5	0.5	<0.05	<0.05	<0.05	<0.05	<0.05	0.3	<0.05	<0.05	0.1	<0.05	<0.05	<0.05	<0.05	<0.05	0.3
V	µg/L	0.1	6	6	1.6	1.8	7.5	0.3	1.4	4.1	0.5	3.6	6.2	1.0	1.7	3.0	0.3	2.1	7.5
Zn	µg/L	0.5	8	2.4	<0.5	<0.5	1.9	<0.5	<0.5	0.8	<0.5	<0.5	2.4	<0.5	<0.5	<0.5	<0.5	<0.5	2.4

Notes: 1. The WQO values for pH, EC and TN refer to the WQO values for physical and chemical stressors in south-east Australia (upland river) that are reported in Tables 3.3.2 and 3.3.3 of ANZECC/ARMCANZ (2000). Toxicant trigger values for the protection of 95% and 99% of aquatic species presented in (ANZG 2018) have been used for reservoir and watercourse receiving waters respectively. Further information on the establishment of WQOs is provided in the water assessment (Appendix J to the EIS).

2. Minimum, maximum and median values for each geological group have been calculated using leachate results from an approximately equal number of 'baseline' and 'enriched' rock samples. The most common attribute of the enriched group being elevated sulphur (S) and trace element concentrations (including metals and metalloids) compared to the baseline group CSIRO (2019b). As most of the emplacement material is expected to be formed from baseline material, the enriched samples are overrepresented in the combined leachate results statistics, which is expected to result in an overestimation of maximum values and conservative median values.

3. Tantangara Zone summary statistics have been calculated using baseline and enriched sample leachate results for all geological groups (Shaw Hill Gabbro, Gooandra Volcanics, Peppercorn/Tantangara/Temperance Formations and Kellys Plain Volcanics) that are expected to contribute to the Tantangara emplacement.

General note: For results, text style '**0.9**' indicates WQO values for both watercourses and reservoirs are exceeded and '**0.9**' indicates WQO values for reservoirs only are exceeded.

Appendix B

Numerical modelling report – Ravine Bay: construction phase

Memo

Haskoning Australia PTY Ltd.
Maritime & Aviation

To:	Chris Kuczera, Mark Trudgett
From:	Rohan Hudson/Arjen Overduin - RHDHV SERP Modelling Team
Date:	23 March 2020
Copy:	Greg Britton
Our reference:	PA2297 - Snowy 2.0 – ERP Sediment Plume Modelling Scenario – Technical Memo
Classification:	Project related

Subject: **Snowy 2.0 – ERP Sediment Plume Modelling Scenario – Technical Memo**

1 Introduction

This memo provides a summary of an additional excavated rock placement (ERP) sediment plume model scenario, which has been undertaken by Royal HaskoningDHV (RHDHV) on behalf of EMM and Snowy Hydro Limited (SHL) in March 2020. This additional model scenario investigates potential water quality impacts during the construction of the proposed Snowy 2.0 project using the contractor's preferred rock placement strategy.

This memo provides a description of the modelling undertaken, a tabular summary of the modelled results (i.e. Total Suspended Sediments (TSS)) and accompanying figures (time-series and maps) of processed modelling results.

For details of the study background, model setup and previous model simulations, reference is made to RHDHV (2019). Furthermore, the modelling exercise uses assumptions based on the below document and recent discussions with EMM:

- EMM (2020). 'Preferred excavated rock management strategy', prepared for Snowy Hydro Limited, March 2020.

2 Model and Scenario Descriptions

The following provides a summary of the input that has been provided with regard the additional ERP scenario. The scenario represents an assessment of the design capacity of the filling of the Ravine Bay reservoir placement location with drill and blast (D & B) material".

Based on discussions with EMM, it has been identified that up to 1,500,000 m^3 (bank) of D & B material is proposed to be placed at the Ravine Bay site. The rate at which material would be placed was provided by the contractor. **Figure 1** provides details of the monthly rates assumed in the new model scenario, whilst a number of assumptions regarding placement material and method are presented in **Table 1**.

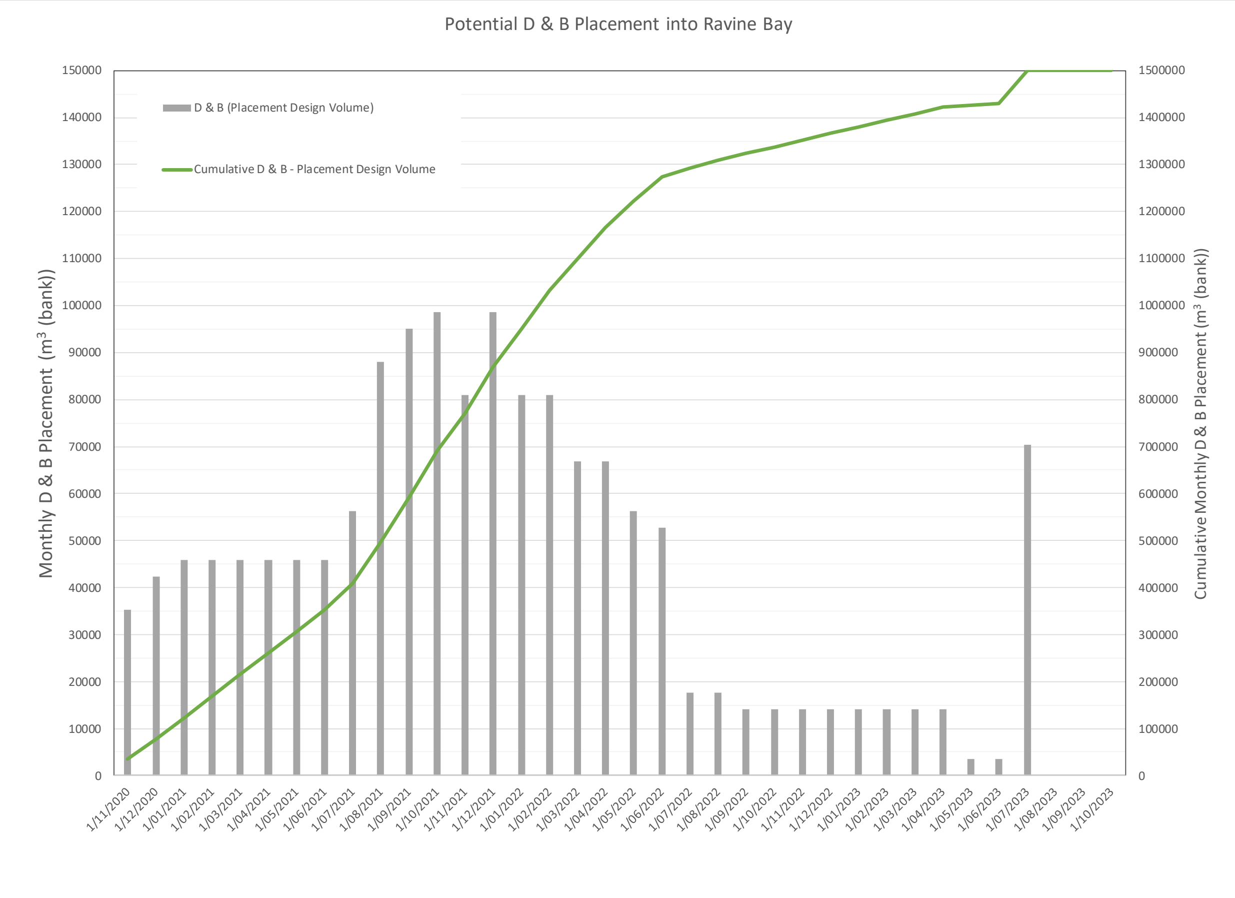


Figure 1: Assumed D & B Placement Rates and Volumes into Ravine Bay

Placement method, Particle Size Distribution (PSD) and source term information is provided in **Table 1**.

Table 1: Assumed Input Parameters for all Scenarios

Item	Assumption
Simulation Duration (months)	36
Curtain (12m depth)	Yes
D+B fines (<63 micron)	2%
D&B - Clay as percent of total	0.3%
Source term – Silt	45%
Source term - Clay	60%

Details of the modelling approach and methodology that has been used on this project to date (including this new modelled scenario) is provided in the EIS Annexure report “Snowy 2.0: Talbingo Reservoir Modelling – Construction”. In brief, this approach includes:

- Simulation of 12 months of 3D reservoir hydrodynamics (using MIKE-3-FM HD) including:
    - Five months (13 November 2016 to 5 April 2017) – a recent summer heating period, and
    - Seven months (5 April 2017 to 13 November 2017) – a recent winter cooling period.
- Calculating (using a number of assumptions) the mass of sediment that will be released into the water column (this is used to create a MIKE-3 dredger file); and

- Simulating sediment transport that results from the placement of excavated rock in the reservoir (using MIKE-3-FM MT).

For each scenario, the model has been run for a period of 36 months to simulate the predicted sediment plume.

3 Model Results

The model results are presented as follows:

- Time-series of predicted suspended sediment concentration at four selected locations presented in **Figure 2**;
- Map of maximum, median and 95 percentile suspended sediment concentration at the reservoir surface, and;
- Map of sediment deposition thickness.

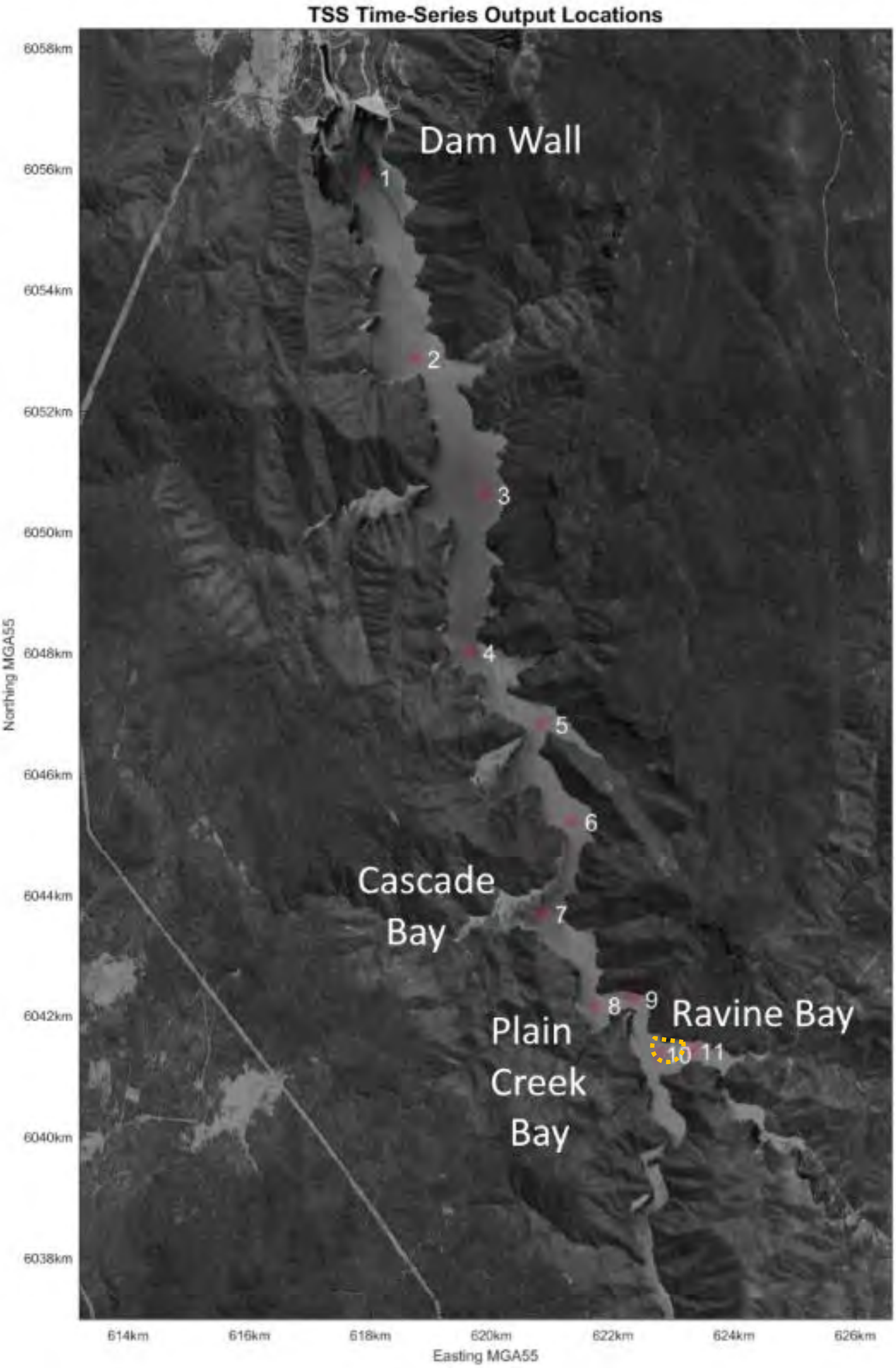


Figure 2 Location of time-series output points in Talbingo reservoir
Note: The placement location indicated in orange dots in Ravine Bay near location 10.

Figure 3, Figure 4, Figure 5 and **Figure 6**, present time-series of predicted suspended sediment concentration at output locations 1, 9, 10 and 11, respectively. A summary of peak TSS levels is presented in **Table 2.** The time-series figures also provide data on the fines placement rate (in kg/s) for included silts and clay fractions and show both the rate and also duration of the placement.

Table 2: Summary of TSS Results for Scenarios

Location	**Graph**	**Peak TSS (mg/L)**	**Comment**
Location 1 (Dam Wall)	Figure 3	5	Peaks during 2nd summer/heating phase due to high placement rate.
Location 9 (~1km North of Ravine Bay)	Figure 4	9	Peaks during 2nd summer/heating phase due to high placement rate.
Location 10 (Ravine Bay Placement Area - inside silt curtain)	Figure 5	750	Towards the end of the first winter/cooling period a peak TSS of 750 mg/L is predicted within the silt curtain. This rapidly drops during the following heating period when TSS become trapped below the thermocline.
Location 11 (Upstream of Ravine Bay towards Yarrangobilly)	Figure 6	35	While TSS is generally below 10mg/L in the Yarrangobilly arm, there is a short 3-4 week peak up to 35 mg/L during the 2nd summer/heating phase.

Under the proposed scenario, suspended sediment surface concentration (surface TSS) at location 1 (near the dam wall) peaks at approximately 5 mg/L (**Figure 3**) at the start of the second heating phase.

A map of peak surface TSS over 36 months is presented in **Figure 7.** This map presents the highest TSS that is predicted to occur at any time over the 36 month simulation. A map showing the 95 percentile surface TSS is presented in **Figure 8**. This map shows the values that would only be exceeded 5% of time (i.e. 5% of 365 x 3 = 55 days). The median (50 percentile) surface TSS is presented in **Figure 9**.

An interpretation of the TSS results show that between Ravine Bay (Location 9) and the Dam Wall (Location 1) peak TSS for the entire placement duration is below 10 mg/L. At the Dam Wall TSS is nearly always below 5 mg/L. Inside the silt curtain at the Ravine Bay placement location (i.e. Location 10), concentrations at the surface can be above 500 mg/L. Upstream of the placement area along the Tumut and Yarrangobilly Arms, peak concentrations above 30 mg/L are possible, though these peaks would occur for less than 55 days.

The 95 percentile TSS data presented in **Figure 8** shows that for 34.2 months out of the 36 month simulation, TSS in the Tumut arm is below 10 mg/L, while the Yarrangobilly arm is below 20 mg/L. The occurrence of high surface TSS in the Tumut and Yarrangobilly Arms occurs due to complex 3D flow behaviour which can transport surface TSS upstream along the Tumut and Yarrangobilly Arms, when T2 or catchment inflows produce downstream flows below the thermocline.

The 50 percentile (i.e. median) surface TSS data presented in **Figure 9** shows that for 18 months out of the 36 month simulation, TSS in the Tumut and Yarrangobilly Arms is below 3 mg/L, while in the remainder of the reservoir it is below 2 mg/L.

A map of bed sediment thickness after 36 months of placement is presented in **Figure 10**.

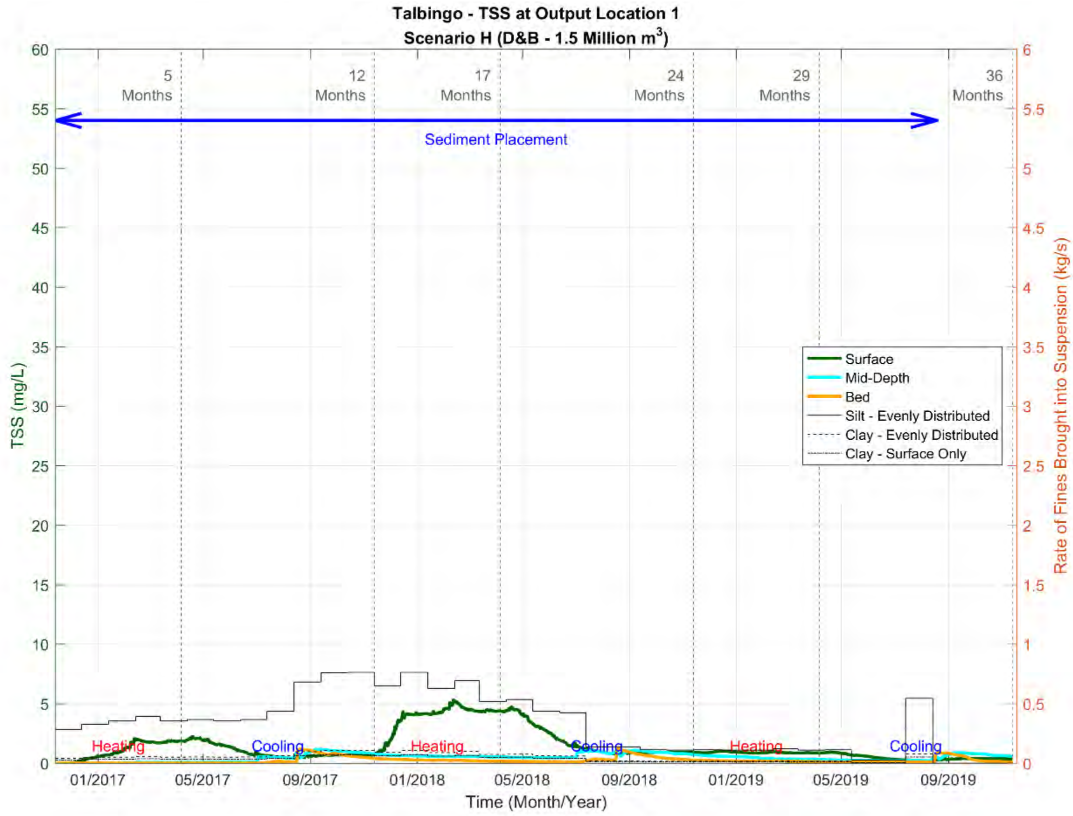


Figure 3: TSS at output location 1 (Near Dam Wall)

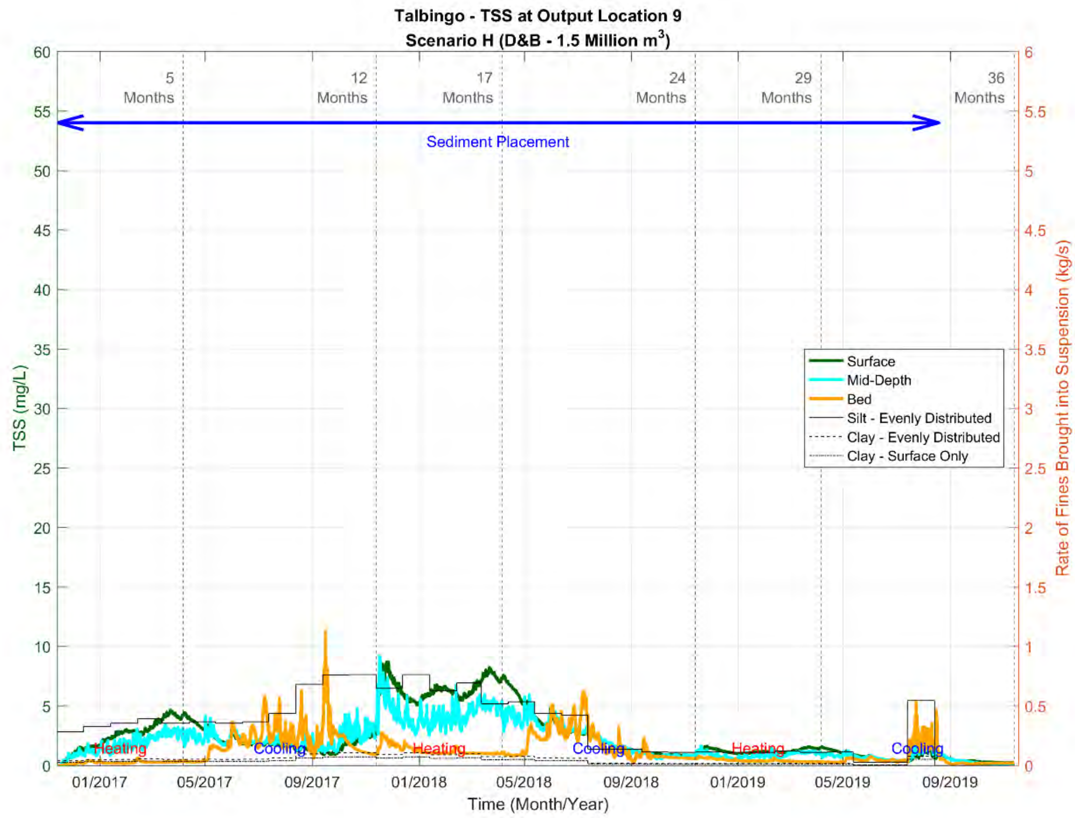


Figure 4: TSS at output location 9 (~1km North of Ravine Bay)

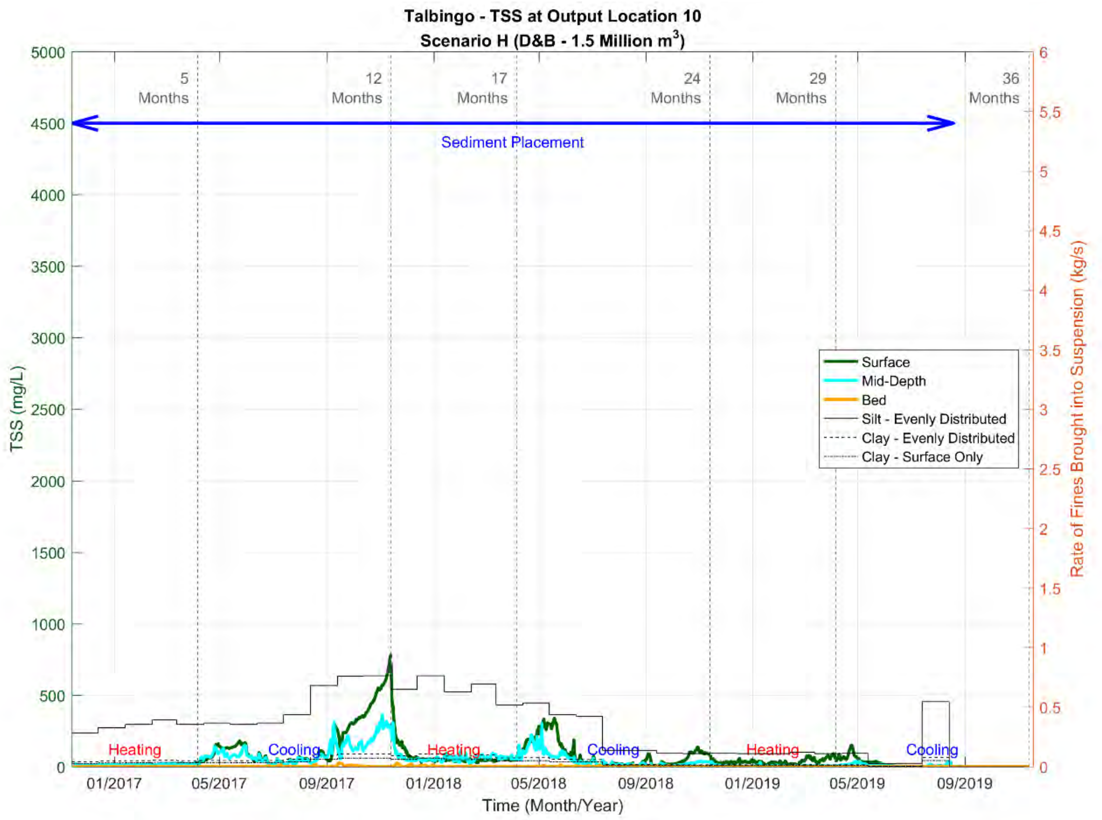


Figure 5: TSS at output location 10 (Ravine Bay Placement Area - inside silt curtain)

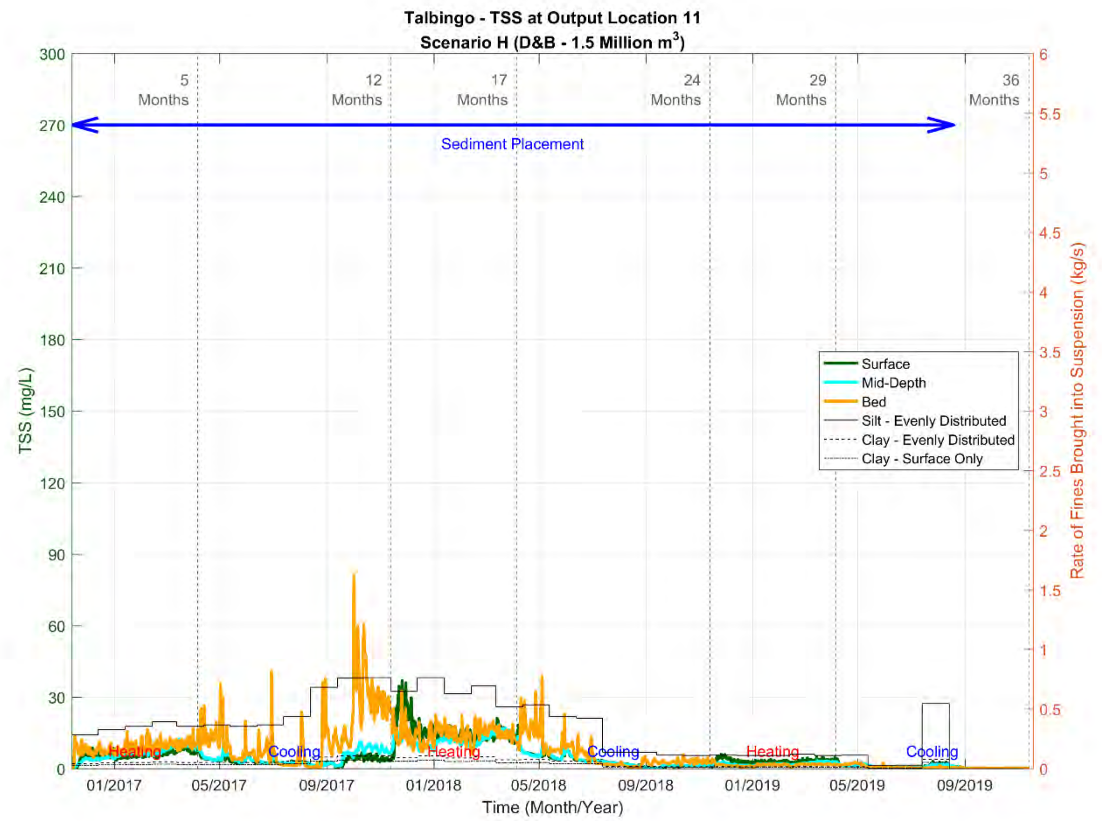


Figure 6: TSS at output location 11 (Upstream of Ravine Bay towards Yarrangobilly)

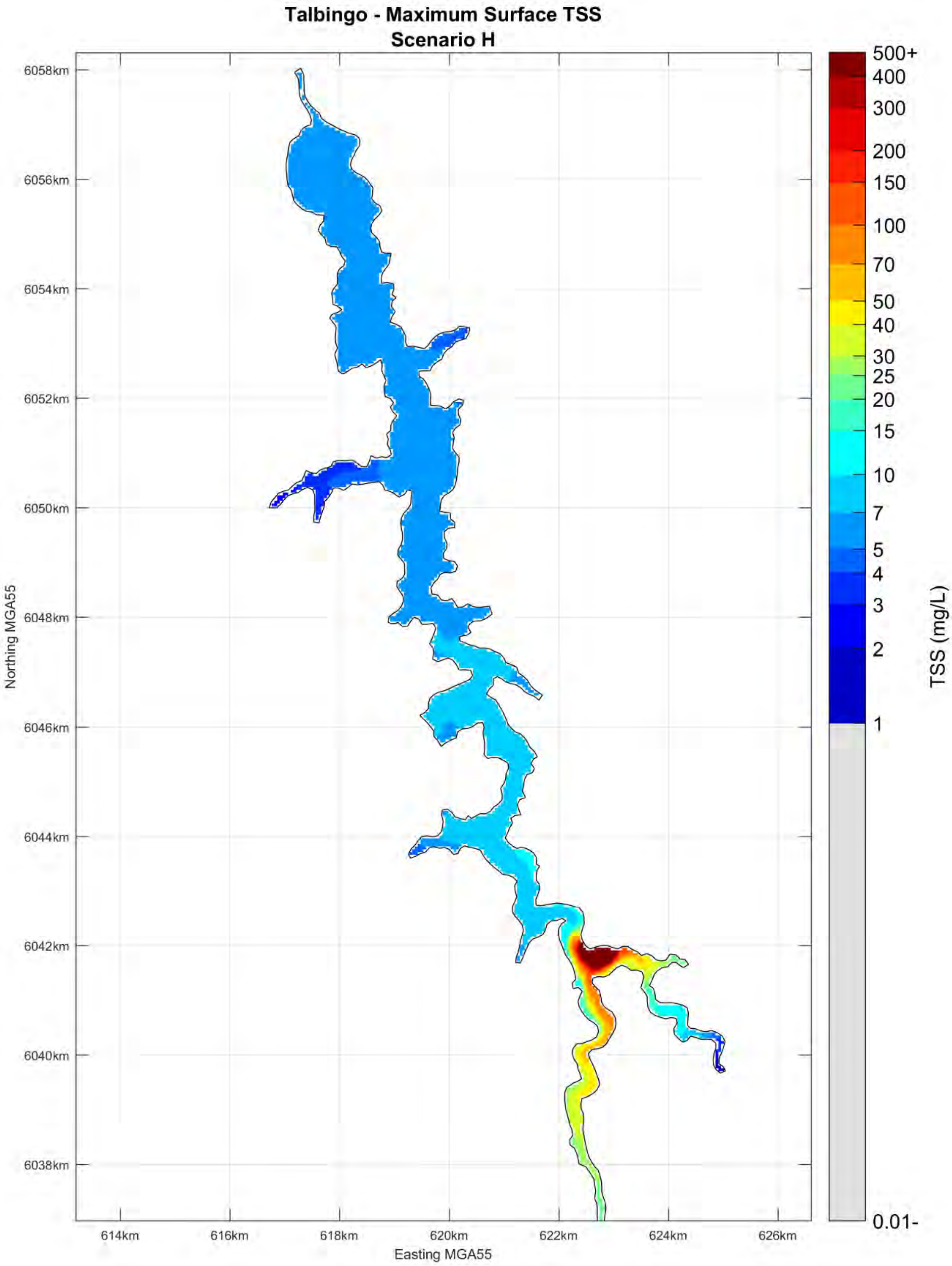


Figure 7: Maximum surface TSS over 36 months

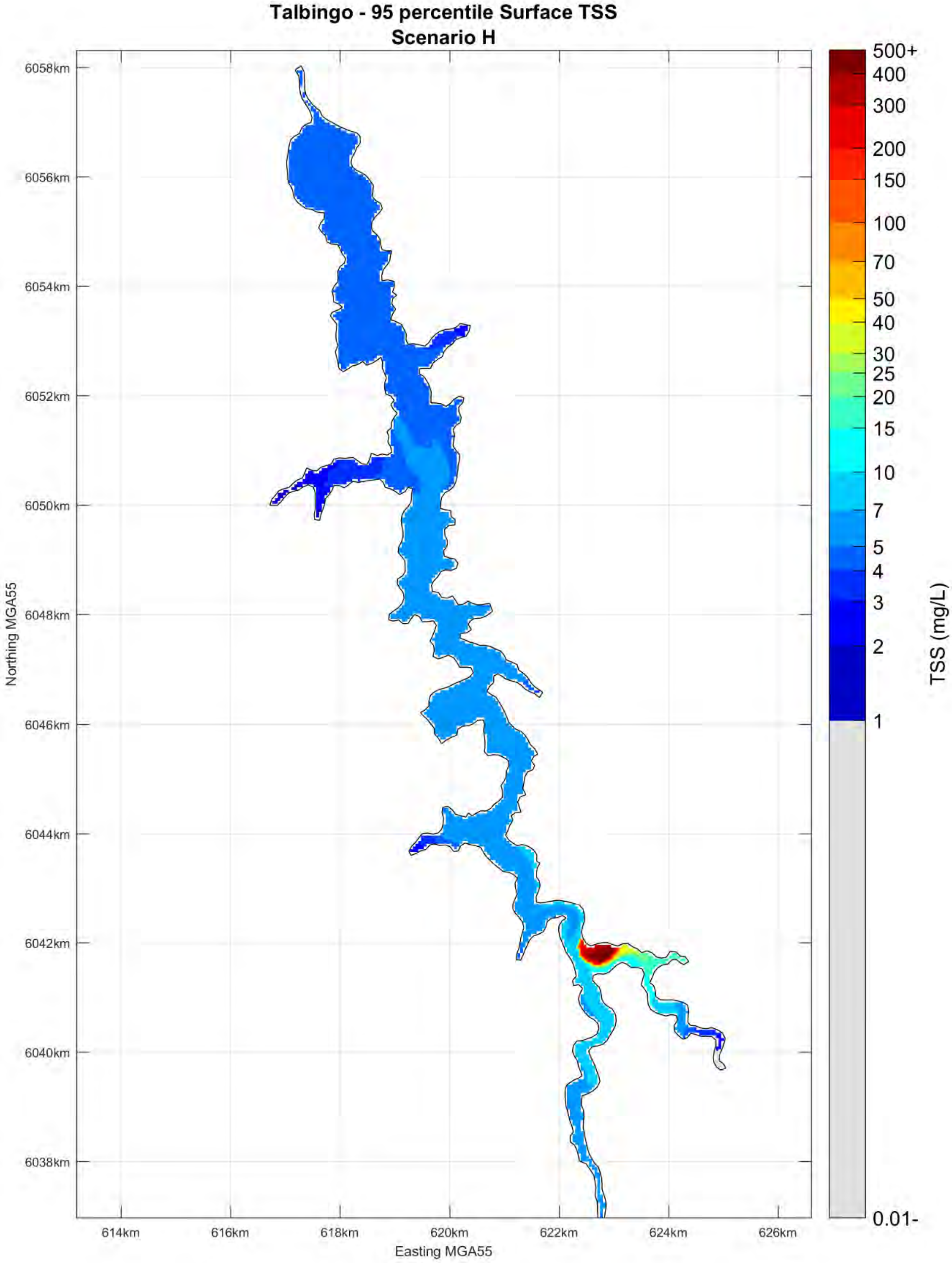


Figure 8: 95% exceedance (over 36 months) surface TSS

Note: TSS would be below this value for all but 1.8 months (0.05 x 36 months)

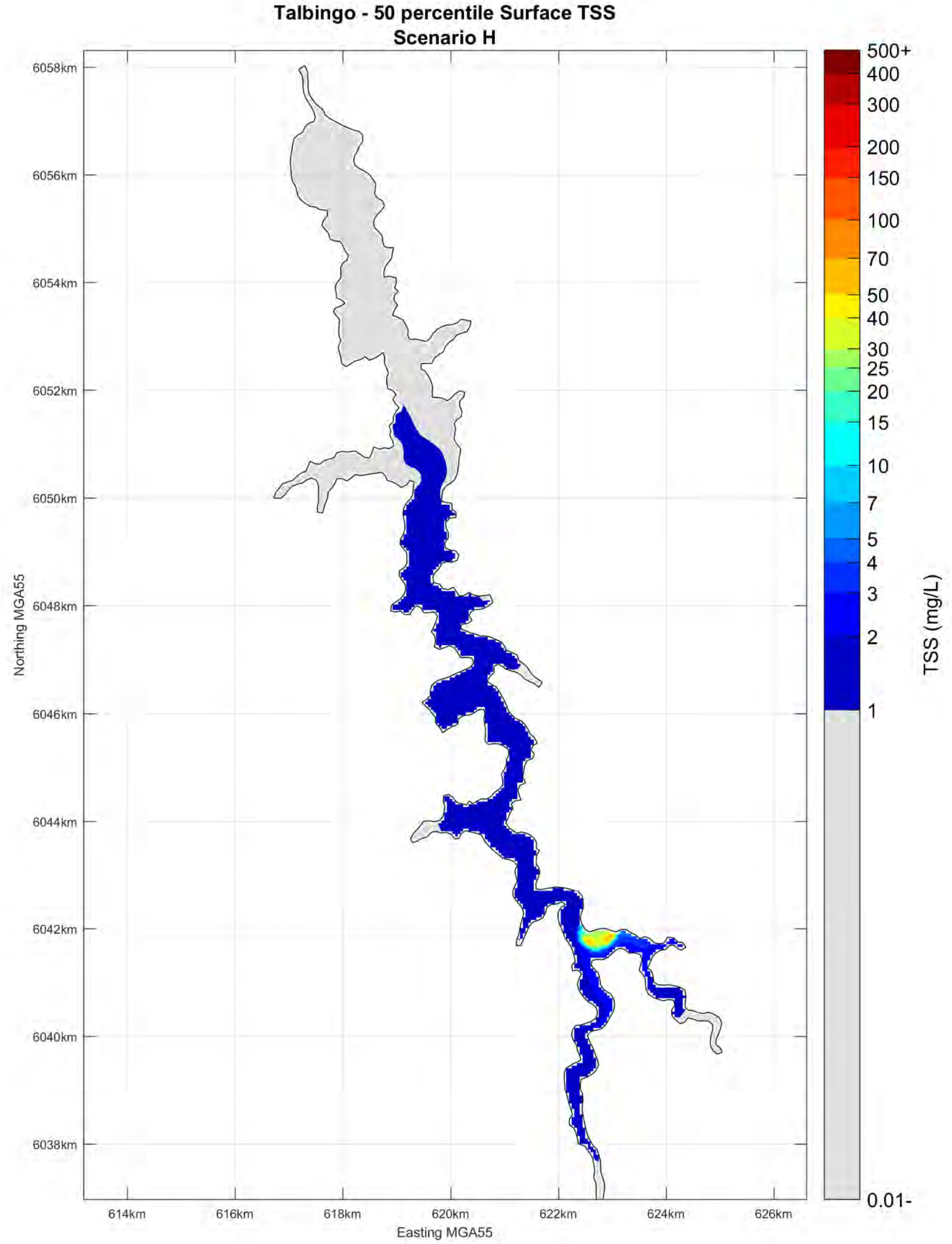


Figure 9: 50% exceedance (over 36 months) surface TSS

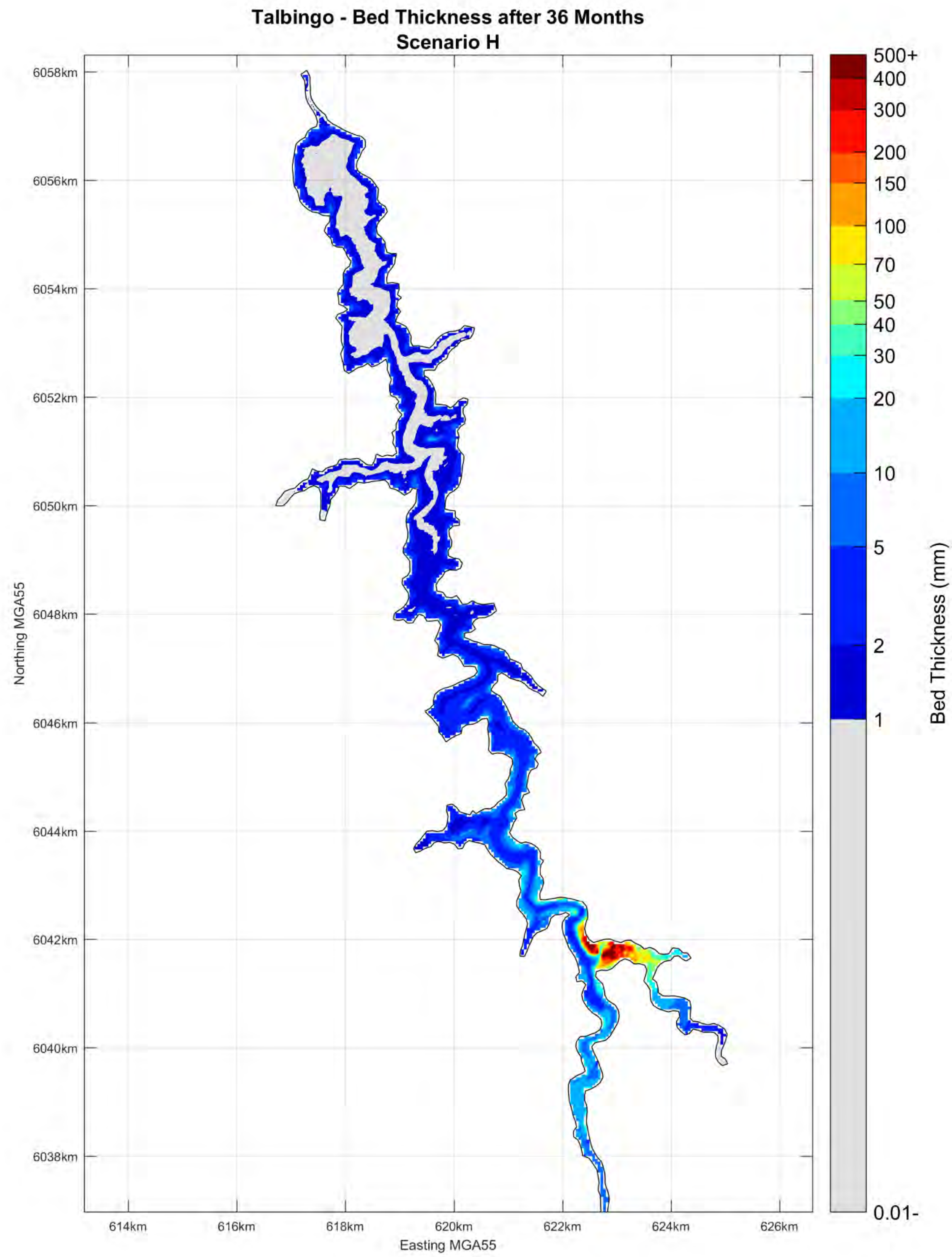


Figure 10: Bed sedimentation thickness after 36 months

4 References

EMM (2020). 'Preferred excavated rock management strategy', prepared for Snowy Hydro Limited, March 2020.

RHDHV (2019). EIS Annexure report "Snowy 2.0: Talbingo Reservoir Modelling – Construction" September 2019. Included as Annexure G to the Excavated Rock Placement Assessment Summary (EIS Snowy 2.0 Appendix L).

Appendix C

Filter concept design

Note / Memo

Haskoning Australia PTY Ltd.
Maritime & Aviation

To:	Duncan Peake (EMM)
From:	Rick Plain, Greg Britton (RHDHV)
Date:	24 March 2020
Copy:	Chris Kuczera (EMM), Mark Trudgett (EMM)
Our reference:	PA1804MANT240320

Subject: **In-reservoir Rock Emplacements**
Filter Layer Concept Design

The memorandum herein documents options for the design of filter layers to prevent leaching of fines from the Snowy 2.0 excavated rock emplacements into Tantangara Reservoir and Talbingo Reservoir.

Snowy 2.0 construction activities would produce two main types of excavated rock, which are:

1. Drill and Blast (D&B) excavated rock; and,
2. Tunnel Boring Machine (TBM) excavated rock.

It is proposed to place D&B excavated rock below the Full Supply Level (FSL) in Talbingo Reservoir and Tantangara Reservoir with TBM and excess D&B excavated rock placed above FSL. Rock armour comprising D&B (200mm plus) excavated rock is proposed to be placed as an armour layer on the outer face of the rock emplacements, below FSL. D&B (200mm plus) is material that would be retained on a 200mm sieve screen and is expected to comprise approximately 30% by mass of the D&B excavated rock based on assumed grading.

D&B excavated rock is widely graded with particle size expected to vary from less than 4μm (clay) up to approximately 500mm (boulders). The percentage of fines (clay and silt sized particles, <63μm) is relatively low at approximately 2% by mass. Hydraulic conductivity of the D&B excavated rock is estimated to be 0.3m/s based on available empirical equations. Local flow of pore water through the D&B excavated rock, as a consequence of fluctuation of operational water levels in the reservoir, may convey fine particles through the voids associated with the coarse particles. This is called **internal erosion** and can only occur in widely graded materials.

Internal erosion would lead to the release of fine particles from the excavated rock placement and may lead to instability and settlement of the placement area. A filter layer can be introduced to prevent the release of fine particles into the reservoirs, should such release be an issue. The filter layer would be designed for two common criteria, which are:

- **Retention criteria** to prevent loss of the base material (excavated rock) due to leaching through the filter layer; and,
- **Permeability criterion**, to ensure adequate permeability of the filter layer to reduce the hydraulic gradient across the layer and to prevent the build-up of pore water pressure behind the filter layer.

Filter layers are typically used in the construction of dams and coastal rock revetments. Two types of filter layers are available, which are:

- Geotextile filter layers; and,
- Granular filter layers.

The traditional design criterion for filter layers can be characterised as **geometrically tight (or closed)**, which implies that pore sizes (in granular filter layers) or opening sizes (in geotextile filter layers) are too small to allow the fine grains from the base material to pass through the filter. Designing for a geometrically tight filter layer is perceived to be the most suitable solution to prevent release of fine grained material into the reservoirs. Such filters require knowledge of the particle size distribution of the base material and the pore or opening size distributions of the filter.

1 Peninsular Rock Emplacement

All surplus excavated rock from the Tantangara construction zone will be disposed in an emplacement area referred to as the Peninsula emplacement. The concept design incorporates an in-reservoir pad constructed using D&B spoil from the Tantangara Reservoir bed up to FSL. Combined D&B and TBM spoil will be placed on top of the D&B pad and on existing land above the FSL. Refer to Chapter 4 of the main report for further details.

The water level at Tantangara Reservoir is proposed to be regulated during construction, therefore all excavated rock would be placed in the dry. It is proposed to compact the excavated rock in maximum 300mm layers, which would be expected to generate additional fines. However, this would have minimal impact on the internal stability or hydraulic conductivity (but would increase the total mass of fines potentially available for leaching). Hydraulic conductivity is typically determined by D_{10} of the excavated rock, being the diameter for which 10% is less than by mass on the sieve curve, while internal stability is dependant on the ratio between D_{10} and D_{60}.

The proposed concept design describes the in-reservoir emplacement, below FSL, to be constructed using D&B material only. Opportunities to blend some TBM material into the in-reservoir emplacement will be assessed at detailed design. The TBM material is internally unstable as it is widely graded. It would behave similar to the D&B material in terms of the potential for the wash out of fines albeit the fines content is expected to be higher. This alternative approach may be implemented if it can be demonstrated that the proposed granular filter will achieve the required water quality outcomes for Total Suspended Solids (TSS) leached from the placement area.

It is proposed to place filter layers at the following locations:

- Location 1 – along the sloping interface between the compacted D&B excavated rock and D&B (200mm plus) armour layer, below FSL; and,
- Location 2 – along the horizontal interface between the compacted D&B excavated rock and overlying TBM and excess D&B excavated rock, at around FSL.

1.1 Geotextile Filter Layer

Bidim A44 was initially proposed by FGJV as a geotextile filter layer for the excavated rock placement. Bidim A44 has a pore size of 75μm and a hydraulic conductivity of $4.3*10^{-3}$ m/s.

The hydraulic conductivity of the geotextile filter layer is less than the hydraulic conductivity of the D&B excavated rock placement. The permeability criterion is not satisfied and there would be a build-up of pore water pressure behind the geotextile filter layer, if it is placed at Location 1. However, this does not necessarily preclude the use of a geotextile filter layer. The difference in pore water pressure on either side of the geotextile and heave should be checked to ensure the tear strength and burst strength of the geotextile is suitable and confining pressure exceeds the heave.

Fine particles that are smaller than the pore size of the geotextile filter layer may flow through the geotextile. Where the flow through the geotextile filter layer is one directional, such as groundwater infiltration through the geotextile filter layer at Location 2, the filter layer would be expected to become blinded by the fines and the leaching of fines through the filter layer would become negligible. However, the geotextile filter layer at Location 1 will be exposed to bi-directional flow due to operation of the reservoir (fluctuating water levels). In this situation, the geotextile is not likely to become blinded since the reversal of flow against the geotextile could wash fines off the fabric as water flows inwards.
It is possible the entire quantity of fines less than say 20μm within the compacted D&B excavated rock placement may leach into the reservoir over time.

Modelling could be undertaken to determine the impact on water quality as a result of fines leaching out of the placement area over time.

Detailed design would need to consider the outer slope of the excavated rock placement to ensure workers can safely place the geotextile filter layer.

1.2 Granular Filter Layer

Granular filter layers may be developed at Location 1, to minimise leaching of fines from the excavated rock placement. As the D&B excavated rock is relatively coarse, satisfying the permeability criteria would result in a coarse filter layer, that would **not** retain fines in the D&B excavated rock. However, a filter layer with a lower permeability, compared to the D&B excavated rock, could be developed. There would be a build-up of pore water pressure behind the filter layer. The thickness of the filter layer would need to consider the difference in hydraulic head across the layer, to minimise risk of piping, and consider the potential for heave due to the difference in pore water pressure across the layer. These factors should be considered during detailed design.

The D&B excavated rock is internally unstable as it is widely graded. It is assumed that the fines in the D&B excavated rock would be dispersive. A sand and fine gravel filter layer, with a D_{15} less than 0.2mm, would satisfy the retention criteria in accordance with Lafleur et al (1989). Due to the difference in particle size between the D&B excavated rock and the sand filter layer, intermediate filter layer/s would be required to prevent the sand from washing into the D&B excavated rock when the flow across the filter layer is reversed. D&B (200mm minus) is internally stable and could be used as a filter layer to prevent this occurrence. D&B (200mm minus) would be produced as a by-product of generating D&B (200mm plus) for the armour layer. Depending on the particle size distribution and availability of material, a third filter layer may be required. However, based on assumed gradings, a single intermediate filter layer comprising D&B (200mm minus) would be sufficient.

A geotextile filter layer, such as Bidim A44, could also be used in lieu of the intermediate filter layer/s. The minimum particle size of the sand is larger than the pore size of Bidim A44 and hence would not be leached through the geotextile filter layer.

Bidim A44 could also be placed between the sand filter layer and the D&B (200mm plus) armour layer, to ensure the sand filter is not eroded. Alternatively, granular filter layers could be developed to retain the sand filter layer.

D&B (200 minus) would be placed in a layer thickness of minimum 350mm and the sand filter layer would be placed with a layer thickness of at least 200mm. These layer thicknesses do not consider piping or heave, which should be considered in the detailed design phase.

The hydraulic conductivity of the sand filter layer is approximately $1*10^{-5}$ m/s, which is less than the Bidim A44 ($4.3*10^{-3}$ m/s). The sand filter layer would therefore govern flow conveyance criteria.

Two concept design options for a filter layer at Location 1 are appended in **Attachment A**. The concept options will be further developed at detailed design.

If a granular filter layer is adopted at Location 1, the risk of leaching of fines into the reservoir during operations would be negligible 'by design' and numerical modelling to determine the impact on water quality would not be considered necessary. Quality control procedures would need to be developed during construction to ensure the filter design is achieved.

2 Ravine Bay Rock Emplacement

The concept design for the Ravine Bay emplacement incorporates an in-reservoir pad constructed using D&B spoil from the Talbingo Reservoir bed up to FSL. The pad will be constructed using the edge push method with an outer armour layer of D&B (200mm plus) placed by a barge or similar. Combined D&B and TBM spoil will be placed on top of the D&B pad and on existing land to the north of the reservoir. Refer to Chapter 4 of the main report for further details.

It was initially proposed to place filter layers at:

- Location 1 – along the sloping interface between the D&B excavated rock and D&B (200mm plus) armour layer, below FSL; and,
- Location 2 – along the horizontal interface between the D&B excavated rock and overlying TBM and excess D&B excavated rock, at around FSL.

The edge push method below water level means that a proportion of the fines within the D&B excavated rock will be progressively lost to the water column during placement. The construction phase will take approximately three years to complete and the impact on water quality as a result of the loss of these fines has been modelled (see Appendix B).

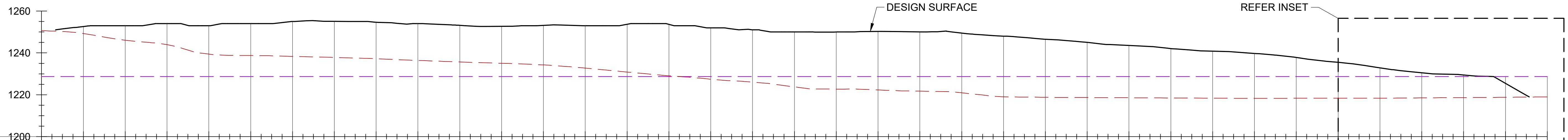
A small quantity of fines would remain in the rock emplacement following the construction phase. These fines would settle in the voids of the coarser rock. It is considered unlikely that the remaining fines would be leached out of the underwater D&B placement to any significant extent during the operational phase as the flow of water through the pores of the excavated rock would be relatively low.

Accordingly, a filter layer at Location 1 is **not** considered necessary from a water quality perspective. However, if a filter layer is installed, consideration would need to be given to the placement technique and tolerances given the water depth at the toe of the emplacement is up to 30m.

Similar to the assessment for Tantangara Reservoir, a geotextile filter layer is considered suitable at Location 2. Flow through the geotextile filter layer, resulting from groundwater infiltration, is one directional. The filter layer would be expected to become blinded by the fines and the leaching of fines through the filter layer would become negligible.

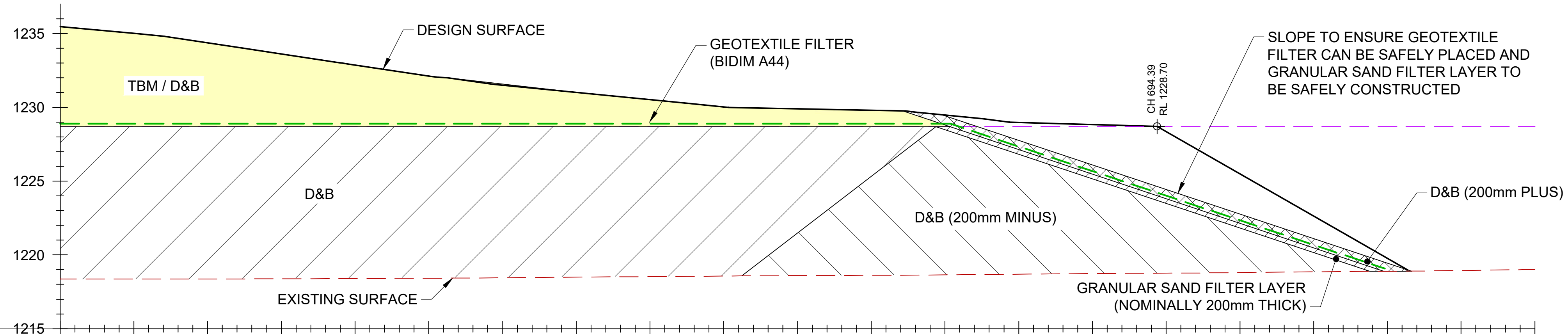
Attachment A – Concept Design Options

TANTANGARA RESERVOIR PENINSULAR EMPLACEMENT
GRANULAR FILTER LAYER CONCEPT DESIGN
SECTIONS



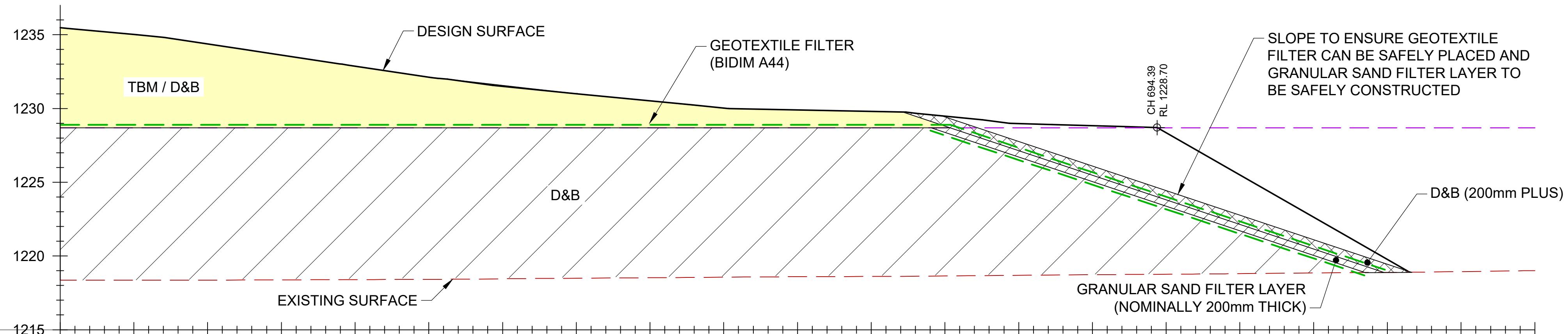
DESIGN LEVELS	1252.60	1253.00	1254.00	1253.00	1254.00	1255.00	1255.05	1254.64	1253.98	1253.17	1252.67	1253.16	1253.00	1253.65	1253.63	1252.00	1251.00	1250.00	1249.98	1250.26	1250.01	1249.47	1248.00	1246.47	1245.02	1243.54	1242.06	1240.84	1239.75	1237.82	1235.47	1232.87	1230.52	1229.47	1225.49	
EXISTING LEVELS	1249.28	1246.07	1243.95	1239.44	1238.77	1238.31	1237.85	1237.22	1236.42	1235.69	1235.05	1234.29	1232.76	1230.89	1229.11	1227.41	1226.04	1223.78	1222.71	1222.34	1221.77	1220.95	1219.04	1218.79	1218.68	1218.59	1218.48	1218.41	1218.31	1218.35	1218.35	1218.40	1218.53	1218.65	1218.80	1219.01
DIFFERENCE	3.32	6.93	10.05	13.56	15.23	16.69	17.21	17.43	17.56	17.48	17.63	18.87	20.24	22.77	24.53	24.59	24.96	26.22	27.27	27.92	28.24	28.53	28.96	27.68	26.35	24.95	23.58	22.43	21.43	19.47	17.12	14.47	11.99	10.83	6.69	
CHAINAGE	20.00	40.00	60.00	80.00	100.00	120.00	140.00	160.00	180.00	200.00	220.00	240.00	260.00	280.00	300.00	320.00	340.00	360.00	380.00	400.00	420.00	440.00	460.00	480.00	500.00	520.00	540.00	560.00	580.00	600.00	620.00	640.00	660.00	680.00	700.00	

LONG-SECTION
1:1000 (A1)



DESIGN LEVELS	1235.02	1234.37	1233.62	1232.87	1232.13	1231.50	1231.00	1230.52	1230.03	1229.90	1229.80	1229.47	1228.98	1228.83	1228.35	1225.49	1222.63	1219.76		
EXISTING LEVELS	1218.36	1218.37	1218.38	1218.40	1218.41	1218.45	1218.50	1218.53	1218.56	1218.60	1218.61	1218.65	1218.69	1218.73	1218.76	1218.80	1218.85	1218.89	1218.94	1219.01
DIFFERENCE	16.65	16.00	15.24	14.47	13.71	13.05	12.51	11.99	11.47	11.31	11.18	10.83	10.29	10.10	9.59	6.69	3.78	0.88		
CHAINAGE	625.00	630.00	635.00	640.00	645.00	650.00	655.00	660.00	665.00	670.00	675.00	680.00	685.00	690.00	695.00	700.00	705.00	710.00	715.00	

INSET - OPTION 1
1:200 (A1)



DESIGN LEVELS	1235.02	1234.37	1233.62	1232.87	1232.13	1231.50	1231.00	1230.52	1230.03	1229.90	1229.80	1229.47	1228.98	1228.83	1228.35	1225.49	1222.63	1219.76		
EXISTING LEVELS	1218.36	1218.37	1218.38	1218.40	1218.41	1218.45	1218.50	1218.53	1218.56	1218.60	1218.61	1218.65	1218.69	1218.73	1218.76	1218.80	1218.85	1218.89	1218.94	1219.01
DIFFERENCE	16.65	16.00	15.24	14.47	13.71	13.05	12.51	11.99	11.47	11.31	11.18	10.83	10.29	10.10	9.59	6.69	3.78	0.88		
CHAINAGE	625.00	630.00	635.00	640.00	645.00	650.00	655.00	660.00	665.00	670.00	675.00	680.00	685.00	690.00	695.00	700.00	705.00	710.00	715.00	

INSET - OPTION 2
1:200 (A1)

LEGEND

EXISTING SURFACE (LIDAR)

FULL SUPPLY LEVEL
(FSL) = RL 1228.69mAHD

20 0 20 40 60 80 100m
1:2000 (A3) 1:1000 (A1)

4 0 4 8 12 16 20m
1:400 (A3) 1:200 (A1)

S2 FOR INFORMATION

NOT FOR CONSTRUCTION

AUSTRALIAN HEIGHT DATUM

Appendix B

Revised Environmental Mitigation Measures – track changes

Table C.1 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Water					
General	WM01	A Water Management Plan will be developed for Snowy 2.0 Main Works that includes: • proposed mitigation and management measures for all construction water management categories; • spill management and response; • a surface and groundwater monitoring program; • water quality trigger levels; • reporting requirements; • corrective actions; • contingencies; and • responsibilities for all management measures. The WMP will be prepared in consultation with DPIE, EPA, WaterNSW and key local stakeholders, and would consider concerns raised during the exhibition and approvals process for the project.	A Water Management Plan will be developed for Snowy 2.0 Main Works that includes: • proposed mitigation and management measures for all construction water management categories; • spill management and response; • a surface and groundwater monitoring program; • water quality trigger ~~levels~~ action response plan; • reporting requirements; • corrective actions; • contingencies; and • responsibilities for all management measures. The WMP will be prepared in consultation with DPIE, EPA, WaterNSW and key local stakeholders, and would consider concerns raised during the exhibition and approvals process for the project.	Construction	Contractor
General	WM02	A water monitoring program will be developed as part of the water management plan to monitor quality and quantity impacts to surface water, groundwater and reservoirs. The water monitoring program will incorporate and update the existing monitoring network and detail monitoring frequencies and water quality constituents.	No change	Construction and operation	Contractor
Water quality impacts from stormwater runoff	WM03	Where practical, clean water will be diverted around or through construction areas. Runoff from clean water areas that cannot be diverted will be accounted for in the design of water management systems.	No change	Construction	Contractor

Table C.1 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Water quality impacts from stormwater runoff	WM04	An Erosion and Sediment Control Plan (ESCP) will be prepared for each construction area that will include relevant information presented in the water management report (Annexure D to water assessment)	No change	Construction	Contractor
Water quality impacts from stormwater runoff	WM05	A suitably qualified erosion and sediment control professional(s) will be engaged to: • oversee the development of ESCPs; • inspect and audit controls; • train relevant staff; and progressively improve methods and standards as required.	A suitably qualified erosion and sediment control professional(s) will be engaged to: • oversee the development of ESCPs; • inspect and audit controls; • train relevant staff; and • provide advice regarding erosion and sediment control. ~~progressively improve methods and standards as required.~~	Construction	Contractor
Groundwater modelling	WM06	The groundwater model developed for Snowy 2.0 Main Works will be validated and, if necessary, recalibrated to new groundwater monitoring data as the monitoring record increases throughout construction. It is recommended that assessment of the monitoring record and groundwater affecting activities, along with model updates, be undertaken at least annually throughout construction and into operation until it is evident that the update frequency can be reduced.	No change	Construction and operation	Contractor Snowy Hydro
Groundwater inflow / drawdown	WM07	Where discrete high flow features are intercepted, pre-grouting and secondary grouting from the TBM may be undertaken to enable tunnel construction.	No change	Construction	Contractor

Table C.1 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Water supply	WM08	A water supply system will be established to supply water for potable water use and construction activities. The system will most likely source water from regional groundwater resources, but may also source water from either Tantangara or Talbingo Reservoirs provided licences are available. Extraction from watercourses will be avoided. The most suitable extraction locations and water sources will be established during detailed design	A water supply system will be established to supply water for potable water use and construction activities. The system will most likely source water from regional groundwater resources, but may also source water from either Tantangara or Talbingo Reservoirs provided licences are available. Extraction from watercourses will be avoided where practicable. The most suitable extraction locations and water sources will be established during detailed design.	Construction	Contractor Snowy Hydro
Reservoir water quality (wastewater management)	WM09	A wastewater management system will be established to manage effluent from construction compounds and accommodation camps. All wastewater will be treated to meet the water quality specifications provided in the water management report (Annexure D to water assessment) and will be discharged to reservoirs. Wastewater discharges to watercourses will be avoided.	No change	Construction	Contractor
Reservoir water quality (process water management)	WM10	A process water management system will be established to manage water from subsurface excavations and large surface excavations during construction; and to supply water to construction activities. All surplus process water will be treated to meet the water quality specifications provided in the water management report (Annexure D to water assessment) and will be discharged to reservoirs. Process water discharges to watercourses will be avoided.	A process water management system will be established to manage water ~~from subsurface excavations and large surface excavations~~ during construction; and to supply water to construction activities. All surplus process water will be treated to meet the water quality specifications provided in the water management report (Annexure D to water assessment) and will be discharged to reservoirs. Process water discharges to watercourses will be avoided.	Construction	Contractor

Table C.1 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Changes to reservoir water quality due to plug removal within the reservoirs	WM11	The specifications and locations of the proposed environmental measures will be determined as part of detailed design, including the installation of silt curtains. They will be designed such that water quality criteria is agreed with the regulators, with the application of a mixing zone if required.	No change	Construction	Contractor
Reservoir bed sediments are disturbed by commissioning water flows	WM12	Investigations to minimise the disturbance of bed sediments due to water flows during commissioning will be undertaken as part of detailed design. Potential measures to minimise the disturbance of bed sediments include: • investigate mitigated design measures; • dredging sediments from the potential disturbance zones and placing them in another part of the reservoir; and/or • armouring the sediments in the potential disturbance zones. These options are currently being assessed.	No change	Construction	Contractor Snowy Hydro
Flooding	WM13	Further consideration of flooding conditions and impacts, including flood modelling where necessary, will be undertaken to support future detailed design of both temporary and permanent works.	No change	Construction Operation	Contractor Snowy Hydro
Flooding	WM14	Flood emergency response plans will be developed for both construction and operational phases	No change	Construction Operation	Contractor Snowy Hydro

Table C.1 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Terrestrial ecology					
Fauna strike to Smoky Mouse and Eastern Pygmy possum	ECO1	Management measures to mitigate the potential impacts of fauna strike are currently being considered. These measures include: • reduced speed limit along Lobs Hole Ravine Road and Marica Trail at night, when fauna species are likely to be most active; • fencing of these roads to prevent access to the road surface; and • construction of fauna underpasses. The adopted measures will be agreed in consultation with DPIE.	Management measures to mitigate the potential impacts of fauna strike are currently being considered. These measures may include: • reduced speed limit along Lobs Hole Ravine Road and Marica Trail at night, when fauna species are likely to be most active; • fencing of these roads to prevent access to the road surface; and • construction of fauna underpasses. The adopted measures will be agreed in consultation with DPIE.	Construction	Contractor
Spread of weeds	ECO2	A weed and pathogen monitoring program will be implemented, with a weed control program to be implemented if weeds are identified along road verges. This will include wash-down stations will be constructed at a suitable location, with wash down for weeds as well as *P.cimmamomi*.	A weed and pathogen monitoring program will be implemented, with a weed control program to be implemented if weeds are identified along road verges. This may ~~will~~ include wash-down stations to ~~will~~ be constructed at a suitable location, with wash down for weeds as well as *P.cimmamomi*.	Construction	Contractor Snowy Hydro
Impacts to GDEs	ECO3	A GDE monitoring program will be implemented to ensure actual impacts are within prediction. If actual impacts are greater than predicted, adaptive management will be implemented.	A GDE monitoring program will be implemented to assess ~~ensure~~ actual impacts against predicted ~~are within prediction~~. If actual impacts are greater than predicted, adaptive management will be implemented.	Construction	Contractor

Table C.1 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Removal of native vegetation and threatened species habitat	ECO4	A Biodiversity Management Plan will be prepared and implemented during construction. It will include the following measures: • establishment of exclusion zones around retained vegetation, including fencing and signage; • pre-clearing surveys conducted prior to clearing, including translocation of fauna into areas of retained vegetation; • vegetation clearing undertaken in accordance with the two-stage process; • mulching and stockpiling of cleared native vegetation for use during rehabilitation; • retention of hollows logs and limbs for placement within retained vegetation and reuse during rehabilitation; • regional surveys for the Smoky Mouse to demonstrate presence of a significant regional population; • collection of native seeds and alpine sod for propagation; and establishment of native plant nursery and propagation of endemic native species for use in rehabilitation works.	A Biodiversity Management Plan will be prepared and implemented during construction. It will include the following measures: • establishment of exclusion zones where required around retained vegetation, including fencing and signage; • pre-clearing surveys conducted prior to clearing, including translocation of fauna into areas of retained vegetation; • vegetation clearing undertaken in accordance with the two-stage process; • mulching and stockpiling of cleared native vegetation for use during rehabilitation; • retention of hollows logs and limbs for placement within retained vegetation and reuse during rehabilitation where practicable; ~~• regional surveys for the Smoky Mouse to demonstrate presence of a significant regional population;~~ • collection of native seeds and alpine sod for propagation; and • establishment of native plant nursery and propagation of endemic native species for use in rehabilitation works.	Construction	Contractor Snowy Hydro
	ECO5	A threatened species monitoring program will be designed and implemented to ensure impacts arising from clearing are within prediction.	A threatened species monitoring program will be designed and implemented to assess ~~ensure~~ impacts arising from clearing~~are within prediction~~.	Construction and operation	Contractor Snowy Hydro
Increase in predatory and pest species	ECO6	A pest and predator monitoring program will be designed and implemented to ensure Main Works does not result in a significant increase in numbers of pest and predatory species and impacts to threatened species remain within prediction.	No change	Construction and operation	Contractor Snowy Hydro

Table C.1 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Aquatic ecology					
Impacts to aquatic habitats	AE01	An Aquatic Habitat Management Plan will be prepared and implemented to guide management of impacts to aquatic habitat. The plan will: • be prepared in consultation with NPWS and DPI-Fisheries; • include a description of measures that would be implemented to: – protect aquatic habitat outside the approved disturbance areas; – minimise the loss of key aquatic habitat; – minimise the impacts of the development on threatened fauna species; – minimise the impact of the development on fish habitat; – relocate Murray crayfish from the shallower parts of the approved disturbance area in Talbingo Reservoir prior to disturbing these areas – notify DPI-Fisheries of any fish kills; • include a trigger action and response plan for the Murray crayfish, which would be implemented if monitoring shows the development is adversely affecting the species;	An Aquatic Habitat Management Plan will be prepared and implemented to guide management of impacts to aquatic habitat. The plan will: • be prepared in consultation with NPWS and DPI-Fisheries; • include a description of measures that would be implemented to: – minimise impacts to ~~protect~~ aquatic habitat outside the approved disturbance areas; – minimise the loss of key aquatic habitat; – minimise the impacts of the development on threatened fauna species; – minimise the impact of the development on fish habitat; – relocate Murray crayfish from the shallower parts of the approved disturbance area in Talbingo Reservoir prior to disturbing these areas – notify DPI-Fisheries of any fish kills; • include a trigger action and response plan for the Murray crayfish, which would be implemented if monitoring shows the development is adversely affecting the species;	Construction and operation	Contractor Snowy Hydro
		• include a program to restore and enhance the aquatic habitat of the approved disturbance area expect for the intake and their approach areas as soon as practicable following the completion of development in these areas; • include a program to monitor and report on the effectiveness of these measures.	• include a program to restore and enhance the aquatic habitat of the approved disturbance area except for the intakes and their approach areas as soon as practicable following the completion of development in these areas; • include a program to monitor and report on the effectiveness of these measures.		

Table C.1 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
	AE02	Bridges or culverts would be designed and constructed in accordance with NSW DPI fish passage requirements for waterway crossings (Fairfull & Witheridge 2003).	Bridges or culverts would be designed and constructed in accordance with NSW DPI fish passage requirements for waterway crossings (Fairfull & Witheridge 2003) where practicable.	Construction	Contractor
	AE03	Construction works within the channel of a permanent waterway with type 1 or 2 key fish habitat would allow some flow to maintain fish passage at all times and be staged to minimise the total disturbance at any given time.	No change	Construction	Contractor
Spread of weeds pest fish and pathogens	AE04	A Weed, Pest and Pathogen Management Plan will be prepared and implemented to minimise and manage the spread of weeds, pest fish and pathogens. The plan will: • be prepared in consultation with NPWS and DPI-Fisheries; • include a description of measures that would be implemented to: – minimise the spread of weeds and pest via vehicle and plant movements; – remove aquatic macrophytes appropriately where required to do so to enable construction activities; • include a program to monitor and report distribution of pest fish within the project area; • include a surveillance plan for EHNV in key locations within the project area.	No change	Construction and operation	Contractor Snowy Hydro
Underwater blasting impacts	AE05	Designated blast limits and other management measures to minimise impacts to aquatic ecology will be outlined in the Blast Management Plan.	No change	Detailed design and construction	Contractor

Table C.1 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Controls	AE06	Install the following: • fish barrier on Tantangara Creek designed to prevent upstream migration of Climbing galaxias; and • fine mesh screens to prevent transfer of key species through releases from the Tantangara Dam River Outlet Works and the Murrumbidgee – Eucumbene tunnel.	No change	Construction	~~Contractor~~ Snowy Hydro

Table C.2 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Land					
Rehabilitation	REHAB01	A Rehabilitation Management Plan will be prepared for the new landforms at Tantangara Reservoir, Lobs Hole and Talbingo Reservoir. The plan will: • include a detailed plan for rehabilitation of the site; • include detailed performance and completion criteria for evaluating the performance of the rehabilitation of the sites, and triggering any remedial action (if necessary); • describe the measures that would be implemented to: – comply with the rehabilitation objectives and associated performance and completion criteria; – progressively rehabilitate the site; – include a program to monitor and report the effectiveness of these measures.	No change	Construction	Contractor
Creation of new landforms	REHAB02	New landforms will: • be safe, stable and non-polluting; maximise surface drainage to the natural environment	No change	Construction	Contractor

Table C.2 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Assessment of surface disturbance and excavation areas	CONTAM01	Targeted investigations will be undertaken prior to construction along the surface disturbance areas using a risk-based approach. The results of these targeted investigations will determine the level of management to be implemented.	No change	Pre-construction	Contractor
Assessment of imported Virgin Excavated Natural Material (VENM)	CONTAM02	Prior to the importation of any VENM during construction, the VENM source(s) will be identified and assessed against the definition of VENM in the *Waste Classification Guidelines* (NSW EPA 2014) and POEO Act. The VENM source(s) will be assessed by an appropriately qualified contaminated land consultant.	No change	Construction	Contractor
Contaminated soil management during construction	CONTAM03	Protocols for the management of contaminated soil during construction will be included in the CEMP.	Protocols for the management of contaminated soil during construction will be included in the CEMP or EMS.	Construction	Contractor

Table C.2 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Excavated rock waste management and transport	CONTAM04	Material which has been assessed as not suitable for reuse on land or for subaqueous disposal or cannot be reused will be classified in accordance with the *Waste Classification Guidelines* (NSW EPA 2014). The excavated rock would be transported to an appropriate excavated rock disposal area. Approval would be obtained prior to transport and would require an estimate of the likely volume of excavated rock to be disposed.	Material which has been assessed as not suitable for reuse on land or for subaqueous disposal or cannot be reused will be classified in accordance with the *Waste Classification Guidelines* (NSW EPA 2014). ~~The excavated rock would be transported to an appropriate excavated rock disposal area. Approval would be obtained prior to transport and would require an estimate of the likely volume of excavated rock to be disposed.~~ Depending on the classification of the material, a licensed waste transport company will be used to transport material which is required to leave the project, to an appropriately licensed facility. Excavated material may be subject to treatment and application on site.	Construction	Contractor
Asbestos management	CONTAM05	An Asbestos Management Plan (AMP) will be developed for areas and items identified during pre-construction investigations as containing Asbestos Containing Materials ACM (ACM), areas suspected of containing ACM (such as historical buildings) and to address unexpected finds of ACM during construction. Specifically, protocols will be stipulated for separation, monitoring, validation and clearance of asbestos.	An Asbestos Management Plan (AMP) will be developed if ~~for~~ areas and items are identified during pre-construction investigations as containing Asbestos Containing Materials ACM (ACM), or areas are suspected of containing ACM (such as historical buildings). The AMP will ~~and to~~ address unexpected finds of ACM ~~during construction~~. Specifically, protocols will be stipulated for separation, monitoring, validation and clearance of asbestos.	~~Pre-construction~~ Construction	Contractor
Asbestos management	CONTAM06	An Occupational Hygienist (Hygienist) will be on-site for the duration of the	No change	Construction	Contractor

Table C.2 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
		excavation works where ACM has been identified from pre-construction or where unexpected finds of ACM are encountered.			
PAF rock	CONTAM07	An Excavated Rock Management Plan would be developed which would include measures identified in the Preliminary Site Investigation – Contamination (Appendix N.1).	An Excavated Rock Management Plan would be developed which would include measures identified in the Preliminary Site Investigation – Contamination (Table 9.1, Item 4 of Appendix N.1).	Pre-construction	Contractor
Unexpected finds	CONTAM08	An unexpected finds procedure will be included in the CEMP. Workers will be trained to identify potential contamination that may be encountered during construction.	No change	Pre-construction and construction	Contractor
Alpine humus soils and peat bogs/fens	SOIL01	Mitigations will be included in the Rehabilitation Management Plan to minimise impacts to Alpine humus soils and peat bogs/fens.	No change	Construction	Contractor
Loss of soil resource	SOIL02	Preservation of the soil resource including quantity and quality to be managed through the implementation of soil management measures incorporated within the rehabilitation management plan which includes: • an inventory of soils to be stripped, including depths and volumes; • a topsoil stripping and stockpiling procedure; • subsoil management measures; and	Development and implementation of soil management measures to assist in the preservation of the quantity and quality of the soil resource including: • an inventory of soils to be stripped, including depths and volumes; and • topsoil management measures including stripping and stockpiling procedure.	Construction ~~and operation~~	Contractor

Table C.2 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
		• a soil reinstatement methodology which includes a topsoil application procedure.			
Soil erosion and sedimentation	SOIL03	Site-based Erosion and Sediment Control Plans (ESCPs) will be prepared by a Certified Professional in Erosion and Sediment Control (CPESC) for the construction works with controls addressing the sensitivity and the proximity of the receiving environment and attention will be given to areas where there is an increased risk of erosion, such as, dispersive soils and steep slopes and subalpine landscapes.	Site-based Erosion and Sediment Control Plans (ESCPs) will be prepared by a suitably qualified erosion and sediment control specialist. ~~by a Certified Professional in Erosion and Sediment Control (CPESC) for the construction works with controls addressing the sensitivity and the proximity of the receiving environment and attention will be given to areas where there is an increased risk of erosion, such as, dispersive soils and steep slopes and subalpine landscapes.~~	Construction	Contractor
Soil capability	SOIL04	The Rehabilitation Management Plan (refer to REHAB01) will be implemented and will include measures to minimise: • loss of soil; • loss of organic matter and nutrient decline; • soil structural decline; and • compaction. The plan will include measures for subsoil management.	The Rehabilitation Management Plan (refer to REHAB01) will be implemented and will include measures to minimise: • loss of soil; • loss of organic matter and nutrient decline; • soil structural decline; and • compaction. ~~The plan will include measures for subsoil management.~~ Regular rehabilitation monitoring will be undertaken to identify any defects, such as slumping, erosion or poor vegetation establishment. Identified defects will be rectified.	Construction and operation	Contractor Snowy Hydro

Table C.2 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Geodiversity – Ravine block streams	GEO1	Design principles identified in the Cenozoic Geodiversity Report will be implemented to minimise impacts to the Ravine block streams during detailed design.	No change	Design and construction	Contractor Snowy Hydro
Geodiversity – Ravine tufa	GEO2	Design principles identified in the Cenozoic Geodiversity Report will be implemented to minimise impacts to the Ravine tufa during detailed design.	No change	Design and construction	Contractor Snowy Hydro
Geodiversity – Lick Hole Formation fossil locality	GEO3	Final road design will consider incorporating interpretive signage and safe stopping space within the proposed road and disturbance footprint where practical.	No change	Construction	Contractor
Geodiversity – Kellys Plain Volcanics Type Locality	GEO4	During construction, ensure that the former Traces Knob quarry is not in-filled.	No change	Construction and operation	Contractor and Snowy Hydro
Geodiversity – Kellys Plain Volcanics agglomeratic porphyry	GEO5	Identify outcrops of agglomeratic porphyry prior to construction at Tantangara portal. Excavated rock placement should leave some of the best examples of the agglomeratic porphyry uncovered.	Identify outcrops of agglomeratic porphyry prior to construction at Tantangara portal. Excavated rock placement should leave some of the best examples of the agglomeratic porphyry uncovered where reasonable and feasible to do so.	Pre-construction, construction and operation	Contractor and Snowy Hydro
Geodiversity	GEO6	A management plan will be prepared that includes measures that minimise impacts to known geodiversity sites and potential undocumented geodiversity sites identified in accordance with the recommendation in the Cenozoic and Paleozoic Geodiversity reports.	No change	Construction	Contractor

Table C.2 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Geodiversity	GEO7	Consult with NPWS regarding opportunities to enhance the geotourism potential of impacted geodiversity sites through the development of the masterplan for recreational use.	No change	Operation	Snowy Hydro

Table C.3 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Aboriginal Cultural heritage					
Impact to known and unknown heritage sites and items	HER01	An Aboriginal Heritage Management Plan (AHMP) will be prepared and implemented to guide the process for management and mitigation of impacts to Aboriginal objects. The AHMP will: • be prepared in consultation with RAPs and DPIE; • describe survey units in which impacts are allowable; and • include procedures relating to the conduct of additional archaeological assessment, if required.	No change	Pre-construction and construction	Contractor Snowy Hydro

Table C.3 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Loss of Aboriginal cultural heritage	HER02	Specific management and mitigation measures are listed for each individual survey unit and Aboriginal object locale in Appendix P.1 and will be included in the AHMP. Management measures to be included in the AHMP are: • for survey units within the project disturbance footprint which are assessed to be of higher significance values, impact mitigation measures will be implemented. These would comprise salvage in the form of archaeological excavation and archaeological analysis prior to impacts; and • the AHMP is to include measures for the management of any Aboriginal objects that may be found during construction.	Specific management and mitigation measures are listed for each individual survey unit and Aboriginal object locale in Appendix P.1 and will be included in the AHMP or salvage strategy. Management measures to be included ~~in the AHMP~~ are: • for survey units within the project disturbance footprint which are assessed to be of higher significance values, impact mitigation measures will be implemented. These would comprise salvage in the form of archaeological excavation and archaeological analysis prior to impacts. Salvage will be undertaken prior to impacts occurring to the relevant item and will be documented in a separate report; and • the AHMP is to include measures for the management of any Aboriginal objects that may be found during construction. • Areas within the project disturbance footprint that warrant further field assessment will be managed under the AHMP or salvage strategy after project approval. These areas are documented in the heritage addendum report (Appendix N).	Pre-construction and construction	Contractor Snowy Hydro

Table C.3 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Historic Heritage					
Loss of historic heritage	HER03	Salvage and/or archival recording of potential and known heritage items to be conducted in respect of certain items that warrant that level of impact mitigation.	No change	Pre-construction and construction	~~Contractor~~ Snowy Hydro

Table C.3 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
	HER04	Specific management and mitigation measures are listed for each individual heritage item in Appendix P.2 and will be included in a cultural heritage management plan (CHMP). A series of management recommendations will be presented. In some instances, no impact mitigation is required. For others a range of measures are recommended ranging the establishment of no-zones to ensure the protection of items, salvage of movable heritage to salvage excavation and archival recording. Appropriate avoidance measures will be taken for Washington Hotel (site R20) and Ravine Cemetery (R118). A minimum 20 m project construction avoidance buffer will be applied to the Washington Hotel (site R20) structure. No ground disturbance will occur within the cadastral boundary of Ravine Cemetery as shown on Figure 6.20 in the EIS. Some non-ground invasive vegetation clearance will be required at the western and northern boundaries of the cadastral boundary of Ravine Cemetery (refer to bush fire risk and hazard assessment, Appendix T).	Specific management and mitigation measures are listed for each individual heritage item in Appendix P.2 and will be included in a cultural heritage management plan (CHMP). A series of management recommendations will be presented. In some instances, no impact mitigation is required. For others a range of measures are recommended ranging the establishment of no-zones to ensure the protection of items, salvage of movable heritage to salvage excavation and archival recording. Salvage will be undertaken prior to impacts occurring and will be documented in a separate report. Appropriate avoidance measures will be taken for Washington Hotel (site R20) and Ravine Cemetery (R118). A minimum 20 m project construction avoidance buffer will be applied to the Washington Hotel (site R20) structure. No ground disturbance will occur within the cadastral boundary of Ravine Cemetery as shown on Figure 6.20 in the EIS. Some non-ground invasive vegetation clearance will be required at the western and northern boundaries of the cadastral boundary of Ravine Cemetery (refer to bush fire risk and hazard assessment, Appendix T).	Pre-construction, construction	Contractor

Table C.3 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
			Areas within the project disturbance footprint that warrant further field assessment will be managed under the HHMP or salvage strategy after project approval. These areas are documented in the heritage addendum report (Appendix N)		

Table C.4 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Transport					
Speed limit reductions	TRA01	At locations where minimum sight distances cannot be achieved, due to the existing road alignments, the posted speed limits adjacent to the intersections will be reduced to satisfy the sight distance requirements and maintain safe manoeuvring conditions for motorists. These intersections and the proposed speeds are: • Snowy Mountains Highway/ Tantangara Road – 60 km/hr • Snowy Mountains Highway/ Rock forest – 80 km/hr • Link Road / Lobs Hole Ravine Road – 60 km/hr • Link Road / Snowy Mountains Highway – 80 km/hr • Based on feedback from community consultation speed limit reductions are also being considered for Snowy Mountains Highway through the township of Adaminaby to 60 km/h. Any speed limit changes will be discussed with the relevant roads authority and documented in the construction traffic management plan as required.	No change	Construction	Contractor

Table C.4 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Intersection upgrades	TRA02	Based on the consideration of construction activities as well as intersection capacity assessment following intersections will be upgraded: • **Snowy Mountains Highway / Marica access -** establish **n**ew construction access (BAR / BAL); and • **Snowy Mountains Highway /Rock Forest access -** establish **n**ew construction access (BAR / BAL).	Based on the consideration of construction activities as well as intersection capacity assessment following intersections will be upgraded: • **Snowy Mountains Highway / Marica access -** establish **n**ew construction access (Basic Right-turn (BAR) / Basic Left-turn (BAL)); and • **Snowy Mountains Highway /Rock Forest access -** establish **n**ew construction access (Basic Right-turn (BAR) / Basic Left-turn (BAL)).	Construction	Contractor
OSOM vehicle movements	TRA03	The TMPs will be prepared, submitted and approved by the RMS under permit, prior to the commencement of any deliveries considered 'high risk' OSOM movements in accordance with RMS guidelines.	No change	Construction	Contractor

Table C.4 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Road maintenance	TRA04	Road maintenance will be managed through the following measures: • a Road Dilapidation Report will be prepared and approved prior to and following Snowy 2.0 Main Works; • routine defect identification and rectification of the internal road network will be managed as part of the project maintenance procedure; and • internal access roads will be designed in accordance with the relevant vehicle loading requirements.	Road maintenance will be managed through the following measures: • a Road Dilapidation Report will be prepared and approved prior to and following Snowy 2.0 Main Works; • routine defect identification and rectification of the internal road network will be managed during construction as part of the project maintenance procedure; and internal access roads will be designed in accordance with the relevant vehicle loading requirements.	Construction and operation	Contractor
Traffic control	TRA05	Road works associated with pavement widening, such as those associated with intersection upgrades, that require temporary occupation of traffic lanes or working adjacent to the road, a Traffic Control Plan (TCP) will be prepared identifying the traffic control measures.	No change	Construction	Contractor
Community consultation	TRA06	Affected communities, visitors and emergency services will be notified in advance of any disruptions to traffic and restriction of access to areas of KNP impacted by project activities.	No change	Pre-construction, construction, operations	Snowy Hydro/ Contractor

Table C.4 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Construction traffic management	TRA07	A Construction Traffic Management Plan will be prepared and will include guidelines, general requirements and procedures to be used when construction activities have a potential impact on existing traffic arrangements.	No change	Pre-construction	Contractor
Marine transport	NAV01	The following measures will be implemented to manage interactions between marine transport and public boating activities during construction: • public exclusion zones will be established around all in-reservoir construction areas; • an aquatic license will be obtained from RMS for all in-reservoir construction activities and exclusion zones; • all work vessels will be limited to 4 knots; • all vessels and barges will be fitted with Automatic Identification System and comply with all licensing requirements of Australian Maritime Safety Authority and Roads and Maritime Services including specific requirements for Alpine Waters; • any fixed obstruction such as marker buoys and moorings will comply with Roads and Maritime Services requirements and are adequately lit at night; and	The following measures will be implemented to manage interactions between marine transport and public boating activities during construction: • public exclusion zones will be established around all in-reservoir construction areas; • an aquatic licence will be obtained from RMS for in-reservoir construction activities and exclusion zones in accordance with Section 12 and 18 of the *Marine Safety Act 1998*; • all work vessels will be limited to 4 knots; • all vessels and barges will be fitted with Automatic Identification System and comply with all licensing requirements of Australian Maritime Safety Authority and Roads and Maritime Services including specific requirements for Alpine Waters;	Construction	Contractor

Table C.4 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
		• notification signs advising of the works and public closures at: – the intersection of Snowy Mountains Highway and Tantangara Road; – the intersection of Snowy Mountains Highway and Long Plain Road; and, – Tantangara Boat Ramp.	• any fixed obstruction such as marker buoys and moorings will comply with Roads and Maritime Services requirements and are adequately lit at night; and • notification signs advising of the works and public closures at: – the intersection of Snowy Mountains Highway and Tantangara Road; – the intersection of Snowy Mountains Highway and Long Plain Road; and Tantangara Boat Ramp.		
Amenity					
Visual and landscape impacts resulting from permanent placement of excavated material	LCV01	The placement of excavated material in Talbingo, Lobs Hole and Tantangara Reservoir will be rehabilitated as guided by the Rehabilitation Strategy and in consultation with NPWS.	No change	Detailed design	Contractor Snowy Hydro ~~NPWS~~

Table C.4 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Visual and landscape impacts resulting from permanent infrastructure	LCV02	Detailed design is to consider: • materials and finishes that complement or where possible recede into the surrounding landscape; • the use of vegetation to screen project elements and re-vegetation of disturbed areas in line with the Rehabilitation Strategy; and • lighting to avoid spill that might affect sensitive areas or receivers.	No change	Detailed design	Contractor

Table C.4 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Construction impacts	NV01	Prepare a construction noise and vibration management plan (CNVMP) that will address noise and vibration management and mitigation options (where required). The CNVMP will include as a minimum: • identification of nearby residences and sensitive land uses; • a description of approved hours of work and what work will be undertaken; • a description of what work practices will be applied to minimise construction noise, in particular how construction noise levels will be managed where predicted noise levels above the NMLs have been identified; • a description of what work practices will be applied to minimise vibration; • a description of the complaints handling process; and • a description of monitoring that is required.	No change	Construction	Contractor
Exceedance of day and night-time criteria at assessment location: R6	NV02	Affected landholders should be consulted prior to and during construction and should be notified of proposed mitigation measures that will be used to manage construction noise levels to below Interim Construction Noise Guideline (EPA 2009) NMLs where practicable.	No change	Pre-construction Construction	Contractor

Table C.4 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Vibration impacts in the vicinity of heritage items	NV03	If the safe working distances are encroached vibration monitoring will be carried out at nearby heritage items. If required, the monitoring system will be fitted with an auditory and visual alarm that triggers when vibration levels reach the nominated criteria. This would indicate if and when alternate work practices should be adopted (such as decrease vibratory intensity, alternate equipment selection, or other measure).	No change	Construction	Contractor
Blasting in the vicinity of sensitive receptors and heritage items	NV04	A Blasting Management Plan will be prepared including specific details to: • address the potential for wet drill and blast activities at Talbingo and Tantangara intakes to ensure potential impacts are managed; • allow for blast practices to be reviewed as needed when blasting occurs in the vicinity of significant heritage items; and allow for blast practices to be reviewed and adapted if complaints are received from residents due to night blasting.	A Blasting Management Plan will be prepared including specific details to: • address the potential for wet drill and blast activities at Talbingo and Tantangara intakes to ensure potential impacts are managed; • allow for blast practices to be reviewed as needed when blasting occurs in the vicinity of significant heritage items; and allow for blast practices to be reviewed and adapted if complaints are received. ~~from residents due to night blasting.~~	Construction	Contractor

Table C.4 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Operational noise	NV05	The design of operational structures, plant and equipment is to consider: • All operational plant and equipment including ventilation, pumps, generators, transformers, variable speed drives or other plant associated with the surface structures of Snowy 2.0 shall be subject to detailed acoustic review prior to final specification. • Design shall be assessed against the requirements of the Noise Policy for Industry (EPA 2017) and consider the amenity criteria for passive recreation. • Building and equipment shall be designed to satisfy the Snowy Hydro design limits of L_{Aeq} 80dB(A) internal.	No change	Operation	Contractor Snowy Hydro
Hazards					
APZs	HAZ01	APZs are established for all Snowy 2.0 Main Works sites to achieve BAL 29.	No change	Construction and operation	Contractor Snowy Hydro
	HAZ02	Vegetation is managed within operational APZs in perpetuity.	No change	Construction and operation	Contractor Snowy Hydro
Construction Standards	HAZ03	All buildings proposed within each development site shall comply with BAL-29 construction standards of Australian Standard AS3959-2018 'Construction of buildings in bush fire-prone areas' or NASH Standard (1.7.14 updated) 'National Standard Steel Framed Construction in Bush fire Areas -2014' as appropriate.	No change	Construction	Contractor

Table C.4 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
On-site Refuge	HAZ04	All On-site Refuge buildings will be within the centre of each Snowy 2.0 Main Works Accommodation site, constructed to BAL-29 construction standard, be of appropriate capacity, signposted and mapped.	All On-site Refuge buildings will be within ~~the centre of~~ each Snowy 2.0 Main Works Accommodation site, constructed to BAL-29 construction standard, be of appropriate capacity, signposted and mapped.	Construction	Contractor
Access	HAZ05	Primary and secondary access is maintained, upgraded and/or constructed to comply where possible with performance criteria and/or acceptable solution requirements of PBP 2018 and NSWRFS Fire Trail Standards (NSWRFS 2019). Consultation with the NSW RFS will be undertaken where compliance is constrained.	No change	Construction	Contractor
Water supply	HAZ06	Water supply requirements for firefighting, including the provision of hydrants and hose reels, is designed, constructed in accordance with the relevant Standards and PBP 2018.	No change	Construction	Contractor
Electricity supply	HAZ07	Electricity supply and distribution is provided in accordance with the requirements of PBP 2018 and the relevant standards.	No change	Construction	Contractor

Table C.4 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Emergency management and response	HAZ08	A Bushfire Emergency Management Plan is prepared for the project area and includes responsibilities associated with and details of: • site specific hazards and risk at each Snowy 2.0 Main Works site; • procedures to maintain bushfire awareness; • bushfire mitigation measures; • fire preparedness actions; • fire response actions including responses to Emergency Alerts issued by emergency services; and bushfire recovery requirements.	No change	Pre-construction	Contractor
	HAZ09	Each main works accommodation camp shall have a full time, onsite Emergency Response Team (ERT), with an appropriate level of training and equipment to respond to potential bushfire and initial structural fire events.	No change	Construction	Contractor
Air					
Exceedances of air quality criteria for PM_{10} and $PM_{2.5}$	AQ01	Sealed treatment of roads 1 km each side of the Lobs Hole and Tantangara accommodation camps	Management of Air Quality in the vicinity of the Lobs Hole and Tantangara accommodation camps to ensure compliance with PM10 and PM2.5 criteria. Management measures will be developed as part of the Air Quality Management Plan prior to commencement of construction and may include: • Targeted watering of unpaved roads in the	Pre-construction and construction	Contractor

Table C.4 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
			vicinity of the accommodation camps; • Installation of appropriate Air Quality monitoring equipment at both accommodation camps; • Development of concentration triggers to alert construction personnel when dust concentrations could result in an exceedance of criteria; • Development of management response measures to be implemented in the event of alarms		
Social					
General	SOC1	Refine and implement the Social Impact Management and Monitoring Plan (SIMMP) provided in the SIA (Appendix X.1).	No change	As specified by the SIMMP	Contractor Snowy Hydro

Table C.4 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
General	SOC2	As part of the CSMPs being prepared for Snowy 2.0 Main Works and to support implementation of the SIMMP, incorporate ongoing liaison activities with representatives from Snowy Valleys Council and Snowy Monaro Regional Council to assist monitoring and reporting of change in indicators relating to: • population change; • housing availability and affordability; • local employment and training rates; • incidences of traffic congestion; • recreation user visitation; • demand for health, education and welfare services; and • cumulative impacts of Snowy 2.0 Main Works.	No change	Bi-annual	Contractor SVC SMRC

Table C.4 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Recreational user impacts	REC01	A recreational plan is to be prepared for sites impacted by the project and should: • be prepared in consultation with NPWS • detail recreational offsets to be provided by the project such as: – permanent boat launch areas in Talbingo and Tantangara Reservoirs – Lobs Hole campground • describe measures to be implemented to minimise impacts during construction, including a process for advance communication to stakeholders and visitors when closures are expected	A recreational plan is to be prepared for recreation sites and their access impacted by the project and should: • be prepared in consultation with NPWS • detail recreational offsets to be provided by the project such as: – permanent boat launch areas in Talbingo and Tantangara Reservoirs – Lobs Hole campground • describe measures to be implemented to minimise impacts during construction, including a process for advance communication to stakeholders and visitors when closures are expected	Pre-construction	Snowy Hydro
Economics					
Positive local employment	ECON1	Provision of employment opportunities for local workers where they have the necessary skills and experience.	Employment opportunities will be provided to local workers where they have the necessary skills and experience.	Construction	Snowy Hydro and contractor
Positive local employment	ECON2	Providing and/or collaborating with local education facilities to provide, ongoing training and certification opportunities for local workers to ensure they have the necessary skills to work on the project.	The project will provide and/or collaborate with local education facilities to provide ongoing training and certification opportunities for local workers to ensure they have the necessary skills to work on the project.	Construction	Contractor

Table C.4 Mitigation measures

Impact/risk	ID#	Original measure(s)	Revised measure(s)	Timing	Responsibility
Positive business opportunities	ECON3	Collaborating with SMRC, SVC, economic development organisations, local chambers of commerce and State Government to: • inform local businesses of the goods and services required of the project, service provision opportunities and compliance requirements of business to secure contracts; • encourage and provide local businesses on how to meet the requirements of the project for supply contracts; and develop relevant networks to assist qualified local and regional businesses tender for provision of goods and services to support the project.	The project will collaborate ~~Collaborating~~ with SMRC, SVC, economic development organisations, local chambers of commerce and State Government to: • inform local businesses of the goods and services that may be provided by ~~required of~~ the project, service provision opportunities and compliance requirements of business to secure contracts; • encourage and provide local businesses on how to meet the requirements of the project for supply contracts; and develop relevant networks to assist qualified local and regional businesses tender for provision of goods and services to support the project.	Construction	Contractor

Appendix C

Visual impact assessment Rock Forest emplacement area

Memorandum

24 March 2020

To: Anthony Ko
From: Duncan Peake
Subject: Rock Forest emplacement area assessment of visual impacts

Dear Anthony,

This memo provides an assessment of visual impacts for the proposed Rock Forest emplacement area.

1 Introduction

As described in the Main Works Preferred Infrastructure Report and Response to Submissions (PIR-RTS) an excavated rock emplacement area will be established at Rock Forest. Once placed at Rock Forest, the excavated rock will be geomorphically landformed to complement the surrounding environment, and then rehabilitated. Rock Forest is within a rural residential area outside of the Kosciuszko National Park (KNP), characterised by large parcels of land with some of these comprising residences. Rock Forest is directly accessed by Snowy Mountains Highway. There is potential for visual impacts to occur for residential and road users both during the construction and in the long-term as the emplacement will be a permanent landform.

1.1 Avoidance and minimisation of impacts

As described in the PIR-RTS the Rock Forest emplacement area has been designed to avoid and minimise visual and landscape impacts by applying geomorphic landform design principles and methodology. The emplacement area has been sited away from the Snowy Mountains Highway and adjacent to heavily vegetated areas to avoid and visibility to nearby residential and road user receptors.

The final rehabilitated landforms will blend and integrate into the surrounding environment to create natural-looking and stable slopes, in balance with the localised environmental conditions. The implementation of a geomorphic design methodology is expected to significantly reduce the visual impacts of the proposed emplacement area in the long-term.

The key mitigation measure for visual impacts of the Rock Forest emplacement area is the progressive rehabilitation of the emplacement area. The Rock Forest emplacement area will be rehabilitated in accordance with the project rehabilitation strategy.

2 Landscape character assessment

A landscape character assessment of Rock Forest was completed as part of the Landscape Character and Visual Impact Assessment (LCVIA) for the Main Works EIS (Appendix S). The assessment found that Rock Forest is characterised by its grazing uses and pockets of vegetation spread throughout the private property. The ability for the zone to absorb change is moderate, and due to the private nature of uses within properties along the highway, the transient means in which observers would be experiencing the zone, and a generally grass covered landscape, the landscape character sensitivity rating is moderate.

3 Visual impact assessment

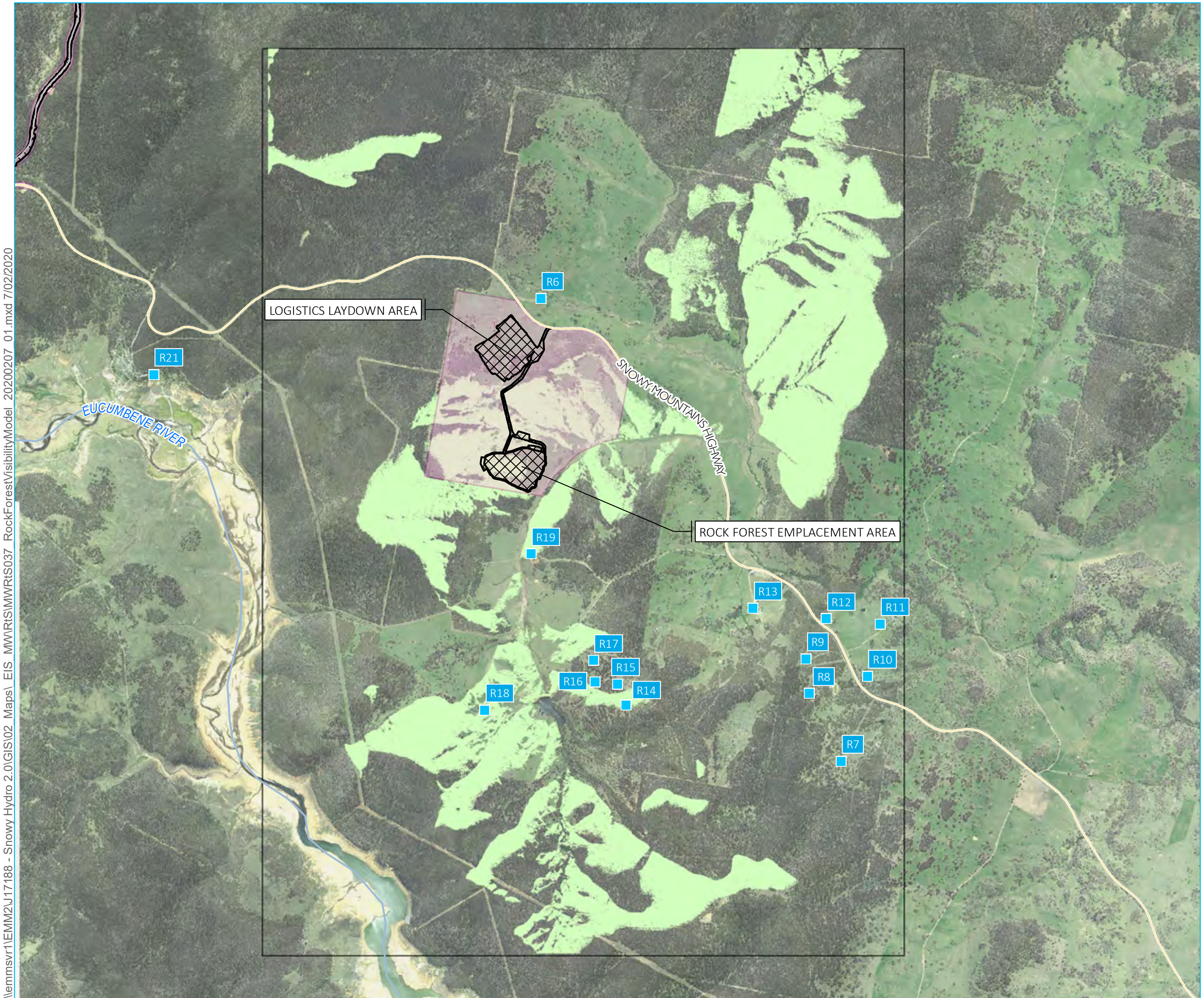
3.1 Visibility analysis

To characterise the visibility of the proposed emplacement area at Rock Forest, a viewshed analysis was completed and is provided in Figure 3.1. The viewshed analysis provides predicted locations where the Rock Forest emplacement area will be visible. As shown in Figure 3.1, there is potential for visual impacts to occur to residences to the south of the Rock Forest emplacement area. In total there are six residences to the south of Rock Forest with potential for visual impacts (R14, R15, R16, R17, R18 and R19). There is also a short section of the Snowy Mountains highway to the north-east, where the emplacement area may be visible to passing traffic. No residences north of the Snowy Mountains Highway will have visibility of the emplacement area.

Of the residences south of the emplacement, five residences (R14–R18) are predicted to experience negligible visual impacts only. These residences have a low level of sensitivity to the proposed visual change as they are distant to the emplacement area at approximately 2 km away. Views from these residences are also expected to be intermittent only and would be substantially screened by the intervening terrain and existing vegetation.

The potential visual impacts to traffic on the Snowy Mountains Highway are also considered negligible as views would be transient only.

The most prominent views are expected at the closest residence (R19) which is approximately 500 m south of the Rock Forest emplacement area. Further assessment of visual impacts has been undertaken for this residence.



KEY

Noise assessment location

Residential

Snowy 2.0 project elements

Disturbance area

Construction envelope

Modelling extent

Modelled emplacement visibility

Existing environment

Main road

Local road

Watercourse

The disturbance area is an estimation of the area required for construction works based on the current level of project design. Detailed design is still required to be completed, therefore it is expected that the precise location of the disturbance area may move within the broader construction envelope and consequently there will be some further refinements to the disturbance area.

Rock Forest - modelled emplacement area visibility

Snowy 2.0
Preferred infrastructure report and response to submissions
Main Works
Figure 3.1

Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

0 0.5 1 km
GDA 1994 MGA Zone 55
N

\\emmsvr1\EMM2\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_MW\RtS\MWRtS037_RockForestVisibilityModel_20200207_01.mxd 7/02/2020

3.2 Visual impact assessment at R19

The potential for visual impacts to R19 were assessed further, with a more detailed analysis of the emplacement area visibility carried out. To determine the visibility of the emplacement area from the nearest residence (R19), a review of the potential for existing vegetation to screen the emplacement area from view was completed. The review used remote sensing (LIDAR) data to determine vegetation height in the area surrounding R19 and the Rock Forest emplacement area. These vegetation heights were also verified onsite (refer to Photograph 3.1). The height of the proposed emplacement area is between 1,172–1,180 mAHD. The height of existing vegetation was categorised relative to the emplacement area as follows:

- >1,180 mAHD – complete screening of emplacement area;
- 1,172–1,180 mAHD – partial screening of emplacement area; and
- <1,172 mAHD – minimal screening of emplacement area.

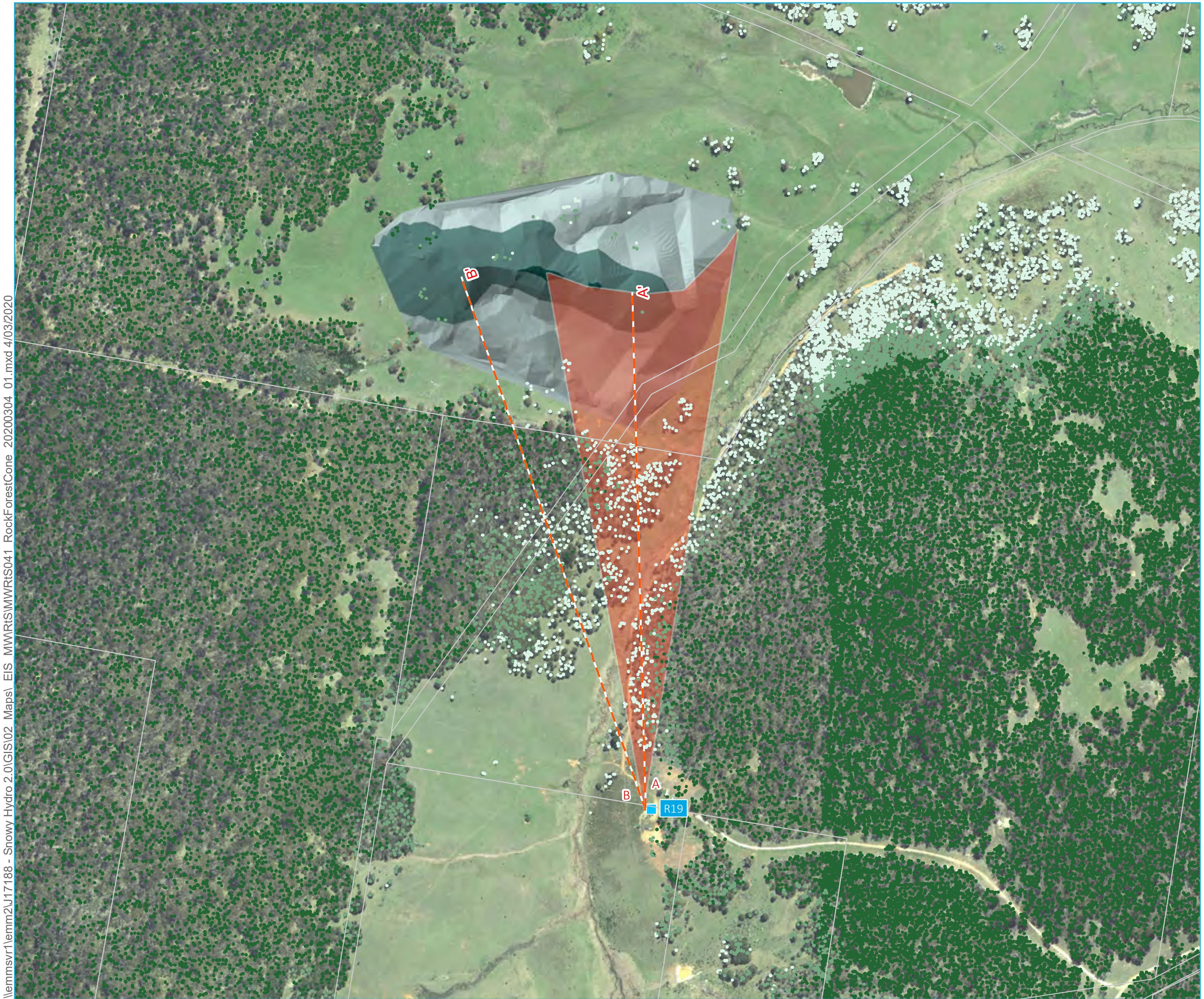
The results of this analysis are provided in Figure 3.2. Stylised cross-sections of the views provided in Figure 3.2 are also provided in Figure 3.3 to demonstrate the level of screening expected due to existing terrain and vegetation.

As shown in Figure 3.2 the Rock Forest emplacement area would be partially screened from view at R19 due to intervening vegetation. The current view from Rock Forest towards R19 is provided below in Photograph 3.1 which shows the intervening vegetation expected to provide partial screening of the emplacement area.

Photograph 3.1 Existing view from emplacement location looking south towards R19

Photograph 3.2 Existing view from the emplacement location looking south-east toward R19

Photograph 3.3 Existing view from the emplacement location looking south-east toward R19



Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

Rock Forest - modelled emplacement area visibility

Snowy 2.0
Preferred infrastructure report and response to submissions
Main Works
Figure 3.2

Figure 3.3 **Cross-section showing partial screening of view (AA) from R19**

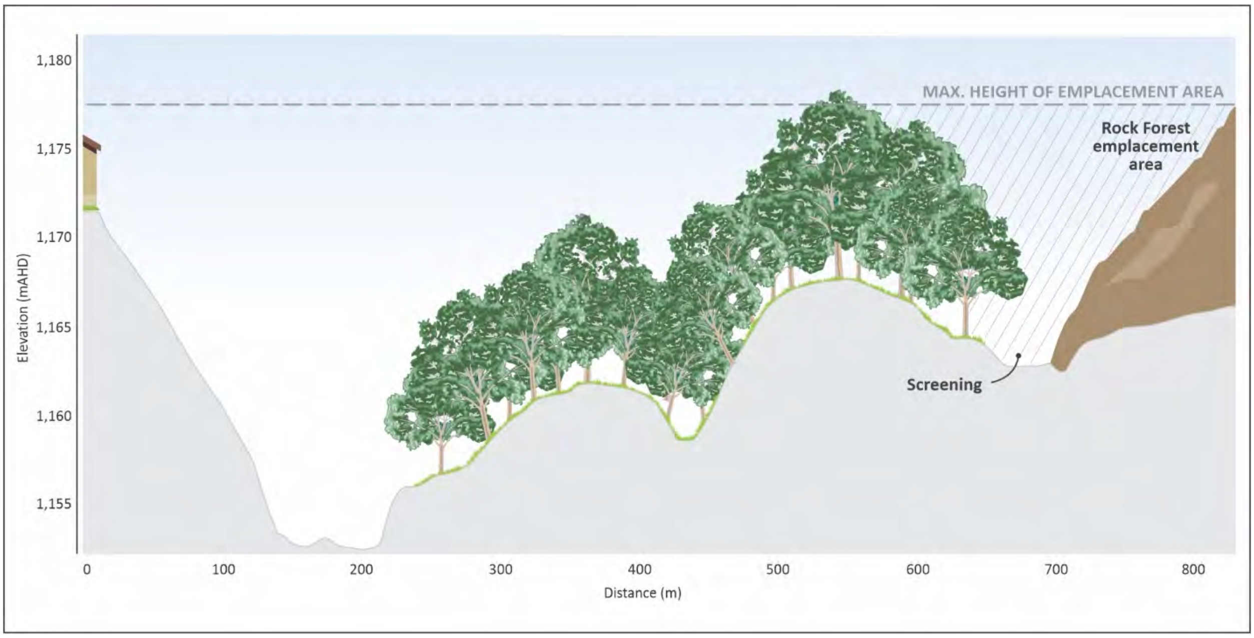


Figure 3.4 **Cross-section showing complete screening of view (BB) from R19**

Visualisations are provided in Plate 3.1 to Plate 3.3 showing the expected change to a viewpoint at R19 through the establishment of the Rock Forest emplacement area.

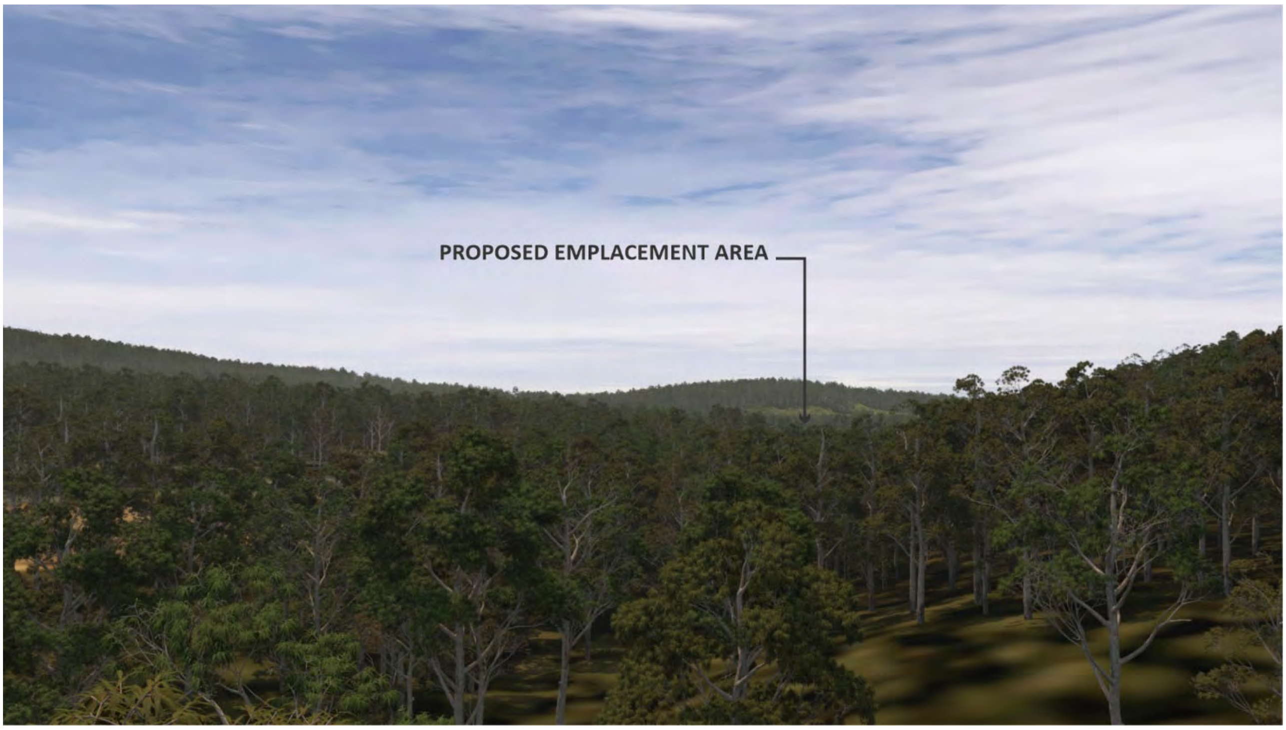


Plate 3.1 Visualisation – view from R19 to Rock Forest emplacement area prior to works

Plate 3.2 Visualisation – view from R19 to Rock Forest emplacement area during construction

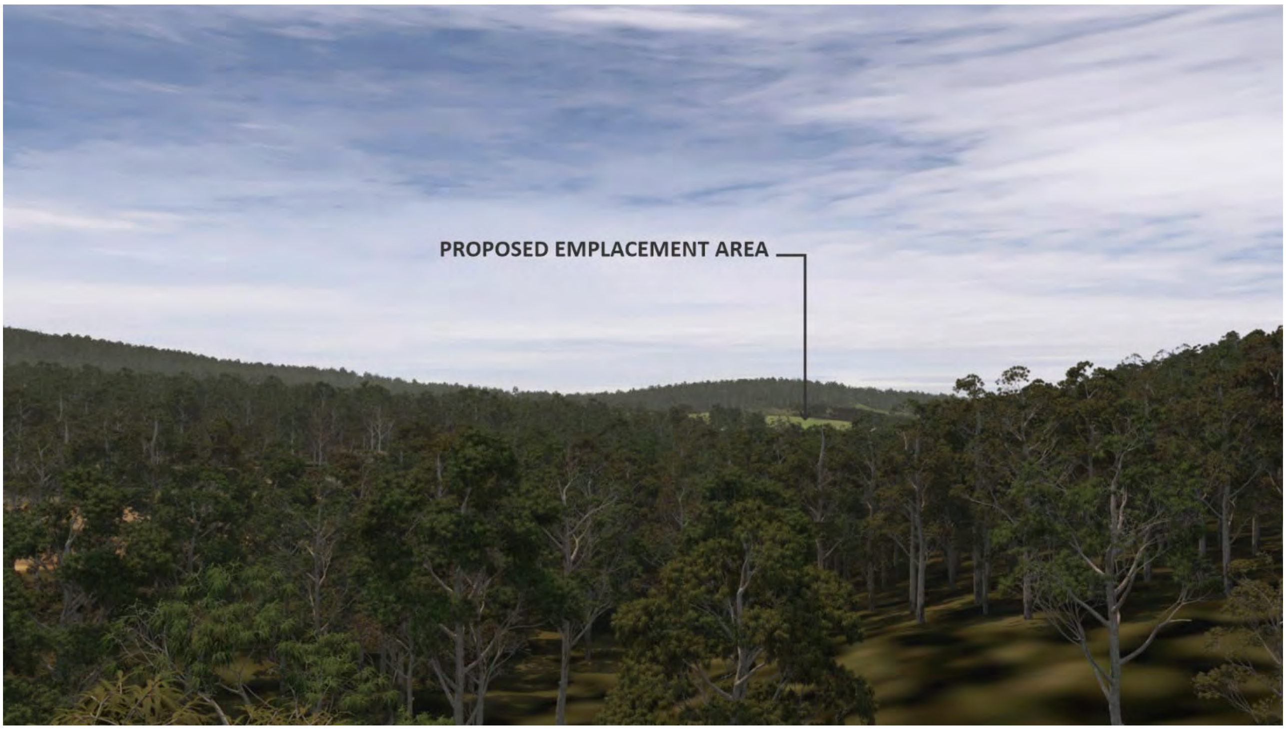


Plate 3.3 Visualisation – view from R19 to Rock Forest emplacement area after rehabilitation

The section of the emplacement area that would be visible from R19 is expected to result in a moderate and temporary visual impact during construction and a low long-term impact at the completion of the project once the landform is rehabilitated.

4 Conclusion

The Rock Forest emplacement area has potential to cause visual impacts during construction and in the long-term. Five residences to the south of Rock Forest have potential for low level impacts during construction. One residence (R19) is expected to experience temporary moderate visual impacts during construction and low long-term impacts after the site is rehabilitated. The use of a geomorphic design methodology has been used to make Rock Forest emplacement area blend and integrate into the surrounding environment. Progressive rehabilitation of the emplacement area will further mitigate visual impacts and provide a landform consistent with the existing landscape in the long-term.

Appendix D

Visual concepts of key infrastructure

Figure D.1 Visual concept of Marica surge shaft

Figure D.2 Visual concept Talbingo intake – View 1

Figure D.3 Visual concept Talbingo intake – View 2

Figure D.4 Visual concept Tantangara intake – View 1

Figure D.5 Visual concept Tantangara intake – View 2

Figure D.6 Visual concept MAT and ECVT portal areas

Figure D.7 Visual concept Tantangara fish barrier

Figure D.8 Visual concept Lobs Hole substation

Appendix E

Aquatic ecology response

Our Ref: 59918111:DP_Rev0_Final
Contact: Dan Pygas

12 March 2020

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SNOWY 2.0 – REQUEST FOR INFOMATION

Introduction

Cardno (NSW/ACT) Pty Ltd (Cardno) has prepared the following response to the Department of Planning, Industry and Environment (DPIE) request for further information on the Snowy 2.0 Main Works EIS, which relates to the Aquatic Ecology Assessment (AEA) prepared by Cardno and included as Appendix M.2 of the Snowy 2.0 Main Works EIS.

Specifically, DPIE requested a:

'*Discussion on impacts to the aquatic ecology within the mid Murrumbidgee and Eucumbene in the event redfin are entrained downstream of the barriers*'

This request is considered in the response provided below.

Response

Section 7.2.3.4 of the AEA assessed the residual impact on the aquatic ecology of the Murrumbidgee River and Eucumbene River catchments following installation of barriers to transfer of redfin perch (*Perca fluviatilis*). The AEA also considered the consequences for aquatic ecology, primarily threatened species and other native fish in these catchments in an unmitigated (i.e. no barriers installed) scenario.

The likelihood of a reservoir spill or a failure of the proposed barriers leading to transfer of redfin perch to the mid-Murrumbidgee River downstream of Tantangara Reservoir and/or to Lake Eucumbene via the Murrumbidgee-Eucumbene tunnel, if redfin perch successfully transfer to Tantangara Reservoir during the operation of Snowy 2.0, was assessed as very rare.

As noted in the AEA, the potential likelihood and severity of impacts to native species in the Murrumbidgee River and Eucumbene River catchments due to any transfer of redfin perch would depend on several variables, in particular:

- the number of individuals transferred;
- the duration of transfer; and
- the persistence of fish in the receiving environments following any transfer.

Native species within these catchments already experience a number of existing impacts and threats, including river regulation, surrounding land use practices (e.g. causing increased sedimentation) and the presence of other non-native aquatic species (such as stocked salmonids). The absence of a full understanding of the interactive or cumulative effects of existing and new potential impacts on native species in these environments, complicates the assessment of any additional impacts to aquatic ecology associated with Snowy 2.0. The assessment of potential impacts to aquatic ecology in the Murrumbidgee River and Eucumbene River catchments in the event of a failure of controls resulting in the transfer of redfin perch is discussed in the following sections based on available information and knowledge.

Mid-Murrumbidgee

Fish Distributions

For the purposes of the assessment, the mid-Murrumbidgee River is the section of river from Tantangara Dam wall to the Australian Capital Territory (ACT) border. The aquatic environment of the mid-Murrumbidgee River catchment was described in Section 5.5.9 of the AEA. Species with catch and / or stocking records from the catchment or with a moderate likelihood of occurrence are listed in Table 1.

Table 1 Threatened, native and non-native aquatic species in the mid-Murrumbidgee River Catchment.

Family	Scientific Name	Common Name
Threatened Species		
Percichthyidae	*Macquaria australasica*	Macquarie perch (FM & EPBC Acts*: End.)
Percichthyidae	*Maccullochella macquariensis*	Trout cod FM & EPBC Acts: End.)
Percichthyidae	*Maccullochella peelii*	Murray cod (EPBC Act: Vul.)
Percichthyidae	*Nannoperca australis***	Southern pygmy perch (FM Act: End.)
Parastacidae	*Euastacus armatus*	Murray crayfish (FM Act: Vul.)
Non-threatened Native Species		
Percichthyidae	*Macquaria ambigua*	Golden perch
Percichthyidae	*Gadopsis bispinosus*	Two-spined blackfish
Galaxiidae	*Galaxias olidus*	Mountain galaxias
Retropinnidae	*Retropinna semoni*	Australian smelt
Eleotridae	*Philypnodon grandiceps*	Flathead gudgeon
Eleotridae	*Hypseleotris* spp.	Carp gudgeon
Parastacidae	*Cherax* spp.	Common yabby
Parastacidae	*Euastacus reiki*	Reik's crayfish
Palaemonidae	-	Freshwater prawn
Atyidae	*Paratya* spp.	Freshwater glass shrimp
Non-Native Species		
Poeciliidae	*Gambusia holbrooki*	Eastern gambusia
Cyprinidae	*Carassius auratus*	Wild goldfish
Cyprinidae	*Cyprinus carpio*	Carp
Cobitidae	*Misgurnus anguillicaudatus*	Oriental weatherloach
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout
Salmonidae	*Salmo trutta*	Brown trout

Notes: Includes species recently recorded or stocked in the catchment and the catchment provides suitable habitat. Records include data provided by third parties, literature and results of surveys undertaken as part of investigations for the AEA.
* FM Act – *Fisheries Management Act 1994* (NSW); EPBC Act – *Environment Protection and Biodiversity Conservation Act 1999* (Cth); End – Endangered; Vul. - Vulnerable.
** Southern pygmy perch are not known to occur within the main stem of the mid-Murrumbidgee River, and there are no catch records from anywhere within the catchment; however, the Numeralla River, a tributary of the Murrumbidgee River, is within the modelled predicted distribution range (DPI 2016).

The species of fish likely to have the greatest conservation significance in the mid-Murrumbidgee River catchment is Macquarie perch. At present, it is thought that the uppermost population within the Murrumbidgee River extends from Cooma to just downstream of Yaouk Bridge (Lintermans 2019), which is 34km downstream of Tantangara dam wall. Environmental DNA sampling undertaken in March 2019 as part of the sampling for Snowy 2.0 detected Macquarie Perch DNA downstream of Tantangara Dam including at Bolaro (near Adaminaby), at Mittagang Crossing and at Bumbalong Road. No DNA was detected upstream (including at Yaouk), in-between and downstream of these locations (Weeks *et al*., 2019). Cardno is not aware of any population size estimates or habitat mapping, in addition to NSW DPI (2016), available for Macquarie perch in this area and, to our knowledge, there is no ongoing monitoring program for this population. Several other threatened and non-threatened native species also occur in the mid-Murrumbidgee River, including the threatened trout cod, Murray cod and Murray crayfish (Table 1). These species predominantly occur in the lower section of the mid-Murrumbidgee River downstream of Cooma. Predictive habitat mapping suggests suitable habitat for southern pygmy perch occurs in Numeralla River (a tributary of the Murrumbidgee River downstream of Cooma), though no known records exist for this species here.

As noted in the National Recovery Plan for Macquarie Perch (Commonwealth of Australia, 2018), salmonids and redfin perch are introduced fish species considered likely to have a negative impact on Macquarie perch populations. Non-native eastern gambusia and carp are also likely to have a negative impact. Of these species, only redfin perch is absent from the entire section of the mid-Murrumbidgee River (**Table 1**). Redfin perch are known to occur in the Murrumbidgee River downstream of the ACT border. Wild goldfish and eastern gambusia are considered present downstream of Adaminaby. It is unclear what proportion of salmonids, if any, present in the Mid-Murrumbidgee River are derived from natural recruitment, though stocking would maintain population levels. The mid-Murrumbidgee River and connected tributaries below Tantangara dam are stocked with rainbow trout (DPI, 2020), including where Macquarie perch are known to occur. Although data for the 2019/2020 stocking season is not yet available online the DPI website indicates 21,000 rainbow trout were released into the mid-Murrumbidgee River upstream of the ACT/NSW border in 2018/2019 and that a total of 22,500 were released into Boundary Creek, Yaouk Creek, Bradley's Creek and the Goorudee Rivulet tributaries of the Mid-Murrumbidgee River. Lintermans (2006) notes that despite a perception from some (Clunie *et al*. 2002 in Lintermans 2006) that rainbow trout are less of a threat than brown trout to native species, there is no apparent evidence for a reduced impact from rainbow trout.

Consequences of Redfin Perch Transfer

The potential for impacts to aquatic ecology following any transfer of redfin perch would depend on the ability of redfin perch to establish in new environments, if transferred. Maximum Entropy (MaxEnt) species distribution modelling undertaken by Baumgartner *et al*. (2017) indicated that the mid-Murrumbidgee River from the Tantangara dam wall down to Cooma provided ‘marginal habitats (<0.2 chance of survival)’ for redfin perch. The chance of survival increased to 0.2-0.4 from Cooma to Michelago and increased further with distance downstream to the ACT border where redfin perch are already known to occur. The marginal habitat for redfin perch in the mid-Murrumbidgee River is likely a result of its primarily flowing water environment, compared with still water environments, and the apparent preference of redfin perch for the latter. The Murrumbidgee River supports structural habitat including wood debris that is potentially suitable as spawning habitat, at least in slower flowing pool sections. Thus, although habitat is marginal, the establishment of a self-sustaining population of redfin perch here cannot be discounted.

If transfer to the mid-Murrumbidgee River occurred in the unlikely event of barrier failure or a spill event, redfin perch would be expected to interact with Macquarie perch, Murray cod, trout cod and the non-native brown trout and rainbow trout via competition for food and predation on juveniles and smaller individuals. Redfin perch could also compete with and / or predate on the other species of fish known to occur (**Table 1**). The magnitude of any impact would depend on the number of individuals transferred, and if transferred, if they were to establish here.

In the case of Macquarie perch, following consideration of the reported outcomes of interactions with redfin perch, Section 7.2.3.4 of the AEA considered that in the absence of the barrier controls and if transferred predation and competition associated with redfin perch would result in impacts to Macquarie perch in the mid-Murrumbidgee River catchment. This could include a reduction in population size or in the worst case, population loss. Any impact would likely be associated with a greater susceptibility to the effects of existing and cumulative threats (including the presence of other existing predatory species, such as stocked rainbow trout and brown trout, and river regulation and its potential influence on spawning cues and sedimentation).

In the case of trout cod and Murray cod, some reduction in population size would be expected in the event of any transfer of redfin perch, though a loss of these populations would be less likely. This is based on the apparent co-existence of these species with redfin perch in the Murrumbidgee River downstream of the ACT and in other locations. Similarly, the transfer of redfin perch here would not be expected to result in the loss of populations of other native species, including the vulnerable Murray crayfish in the mid-Murrumbidgee River catchment, though a reduction in population size could occur. The persistence of any depressed population sizes of any species would depend on the successful establishment of redfin perch, which based on species distribution modelling by Baumgartner *et al*. (2017) would be considered unlikely.

Lake Eucumbene

Fish Distributions

Section 5.5.11 of the AEA described the aquatic environment of the Lake Eucumbene catchment, which includes Lake Eucumbene and the flowing section of the Eucumbene River and other tributaries. Fish species considered to occur are listed in **Table 2**. Redfin perch are considered absent from Lake Eucumbene and its tributaries, but present in the lower Snowy River catchment downstream of Jindabyne Dam. Whilst the catchment appears dominated numerically by introduced salmonids, particularly within the lake itself, native aquatic species known to occur in the broader catchment that could be affected by redfin perch transfer include climbing galaxias, mountain galaxias, Australian smelt, flat-headed gudgeon and Reiks crayfish (**Table 1**).

Table 2 Threatened, native and non-native aquatic species considered to occur in the Lake Eucumbene Catchment

Family	Scientific Name	Common Name
Non-threatened Native Species		
Galaxiidae	*Galaxias brevipinnis*	Climbing galaxias
Eleotridae	*Philypnodon grandiceps*	Flathead gudgeon
Parastacidae	*Cherax* spp.	Common yabby
Parastacidae	*Euastacus reiki*	Reik's crayfish
Non-Native Species		
Cyprinidae	*Carassius auratus*	Wild goldfish
Cobitidae	*Misgurnus anguillicaudatus*	Oriental weatherloach
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout
Salmonidae	*Salmo trutta*	Brown trout
Salmonidae	*Salvelinus fontinalis*	Brook trout

Notes: Includes species recently recorded or stocked in the catchment and the catchment provides suitable habitat. Records include data provided by third parties, literature and results of surveys undertaken as part of investigations for the AEA.

Consequences of Redfin Perch Transfer

As is the case in the Murrumbidgee River, the potential for impacts to aquatic ecology in the Eucumbene River catchment would depend on the ability of redfin perch to establish in new environments, if transferred. The MaxEnt species distribution modelling undertaken by Baumgartner *et al*. (2017), indicated that the majority of tributaries of the Eucumbene River upstream of Lake Eucumbene were unlikely to support redfin perch, with a lower section of the Eucumbene River providing marginal habitat (<0.2 chance of survival). Baumgartner *et al.* (2017) concluded that Lake Eucumbene provides habitat suitable for redfin perch.

As is the case in the mid-Murrumbidgee River catchment, the marginal habitat for redfin perch provided by the tributaries of Lake Eucumbene is likely a result of the flowing watercourse environments. Given the apparent smaller size (channel depth and width) and relatively lower abundance of structural habitat in the Eucumbene River, coupled with the reported relatively poor swimming ability of redfin perch compared with salmonids and many native species, it is even less likely redfin perch would be able to establish in these flowing watercourses compared to the mid-Murrumbidgee River. The potential for establishment in Lake Eucumbene is more likely than in flowing watercourses.

Section 7.2.3.4 of the AEA considered the consequences for the aquatic ecology of the Lake Eucumbene Catchment in the event of transfer of redfin perch here. As noted in the AEA and **Table 2**, no threatened species are known to occur in this catchment, although the aquatic ecological community of the Snowy River catchment in NSW has been listed as an endangered ecological community (EEC) under the *Fisheries Management Act 1994*.

If redfin perch are transferred, there is potential for them to predate on these native species. As for most species in the Murrumbidgee River, the apparent generally unsuitable habitat for redfin perch in the Eucumbene River (and other flowing tributaries of Lake Eucumbene), and the apparent co-existence with redfin perch elsewhere suggests that the loss of populations of native species in these watercourses due to transfer of redfin perch would be unlikely. Reductions in population size due to interactions with redfin perch could, however, be expected in areas where redfin are able to access in sufficient numbers. Whether reductions in population sizes of native species would persist would depend on whether redfin perch establish in these catchments. While it may be unlikely in flowing watercourses, establishment of redfin perch in Lake Eucumbene is more likely. This assumes sufficient numbers would be transferred and conditions prove suitable for breeding. As redfin are unlikely to be able to establish in large areas of flowing watercourses within the catchment, a significant impact on the Snowy River EEC is considered unlikely.

Should redfin perch establish in Lake Eucumbene, there is the potential to impact rainbow trout and brown trout by predation. In the most conservative impact scenario, there could be noticeable reductions in the number of juvenile and smaller salmonids in the reservoir (larger trout are unlikely to be eaten by redfin perch), resulting in depressed populations sizes for salmonids here if this is not mitigated with additional stocking. Other measures could also be used to mitigate such impacts. For example, it is possible that post release survival of trout could be improved by predator conditioning of fry or the stocking of larger yearling salmonids (Molony *et al.,* 2004).

Conclusion

Following installation of the proposed barrier controls at Tantangara Reservoir, the likelihood of transfer of redfin perch to the Murrumbidgee River and Eucumbene River catchments would be very rare and occur only if the barriers upstream of Murrumbidgee River and Eucumbene River failed, or if a spill event to the mid-Murrumbidgee River could not be prevented. If transfer did occur, it would likely be relatively short-duration and far fewer individuals would be transferred compared with transfers that would otherwise occur in an unmitigated scenario.

If transferred, it is uncertain whether redfin perch would establish in flowing sections of the Murrumbidgee River and Eucumbene River. Flowing environments have been modelled as having unsuitable or marginal habitat suitability for redfin perch. Establishment in the lentic environment of Lake Eucumbene is considered possible. The uncertainty regarding the potential establishment of redfin perch in the event of transfer is due to the many unknown variables surrounding the numbers of redfin perch that may be transferred in the rare event of a failure of controls and the ability of redfin perch to establish in these environments.

Threatened species within the mid-Murrumbidgee catchment are subject to multiple current stressors including but not limited to other non-native species of fish, including stocked salmonids, and impacts associated with river regulation, drought and potentially impacts associated with recent bushfires. How these existing impacts may interact with new potential impacts cannot be predicted with certainty. The presence of multiple other existing stressors, unrelated to Snowy 2.0, particularly ongoing stocking of salmonids, should be considered in future management of this species and population.

Given the apparent susceptibility of Macquarie perch to impact from redfin perch, potential consequences for the population in the mid-Murrumbidgee River include a reduction in population size or in the worst case, local population loss. Consequences for other native and threatened species known to occur in the Murrumbidgee River are likely to be limited to a reduction in population size. This is based on their apparent co-existence with redfin perch downstream of the ACT and in other locations.

Similarly, all species found in the Eucumbene Catchment appear to co-exist with redfin perch elsewhere in other catchments and loss of populations as a result of any redfin perch transfer is unlikely. All native species could experience a decline in population size following transfer and successful establishment of redfin perch.

Should redfin perch establish in either of these catchments, impacts to recreationally important salmonids could occur, though these species are known to co-occur in several other locations (e.g. Blowering Reservoir and Talbingo reservoirs). Any potential impacts to salmonids could be mitigated via increased or altered fish stocking regimes in these catchments.

Yours sincerely,

Daniel Pygas
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Email: Daniel.Pygas@cardno.com.au

References

Baumgartner LJ, Boys, CA, Gilligan DM, Silva, LG, Pflugrath B, Ning N (2017). *Fish transfer risk associated with Snowy 2.0 pumped hydro scheme.* Report prepared for Snowy Hydro Ltd by the Institute for Land, Water and Society, Charles Sturt University. 35 pp.

Commonwealth of Australia (2018). *National Recovery Plan for Macquarie Perch (Macquaria australasica).* Available at: https://www.environment.gov.au/system/files/resources/bdee49ef-45da-4eb7-b548-bcfce460a21b/files/recovery-plan-macquarie-perch-2018.pdf

Clunie, P., Stuart, I., Jones, M., Crowther, D., Schreiber, S., McKay, S., O'Connor, J.,McLaren, D., Wess, J., Gunasekera, L. and Roberts, J. (2002). A Risk Assessment of the Impacts of Pest Species in the Riverine

Environment in the Murray-Darling Basin. Report to the Murray-Darling Basin Commission. Department of Natural Resources and Environment, Victoria.

Lintermans M (2006). T*he re-establishment of endangered Macquarie perch Macquaria australasica in the Queanbeyan River, New South Wales, with an examination of dietary overlap with alien trout.* Technical report. CRC for Freshwater Ecology, Canberra.

Lintermans, M (2019). *A review of fish information from the Upper Murrumbidgee and Upper Tumut catchments*. Consultant's report to EMM Consulting Pty Ltd.

Molony BW, Bird C and Nguyen VP (2004) The relative efficacy of stocking fry or yearling rainbow trout (*Oncorhynchus mykiss*) into a large impoundment dominated by redfin perch (*Perca fluviatilis*) in south-western Australia. *Marine and Freshwater Research 55, 781-785.*

NSW DPI (2016). *Fish communities and threatened species distributions of NSW*. NSW Department of Primary Industries (DPI).

NSW DPI (2020). *Fish stocking.* Available at: https://www.dpi.nsw.gov.au/fishing/recreational/resources/stocking [accessed February 2020]